Design for peripheral interaction

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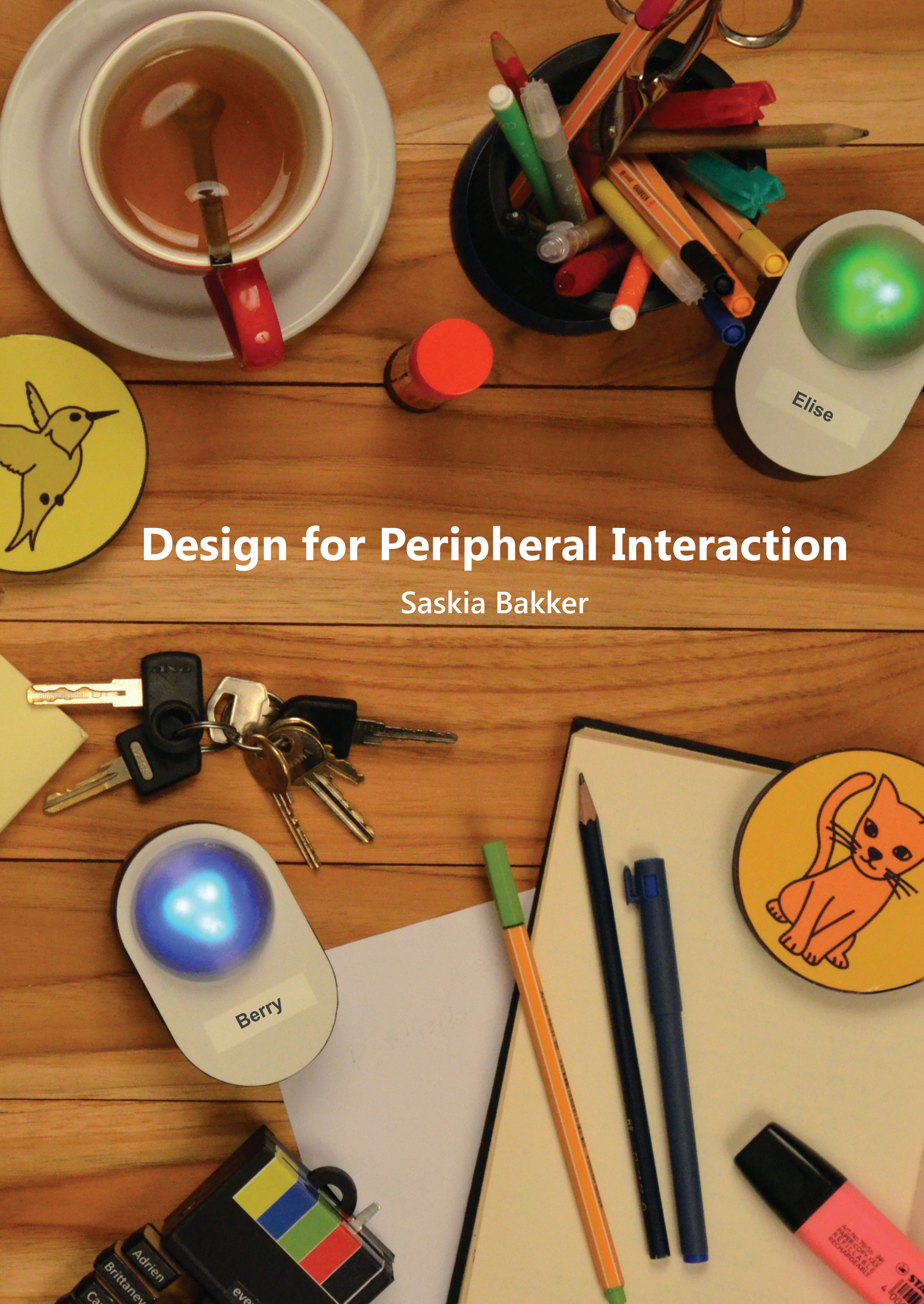

Design for Peripheral Interaction

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Design for Peripheral Interaction

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1.

Introduction

It is Friday evening, Tim just arrived home. He forgot to send some documents to his colleague and wants to have it done right away. He starts his laptop computer and logs into an online webmail application. Fortunately he stored the documents locally and finds them after going through a number of folders. He opens them and spots a typo in the first paragraph, but cannot correct it in the reader he uses. Luckily he saved the source file too and can correct the mistake. Back to the email application, he notices that his session ran out and he has to log in again. This is taking more time than he had hoped; he still has to prepare lasagna for tonight as Susan is coming over. After sending the email he takes his tablet computer. He used it yesterday to find a lasagna recipe and while he prefers to use his laptop for typing documents, the tablet is more convenient in the kitchen. He puts the tablet on the kitchen counter and searches for the recipe. He decides to pour himself a drink but wonders if he should open a bottle of wine. 'Would Susan want to drink wine?', he thinks. In the mean while he puts some cutlery on the counter and decides to take a glass of wine anyway. While taking a sip, he opens the refrigerator door to collect ingredients, but notices that he is out of orange juice. He puts down his drink, walks to the memo board next to the window and writes down 'orange juice'. He realizes it is getting dark outside, is it already that late? Tim looks at his watch, almost eight o'clock; he decides to turn on the TV to catch something of the news. He takes some tomatoes from the refrigerator and washes them in the sink. Having forgotten how many tomatoes were needed, he looks at the tablet again, but the screen went black. 'How annoying', he thinks and dries his hands, presses the power button, unlocks the screen, scrolls to the ingredients section: five tomatoes are needed. The tomatoes should be sliced, 'I'd best use my serrated knife', he thinks, and then realizes it is already lying on the counter, he must have taken it out with the other cutlery. While cutting the vegetables, the news has started and he listens to the newsreader's report. Suddenly, Tim hears a ring from his smart phone; an incoming email. Why does this always happen when he is busy? Maybe his colleague has a question about his earlier message? He puts down his knife and takes his phone to open the email; some advertisement. 'I could have known', he thinks. While continuing the dinner preparations, Tim turns off the TV, the news has finished. Just when he puts the lasagna in the oven, Tim hears a car stop in front of his house. That must be Susan!

1.1. Attention in everyday life

The above story illustrates an everyday scenario in today's world. Lots of things are happening at the same time, some of which are supported by modern computing technologies. When first looking at the activities that do not involve technology, we see that Tim almost continuously interacts with his physical surroundings. This everyday environment contains lots of information, for example about the time of day or the activities going on in the proximity. This information however, typically does not require focused attention to be perceived: it is available as part of the environment, allowing us to be aware of it without thinking, while we may also consciously perceive it. For example, Tim's attention was shortly attracted to the darkness outside when he recognized it was getting late, to the contents of the refrigerator when he noticed he was out of orange juice and to the noise outside when he realized that Susan must have arrived. Such *perceptions* of everyday information typically take place in the background or *periphery* of attention, and shift to the center of attention once they become relevant. Similarly, several everyday *physical actions* can be performed in the periphery of attention. For example, Tim could take the cutlery out of the drawer while contemplating about what to drink, he could drink wine while looking into the refrigerator, and cut vegetables while listening to the news. Thought some of these actions seem rather complex, there is no apparent problem in performing them without conscious attention. Such actions are often performed on a routine basis and we may even forget that we have performed them, for example Tim did not recall having taken his serrated knife from the drawer. Such actions can take place in the periphery of attention, but may also shift to the center of attention when this becomes relevant, for example when the glass is so full that Tim needs to consciously take the first sip to avoid spilling, or when he wants to cut the vegetables in very precise pieces.

In everyday life, we clearly perceive all sorts of information and perform various physical actions. Usually, numerous such activities are going on at the same time, some in our periphery of attention and others in our center of attention. When in the periphery, such perceptions and actions require minimal attention and effort, but when in the center, they are performed with conscious focus. As evident from Tim's Friday evening, perceptions and actions can easily *shift* from the periphery to the center of attention and back whenever this is required. Since we can perceive and interact both in the periphery and in the center of attention, these perceptions and actions do not overwhelm or overburden us, but instead form a fluent part of our everyday routines.

1.2. Technology in everyday life

When considering the use of computing devices in the above story, it is clear that the role of such devices would be different if the story was written five or ten years ago and will be different if someone writes a similar story five or ten years from now. Over the years, computing technologies have become significantly smaller and less costly and, as a result, modern devices such as smart phones, laptops and tablet computers allow us to access and interact with digital information via the internet virtually anywhere, anytime. The number of computers in our everyday environment will likely increase in the coming years; not only as part of personal devices, but also integrated in everyday objects and environments, further expanding our connections to the digital world. These developments clearly bring along numerous opportunities, while they also raise challenges for interaction design. As evident from the story above, accessing and interacting with digital information through today's devices can be done anywhere, but also requires the user's focused attention. For example, Tim needed to focus on his laptop to perform the simple task of sending a document via email, he consciously performed actions on his tablet to access the recipe information and his smart phone needlessly attracted his attention away from the activities of cutting the vegetables and listening to the news. On the contrary, Tim's other activities, which did not involve interactive devices (e.g. collecting cutlery and ingredients, drinking, washing and cutting vegetables) seemed to demand much less attention.

Given the observation that interactions with computing devices seem to require focused attention, these interactions are usually performed in the center rather than in the periphery of attention. Although computing technologies are playing an increasing role in our everyday lives, it therefore seems challenging to fluently embed interactions with these technologies in our everyday routines, which are characterized by activities shifting between center and periphery of attention.

1.3. Calm technology

The observation that technology is becoming ubiquitous in everyday life is not new. This development was already foreseen over 20 years ago by Weiser (1991), who envisioned that hundreds of computers of various sizes and functionalities would be integrated in the 21st century everyday environment. Weiser furthermore recognized that traditional methods of human-computer interaction (HCI) demanded focused attention, which prevented them from being seamlessly integrated into the everyday world. He therefore suggested that computing technology should vanish into the background. By this, he meant not only that the technology should be 'hidden' in physical artifacts and environments, but rather that their use should be integrated in the everyday routine such that interactions can take place outside the attentional focus. Weiser envisioned that when computers would be interacted with in this way, we would be "freed to use them without thinking and so to focus beyond them on new goals" (Weiser, 1991, p. 94). Weiser and Brown (1997) later coined the term *calm technology*, which "engages both the center and the periphery of our attention, and in fact moves back and forth between the two" (Weiser and Brown, 1997, p. 79). As they envisioned, when interactions with technology could be available to be undertaken both in the periphery and in the center of attention, people would be in control of technology without being overburdened by it. This is similar to the way we interact with our everyday environment, and the calm technology approach is therefore intended to support technology in becoming a seamless or *unremarkable* (Tolmie et al., 2002) part of everyday routines.

Building on the ideas of Weiser and his colleagues, many researchers have aimed to employ the user's periphery of attention. Although the initial idea of calm technology (Weiser and Brown, 1997) does not specifically focus on peripheral *perception*, by far most of the work it inspired aims to develop and evaluate visual and auditory displays which subtly present information such that people can perceive it in the periphery of attention (Hazlewood et al., 2011; Heiner et al., 1999; Ishii et al., 1998; Matthews et al., 2004; Mynatt et al., 1998; Pousman and Stasko, 2006). Only few recent studies are known that explore *physical interactions* with technology to take place in the periphery of attention (Edge and Blackwell, 2009; Hausen et al., 2012). Since both actions and perceptions seem to shift between the center and periphery of attention in everyday situations, we believe that to fluently embed interactive systems in the everyday routine, it would be valuable to explore if and how *both* perceptions of and interactions with these systems can take place in the periphery of attention.

1.4. Peripheral interaction

While the idea that computers would become ubiquitous in everyday life was merely a future vision 20 years ago (Weiser, 1991), we now see that much of this vision has become reality. Computers and digital information can indeed be found everywhere nowadays. We therefore believe that enabling interactions with these technologies to shift between the center and periphery of attention is highly relevant today (also see (Brown, 2012)) and its relevance will only increase in the coming years. Although the way we currently interact with computing technology is vastly different from the way computers were operated 20 years ago, our current interactions still mainly seem to engage the center of attention. As a result, the seamless integration of these technologies in our everyday routines remains a challenge.

This thesis therefore explores the concept of *peripheral interaction*: interaction with computing technology which can take place in the periphery of attention and shift to the center of attention when relevant for or desired by the user. When in the periphery, such interactions require only few mental resources, while they can also be fully focused on in the center of attention. The goal of peripheral interaction is to fluently embed meaningful interactive systems into people's everyday lives. Peripheral interactions encompass perception of digital information, physical actions performed on interactive devices and combinations of these two. Therefore peripheral interactions are possible through a variety of interactive technologies, such as interactive products, information displays or larger systems of products and services. In this thesis, we use the term *interactive system* to encompass all kinds of products, systems and services, that are enhanced with digital technology, with which a user can interact.

Clearly not all interactions with computing systems are suitable to be performed in the periphery of attention. For example interactions which require great precision, such as when entering credit card details for an online purchase, or perceptions which demand direct action, such as a fire alarm, will likely always take place in the center of attention. However, an increasing number of interactive systems is used for less critical everyday activities, such as interacting with a music player or controlling your lighting system. Peripheral interaction seems particularly suitable for such important but non-crucial everyday interactive systems.

Though peripheral interaction is essentially not different from Weiser and Brown's original description of calm technology, the term calm technology at present seems mainly associated with peripheral perception, rather than with peripheral physical interaction. Additionally, the word 'calm' in calm technology makes that the concept is sometimes interpreted to aim for a quiet and serene everyday life, in which full engagement with computing technology is not desired (Graves Petersen, 2004; Rogers, 2006). We do not aim for this with peripheral interaction. As evident from the scenario of Tim preparing his Friday night dinner, everyday life is not always quiet and serene, but often messy and turbulent, with numerous activities taking place simultaneously. We hope for an equally 'turbulent' future everyday life, in which technology similar to current everyday activities, shifts between periphery and center of attention. In this future life, technology will sometimes be the focus of attention, but at other moments reside in the periphery of attention, where it can be interacted with while demanding little attention. In this future everyday life, glancing at an interactive device would be enough for Tim to know how many tomatoes are needed, a simple gesture would allow him to find out who sent him an email, or communicating to his colleague would be as straightforward and effortless as simply talking to his colleague or physically handing over a document, while he would be able to continue with whatever he was doing in the mean while.

Many of the issues that prevent interactive systems from fluently embedding in everyday routines could seemingly be addressed by having computers act autonomously and automatically. For example, if a computer would be aware of the fact that Tim is taking the tomatoes from the refrigerator, it could automatically tell him how many are needed. Or if a computer would see that Tim is cooking, it may decide not to notify him of an unimportant email coming in. This would require no direct interaction from the user and therefore no conscious attention. Though some automation of computing systems could clearly be beneficial, we find it hard to believe that computers could be fully aware of, and flawlessly adapt their behavior to the user's whishes, desires and the nuances of everyday life. Moreover, we think it is desirable for users to remain in control of many of their interactions with computing technology, enabling them to use it to their advantage as much as possible. Peripheral interactions with technology could enable users to remain in control of their interactions, without technology excessively influencing or overwhelming their everyday routine. We believe that this can be achieved by building on human attention and perception abilities, which are gained through interaction with the everyday physical environment. Therefore, peripheral interaction does not necessarily need computers that are more intelligent, but instead it could utilize the intelligence of users to fit upcoming technologies better into their turbulent everyday life routines.

1.5. Physical interaction and auditory display

Peripheral interaction is inspired by the way we interact with our everyday physical environment. As evident from the example of Tim's Friday evening, many everyday peripheral activities involve manipulations of physical artifacts or tools, such as when drinking from a glass or cutting vegetables with a knife. We therefore expect that physical interaction styles, such as tangible or embodied interaction could be suitable for systems that enable peripheral interaction. *Tangible interaction* (Hornecker and Buur, 2006; Mazalek and Hoven, 2009; Shaer and Hornecker, 2009; Ullmer and Ishii, 2000) combines the benefits of both physical and digital worlds through the use of physical artifacts to both represent and control digital data. *Embodied interaction* (Dourish, 2001) overlaps with tangible interaction as it also views tangibility as a key factor in interaction with the physical world. Embodied interaction however takes a broader stance by envisioning meaningful interaction with technology inspired by not only physical but also social phenomena of everyday life.

Although many current interactive systems rely on the visual modality (e.g. screens), we see a lot of potential in audio as a modality for peripheral information display. In everyday situations, audio seems to play a major role in creating awareness of the surroundings. In addition, one does not have to look at the source to perceive auditory information (Gaver, 1993), which enables hearing one thing while being visually focused on something else. We therefore think that *auditory displays* (Kramer, 1994), which use audio (particularly non-speech sounds) during interaction with computing systems, would be a relevant means to communicate peripheral information to potential users.

Though peripheral interaction could potentially be facilitated through various types of interactive systems, this thesis particularly explores physical interaction, auditory display, and a combination of these two styles for peripheral interaction.

1.6. Research objectives

The aim of peripheral interaction is to enable interactive systems to become an integrated, meaningful and fluent part of people's everyday routines, by facilitating interaction to take place in the periphery of attention and shift to the center when relevant or desired. Since current interactive systems are usually interacted with in the center of attention, the first priority of our research was to study how actions and perceptions in the everyday physical world are performed in the periphery of attention. Secondly, we aimed to explore if and how perceptions of and interactions with technology could take place in the periphery of attention. More specifically, our work aimed to answer the following four research questions.

1) When and under which conditions do everyday perceptions and physical actions take place in people's periphery of attention?

2) Can interactive systems be perceived and physically interacted with in people's periphery of attention?

3) Can interactive systems, which are designed for peripheral interaction, become a seamless and meaningful part of people's everyday routines?

4) How can peripheral interaction be characterized and what should be considered when designing and evaluating peripheral interaction?

1.7. Research-through-design approach

We have decided to explore peripheral interaction by conducting research-through-design (Zimmerman et al., 2007), an approach that is also known as action research (Archer, 1995), design-oriented research (Fallman, 2007) or design research (Hoven et al., 2007). The intention of research-through-design is to generate knowledge through a process in which both the act of designing and the act of evaluating designs play an important role. Designs generated in research-through-design processes are founded in theoretical knowledge and aim both to explore implications of this theoretical knowledge in practice (Hoven et al., 2007) and to yield new, generalized knowledge which can add to and steer theory. When developed into prototypes, such designs can be deployed and used by people in a real-life context, in order to evaluate and understand the resulting user behavior or experience (Fallman, 2007). Therefore, methods known in user centered design (Norman, 1998) are applied in research-through-design processes. The knowledge that is gained through the development and deployment of designs is to be generalized, such that it applies not only to the specific design and context in question, but to a larger area of designs or products (Hoven et al., 2007). Different from design practice (e.g. product design), in which user centered design methods are applied in a process that starts from user needs and aims to result in commercially viable products, research-through-design starts with research questions and aims to result in communicable knowledge (Hoven et al., 2007; Zimmerman et al., 2007).

We believe that research-through-design is a suitable method for exploring the concept of peripheral interaction, for two main reasons. First, peripheral interaction is a clear example of theoretical knowledge applied in practice. The phenomena that are associated with attention have been widely explored in psychology theory. Human factors research have also applied this theory, for example to increase the efficiency of specific, high attention-demanding interfaces such as airplane cockpits (Wickens and McCarley, 2008). With peripheral interaction, we are interested in applying attention theory in the design of interactive systems for everyday use. By conducting research-through-design, we aim to translate theoretical knowledge of attention phenomena into design and thereby to explore and evaluate the implications of this theory in practice. Second, peripheral interaction seems to depend highly on the real-life context in which it takes place and on the particular user who experiences it. As stated before, real-life routines and contexts are often turbulent and messy. Such contexts are hard to be accurately modeled or recreated in a controlled setting, as is required for many other approaches to scientific research (Zimmerman et al., 2007). Since research-through-design processes typically involve evaluation of designs in the real context of use (Fallman, 2007), this approach seems particularly suitable when studying topics that are inherently connected to complex everyday life situations (Stolterman, 2008).

In the research-through-design work we conducted, we have developed and evaluated prototype versions of interactive systems intended to explore the concept of peripheral interaction. Since peripheral interaction aims to enable interactive systems to fluently embed in people's everyday routines, our prototypes were evaluated in the real context of use and for a number of weeks. In order to study peripheral interaction in a specific context, we chose to develop some of these prototypes for the target group of primary school teachers. Despite this specific context and, in some cases, specific functionality, the designs and prototypes we present in this thesis are not finished products. Rather, they are research tools aimed to study peripheral interaction and answer our research questions. The knowledge gained in our research-through-design processes is to be generalized to the overall area of interactive systems for everyday use.

1.8. Thesis outline

Figure 1.1 provides a visual overview of the structure of this thesis, which is divided into three sections, each containing two or three chapters. Throughout these chapters, we will summarize the important insights we gain about peripheral interaction in grey text boxes, such as the one below. These insights do not necessarily present novel findings but rather they present findings that served as a ground for later research. These insights are therefore numbered and referred to in later chapters.

> These grey text boxes will summarize the important insights gained regarding peripheral interaction.

SECTION I ANALYSIS

In Section I of this thesis we explore people's peripheral actions and perceptions in everyday (non-technological) contexts. In Chapter 2, we review psychology literature on attention. Based on these attention theories, we formulate and illustrate our understanding of the center and periphery of attention.

In Chapter 3, we explore how peripheral actions and perceptions take place in everyday practice. We present a qualitative contextmapping study on how people 'use' their periphery of attention in their everyday routines in the home environment. This study led to a large number of everyday examples of peripheral actions and perceptions and gave insight into the conditions under which activities may shift between the center and periphery of attention. The contextmapping study furthermore revealed that auditory perceptions and physical actions with the hands play a major role in the everyday periphery of attention.

Chapter 1
Introduction

Background, motivation and outline.

Section I Analysis

Chapter 2
A review of attention theory

Chapter 3
Qualitatively exploring the everyday periphery

Research question addressed:

(1) When and under which conditions do everyday perceptions and physical actions take place in people's periphery of attention?

Section II Design, deployment and evaluation

Chapter 4
Related research and design

Chapter 5
Exploring peripheral interaction designs

Chapter 6
Designing and deploying FireFlies

Research questions addressed:

(2) Can interactive systems be perceived and physically interacted with in people's periphery of attention?

(3) Can interactive systems, which are designed for peripheral interaction, become a seamless and meaningful part of people's everyday routines?

Section III Reflection and generalization

Chapter 7
Six considerations for peripheral interaction

Chapter 8
Conclusions

Research question addressed:

(4) How can peripheral interaction be characterized and what should be considered when designing and evaluating peripheral interaction?

Figure 1.1. Visual overview of the structure of this thesis.

SECTION II DESIGN, DEPLOYMENT AND EVALUATION

Section II addresses design and evaluation of interactive systems developed for peripheral interaction. We start this section by providing an overview of related work on interactive systems that employ people's periphery of attention, in Chapter 4.

In Chapter 5, we present our first design iterations which aimed to translate the insights gained in Section I into meaningful interactions with technology. Five interactive systems are presented, each developed as research tools to explore perception of or physical interaction with computing technology in the periphery of attention. These five interactive systems were qualitatively evaluated for two to three weeks in the context of use: three of them in an office context and two of them in a primary school classroom context. As a result, we concluded that the perceptions of auditory displays seemed to shift to user's periphery of attention, while this was not the case for the physical interactions.

Chapter 6 presents our final research-through-design cycle, in which a design called FireFlies was developed and studied. The FireFlies design, which builds on the insights gained in Chapter 5, was deployed in the context of a classroom for six weeks. Interviews and video analyses revealed that the physical interactions performed with the FireFlies interactive device indeed seemed to shift to the teachers' periphery of attention. Furthermore, we concluded that FireFlies became a part of the everyday routine in the participating classrooms.

SECTION III REFLECTION AND GENERALIZATION

Section III aims to generalize the findings of the studies presented in earlier sections and discusses the contributions of this research to the field of interaction design for everyday interactive systems. In Chapter 7, we argue that this area could benefit from the insight that interaction with technology may take place in the periphery of attention and that this may support the integration of such technologies in people's everyday routines. We present six considerations which can support interaction design researchers and practitioners in order to anticipate and facilitate peripheral interaction with their designs.

Finally, Chapter 8 reflects on the research presented in this thesis. We revisit our research questions and present conclusions and future directions.

Section I
Analysis

Chapters 2 & 3

2.

A review of attention theory

Abstract

This thesis explores the concept of peripheral interaction: interaction with dedicated technology that can be performed in the periphery of attention, but that can also shift to the center of attention when this is relevant. In order to study such interactive systems, a detailed understanding of human attention abilities is important. This chapter therefore provides an extensive theoretical background of attention theory, as a result of which we have defined attention as the division of mental resources over potential activities. Furthermore, we have described the center of attention as the one activity to which most resources are allocated and the periphery of attention as all remaining potential activities. We conclude the chapter with specific insights gained from this theoretical overview, which are relevant when designing for peripheral interaction.

This chapter is based on:

Bakker, S., Hoven, E. van den, and Eggen, B. (2010). Design for the Periphery. In Proceedings of the Eurohaptics 2010 Symposium on Haptic and Audio-Visual Stimuli: Enhancing Experiences and Interaction (pp. 71–80).

2.1. Introduction to this chapter

In everyday life, several sensorial stimuli can be perceived without consciously thinking about it. Furthermore, various everyday physical activities are performed outside our focus of attention. For example, we are aware of what the weather is like or what time of the day it is, without actively needing to think about it. Also we can tie our shoelaces, wash our hands or walk our usual route home without focusing attention on these activities. These perceptions and actions take place in the background or *periphery* of attention, while they may easily shift to the center of attention when they become relevant. This thesis explores the concept of *peripheral interaction*; interaction with technology designed to enable it to easily shift between the center and periphery of attention. We believe that, when leveraging everyday human attention abilities in interaction, computing technology may better fit into our everyday routines.

Since the second half of the twentieth century, several theories of human attention skills have been developed. Though developed to gain insight into human capabilities from a psychological or neuro-scientific point of view, these theories also provide valuable insights for designers and researchers in the area of interactive systems which leverage these skills in interaction. Currently, only few related studies (e.g. (Matthews et al., 2004)) are grounded in theory on human attention abilities. This chapter, therefore, aims at laying a basis for research-through-design on peripheral interaction, by providing an extensive theoretical background on attention theory and by concluding with a working definition of the center and periphery of attention.

2.2. Attention theory

During the 19th century, James (1890) stated that “everyone knows what attention is” (James, 1890, p. 403), referring to the many different ways the word ‘attention’ is used in everyday situations. Attention can be devoted to stimuli that we perceive through our senses, but also to action or thought processes. The world around us is constantly full of stimuli that we can potentially attend to. Furthermore, many interactions with the physical world and various thought processes are usually available to us. As “we cannot fully appreciate all that takes place at any one time” (Norman, 1976, p. 6), a process of selective allocation of attention is needed. As a result of this process, attended stimuli or performed actions or thoughts will always be just a small fraction of all available options (Wrigley, 2002).

Throughout the past decades, several models of this process of attention management have been developed in the areas of cognitive psychology and neuropsychology. Although several different functions of attention are distinguished in literature, the two most important functions described are selective attention and divided attention (Pashler, 1998; Sternberg, 1999; Wickens and McCarley, 2008). *Selective attention* is the process of selectively focusing ones attention on one stimulus while intentionally ignoring others (Sternberg, 1999). Models of selective attention therefore describe attention by analogy with a mental filter (Wickens and McCarley, 2008) that selects certain stimuli to attend to and rejects others. Such models are therefore often referred to as filter-models. *Divided attention* is the process in which we carefully divide mental resources over multiple attentional tasks at once (Sternberg, 1999), e.g. when multitasking (Wickens and McCarley, 2008). Models of divided attention therefore see attention as a finite amount of mental resources that can be divided over several sensorial or cognitive processes. Although these two functions of attention may not be mutually exclusive, we will first separately review literature on both functions. Subsequently, we will present a model that captures our current understanding of the theory that can be used to inform design and research in the area of peripheral interaction.

2.2.1. Selective attention

Selective attention theories usually only concern sensorial attention (Pashler, 1998) and are often grounded in research on speech perception (Broadbent, 1958; Moray, 1959; Treisman, 1964). In almost any given situation, several stimuli of multiple modalities will reach our senses simultaneously. Literature on attention (Wickens and Hollands, 2000; Wrigley, 2002) however suggests that these stimuli are processed before mechanisms of selective attention take place. This processing, for example, enables us to distinguish our friend's voice from the voice of a passerby. In psychoacoustics this is called *auditory scene analysis* (Bregman, 1990), which takes place when incoming signals are grouped into different streams based on the likelihood of them coming from the same source. Stimuli in other modalities are expected to be processed in a similar manner (Bregman, 1990). The attention theories we describe in this section assume that incoming stimuli have been grouped into streams, and that one can attend to these streams rather than to individual stimuli.

Selective attention theories describe attention as a mental filter. Influential early work by Cherry (1953) forms the basis of a series of theories of selective attention (Norman, 1976). Cherry's experiments addressed the problem of selective attention, which he called "the cocktail party problem" referring to the situation at a cocktail party where one stands in a room full of sounds and is able to focus attention on a single conversation (Sternberg, 1999). Cherry presented subjects with two spoken messages simultaneously and instructed them to attend to one message by directly repeating, or *shadowing* it. The other message had to be ignored, and is referred to as the rejected message. As a result, Cherry found that subjects were able to almost entirely separate the two messages. Furthermore, the subjects did not remember any words mentioned in the rejected message. They could only recall that another message was present. Many researchers performed experiments similar to the ones performed by Cherry (1953), which lead to a series of theories of the cognitive mechanisms behind selective attention. We will now discuss three such theories, which are widely referred to in psychology literature (e.g. (Pashler, 1998; Styles, 1997)); *early selection theory*, *late selection theory* and *attenuation theory*.

EARLY SELECTION THEORY

Early selection theories suggest the existence of a limited capacity channel in the perceptual process that is only capable of handling one perceptual stream at a time (Pashler, 1998). The first well-known early selection theory was proposed by Broadbent (1958), who suggested that a selective filter in the brain allows only one channel of information to pass and rejects others. One stream is selected based on the subjective attributes of sound (e.g. pitch, volume). As became clear from Cherry's experiments, words in the rejected messages are not remembered. Broadbent's model (Broadbent, 1958) therefore assumes that the meaning of words is extracted after one stream has been selected (Norman, 1976). The selection thus takes place early in the process, see Figure 2.1.A.

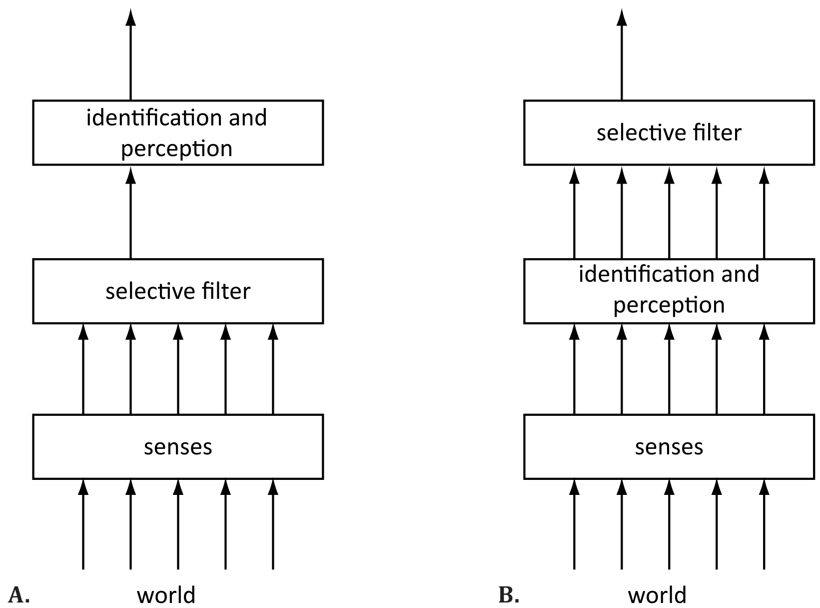


Figure 2.1. Simplified illustration of an early selection model (A), adapted from (Sternberg, 1999, p. 94), and of a late selection model (B), adapted from (Sternberg, 1999, p. 96).

LATE SELECTION THEORY

In shadowing experiments similar to the ones performed by Cherry (1953), Moray (1959) showed that words that are important to the person in question (e.g. one's own name) are consciously noticed when present in a rejected stream (Norman, 1976). Counter to early-selection theory, this shows that the meaning of at least some words must be extracted before one channel is selected. Based on such evidence, an alternative theory was proposed by Deutsch and Deutsch (1963), who suggested that the selection of attention occurs later in the process, at a moment in which the meaning of all incoming streams has been identified (Norman, 1976; Sternberg, 1999), see Figure 2.1.B. This late selection theory proposes that the identification process happens involuntarily and below the level of awareness.

ATTENUATION THEORY

Around the same time Deutsch and Deutsch (1963) proposed their late-selection theory, Treisman (1964) found that listeners did notice words of the message in the rejected channel when these words were related to the information in the attended channel (Norman, 1976). Given the results of her experiments, Treisman (1964) suggests that the selection process is among other things influenced by the relevance of the information in the incoming channels. She suggests that this happens through activations of detector units for related concepts. This process is called *priming*. Based on the content of the information in the attended channel, related concepts are primed and therefore the threshold for identifying them is lowered. For example, when having a conversation about a concert, related words such as the location or performing artist, or words that belong to the same semantic category (Meyer and Schvaneveldt, 1971) such as 'performance' or 'show', may be primed. When a passerby says any of these words, one is more likely to recognize them and attend to this channel than when words with a less relevant meaning are heard.

Different from late-selection theories, Treisman proposes that the meaning of words in rejected channels is not identified before reaching the selective filter. Counter to early-selection theories however, Treisman (1964) proposes a filter that attenuates unattended channels rather than completely blocking them. This way, a weakened version of these unattended channels is passed on (Sternberg, 1999). Given the lower threshold for detecting primed stimuli, even an attenuated version of them is enough to be recognized and attended to. The idea of priming could also explain Moray's (1959) finding showing that listeners tend to notice their own name in rejected channels; detectors for one's own name are primed, see Figure 2.2.

The process of priming was already noticed by James (1890), who referred to it as preperception. He illustrated this phenomenon by giving the following example.

“If I have received an insult, I may not be actively thinking of it all the time, yet the thought of it is in such a state of heightened irritability, that the place where I received it or the man who inflicted it cannot be mentioned in my hearing without my attention bounding, as it were, in that direction, as the imagination of the whole transaction revives” (James, 1890, p. 449). In other words, we may not only be primed for topics related to our current attentional focus or for stimuli that are generally relevant to us (such as our own name), we may also be primed for topics that are ‘in the back of our minds’ for other reasons.

Knudsen (2007), who recently investigated attention in terms of neurobiological components, mentions ‘top-down sensitivity control’ as one of the processes fundamental to attention. Though describing a neurobiological phenomenon, this is rather similar to Treisman’s idea of priming. The process of top-down sensitivity control increases the sensitivity of neural representations of attended information, which increases the chances of high signal strength at these representations. Knudsen (2007) furthermore describes a ‘bottom-up salience filter’. Stimuli with high *salience*, such as a loud noise, a sudden flash of light or a sudden movement, will pass this filter and can be attended. Where priming lowers the threshold for stimuli to be perceived based on their meaning and personal relevance, salience

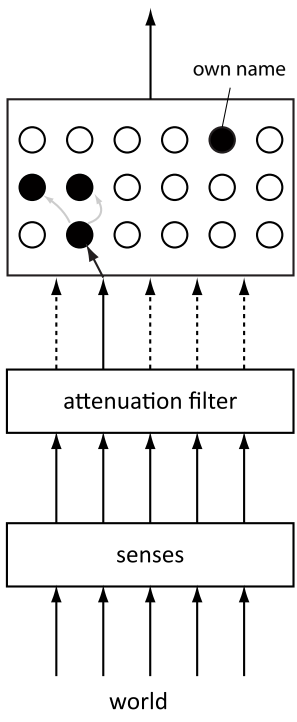


Figure 2.2. Illustration of an attenuation model, adapted from (Styles, 1997, p. 25). Representations of words in memory are illustrated by circles. Primed words, that have a lower threshold for being recognized, are illustrated by black circles.

enables stimuli to pass the filter as a result of their physical properties rather than their meaning.

Most psychology literature that summarize attention theory address both early and late selection theories (e.g. (Pashler, 1998; Styles, 1997)). However, early selection theories cannot explain why relevant words in rejected channels are recognized. The amount of processing required to identify all incoming information in late selection theory on the other hand, does also not seem likely as most of the information is never used. Therefore, attenuation theory is often seen as the most plausible explanation of results of shadowing experiments (Pashler, 1998; Styles, 1997).

2.2.2. Divided attention

As mentioned before, theories of selective attention usually only concern attention devoted to sensorial stimuli. Furthermore, most previously mentioned theories are grounded in research on the auditory modality only. Taking a broader approach, divided attention theories explain how we can perform multiple attentional tasks at once. These tasks may involve perceptions, physical actions and thought processes and may include multiple modalities. Divided attention theories describe attention as the division of a limited amount of mental resources over different activities (Sternberg, 1999).

DIVISION OF MENTAL RESOURCES

A theory of divided attention proposed by Kahneman (1973), suggests that a limited amount of mental resources are available. Kahneman's model centers around a number of possible activities that one can perform as a result of sensorial or intellectual information input. However, these *potential activities* can only be carried out when mental resources are allocated to them.

The amount of mental effort, and thus the amount of mental resources, needed for an activity decreases with practice and experience (Wickens and McCarley, 2008). For example when learning how to walk, the activity of walking requires a lot of mental effort and cannot be performed simultaneously with other activities. However, when we get more experienced, less effort is required and more activities can be done simultaneously. Highly trained processes such as walking require hardly any resources and are therefore called *automated processes*. Such processes need little mental effort, involve no conscious control and many of these processes can be performed in parallel. On the contrary, *controlled processes* are processes that always require conscious control (such as reading a book). Only one controlled task can be performed at once. A controlled process may become an automated process as one gets more experienced in performing it.

HABITS AND GOALS

Related to the concept of automated processes, are the terms *habit* and *habitual behavior*. As stated by Aarts and Dijksterhuis (2000), habits are “a form of goal-directed automatic behavior” (Aarts and Dijksterhuis, 2000, p. 55) and are “mentally represented as associations between goals and actions” (Aarts and Dijksterhuis, 2000, p. 53). The strength of the association between goal and action is enhanced when it is performed more frequently, and when it always occurred in a consistent situation. Behavior can become habitual when performed frequently in the past to achieve the associated goal in a satisfactory manner. When a goal is (consciously or subconsciously) activated, the associated habitual behavior is automatically and immediately activated and thus performed with a low amount of mental resources. For example, when somebody always goes to university by bike, that person may automatically (without focused attention) walk to the shed to take the bike when deciding to go to university. It is even stated that, once behavior has become habituated, it is often performed directly in response to the context (Wood and Neal, 2007) . For example, when somebody always goes to university on weekdays after breakfast, being in the context of a weekday after breakfast may automatically initiate the goal ‘going to university’. As a result, the associated habituated activity (e.g. getting the bike) may be performed, even when that person was not planning to go to university. This is similar to skill-based behavior (Rasmussen, 1983), which describes actions that are, as a result of practice, automatically initiated in response to the perception of certain stimuli. Habits and skill-based behavior should not be confused with tics, which are “brief, suppressible, nonrhythmic, stereotyped abnormal movements” (Black, 2010, p. 231), such as repetitively blinking the eyes.

As becomes clear from these theories, habitual behavior (which is automatically performed outside the focus of attention) origins in goal-directed behavior. Behavior will only become habitual when it is goal-directed and when performed frequently.

SUPERVISORY ATTENTIONAL SYSTEM

Certain activities may, at certain moments, be more likely to be performed compared to others. Shallice and Burgess (1993) discuss attention mechanisms for controlling action and thought. They discuss the ‘Norman-Shallice model’, which assumes schemata of action or thought processes in long term memory, that can be activated (Styles, 1997). The model suggests that the selection of which schemata are activated involves a mechanism called the *supervisory attentional system* (Shallice and Burgess, 1993). The supervisory attentional system is in charge of top-down exciting schemata of actions which increases the probability of these actions being performed (Styles, 1997), similar to the earlier discussed principle of *priming* (Treisman, 1964).

MULTIPLE RESOURCE THEORY

Apart from their likelihood of being performed, certain activities may also be more suitable to be performed at certain moments. This relates to the *multiple resource theory* (Wickens and McCarley, 2008), which describes the influence of the type of activities on people's ability to perform them simultaneously. For example, it is rather difficult to drive a car and read a book at the same time, but driving while listening to the same book on tape is possible. As described by multiple resource theory (Wickens and McCarley, 2008), bodily activities are more easily performed simultaneous to sensorial activities compared to performing two bodily activities at the same time. Mental resources can therefore not arbitrarily be divided over activities, but the division depends on the types of activities.

ATTENTION AND AROUSAL

In his model of divided attention, Kahneman (1973) suggests a link between arousal and attention. The more aroused we are, the narrower our focus of attention will be. This means that as arousal increases, attention to controlled processes increases, but also implies that attention to automated processed decreases. For example, when we are highly engaged while reading a book, we may not notice any other streams of information, even when highly relevant information is present such as our own name. Another example: normally we are able to read (controlled process) and walk (automated process) at the same time, but when the reading task either requires deep thought or causes high levels of arousal, we will often stop walking to focus on the reading (Norman, 1976).

2.3. Our understanding of human attention abilities

The purpose of this theoretical overview is to gain a better understanding of human attentional processes and abilities in order to inform design for peripheral interaction. Such designs are interactive systems that leverage these abilities so that interactions can take place in the user's periphery of attention, while they may shift to the center of attention when they become relevant. For this purpose, we have created an illustrative overview of the parts of the attentional process that we think are important in everyday life situations, see Figure 2.3. This overview is primarily meant to structure our own understanding of the process and is based on the above-mentioned literature.

We have seen that one may attend to sensorial stimuli, physical actions, or thought processes. In many everyday situations however, an attentional activity may involve perception, action and cognitive processes. For example when in a conversation, one will attend to sensorial streams (e.g. listening to conversational partners, looking at their facial expressions), engage in physical actions (e.g.

gesturing) as well as require cognitive processes (e.g. speaking, recalling information from memory). In line with theories of divided attention, we will therefore not refer to streams that can be attended, but to *potential activities* which may consist of several kinds of actions and involve multiple modalities. At any given moment in time, there will be multiple potential activities that we can attend to. These potential activities emerge from sensorial stimuli (e.g. hearing music makes the activity of listening to this music available or hearing a passerby speaking about politics may elicit potential thought processes about this subject) or from intellectual processes (e.g. planning to go call a friend or planning to take a shower). These potential activities form the center of the overview in Figure 2.3 and are represented by vertical bars of varying height and brightness. To keep the overview clear, Figure 2.3 only illustrates ten potential activities, however at any moment many more will be possible.

Obviously, not all these potential activities can be performed at the same time. As suggested by divided attention theory, mental resources have to be divided over these potential activities and only the ones to which resources are allocated will be performed. The height of the different bars indicates the resource demand of the activity, which is the amount of resources needed to perform the task. The brightness of the bars indicates the likelihood of resources being allocated to that specific activity. The darker the bar, the more likely the activity is to receive resources. This likelihood is influenced by a person's own intentions (consciously deciding which activity to undertake), as well as by (subconscious top-down) mechanisms such as *priming* and the *supervisory attentional system*. As a result of these latter mechanisms, certain activities are more likely to receive mental resources, because they are generally relevant to us (e.g. hearing our own name in a distant conversation), because they relate to our current context (e.g. automatically taking your bike in the context in which you usually go to the university by bike), or because they relate to things that are 'in the back of our minds' (e.g. hearing a word related to the current conversation, or related to a topic that is on your mind for other reasons).

We discussed theories of both selective and divided attention proposed in literature. The difference between these two functions of attention is not straightforward. As a matter of fact, both selectivity and resource allocation characterize the attentional process (Shallice and Burgess, 1993). Selectivity primarily seems to play a role when attention is devoted to perception of sensorial stimuli, whereas perception, physical actions and thought processes involve resource allocation. We therefore suggest that the attentional process does involve a selective filter, but we define attention as the allocation of resources to one or more potential activities. In line with Treisman's attenuation theory, the filter illustrated in Figure 2.3 attenuates unattended incoming stimuli, illustrated

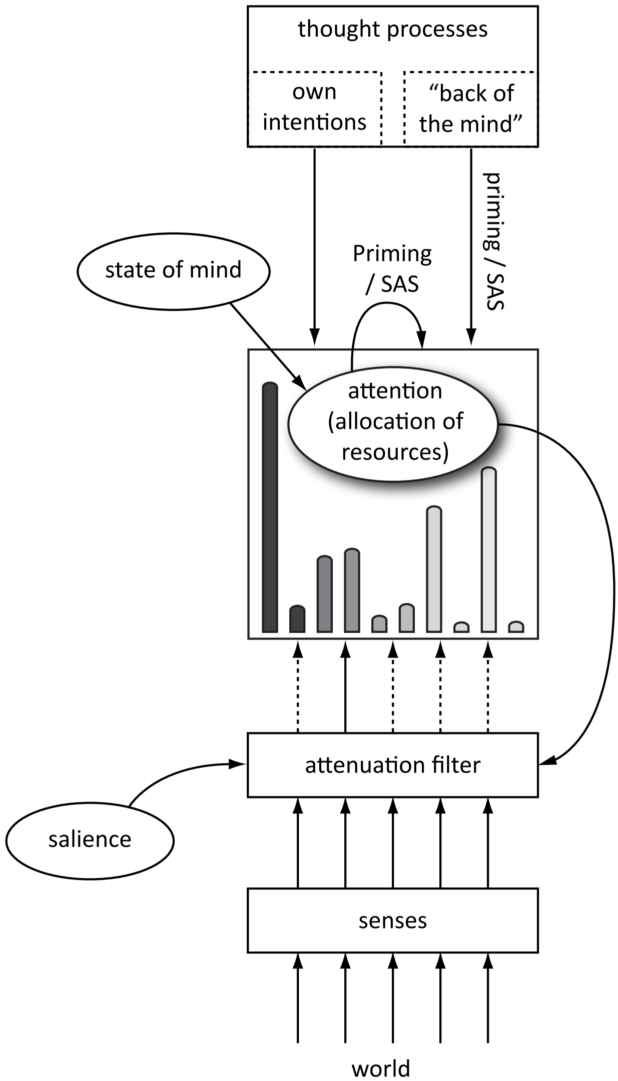


Figure 2.3. Illustrative overview of the attentional process, involving the influences of own intentions, priming, the supervisory attentional system (SAS), state of mind (e.g. arousal), salience and the attenuation filter on the availability of potential activities (illustrated as vertical bars) and on the allocation of mental recourses to these activities, aimed to structure our understanding of this process to inform and support design for peripheral interaction.

as dotted arrows. This filter is influenced by the *salience* of incoming stimuli, for example a loud noise will pass the filter without attenuation.

The division of resources further depends on the state of mind of the individual, such as the level of arousal. Figure 2.4 illustrates examples of the division of resources in two different situations. In these overviews, mental resources are illustrated by white circles. In a situation in which one is highly engaged in reading a book, all mental resources are allocated to this activity and no other activities can be performed (Figure 2.4.A). A more frequently occurring everyday situation is illustrated in Figure 2.4.B. In this situation, somebody's main activity is preparing dinner, but at the same time this person is listening to the radio and monitoring the progress of the dishwasher. The other listed potential activities do not receive resources and are thus not performed. As illustrated in Figure 2.4.B, not all resources are used in this situation. At any moment one may (consciously) decide to call a friend or (subconsciously) be attracted to the sound of the radio as one's name is suddenly heard in that stream. This would change both the resource demand of some activities (e.g. carefully listening to the radio requires more resources than using it as background audio) and the likelihood that certain activities are selected (e.g. the activity of listening to the radio becomes more likely to be performed when a primed stimulus such as one's own name is heard on the radio). This illustrates that the process of dividing resources over potential activities is highly dynamic and may in fact be at no moment a static overview.

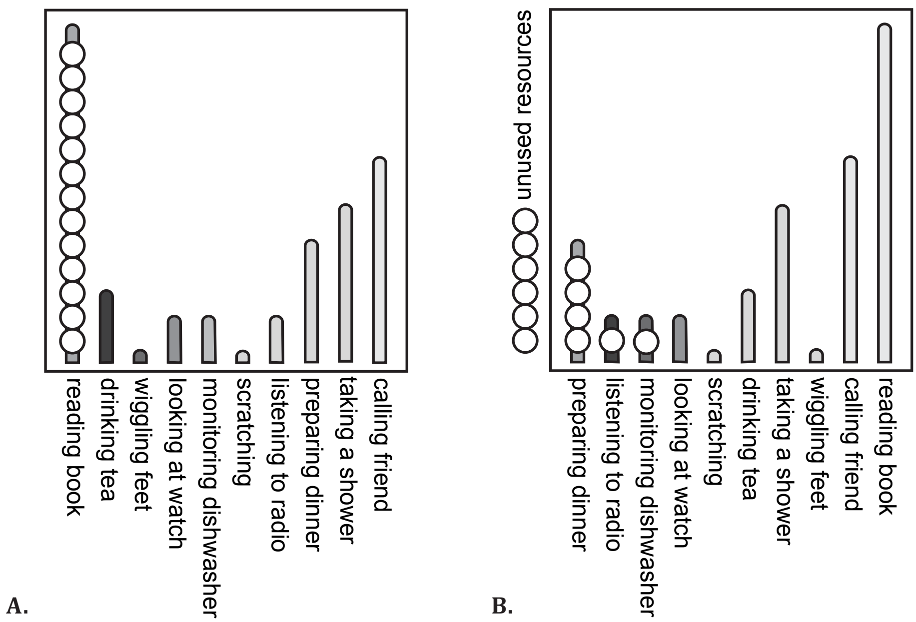


Figure 2.4. Division of resources over potential activities in two situations: a high attentional task, reading a book (A) and a combination of low attentional tasks (B).

2.4. Center and periphery of attention

In the previous section, we have presented an overview of our understanding of the attentional process, which may be useful for design for peripheral interaction. This means, the design of systems that can be perceived or interacted with in our periphery of attention, but also be focused on in the center of attention when relevant. However, to inform design and research in this area, it is essential to define what we mean by *center* and *periphery* of attention.

OUR UNDERSTANDING OF THE CENTER AND PERIPHERY OF ATTENTION

In psychology literature reporting on attention (Wickens and Hollands, 2000; Wickens and McCarley, 2008), the word periphery, which literally means external boundary or outward boundary[1], is generally used in the context of visual perception. In that area, the concept of peripheral vision refers to the parts of vision that occur outside the center of the visual field (Wickens and Hollands, 2000). Vision in the center of the visual field is referred to as central or foveal vision (Wickens and Hollands, 2000). Although many designs intended to be perceived in the periphery of attention use visual displays, for example *peripheral displays* (Matthews et al., 2004), authors in the area of ubiquitous computing often use the term 'periphery' in a broader context. Brown and Duguid (1996) describe how media contain peripheral cues that "subtly direct users along particular interpretive paths by invoking social and cultural understandings" (Brown and Duguid, 1996, p. 131). These cues help us shape our expectations of the content. For example, by the cover, paper and typeface of a book we can determine if it is a novel or a study book. A little broader, Weiser and Brown (1997) use the word periphery to name "what we are attuned to without attending to explicitly" (Weiser and Brown, 1997, p. 79). Although this definition involves multiple modalities, it is not yet very explicit. We consider a more explicit definition of the word periphery important to inform research-through-design processes.

Since we describe attention as the division of resources over potential activities, we will explain the center and periphery of attention in the same context, which is illustrated in Figure 2.5. What we see as the center of attention is the one activity to which most mental resources are allocated. In the situation illustrated in Figure 2.5.A, the center of attention is the activity of reading a book, while Figure 2.5.B illustrates preparing dinner as the center of attention. The periphery of attention consists of all potential activities that are not in the center, regardless of the number of resources being allocated to them. For example, in both situations illustrated in Figure 2.5, the activity of listening to the radio is in the periphery of attention, while in situation 2.5.A it is not performed and in situation 2.5.B it is performed, be it with only a low amount of resources. However, the activity of listening to the

[1] *http://www.merriam-webster.com, last accessed 25-04-2013*

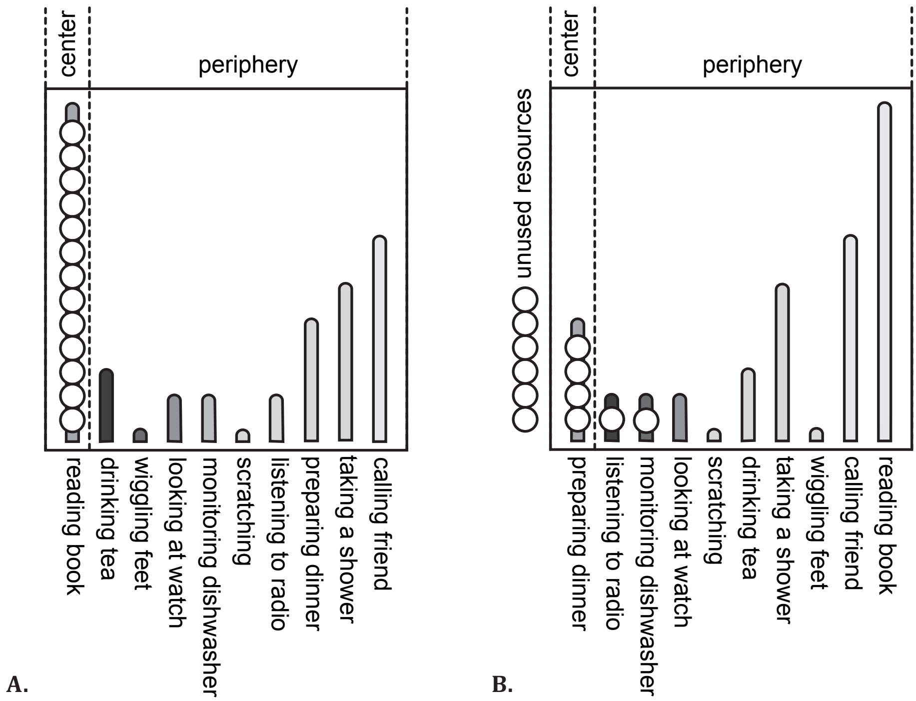


Figure 2.5. Illustration of the center and periphery of attention in two situations. a high attentional task, reading a book (A) and a combination of low attentional tasks, in which not all available resources are used (B).

radio is closer to the center in Figure 2.5.B compared to Figure2.5.A, which means that it is more likely to shift to the center of attention. As mentioned before, the attentional process is highly dynamic; the resource demand, likelihood of being selected and 'proximity to the center' of each potential activity (represented by respectively height, brightness and location of each vertical bar) are subject to constant change. For example when driving a car and having a conversation with a passenger simultaneously, both the activity of driving and the conversation will constantly move between the center and the periphery of attention.

CENTER AND PERIPHERY IN LIGHT OF ACTIVITY THEORY

In line with theories of divided attention (Kahneman, 1973), the illustrations in Figures 2.3, 2.4 and 2.5 center around a number of 'potential activities' that one may devote attention to. To make our understanding of the center and periphery of attention more explicit however, it is important to define what we mean by an *activity*. Activity theory (Kuutti, 1997) distinguishes three hierarchical levels of an activity. The highest level is the *activity* itself, which is directed towards a *motive*. For example the activity of preparing dinner, may be directed toward the motive of having dinner. As defined by activity theory, activities are realized as *actions*, which are directed at *goals*. For example cutting meat can be an action that is needed for the activity of preparing dinner, and may serve the goal of having meat in certain portions. The lowest level of an activity consists of *operations*, such as moving the knife when cutting the meat. Operations are "well-defined habitual routines used as answers to conditions faced during the performing of the action" (Kuutti, 1997, p. 31). In other words, operations are performed outside the focus of attention, and initiated automatically in response to the context, similar to earlier discussed habitual behavior (Aarts and Dijksterhuis, 2000; Wood and Neal, 2007). For example, when cutting meat, one's attention may be focused on the size of the portions, rather than on the operation of moving the knife itself.

The vertical bars presented in Figures 2.3, 2.4 and 2.5, could be interpreted as *activities*, *actions* or *operations*. For our understanding of the center and periphery of attention, we have depicted the bars on the level of *activities*. For example, the *activity* of preparing dinner is depicted as a bar rather than the separate *actions* or *operations* that are required for this activity such as cutting meat, cleaning vegetables, moving the knife or stirring a sauce. In the example of cutting meat while focusing on the size of the portions, the *operation* of moving the knife may be performed while the main focus of attention is on *action* of judging the size of portions. Since both this operation and action are related to the same *activity* (preparing dinner), this activity is in the center of attention, even though the operation of moving the knife requires only few mental resources. In another situation, the operation of stirring a sauce may be performed, while one's attention is focused on the news on the radio. In this scenario, the *activity* of listening to the radio is in the center of attention while the *operation* of stirring in the sauce is also being performed. In that case the activity of preparing dinner has therefore moved to the periphery of attention.

2.5. Insights gained regarding design for peripheral interaction

As a result of the theoretical overview provided in this chapter, we have defined attention as the division of mental resources over potential activities. Furthermore, we have described the center of attention as the one activity to which most resources are allocated and the periphery of attention as all remaining potential activities. Most current interaction with technology takes place in the center of attention: mobile phones, laptops and touch screens are all designed to be operated with focused attention. As interaction with the physical world often takes place outside the center of attention, we see major opportunities for leveraging the above described human attention abilities in interaction with technology. This is what we refer to as *peripheral interaction*. Most related research-through-design work explores the design of information displays that are intended to be *perceived* in the periphery of attention (Ishii et al., 1998; Matthews et al., 2004; Mynatt et al., 1998; Pousman and Stasko, 2006). However, as evident from the literature reviewed in this chapter, *physical actions* may also be performed in the periphery of attention, for example tying your shoelaces while watching TV. In this thesis, we therefore address design for peripheral interaction through a *combination* of perception and physical action that may take place in the periphery of attention. We will now address the particular insights we gained regarding design for peripheral interaction, as a result of the literature review presented in this chapter.

Given our definition of the center and periphery of attention, as presented in Figure 2.5, activities can be performed in the periphery, when a more demanding activity is simultaneously being performed in the center of attention. Furthermore, it is important that this central activity does not require all mental resources, as that would leave no room for activities being performed in the periphery.

Insight 1. An activity can be performed in the periphery of attention when another activity is being performed simultaneously in the center of attention, which requires more but not all mental resources.

As evident from divided attention theory, physical actions can be performed simultaneously, provided that they are automated or habituated. This entails that these actions have been trained extensively in a consistent context and that they are directed towards a clear goal.

Insight 2. A physical action can become *habituated* and thereby be performed in the periphery of attention, when the action has a clear goal, and when it has frequently been performed in the past in a consistent context.

The value of peripheral interaction primarily lies in the idea that potential activities (related to interactive technology) can reside and be performed in the periphery of attention, where they hardly require resources. However, when such an activity becomes relevant to the user, it may shift to the center of attention and intentionally be performed. By relevant, we mean that it becomes valuable or sometimes even crucial for the user to focus attention on the activity, which can be a result of various influences such as the user's interests, context, future plans or state of mind. For example, information about the weather is in most everyday situations perceived in the periphery of attention. However, when one is about to go for a walk, this information is more relevant and may shift to the center of attention. Similarly, everyday physical activities such as washing your hands, may be performed in the periphery (e.g. when washing your hands as part of the routine related to preparing dinner), but also in the center of attention (e.g. when you have paint on your hands and are focused on getting all the paint off). Such shifts between the center and periphery of attention are crucial for design for peripheral interaction: though named *peripheral* interaction, interactions with such designs may of course be performed in the center of attention when this is relevant for the user. In design for peripheral interaction, it is therefore important to think about how these intended shifts may be facilitated. A principle that may be drawn upon is that of *salience*, e.g. by presenting perceptual information in a salient way (such as through loud noise or suddenly moving objects), ensuring that it is immediately noticed. Drawing upon salience, however, would not contribute to technology being calm and unobtrusive. More interesting principles to draw upon would be the mechanisms of *priming* and the *supervisory attentional system*, which lower the threshold for perception of relevant stimuli (priming) or for relevant actions being performed (supervisory attentional system). Different from salience, these latter principles originate in the user's personal interests and state of mind, and (in the case of priming) ensure that stimuli attract the attention because of their meaning rather than because of their physical properties.

Insight 3. Activities can shift from the periphery to the center of the attention as a result of *salience* or *priming* of a perceptual stimulus, or as a result of the *supervisory attention system*.

2.6. Conclusions

In this chapter, we have given an overview of attention theory. We have described our understanding of the human attentional process, and defined the center and periphery of attention. Furthermore, relevant insights for design for peripheral interaction, which we see as a valuable approach for fitting new technologies into everyday life, have been discussed. We now have a detailed theoretical understanding of human attention abilities, which lays a basis for future research-through-design work in this area. In the next chapter, we present a contextmapping study in which we explore how people use their center and periphery of attention in everyday life situations.

3.

Qualitatively exploring the everyday periphery

Abstract

Interactions in and with the physical world have enabled us to perceive everyday stimuli and perform everyday activities in our periphery of attention. We think that interactive systems inspired by our peripheral interactions with the physical world, will enable digital technologies to better blend into our everyday lives. Although psychological theories have provided valuable insights in the cognitive mechanisms that underlie the human attention process, we believe that in order to inform design and research in the area of peripheral interaction for the everyday context, it is also important to gain extensive examples of how the periphery of attention is 'used' in everyday life settings. This chapter therefore presents a qualitative study on everyday perceptions and activities that may shift between the center and periphery of attention. The focus on this study is on perceptions and interactions in and with the physical world rather than with computing devices. We provide a broad range of examples of such everyday perceptions and activities and cluster them to present the conditions under which they may take place in the periphery of attention. Furthermore, we discuss how our findings may be relevant for peripheral interaction design and research.

This chapter is based on:

Bakker, S., Hoven, E. van den, and Eggen, B. (2012). Knowing by ear: leveraging human attention abilities in interaction design. Journal on Multimodal User Interfaces, 5(3), 197–209.

Bakker, S., Hoven, E. van den, and Eggen, B. (2012). Acting by hand: Informing interaction design for the periphery of people's attention. Interacting with Computers, 24(3), 119–130.

3.1. Introduction to this chapter

Today, we see that digital technologies are being integrated in everyday environments. These developments have led to wide discussions on how the computer of the future can fit into everyday life in the physical world. To address this challenge, this thesis proposes to design for *peripheral interaction*: interactive systems, which are designed such that users can interact with them in their periphery of attention, while this interaction may also shift to their center of attention when it becomes relevant. Peripheral interaction extends related research and design work (Hazlewood et al., 2011; Matthews et al., 2004; Pousman and Stasko, 2006; Weiser and Brown, 1997) by aiming at both *perception* and *interaction* with interactive systems to take place in the periphery of attention. While most related examples motivate their design choices by referring to everyday perception, hardly any of them support this with extensive experiential data about such interactions. We argue however, that thorough investigation of everyday peripheral perceptions and actions could significantly benefit the design of interactive systems that are to be used in similar ways.

In the previous chapter, we described our theoretical understanding of the attention process, involving the allocation of mental resources to potential (perceptual, bodily or cognitive) activities. This understanding is based on psychology literature, describing controlled experiments in specific settings that usually involve a mixture of high attentional tasks, such as when driving a car or flying an airplane (Wickens and Hollands, 2000; Wickens and McCarley, 2008). In most everyday situations however, the division of resources will be very diverse, including both high and low attentional tasks, and likely not all mental resources will be ‘in use’ at any moment. Next to the theoretical knowledge presented in Chapter 2, it is thus also important to gather more practical knowledge regarding interactions that can take place in the periphery of attention in the everyday context. We therefore set up a qualitative user study on how the periphery of attention is ‘used’ in everyday life.

The main goal of this qualitative study was to gain a broad and rich overview of examples of both everyday *peripheral perceptions* and everyday *peripheral activities* that can be completely or partially performed in the periphery of attention. These examples were intended to provide us with a better understanding of the preconditions that enable events to take place in the periphery of attention. Such understanding will enable us to lay-out and verify the design space for systems that can be interacted with in the user’s periphery of attention.

3.2. Everyday periphery study setup

Most applied research on attention is meant to improve human performance of tasks that require a lot of mental resources (Wickens and Hollands, 2000; Wickens and McCarley, 2008). This seems a valuable approach since the efficiency of performing such tasks may be improved when human attention abilities are leveraged. However, computing technology is increasingly becoming present in our everyday lives, and is not only being used for tasks that require high concentration, but also for less demanding activities. To gain broad insights in the everyday periphery, we have focused the study described in this chapter on the home environment, a context that involves activities of all levels of concentration.

The aim of this research is to study everyday perceptions and actions that can be performed without much attention being devoted to them. Such perceptions and activities could therefore take place in the periphery of attention, but also engage the center of attention at certain moments, e.g. when this is relevant for or desired by the user. As people are by definition not consciously aware of what is happening in their periphery of attention, our goals will not be reached by directly interviewing participants about it. Observation could provide us with an overview of people's activities in the home environment, and give an idea of activities that are performed in parallel, possibly indicating peripheral activities. Although observation may reveal certain information about physical activities, it may not provide reliable data about people's perceptions (e.g. what people are seeing, hearing, smelling). Additionally, the presence of an observer or recording-device in people's homes could intrude their everyday activities in such a way that these activities may become unrealistic. Furthermore, we expected that most interesting data would be gathered from people reflecting upon their own peripheral behavior rather than independent observers interpreting people's behavior. We have therefore decided to use the approach applied in the method 'contextmapping' (Sleeswijk Visser et al., 2005), in which several methods are combined including interviews, discussions, diaries and video-recordings which are reflected on by participants. In contextmapping studies, which are often conducted in design projects that aim at solving a specific problem or improving a specific experience, participants are 'sensitized' for the topic of interest before they are invited to take part in a creative group interview. Using this approach in our study would allow for participants to reflect on the way they 'use' their periphery in everyday situations over a period of time. This reflection period is intended to increase the participant's awareness of their peripheral activities and therefore make it easier to share and discuss this in an interview with a group of participants. Furthermore, the different phases used in contextmapping studies enable us to approach the rather complex topic of our study in several different ways, which may increase the richness of the information we gain about it.

In line with the contextmapping approach (Sleeswijk Visser et al., 2005), our study consisted of two phases; the *sensitizing phase* and the *discussion phase*. Although we naturally had certain expectations about the types of actions or perceptions that are likely to take place in the periphery of attention (e.g. we expected that audio plays an important role in everyday peripheral perception), we intentionally kept our study open to all types of actions and perceptions. For example, we asked “what do you perceive?” rather than “what do you hear?”. In this section we will describe the study design.

PARTICIPANTS

Since we had not yet defined the target group for our future design iterations, we selected a diverse group of participants for our user study. We decided to recruit 13 participants in total, so that we could divide them over three groups that are of suitable size for the discussion phase of our study and leave room for unexpected cancelations. When having only one discussion session, potentially dominant participants could have too much influence on the results (Sleeswijk Visser et al., 2005). We therefore decided to organize three separate sessions in the discussion phase. The 13 participants, none of whom were familiar with the topic of research, differed in age, gender and occupation (see Table 3.1 for an overview). We furthermore took family living situation into account when selecting the participants, as this factor may likely influence the everyday activities people perform in their home environments. For example, the everyday routine of a parent with children living at home will largely differ from a person who lives alone. As evident from Table 3.1, most of the participants were highly educated.

	Gender	Age	Occupation	Family living situation
P01	M	23	Design researcher	Alone
P02	M	25	Mechanics researcher	Partner
P03	F	27	Teacher	Partner
P04	M	29	Teacher	Partner
P05	M	30	Software engineer	Alone
P06	F	31	Project manager	Partner and 1 child (0)
P07	F	34	Housewife	Partner and 3 children (1, 4, 6)
P08	F	35	Student advisor	Partner and 2 children (0, 2)
P09	F	37	Psychologist	Partner and 2 children (9, 10)
P10	F	52	Housewife	Partner and 1 child (16)
P11	M	58	Journalist	Partner
P12	F	58	Hydrology engineer	Partner
P13	M	60	Food engineer	Partner

Table 3.1. Overview of the demographics of the participants in our study.

We saw this as an advantage; they may be used to abstract thinking, which can be helpful in our study and which is regarded to be useful in contextmapping studies (Sleeswijk Visser et al., 2005). Due to personal circumstances, two participants (P07 and P09) could only participate in the sensitizing phase. In the discussion phase of the study, participants were grouped in one group of three and two groups of four. In the groups of four, the participants did not know each other, whereas in the group of three, the participants knew each other: two of them were partners and the other lived in the same street.

PILOT STUDY

To evaluate the experimental setup, we ran a pilot study with two female participants (ages 29 and 31) who were both researchers, one of whom lived alone and one with her partner. Both performed the sensitizing phase and the discussion phase. As a result, we found that some of the exercises used in the sensitizing phase were not explained specifically enough and therefore the examples of everyday peripheral perception and activities we found were too broad. Possibly as a result of this, the pilot-participants had difficulty in discussing their peripheral behavior during the discussion session. To prevent these issues, we decided to refine the description of the sensitizing exercises and the instructions provided during the discussion phase.

SENSITIZING PHASE

The aim of the sensitizing phase is to make the participants reflect on the way they use their periphery during everyday activities in the home environment. As this reflection process will likely take some time, this phase lasted for a period of one week, which is the usual length of sensitizing phases in contextmapping studies (Sleeswijk Visser et al., 2005). In the beginning of this week, the participants were given a booklet with six exercises and some materials that were needed to perform these exercises (see Figure 3.1). As we were interested in perceptions and activities that took place in the home environment, these exercises were to be executed in the home of the participant at a moment of choice. Each exercise was meant to take about ten minutes and participants were instructed to perform no more than two exercises in one day, to enable time for reflection.

The exercises in the sensitizing package were meant to trigger participants to explore and think about everyday perceptual stimuli, and everyday activities that they perceive or perform without directly paying attention to them. For example, participants were asked to consciously notice everything they can hear, see or smell in their home, draw a timeline of all activities they performed in the last two hours and to record a video of an everyday activity and reflect on their own (peripheral) behavior while looking at this video. The pages on which participants

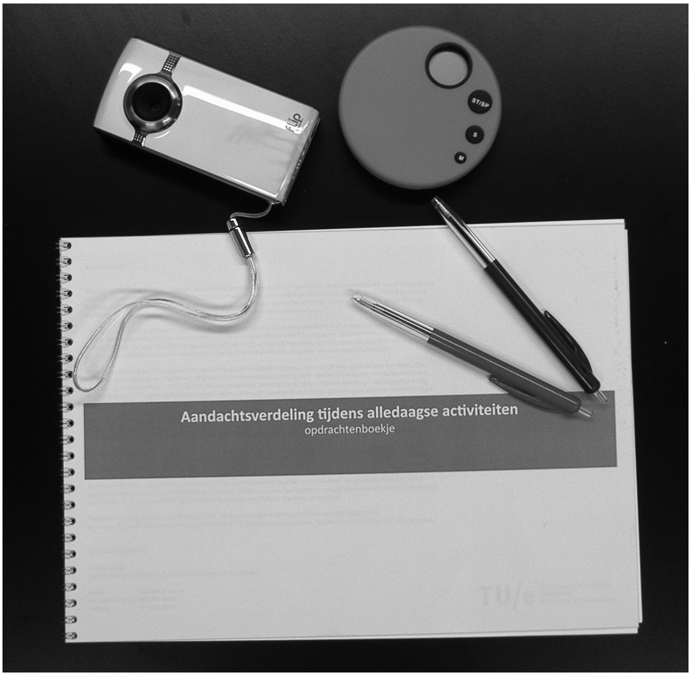


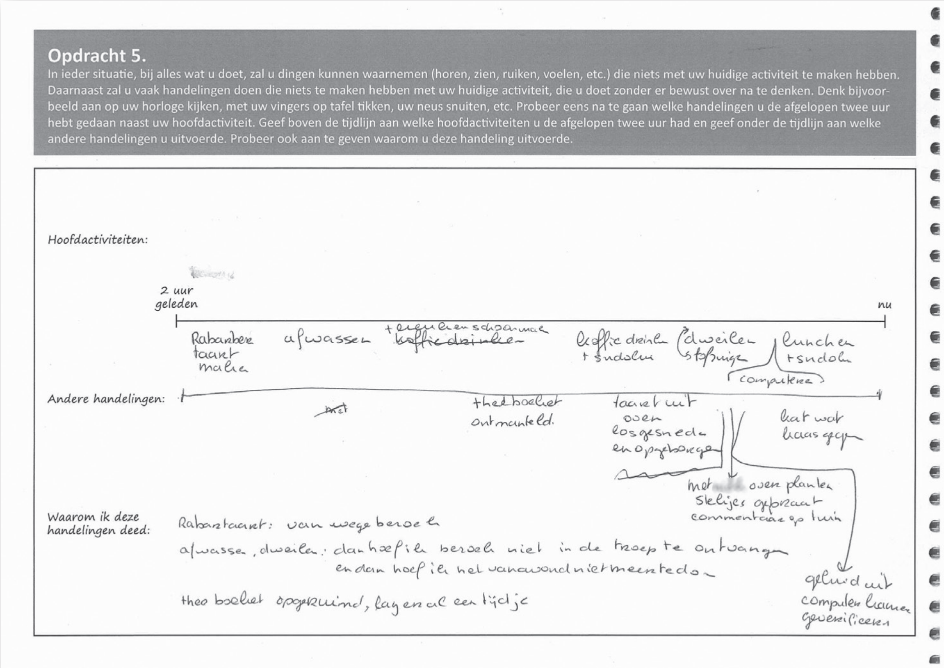
Figure 3.1. The sensitizing package.

performed the exercises intentionally included lots of open space, allowing the participant to put their thoughts on paper in a way they preferred, e.g. by including drawings or by leaving comments. See Figure 3.2 for an impression of how the participants used the booklets while performing the exercises. Appendix 1 shows all six sensitizing exercises as the participants received them.

DISCUSSION PHASE

After individually performing the sensitizing exercises in their own homes, we invited the participants for a creative interview session in groups of three or four. Sharing and discussing experiences with others was expected to result in a richer and broader range of data compared to individual interviews. The three group sessions lasted about 90 minutes each and were lead by the author. The sessions took place in a general meeting room (see Figure 3.3 for an impression of the setting), and video recordings were taken to enable analysis. The sessions were divided into three separate parts; a group interview and two exercises.

The discussion phase started with a *group interview* consisting of open questions to stimulate discussion between participants. The aim of this interview was to gather everyday examples and experiences of perceptual stimuli and activities the participants can perceive or perform in their periphery of attention. To ensure that they indeed talked about the periphery rather than the center of attention,



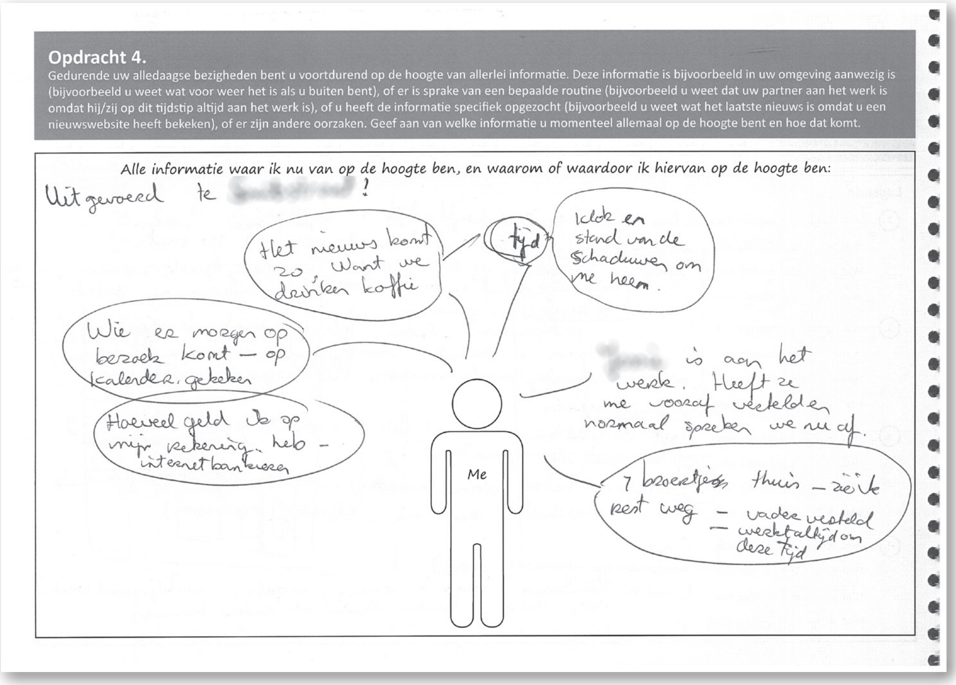
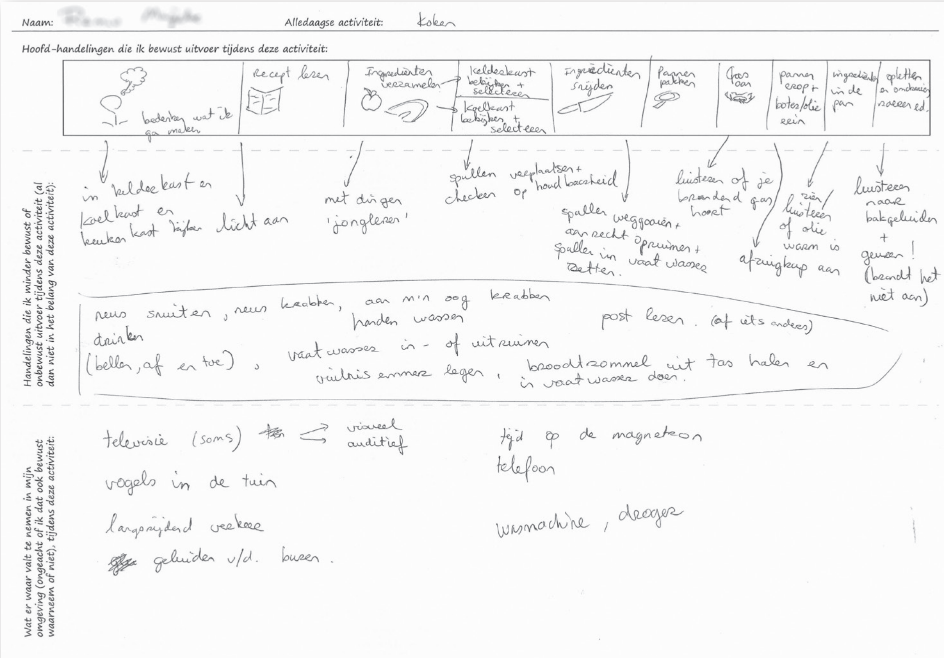


Figure 3.2. Two filled in sensitizing exercises to give an impression of the way they were performed by different participants (in Dutch).

we steered our questions in such a way that they focused on activities that are performed apart from the main focus of attention. For example “When you are doing everyday activities at home, what can you perceive that is not related to your activity?”, and “When you are doing everyday activities at home, what are you doing that is not related to your activity?”. Other questions that we used in the group interview included “Can you name examples of things you perceive without being fully aware of it?”, “Which activities can you perform with minimum attention and why do they require minimal attention?”, and “Are there situations in which you are better able to perform such activities compared to other situations?”.

After this open group interview, the participants were given an exercise that was meant to result in more specific and detailed examples of peripheral perceptions and activities. In this exercise, which was called the *scenario exercise*, the participants were asked to make a detailed overview of an everyday activity they perform at home. They could choose the activity they described from six options we provided: cooking, having dinner or breakfast, personal hygiene activities, cleaning, reading or watching TV. We gave the participants these options as these are activities that usually require few mental resources so that there is room for other activities and perceptions to take place simultaneously. First, the participants were asked to create a timeline describing a brief chronological overview of the main actions taken during the selected activity. Second, the participants were asked to write down what other activities they performed and what they perceived during this activity. These activities and perceptions could be connected to the timeline (e.g. ‘before cutting the vegetables, I always wash my hands’), or not (e.g. ‘while cooking, I usually see children playing outside’). These examples may indicate types of stimuli and activities that can be perceived or performed in the periphery of attention. After creating these scenarios, they were discussed in the group. Similar to the sensitizing exercises, we provided a sheet with ample open space. See Figure 3.4 for two filled in examples of the scenario

Figure 3.3. Picture taken during one of the group sessions of the discussion phase.



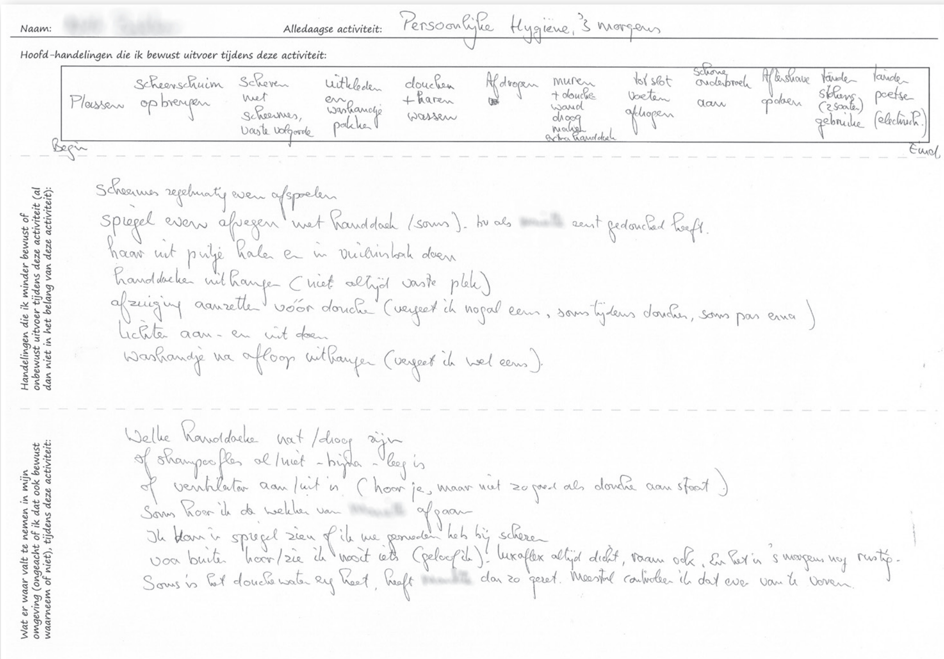


Figure 3.4. Examples of the results of the scenario exercise (in Dutch).

exercise, which show how different participants put their thoughts on paper. The empty sheet can be found in Appendix 1.

The final exercise of the discussion phase, called the *collage exercise*, was aimed at gathering inspiration for the design of peripheral interactive systems and was not intended to result in examples of everyday peripheral perceptions or activities. While the insights gained through this exercise have been useful in the design processes described in Chapters 5 and 6, the aim of the current chapter is to explore the everyday periphery of attention. We will therefore not discuss the specific results of the collage exercise in this chapter.

DATA ANALYSIS PROCEDURE

As a result of the sensitizing exercises, the group interview and the scenario exercise, we had gathered both handwritten and video data usable as input for a qualitative analysis. We were mainly interested in studying the role of the periphery of attention in everyday situations in the home environment in order to inform research on, and design of (peripheral) interactive systems. Since not much related research was available, we were looking for a broad range of examples of everyday peripheral perceptions and activities. We analyzed the data using 'open coding' (Liamputtong and Ezzy, 2005) or 'conventional content analysis' (Hsieh and Shannon, 2005), which entails that data is clustered without a predefined elaborate coding scheme. Instead, detailed clusters emerged during the analysis. In this section we explain the process in which we analyzed the data. This process is also visualized in Figure 3.5.

In order to come to a diverse selection of examples, we used both the results from the sensitizing and discussion phase in our analysis, which is common practice in contextmapping studies (Sleeswijk Visser et al., 2005). All handwritten and video data gathered in the study were transcribed verbatim and quotes were selected from these transcripts that seemed to capture interesting examples or insights related to everyday events that may or may not take place in the periphery of attention. These quotes were divided in two sets, one addressing everyday *perceptions* that may shift between periphery and center of attention and the other addressing everyday peripheral *activities*. In the perception set, we found 274 quotes, which could be short statements (e.g. "I hear music while cooking") or richer explanations (e.g. "sometimes when I am reading a book, someone calls me or asks me something, but this does not come through, I simply do not hear it"). The activity set contained 281 quotes, also ranging from simple statements (e.g. "I often play with my pen while reading") to more elaborate explanations (e.g. "When I am cooking, I look at the clock very frequently for example to monitor how long the rice is already cooking. However, often I do not really register the time and one minute later I have already forgotten how long the rice was cooking").

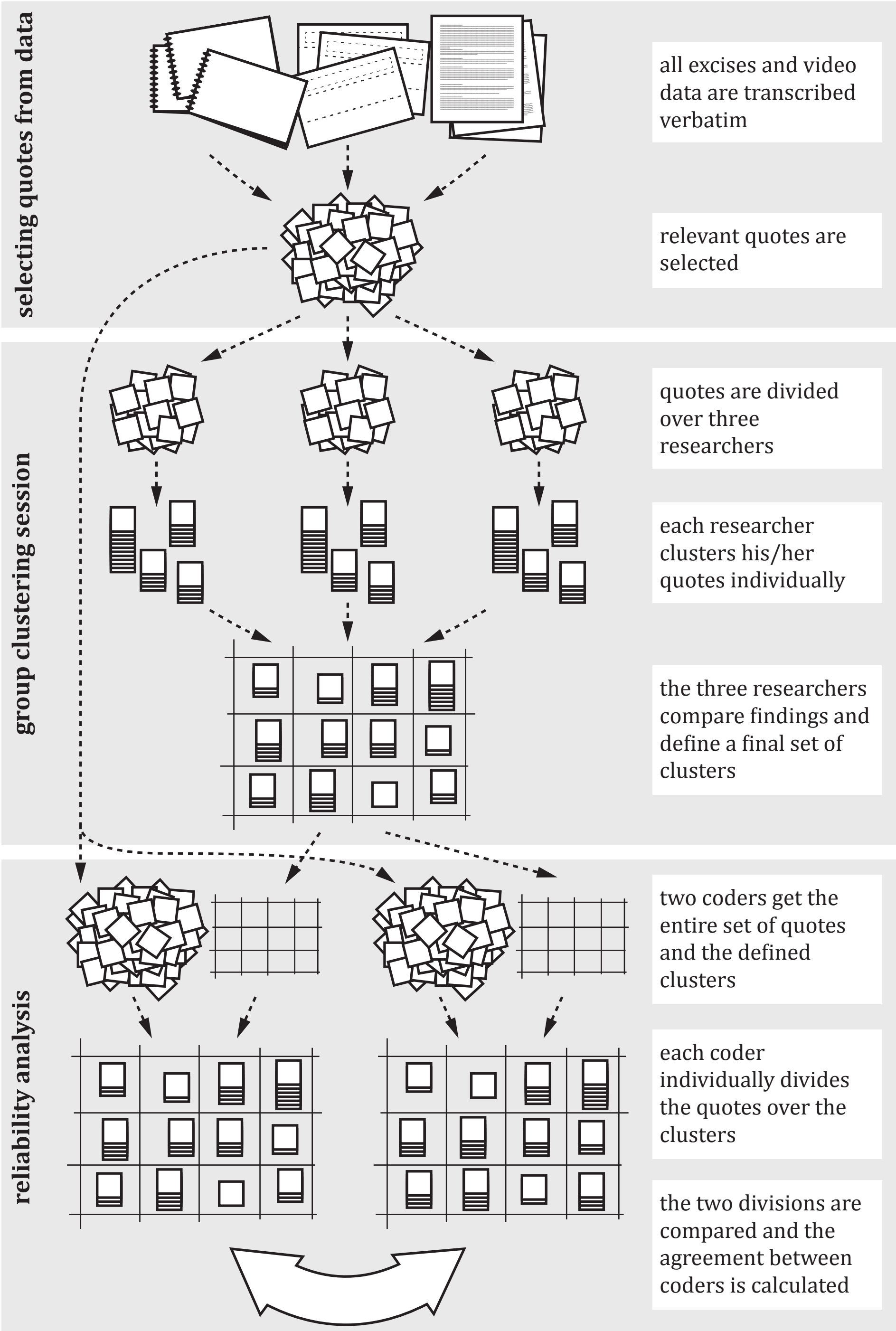


Figure 3.5. Overview of the data analysis procedure, including selecting quotes from the data (top), a group clustering session (middle) and a reliability analysis (bottom). This procedure was followed for both the 277 quotes about perception, and the 285 quotes about activities.

Some quotes selected for the activities set also involved perception (e.g. "while cooking, I look into the refrigerator to decide what to eat", or "I am sitting in the garden and listening to bird and nature sounds"). Though these quotes could also have been selected for the perception set, we placed them in the activities set because they either involve multiple types of actions (e.g. bodily actions combined with perceptions) or because they describe prolonged activities which require a varying amount of resources rather than shorter perceptions of stimuli.

To find common themes and overall results from these quotes, we set up a group clustering session in which three researchers took part: the author and two other researchers who had not been involved in the study before (also see Figure 3.5). These two other researchers were involved to enable an unbiased view on the data. The two sets of quotes (one addressing everyday perceptions and the other addressing everyday activities) were analyzed in two separate sub-sessions. In each sub-session, small pieces of paper, that each contained one quote of the discussed set, were divided among the three researchers. The main aim of this study was to inform research-through-design processes. When discussing the *perception* set, we were thus most interested in gaining insights in the preconditions that enable peripheral perceptions or shifts between periphery and center of attention. The researchers were therefore instructed to cluster their quotes in a way that it would address the question 'why is the described stimulus perceived?'. In some quotes, participants described a situation in which a certain stimulus was *not* consciously noticed (e.g. "which I am very focused on reading, I do not notice someone calling me"), in which case the question 'why is the described stimulus *not* perceived?', was used as input for clustering. When discussing the activity set, which could reveal preconditions that enable actions to take place in the periphery of attention, the researchers were instructed to cluster their quotes in a way that would provide an answer to the question 'why does the described activity require little or no attention?'. In each sub-session, the researchers started by individually clustering their quotes according to the question relevant to the discussed set of quotes, after which they compared their clusters. The differences in clusters were discussed and as a result, the three researchers agreed to an overview of clusters that captured the essence of the data. See Figure 3.6 for an impression of the group clustering session.

When discussing the clusters in the group clustering session, we concluded that not only clusters describing different preconditions for peripheral perceptions and activities were needed, we also thought it would be interesting to create an overview of the *types* of perceptions and activities. In the perception set, we separated the different modalities (hearing, seeing, smelling, tasting and touching), while in the activities set, we distinguished three main types of activities: bodily activities (e.g. walking), cognitive activities (e.g. thinking) and sensorial activities

Figure 3.6. Picture taken during the group clustering session.

(e.g. listening to the radio). Having an overview of which types of perceptions and activities can potentially take place in the periphery of attention could provide a direction for the interaction styles suitable for peripheral interactive systems. To provide a valuable overview of the data in each set of clusters, we therefore chose to group the quotes on a two-dimensional scale; one dimension indicating the type of perception or activity and one dimension indicating why the perception or activity may or may not take place in the periphery.

To determine the reliability of the clusters on the two dimensions in each set of quotes, that were established in the group clustering session, two coders clustered all perception related quotes and all activity related quotes according to the two dimensions that were identified for each set (also see Figure 3.5). These two coders were the author, and an independent second coder who had not participated in the group clustering session. This second coding exercise was solely meant to assess the reliability of the clusters, rather than to revise the clusters. Both coders were allowed to duplicate a quote when it fit in two clusters, but this happened only in very few cases (the first coder duplicated 7 quotes and the second coder 4 quotes). After both coders had divided the quotes over the clusters, the divisions of quotes were compared and discussed. As a result, some quotes were moved between clusters to correct some mistakes. To determine the extent to which the two coders agreed in their clustering, we calculated Cohen's Kappa statistic, which provides the agreement between the two coders as a number between 0 and 1 (0 indicating no agreement and 1 indicating perfect agreement) (Siegel and Castellan, 1988). This resulted in a Kappa Coefficient of 0,88 in the perception set and 0,81 in the activity set. Both these numbers are generally regarded as high agreement between coders (Landis and Koch, 1977).

To keep the overview of data clear, we will present only the first coder's (the author's) division of quotes over the clusters in the remainder of this chapter. Given the high agreement between coders, we believe this gives a reliable overview of our findings. Taking into account the 7 duplicated quotes, the first coder clustered 277 quotes in the perception set and 285 quotes in the activity set. Having clustered the examples of everyday perceptions and activities separately, led to two overviews of findings, which we will also discuss separately in this chapter.

3.3. Findings: everyday peripheral perceptions

The objective of our study is to gain insight in the way the periphery of attention is used in everyday life situations. This section discusses findings regarding everyday stimuli that may potentially be perceived in the periphery of attention. More specifically we were interested the find out if and why such stimuli may or may not shift between the periphery and center of attention. 277 quotes, selected from several parts of the study, have been clustered to identify *types of perceptions* and to find common themes regarding *why everyday stimuli may or may not shift between the center and periphery of attention*.

3.3.1. Types of peripheral perceptions

The quotes related to everyday perception, describe examples of stimuli that may or may not be perceived in the periphery of attention, and/or factors that may influence the perception of stimuli and therefore facilitate shifts between the periphery and center of attention. During the clustering session in which we discussed these quotes, we decided to sort them based on the types of perceptions they describe: hearing, seeing, smelling, tasting or touching. In some cases the type of perception was unclear. As a result of our clustering, we found that our participants described much more examples of auditory perceptions (125 out of 277 quotes), compared to examples related to seeing (36 quotes), smelling (12 quotes), touching (6 quotes) or tasting (0 quotes). This is a noticeable result, since all our questions related to perception were deliberately formulated in such a way that no preferred modality was indicated (e.g. 'what do you perceive?' rather than 'what do you hear?').

Table 3.2 provides an overview of the number of quotes in each cluster in the two dimensions found in the group clustering session: 'type of perception' and 'why the stimulus is (not) perceived'. The coming section discusses these clusters in detail. The quotes which are represented in Table 3.2 describe examples of everyday stimuli which were or were not perceived by the participants. For example "my attention is attracted to an ambulance passing by" (the stimulus was consciously perceived), or "I am so focused on my book, I did not hear my partner calling me" (the stimulus was not consciously perceived). The first example describes a stimulus which shifted to the *center* of attention, while the stimulus in the second example seemed to stay in the *periphery*. When reading Table 3.2, it is therefore important to realize that not all quotes describe examples that are equally 'peripheral'. Table 3.2 should not be used to count the number of everyday peripheral versus central perceptions that we found, but simply to gain insight in how frequently certain types of perceptions and certain factors that influence these perceptions were discussed by our participants.

3.3.2. Why everyday stimuli shift between the center and periphery

As a result of the group clustering session, we identified four main clusters that each describe a factor that may influence the perception of stimuli and therefore facilitate shifts between the periphery and center of attention. These four main clusters - (1) *content of the stimulus*, (2) *expectations of the perceiver*, (3) *current activity of the perceiver* and (4) *other factors* - will be discussed in this section. The

Why the stimulus is (not) perceived			Type of perception						Total
			Hearing	Seeing	Smelling	Touching	Tasting	Unclear	
Content of the stimulus	Related to current / future activity		7	13	3	2		10	35
	Emotions	Positive	2	1				2	5
		Negative	3		6			4	13
	Personally relevant		6	1				5	12
Expectations of the perceiver	In line with expectations		6					2	8
	Not in line with expectations		11	3				14	28
Current activity of the perceiver	A lot of attention		12	2				3	17
	Little / no attention		2	1				7	10
	Choice		4					1	5
Other factors	Physical properties of the stimulus		7	7				2	16
	Personal factors of the perceiver		1	1	1			2	5
	Environmental factors		4						4
Unclear			60	7	2	4		46	119
Total			125	36	12	6		98	**277**

Table 3.2. For each (sub-)cluster indicating why a stimulus was or was not perceived, the number of quotes assigned by the first coder, categorized over the different possible types of perception. For example, the first coder found 7 quotes that indicated auditory stimuli that were perceived because the content of these stimuli related to the current or future activity of the perceiver.

numbers of quotes found in these clusters and identified sub-clusters are shown in Table 3.2.

CONTENT OF THE STIMULUS

The first factor that seems to influence the perception of stimuli is the *content of the stimulus*. In this cluster, we found 65 out of 277 quotes, see Table 3.2.

The majority of these quotes (35 out of 65), described stimuli that attracted attention (and thus shifted from the periphery to the center of attention) because they were *related to the current or future activity* of the perceiver. In the scenario exercises performed during the discussion phase, the participants were asked to describe an everyday activity they perform at home in detail. One participant described how she cleans her house. While writing down the steps she takes when cleaning, she mentioned at one point, “it suddenly comes to my mind that while cleaning, I always notice more things that have to be cleaned, that I do not notice otherwise. For example when sweeping the floor, I see some dirt on the window, which must have been there for days, but I have not seen it before”. Similarly, another participant described in a sensitizing exercise “When doing the laundry, I suddenly notice a sock lying in my child’s room, that also needs to be washed. I may not have noticed this otherwise”. These examples indicate that stimuli related to your current activity may attract attention. The same seems to hold for stimuli that relate to a future activity. For example, when asked what she perceives during breakfast, a participant said “I notice that the peanut butter is almost empty, so I have to buy a new jar when I am in the store”.

18 out of 65 quotes in this cluster described situations in which stimuli shifted to the center of attention as they evoked certain *emotions*. When asked to name examples of things she perceived during everyday activities, a participant mentioned that while cooking, her attention often wandered off to things happening in the street that she can see through the window, particularly when children were playing there. This attracted her attention because she enjoyed watching them having fun and it reminded her of the time her children were younger. This example may indicate that a stimulus which evokes certain emotions, in this case *positive emotions*, easily attracts attention. This also seems to hold for stimuli that evoke *negative emotions*. For example, another participant noted that when at home, he always knows if his upstairs neighbor is home. He experiences this person as ‘annoying’ and mentioned that this made him notice almost every sound.

Furthermore, a number of quotes described stimuli which were noticed because their content or meaning was *personally relevant* (12 out of 65 quotes). For example, one participant mentioned that she is always aware of what her cat is doing, even if it is not attracting attention. When discussing what causes this awareness, she came to the conclusion that she feels the cat is part of the family and it is therefore important for her to monitor its activity. Another participant mentioned "I am allergic to mess, so whatever I am doing or wherever I am in my house, I always see mess". Another participant reacted to this by saying "I don't experience this at all, my house is often messy, but it does not bother me". Apparently, certain kinds of information (e.g. activity of the cat or cleanness of the house) are personally highly relevant to some participants and related stimuli are therefore quickly noticed.

EXPECTATIONS OF THE PERCEIVER

Another factor that seemed to influence the perception of stimuli is the *expectations of the perceiver*. In this cluster, we found 36 out of 277 quotes. In this cluster, we distinguished stimuli that were *in line with the expectations* (8 quotes) and those that were *not in line with the expectations* (28 quotes).

In one of the discussion sessions, a participant addressed an exercise he had performed in the sensitizing phase. In this exercise, he had to write down everything he was aware of at that moment. One of the things he wrote down was "I thought that the cat was outside, but I hear it moving on the kitchen table, so it is indoors after all". In another discussion session, a participant described a situation in which he had turned on the dishwasher about 15 minutes ago, "while I was already doing something else, I noticed that I did not hear any sounds from the dishwasher. I looked and it was not on". In both these examples, the participant had a certain expectation before hearing a sound (or in the second example the absence of a sound) that was not in line with this expectation. The first participant may not have noticed the cat's sound if he expected that it was indoors, and the second participant would likely not have noticed the absence of the dishwasher sound if he did not expect the machine to be on. The sounds would then be in line with their expectations. This was also seen in other discussions. For example another participant, who lived near a busy road, mentioned that although rather loud traffic sounds are to be heard in his apartment, he normally does not notice them at all. However, he remembered an incidence where the road was blocked and no traffic was to be heard. Interestingly, he immediately noticed the absence of the (expected) sound. It seems that stimuli that are not in line with the expectations of the perceiver may more easily shift to the center of attention compared to stimuli which are expected.

CURRENT ACTIVITY OF THE PERCEIVER

Resulting from our data, we furthermore found that it may depend on the *current activity of the perceiver* if a stimulus is perceived or not. 32 quotes were identified in this cluster. These quotes were divided over three sub-clusters, describing situations in which the current activity of the perceiver required *a lot of attention* (17 quotes), *little or no attention* (10 quotes), and situations in which the perceiver made a conscious *choice* (5 quotes) to (not) pay attention to a stimulus.

Several participants indicated that when their current activity requires a lot of attention, e.g. when reading a book, they do not notice stimuli that they would notice otherwise. Even when someone directly speaks to them, they may not notice it. For example "sometimes when I am reading, someone calls me or asks a question, but this does not reach me, so I do not answer". On the other hand, we also saw that when little or no attention is paid to an activity, external stimuli are quickly noticed. For example "when I am watching TV, but nothing interesting is on, then I notice everything that happens around me". In few cases, we saw that the perceiver made a choice not to pay attention to a stimulus, after consciously perceiving it for a few seconds, because this would interfere with his current activity. For example "If I am watching an exciting movie, and someone asks me something, then I do not answer, otherwise I will miss something".

OTHER FACTORS

Apart from the previously mentioned clusters, we found 25 quotes indicating *other factors* that can influence everyday perception. 16 of these quotes showed that the perception of stimuli may be influenced by *physical properties of the stimuli*, for example "a very loud sound attracts the attention". Additionally, 5 quotes indicated that *personal factors* of the perceiver may influence his or her perceptions (e.g. "I personally do not smell very well, so I often do not notice strange smells"). Finally, we found 4 quotes that described environmental factors which determined whether or not a stimulus was perceived (e.g. "only when it is very quiet, I can hear trains from my house").

UNCLEAR

Apart from the factors above, we also gathered a large number of quotes in which the participants did not state a clear reason why the stimulus was (not) perceived. For example "while cooking, I perceive the washing machine". This could relate to a future activity, be unexpected or be perceived as annoying. These 119 quotes were clustered as *unclear*.

3.4. Findings: everyday peripheral activities

The objective of the qualitative study described in this chapter is to gain an understanding of the way the periphery of attention is used during everyday life situations. Apart from the perception of everyday stimuli, we were interested in everyday activities that require little or no attention and can therefore be performed in the periphery. To gain this knowledge, we selected 285 quotes from our qualitative data, which describe activities that our participants performed with minimum mental resources.

In Chapter 2, we have presented our own understanding of the center and periphery of attention: we see the center as the one activity to which most mental resources are currently allocated, while the periphery contains all other (potential) activities. It is important to note that not all the 285 quotes we found describe activities that are clearly peripheral according to this understanding. For example, a participant mentioned to be thinking about his day while having a shower. In this example it is unclear to which of these two activities most resources are allocated. In fact, the division of resources over these two activities is likely to be constantly changing. So according to our own understanding of the periphery of attention, having a shower will be in the periphery at one moment, and thinking will be peripheral the next moment, which can also be expected based on the dynamic nature of the overview we drew in Figure 2.5 on Page 28. Since the main goal of our study is to inform research-through-design on systems that can be interacted with in the periphery of attention, we are interested in all activities that can be in the periphery of attention, but which can also engage the center of attention at certain moments, e.g. when this is relevant for or desired by the user. We are therefore confident that our findings provide a valid overview of potential peripheral activities.

The 285 selected quotes have been clustered to find common themes that give an impression of the types of everyday activities that may require little or no attention and of why this is the case. In this section, we will discuss the results of this clustering.

3.4.1. Types of peripheral activities

The quotes gathered in our study all describe activities that may be performed in the periphery of attention. When clustering these quotes we distinguished three types of activities: sensorial activities, cognitive activities and bodily activities, which we subdivided in activities performed with the hands and other activities (e.g. those involving the whole body). Clearly, many activities may involve multiple types of actions, for example cooking will involve bodily actions, but seeing and thinking is likely also required to successfully perform these activities. To keep the overview of peripheral activities clear however, when clustering the quotes we looked at the type of action that seems most required in the described activity. Cooking is therefore considered a bodily activity that is mainly performed with the hands.

As a result of our clustering, we found that by far most activities described by the participants were bodily activities (204 out of 285 quotes). The majority of these bodily activities were performed with the hands (167 quotes). Table 3.3 provides an overview of the number of quotes in the clusters of the two dimensions ‘type of everyday activity’ and ‘why the activity required little or no attention’, which will be discussed in the next subsection.

3.4.2. Why everyday activities require little or no attention

To gain a better understanding of why everyday activities require little or no attention, we asked the participants several different questions. When asked to name activities that required little or no attention, we experienced that participants usually named *main* activities, such as cooking or ironing. Another approach we used however, was to ask participants which other activities they performed during everyday activities at home. When such activities can be performed alongside or during other activities, they can likely be performed in the periphery of attention. As a response to these questions, participants naturally described *side* activities such as “while cooking, I often wash my hands”. In the latter case, the described side activity (washing hands in the example) was used for clustering.

Why the activity required little or no attention			**Type of activity**									
			Sensorial activities					Cognitive activities	Bodily activities		Unclear	Total
			Hearing	Seeing	Smelling	Touching	Tasting		Hands	Other		
Main activity	Routine							2	61	25	3	91
	Resting / relaxing		1	7				8			5	21
Temporary side activity internally triggered	Clear goal	Related to main act.	1	2				2	14		1	20
		Not related to main act.		12				3	36	6	5	62
	No clear goal			6					16	4	4	30
Temporary side activity, externally triggered			2						34	2		38
Ongoing side activity			4	2	1		1	8	6		1	23
Total			8	29	1		1	23	167	37	19	**285**

Table 3.3. For each (sub-)cluster indicating why an activity required little or no attention, the number of quotes assigned by the first coder, categorized over the different possible types of activities. For example, the first coder found one quote that indicated a hearing activity (e.g. listening to the radio) that required little or no attention because it was done to rest or relax.

As a result of the group clustering session, we identified four main clusters that each describe a factor that pays a role in the amount of attention required for an activity. These four main clusters – (1) *main activities*, (2) *temporary side activities* that are *internally triggered*, (3) *temporary side activities* that are *externally triggered*, and (4) *ongoing side activities* - and the sub-clusters that were identified, will be discussed here in detail.

MAIN ACTIVITIES

The first cluster we found describes *main activities* that require little or no attention. We see a main activity as the primary task that a person is performing, even though this may not require a lot of attention. In other words, one's main activity is the activity that would be written down if one was to keep a logbook of the day. For example when having dinner and thinking about the day planning at the same time, having dinner would be the main activity, even though thinking may require more mental resources at certain moments. In this cluster, we found 112 out of 285 quotes.

Most of these quotes (91 out of 112) described activities that required little or no attention because they are *routines*, activities in which one is very experienced and therefore do not require much thinking. The majority of these activities (61 out of 91) were bodily activities performed with the hands. For example one of the participants described ironing, "I sometimes need to pay a little attention to make sure that the clothes are laid down correctly, but I have done it so often that the rest of the time I am usually more focused on the TV than on the ironing itself". Another bodily activity that was named by several participants was taking a shower, for example "the ultimate example of an activity that hardly requires attention for me is taking a shower. When in the shower, every physical action goes automatically and in the meanwhile, I am still waking up and thinking about what my day will be like. I do not even notice how much time I spend in the shower, or forget if I already used the shampoo or not". Other examples of such bodily activities were cooking, eating and cleaning. These examples give the impression that although such routine activities are likely initiated in the center of attention (i.e. one intentionally starts to iron), they regularly shift between the center (when laying down clothes) and periphery (when using the iron) during the course of the activity. Meanwhile, other activities that are done simultaneously, e.g. watching TV, may also shift between center and periphery of attention. As defined in our understanding of the center and periphery of attention (see Chapter 2), only one activity can be in the center of attention at a time. Ironing will therefore be in the periphery when watching TV is in the center of attention.

In addition, we saw that main activities may require little attention because they are done for *resting or relaxing* purposes, in which case the majority of quotes (16 out of 21) described sensorial or cognitive activities. For example "watching a dull soap on TV hardly requires attention, it is a moment of relaxation for me". Another participant mentioned "just browsing through a magazine or brochure without actually reading it is something that hardly requires attention. I do it often when I come home after work. At that moment I am tired and just want to do something relaxing before I start cooking".

All main activities we found seem to frequently shift between the center and periphery of attention. However, given the kinds of activities described (cleaning, cooking, having a shower, watching TV) it seems likely that these main activities are usually initiated in the center of attention. See Figure 3.7 for an illustration of the way in which main activities may shift between center and periphery of attention.

TEMPORARY SIDE ACTIVITIES, INTERNALLY TRIGGERED

Apart from the previously discussed main activities, we also found various examples of activities that require little or no attention and can be performed as side activities during another main activity. Most these examples we found were *temporary side activities* that are quickly finished. Furthermore, the majority of these activities were *internally triggered*, meaning that they were initiated cognitively and that no sensorial stimuli clearly preceded the activity. In this cluster, we found 112 out of 285 quotes, 64 of which described bodily activities performed with the hands.

During one of the discussion sessions, the participants were talking about the side activities they perform during their breakfast ritual. Several (bodily) temporary side activities were mentioned such as "letting the cats outside", "opening the curtains" and "putting things in my bag". Apparently, several such temporary

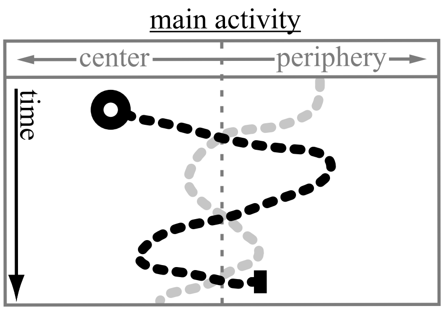


Figure 3.7. Illustration of the way a *main activity* may shift between the center and periphery of attention. The described main activity is indicated in black while a second activity is illustrated in grey. The start of the activity is indicated by a circle and the end by a short bar: a main activity may shift between the center and the periphery of attention, while it will always be initiated in the center of attention.

side activities are *not directly related to the main activity*, but have a *clear goal*. In one of the discussion sessions, a participant said “I got my ears pierced two years ago and in the beginning I was afraid that I would lose my earrings. I frequently feel with my fingers if they are still in. I do this much more often than needed”. Another participant mentioned “I recognize that, what I very often do is check if my zipper is not down. I certainly do this multiple times per day. I don’t know why but probably to avoid embarrassing moments”. The latter two examples also indicate *temporary side activities* that are *not directly related to the main activity* and that were first performed to reach a certain goal which seemed very relevant for the participant (checking earrings or zipper). However, it seems that after a while these activities are performed more often than necessary to reach the goal.

In the scenario exercise of the discussion phase, participants were asked to describe an everyday activity and write down what other activities they perform during this activity. In this exercise, many participants wrote down activities that were closely related to or even part of the main activity (clustered as *related to the main activity*) and also had a *clear goal*. For example “cleaning the mirror while shaving” or “pouring out drinks during dinner”. When discussing the scenario exercise in the group, one participant said “when I am cooking, I often stir the sauce or turn the meat much more often than needed. I do these things as a routine and often I forget if and when I have done it”. Another participant mentioned “While cooking, I always wash my hands multiple times. Sometimes I have forgotten if I already washed my hands and I do it again”. Again we see here that some temporary activities are performed more often than needed; they seem a result of a certain routine.

Apart from temporary activities that have (or started with) a clear goal, we also found temporary side activities that have *no clear goal*. For example “when I am reading something and taking notes, I often play with my pen. This does not really serve a goal, I just do it because I have nothing to do with my hands”. Another participant mentioned “I very often play with my hair. This is not meant to straighten my haircut or anything, it is just a habit”.

Regardless of the goal of temporary side activities that are internally triggered, all these activities are short. The fact that we found several examples where participants had forgotten if they already performed the activity or not indicates that once practiced the entire activity may take place in the periphery of attention. However, such activities can of course also be focused on in the center of attention when desired, see Figure 3.8.

TEMPORARY SIDE ACTIVITIES, EXTERNALLY TRIGGERED

Apart from the previously mentioned temporary side activities, which were initiated as a result of a cognitive process, we also found examples of such activities that were *externally triggered*. In other words, these activities were performed as a result of perceiving a certain sensorial stimulus. The difference between temporary side activities that were internally triggered and those that were externally triggered may not be straightforward: earlier mentioned examples such as "cleaning the mirror while shaving", may have been internally triggered (e.g. cleaning the mirror as a routine activity) or externally triggered (e.g. cleaning the mirror as a result of seeing fog on the mirror). Only quotes which clearly describe that the activity was initiated as a result of a perception were clustered as being externally triggered. We found 38 quotes in this cluster, 34 of which described bodily activities performed with the hands.

One participant described in her scenario: "I am cleaning the kitchen and I suddenly see that my breadbox is still in my bag, so I quickly take it out and put it in the dishwasher". Another example: "While putting my daughter in the bath, I put the cap on the tube of toothpaste, I saw it was off". These (bodily) activities are no routines or rituals, but short and simple actions as a direct result of a perception. Most examples were directly or indirectly related to the main activity.

Similar to temporary side activities that are internally triggered, all examples of those that were externally triggered were short activities. Even though they do not seem the result of a routine, it seems as though these activities may entirely take place in the periphery, while of course one may also focus on it in the center of attention, see Figure 3.8.

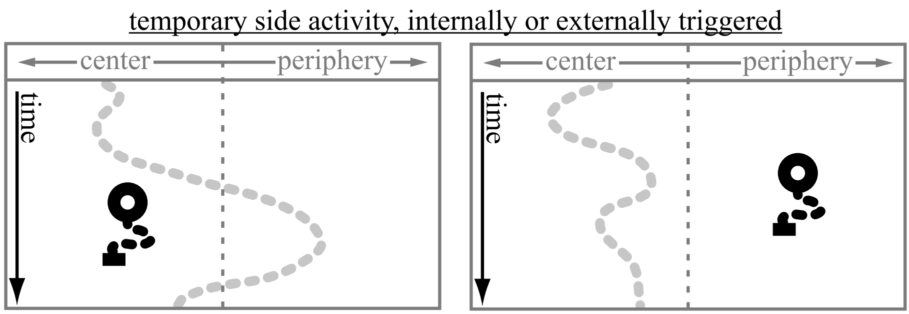


Figure 3.8. Illustration of the ways a *temporary side activity* may shift between the center and periphery of attention. The described temporary side activity is indicated in black while a second activity is illustrated in grey. The start of the activity is indicated by a circle and the end by a short bar: a temporary side activity is performed entirely in the center or entirely in the periphery of attention.

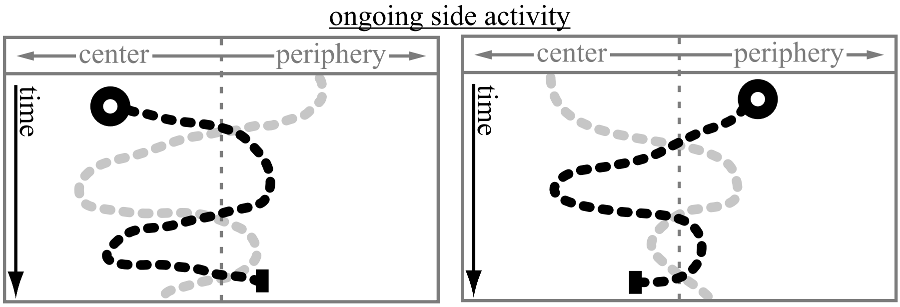


Figure 3.9. Illustration of the ways an *ongoing side activity* may shift between the center and periphery of attention. The described ongoing side activity is indicated in black while a second activity is illustrated in grey. The start of the activity is indicated by a circle and the end by a short bar: an ongoing side activity is initiated in the center or in the periphery of attention and shifts can take place during the activity.

ONGOING SIDE ACTIVITIES

Other than temporary side activities that last only a short period of time, we also found several examples of *ongoing side activities*, which are performed over a longer period of time during a different main activity. We found 23 examples of such activities, of which only 6 were bodily activities; the majority of quotes described sensorial and cognitive activities. For example, several participants mentioned that they listen to music or the radio while cooking. In such a situation, the activity of listening will likely regularly shift between the center and periphery of attention. For example one might consciously listen to the music at some moments while one may focus their attention on cooking at other moments.

This cluster seems to include activities that are not a result of a routine, rather they can be performed with varying amount of resources and therefore easily shift between the center and periphery of attention. Ongoing side activities may be started in the center of attention, for example when intentionally turning on the radio. However such activities can likely also start in the periphery of attention, such as when the radio has been turned on by another person, see Figure 3.9.

3.5. Discussion

The research described in this chapter was aimed at gaining a better understanding of how the periphery of attention is used in everyday situations. We were particularly interested in perceptions and activities that can take place in the periphery of attention, and shift to the center when relevant. This knowledge is needed to inform research on, and design of interactive systems that can potentially be interacted with in the periphery, while these interactions may also shift to the center of attention when desired. We will now discuss our current understanding of everyday peripheral perceptions and activities, and the insights we gained regarding design for peripheral interaction. However, we will first address the methodology we used in this study.

METHODOLOGY

In our study, we were interested in finding a diverse range of qualitative examples of how the periphery of attention is used during everyday activities. Based on attention theory (Kahneman, 1973; Wickens and Hollands, 2000), we have described the periphery of attention as all activities that one can potentially perform, apart from the one to which most mental resources are currently allocated (see Chapter 2). Given this description, which entails that little mental resources are allocated to peripheral activities, one may question if it is at all possible to interview people about their periphery of attention. We tried to overcome this problem by including a sensitizing phase in our research, to enable the participants to start thinking about and reflecting upon their use of the periphery, before the actual interview took place. During the discussion phase of our study, participants frequently made remarks such as “when making the exercises at home, I started to realize how much sound is always around me”, or “when looking back at the video I took during one of the exercises at home, I noticed that I very often touch my hair, I did not realize this before”. As a result of these kinds of remarks, we have a strong impression that the sensitizing phase effectively helped the participants in becoming more aware of their periphery of attention, which enabled them to better discuss it in the discussion session.

However, we must also conclude that not all examples we found are clearly peripheral according to our description. For example, while cooking a participant’s attention was attracted to children playing outside. This means that though cooking was in her center of attention at first, the activity of looking outside shifted to the center and was therefore no longer peripheral. The main goal of our study is to inform the design of systems that can reside in the periphery of attention but shift to the center when relevant for or desired by the user. We were therefore interested in all stimuli and activities that can be in the periphery of attention (e.g. sound or movement of children playing outside while cooking), even though they may also be focused on in the center (when paying more attention to these children than to cooking).

Particularly in the overview of quotes in the *perception* set, see Table 3.2, we had to cluster quite a lot of quotes as ‘unclear’. For these quotes it was unclear why the stimulus was perceived. One may question if the overview of identified clusters is complete, as additional motivations for (not) perceiving stimuli could be present in the ‘unclear’ cluster. However, both the first and second coder agreed that they only used the ‘unclear’ cluster when indeed no clear reason for perception was described. Both coders were therefore confident that no other factor is hidden in the ‘unclear’ cluster. The large number of quotes in this cluster could be a result of our questions ‘what do you perceive at this moment’ or ‘what do you perceive during everyday activities?’. Even though we asked participants to indicate why they thought they perceived it, not all participants did this.

AUDITORY PERCEPTIONS AND THE EVERYDAY PERIPHERY OF ATTENTION

In the set of results that regard everyday perceptions, we found several examples of auditory perception. Some of these examples describe auditory stimuli that attract attention (e.g. “I thought the cat was outside, but I hear it moving in the kitchen now”), while others explain how certain sounds are easily ignored (e.g. “I am used to hearing cars outside, so I don’t notice them anymore”). This indicates that many sounds that are monitored in the periphery of attention may shift to the center when they become relevant to the perceiver. Since we found many more examples of hearing compared to other modalities, see Table 3.2, our data indicates that audio plays a major role in the everyday periphery of attention.

This result is noteworthy, since we deliberately phrased our questions in such a way that no preferred modality was indicated. The sensitizing exercises contained questions such as ‘what do you perceive at this moment?’, or ‘what can you perceive in your living room?’. In response, participants mostly wrote down things of a dynamic nature, for example “I hear birds outside” or “I hear my wife in the other room”. Static things such as “I see a chair” or “I hear the lights humming” were hardly mentioned. These latter examples may be so obvious that the participants may not have thought about it when doing the exercises. Such stimuli were likely present, but may never have become relevant enough to shift from the periphery to the center of attention. As in everyday situations, auditory stimuli are more dynamic than visual stimuli, which may have caused the large number of examples of hearing. A further explanation could be the fact that audio can be heard over a large distance; the things that you can see from your own home may be much less unexpected or new than the things you can hear. We found quite some examples of distant hearing (e.g. “I hear the neighbors”, “I hear trains”, “I hear there is an event at the marketsquare”), but only few such examples of seeing (e.g. “I see a man in the street that does not live here”). Although such examples were mainly found in the sensitizing phase, this has likely also influenced the discussion phase. If participants thought more about audio in the sensitizing exercise, they likely also thought more about audio during the discussions. Although these factors may have influenced the numbers presented in Table 3.2, the fact that we found more than twice as many quotes related to hearing compared to all other modalities together, gives us reason to believe that audio indeed plays an important role in the everyday periphery of attention.

Insight 4. Everyday perceptions that shift between the center and periphery of attention often involve auditory perception.

THE HANDS AND THE EVERYDAY PERIPHERY OF ATTENTION

In both the sensitizing and discussion phase of our study, we asked our participants to name activities that require minimum attention or that can be performed alongside other activities. A large majority of the examples we found in the set of results that regarded activities described bodily activities (204 out of 285 quotes), most of which were actions with the hands (167 out of 204 quotes), see Table 3.3. We did not specifically ask the participants to name bodily activities, but asked about activities in general. However, the wording of our questions may have been of influence here; when asked to name *activities*, people may naturally first think of bodily activities that involve physical actions (e.g. preparing dinner), rather than of cognitive activities that mainly involve thought processes (e.g. daydreaming). However, it seems that sensorial activities such as watching TV or listening to the radio, and cognitive activities such as reading or having a conversation are clearly seen as 'activities' as well since these examples were mentioned by our participants in response to some of the first questions we asked them. Given the fact that more than half of the found examples described bodily activities performed with the hands, our results indicate that the hands play a major role in the everyday periphery of attention.

Insight 5. Everyday physical activities that shift between the center and periphery of attention are often performed with the hands.

Although the majority of activities we found involved the hands, the two clusters 'main activities – resting or relaxing' and 'ongoing side activities', which described activities of a longer duration such as listening to music, or chatting with one's partner, included mostly sensorial and cognitive activities. Especially in case of ongoing side activities, this may be related to *multiple resource theory* (Wickens and McCarley, 2008). These ongoing side activities are usually performed alongside (bodily) main activities such as cooking or eating, making it physically impractical to perform other bodily activities of a long duration simultaneously.

Our findings also seem related to Heidegger's (1996) notion of tools being either 'ready-to-hand' or 'present-at-hand'. Artifacts or tools are *ready-to-hand* when they are used to accomplish a task; the user focuses on the task rather than on the artifact itself. For example when using a hammer, ones focus will be on the act of hammering rather than on the hammer. In a sense, the hammer becomes an extension of the arm. Artifacts are *present-at-hand* when the user focuses on the artifact itself, such as when one sees a hammer for the first time and is figuring out its purpose. When an artifact or tool is used for an everyday activity, this tool will therefore usually be ready-to-hand. Since no attention is then needed for the artifact, this may enable the activity with the artifact to take place in the periphery of attention. In fact, performing an activity in the periphery means that neither the artifact nor the activity will be the user's main focus of attention. Readiness-to-hand therefore almost seems to be a prerequisite for an activity with an artifact to take place in the periphery of attention.

Insight 6. For a physical activity that involves manipulation of a physical artifact to take place in the periphery of attention, the artifact should be ready-to-hand.

OUR FINDINGS IN LIGHT OF ATTENTION THEORY

The study presented in this chapter is grounded in psychological theories of attention which were discussed in Chapter 2. However, the present study was not focused on verifying a hypothesis about the psychological mechanisms underlying peripheral perceptions and activities. Rather our aim was to gain insight in the everyday execution and implications of such activities in order to inform research and design. By providing an overview of everyday perceptions and activities that take place in the periphery of attention, we wanted to contribute to a bridge between the relevant and insightful work performed in the area of psychology and the more applied work performed with research-through-design. We will now discuss how the study presented in this chapter links to attention theories discussed in Chapter 2.

Our findings regarding everyday perception provide an overview of reasons why stimuli may (not) shift from the periphery to the center of attention. This may for example be due to the content of the stimulus, or the expectations of the perceiver. Attention theory (Cherry, 1953; Moray, 1970; Treisman, 1964) also describes reasons for stimuli shifting from the periphery to the center of attention; *salience* (e.g. a sudden loud noise) and *priming* (e.g. hearing your own name in an unattended conversation). When looking at our results, we see that only the cluster 'physical properties of the stimulus' describes examples of salience. Priming is a cognitive mechanism that increases the likelihood that relevant stimuli are perceived (Treisman, 1964), e.g. those related to the current focus of attention or those that are always relevant such as your own name. Examples of priming are found in the clusters 'expectations of the perceiver' and 'content of the stimulus'. Although salient stimuli may seem most obvious to attract attention, the cluster 'physical properties of the stimulus', contains only 16 quotes. Even if not all examples in the clusters 'expectations of the perceiver' and 'content of the stimulus' may be evident examples of priming, these clusters together contain 101 quotes. Interestingly, we must therefore conclude that priming seems to play a more important role in everyday attention than salience.

Insight 7. Everyday perceptions mostly shift between the center and periphery of attention as a result of priming, rather than as a result of salience.

In psychology literature, experiments on priming usually study the auditory modality and focus on speech perception (Cherry, 1953; Moray, 1970; Treisman, 1964). For example; two auditory channels are presented and the subject is instructed to focus attention on one channel, while the name of the subject is presented in the other channel (Moray, 1970). Such experiments prove that one's own name is a primed stimulus. Most examples of primed auditory stimuli we found in our study however were non-speech sounds. For example "I hear the cat in the kitchen" or "I hear my annoying neighbor". It seems as though not only words, but also other kinds of sounds can be primed.

When looking at the examples of priming found in our study, we see that these stimuli may have been primed because of expectations of the perceiver, because of an emotional content of the stimuli, because of personal relevance or because they relate to a current or future activity of the perceiver. This overlaps with theory, describing one's name (Moray, 1970) (personally relevant) and words related to the current focus of attention (Meyer and Schvaneveldt, 1971; Treisman, 1964) (current activity) as primed stimuli. In line with what we concluded in Chapter 2, our results furthermore give the impression that other things may also be 'on the back of one's mind', that could be likely to be noticed in unattended channels (i.e. stimuli about which one has a certain expectation or those with emotional content). Our results therefore provide a more specified overview of the kinds of stimuli that may be primed.

Our findings in the set of results that describe everyday activities, presented in Table 3.3, also seem largely in line with attention theories discussed in Chapter 2. Divided attention theory for example describes automaticity (Wickens and Hollands, 2000; Wickens and McCarley, 2008) as one of the factors enabling activities to be performed simultaneously. In our data, we found numerous examples of routine activities which are likely (partially) automated, for example ironing, cooking or cleaning, but also opening the curtains in the morning or switching on the lights. Additionally we found several examples of habitual activities which participants performed much more often than needed, such as washing their hands and checking their earrings or zippers. These internally triggered activities seem automatically performed, sometimes without being fully aware of it. This may be a result of the *supervisory attentional system* (Shallice and Burgess, 1993), a cognitive mechanism that increases the likelihood that certain actions or thought processes are executed. Since the goals of these activities seem highly relevant to the person (e.g. hygiene, not losing earrings, preventing embarrassment) their likelihood of being performed may be higher than other activities.

As a result of our analysis of both everyday perceptions and activities, it seems that the cognitive mechanisms *priming* and the *supervisory attentional system* play an important role in activities shifting between the center and periphery of attention. These mechanisms also seem highly personal, and depend among other things on expectations, emotions, personal importance and current activity, which will probably be different for different people. It therefore seems as though the everyday periphery of attention cannot easily be generalized for a large group of people.

Insight 8. Everyday perceptions and activities often shift between the center and periphery of attention as a result of highly personal factors, which vary across people.

DESIGN FOR PERIPHERAL INTERACTION

The study described in this chapter was aimed at gaining better understanding of the everyday periphery of attention in order to inform research-through-design on interactive systems that leverage human attention skills. Now that we have presented our findings, we will discuss what implications these findings have regarding design for peripheral interaction.

Several researchers and designers have taken Weiser and Brown's (1997) vision of *calm technology* as a starting point for developing new systems and interfaces. Most of these designs aim at presenting information that people can potentially *perceive* in their periphery of attention (Eggen and Mensvoort, 2009; Ishii et al., 1998; Matthews et al., 2004; Mynatt et al., 1998). In the study presented in this chapter however, we have seen that in everyday life, not only perceptions engage the periphery of attention, but so do meaningful and goal-oriented physical actions. Although only few designs are known that are to be *manipulated* peripherally (Edge and Blackwell, 2009; Hausen et al., 2012), we believe that this direction can broaden the scope of areas such as calm technology (Weiser and Brown, 1997), ambient information systems (Pousman and Stasko, 2006) and peripheral displays (Matthews et al., 2004), by going beyond displaying information only. This would mean that much more kinds of interactions with technology could be designed to shift between center and periphery of attention, and thereby fit into daily life the way the everyday activities described in this chapter fit into it.

A large majority of the everyday activities we found were bodily activities. We particularly found many examples of activities performed with the hands, which seems in line with Heidegger's (1996) notion of tools or artifacts being ready-to-hand. Our results therefore confirm our approach to explore physical interaction styles such as embodied interaction (Dourish, 2001) and tangible interaction (Hornecker and Buur, 2006; Mazalek and Hoven, 2009; Ullmer and Ishii, 2000) as interaction styles for our purpose.

As we have seen, hearing plays an important role in peripheral perception. This confirms our approach to explore auditory displays (Kramer, 1994) as a means to present peripheral information. Regarding the design of such peripheral auditory displays, the main objective should be to design audio that can be monitored in the periphery of attention and shift to the center of attention only when this is required, e.g. as it becomes relevant to the user. As our data showed that priming is more common in everyday situations than salience, it would therefore be interesting to see if we can leverage the process of priming in the design of interactive systems. Interestingly, this approach has not often been attempted in related work. Matthews et al. (2004) for example, describes a "toolkit for managing user attention in peripheral displays" (p. 247). Though mainly focused on visual displays, Matthews et al.'s research distinguishes different notification levels such as 'make aware' or 'interrupt'. This enables designers to assign higher notification levels to more urgent or important information. Notifications of such information will then be presented more saliently. This however, assumes that the designer can decide which information is relevant and at which moments it is relevant, which seems rather difficult. Given our results, it would entail that the system should have an understanding of the user's expectation, his or her current activity, the things that are of personal relevance to the user, and so on. Our results therefore suggest that presenting information multiple times in a non-salient manner should enable the user to pick up the information when it is relevant for him or her, while it can otherwise be in the periphery of attention. When in the periphery, the audio does not attract attention and is thus easily ignored. This approach would clearly not be suitable for urgent information, but seems interesting for less urgent, but still potentially interesting or relevant information. For example when a system provides auditory information that can be heard by multiple people; in case a stimulus is relevant for one user, but not for another, it should only shift to the center of attention of the first user. This will obviously not be achieved if the stimulus gets more salient (e.g. by increasing the volume) to attract attention. We therefore argue that auditory information should not be made louder or otherwise more distinctive when it becomes more relevant to the user, as is done now in many systems such as most computer applications that use sound. Instead, audio could be provided in a way that the user can easily pick up the presented information. When this information is relevant to the user (for example because it differs from his expectations or evokes emotions) it will likely shift to the center of attention as a result of priming.

3.6. Conclusions

In this chapter, we have described a qualitative study aimed at investigating how the periphery of attention is used during everyday activities in the home environment. This knowledge was gathered to inform the design of systems that a user can interact with in the periphery of attention, while it may also shift to the center of attention when this is relevant for or desired by the user.

As a result of this study, we conclude that audio plays a major role in peripheral perception. Additionally, we found that most everyday peripheral activities are performed with the hands. Our data therefore indicate that, as expected, auditory display (Kramer, 1994) and tangible interaction (Hornecker and Buur, 2006; Mazalek and Hoven, 2009; Ullmer and Ishii, 2000) seems a suitable interaction styles for our purpose. In addition, we have identified different clusters that indicate why everyday perceptions and activities may shift between the center and periphery of attention.

The clusters that regard everyday perception, are conform our theoretical understanding of the attention process, indicating that salience and priming can cause stimuli to shift to the center of attention. Interestingly, we found that priming plays a more important role in everyday life compared to salience. This indicates that when leveraging human attention abilities in interaction design, priming could be an interesting cognitive mechanism to consider. The clusters that describe why everyday activities require minimal mental resources, are also in line with attention theories, which suggest that activities that are automated usually require a low amount of mental resources. Furthermore, we found that activities are more likely to be performed in the periphery of attention when they are personally highly relevant.

Most related research and design work aim at presenting information that is to be perceived in the periphery of attention. However, since we observe that everyday physical activities are frequently performed without paying much attention to them, we find it remarkable that only few studies are known that aim at creating physical interfaces that can be manipulated in the periphery of attention. In the next section, we therefore adopt a research-through-design approach to explore a combination of audio and physical interaction in the periphery of attention.

Section II
Design, deployment and evaluation

Chapters 4, 5 & 6

4.

Related research and design

Abstract

This and the upcoming two chapters explore the design and evaluation of peripheral interaction. In this chapter, we review related research and design, starting by addressing visions that inspired our peripheral interaction approach, and critical views towards these visions. We furthermore discuss related work on peripheral information displays, on physical interaction designs that employ the periphery of attention, on computing technologies for the classroom (the target context of our own designs) and on related evaluation strategies. Moreover, we discuss what we can learn from these related examples and how our work contributes to them.

4.1. Introduction to this chapter

The role of the computer is rapidly changing in everyday life. Not only do many people carry around computing devices such as mobile phones and laptop or tablet computers, these technologies are also being integrated in everyday artifacts and environments. These developments have lead to wide discussions on how the computer can fit into everyday life in the physical world. This thesis explores *peripheral interaction*, an approach to this challenge which aims to leverage human attention abilities in interaction with technology.

In this thesis, we adopt a research-through-design approach to explore the concept of peripheral interaction, which encompasses both perceptions of and physical interactions with computing technology that may shift between the periphery and center of attention. In previous chapters, we have studied how people perceive stimuli and perform actions in their periphery of attention in everyday life. The present and coming two chapters focus on the design and evaluation of interactive systems that aim to be perceived and interacted with in the periphery of attention. In this chapter, we review related research and design and discuss what we can learn from and contribute to earlier work on peripheral interaction and related topics. We start by discussing *visions of employing the periphery of attention* and also address *critical views* on these visions. We then proceed to discuss more concrete examples of related research and design on *awareness through peripheral perception* and on *physical peripheral interaction*. Additionally, we will motivate our decision to conduct some of our own research-through-design studies (which are presented in Chapters 5 and 6) in a primary school classroom setting, and we will go into related work on *peripheral interaction in a classroom context*. Finally, we will discuss *evaluation strategies* that have been proposed for interaction designs that employ the periphery of people's attention.

4.2. Visions on employing the periphery of attention

The idea of employing the periphery of attention in interaction with technology was first envisioned by Weiser (1991), in his discussion of the computer for the 21st century. In this influential article, Weiser (1991) foresaw that computing technology would be omnipresent in everyday life and suggested that the aim should be to seamlessly integrate such 'ubiquitous computers' into the world. As one of the means to achieve this, he later introduced the term *calm technology*: "technology that engages both the center and periphery of our attention and in fact moves back and forth between the two" (Weiser and Brown, 1997, p. 79). The concept of calm technology envisioned that when we could perceive and interact with information from computers in our periphery of attention, computing technology could fit into our everyday lives the way everyday information sources fit into our lives. Weiser and Brown (1997) used the inner office window, which connects the office to the hallway, as an everyday example of calm technology. This window allows all kinds of subtle informative clues to pass through: a lot of motion in the hallway informs you of an upcoming event and a light shining into the hallway late at night says that someone is working late. These clues are part of the ambience of the environment and are usually in the background, but may be focused on when relevant. Similarly, the aim of calm technology is to form a part of the ambience so that it can be utilized without focused attention, but also focused on if desired.

The vision of calm technology has inspired several related visions on how future technologies should be interacted with. Ishii and Ullmer (1997), for example envisioned 'tangible bits', part of which could be achieved through *ambient media*, aiming at "enabling users to be aware of background bits at the periphery" (Ishii and Ullmer, 1997, p. 235). Further elaborating on calm technology, Tolmie et al. (2002) built on the importance of routines in everyday life when presenting the concept of *unremarkable computing*. The aim of unremarkable computing is to make interactive technology 'invisible in use'; unremarkably embedded in everyday routines. Clark (2004) refers to a similar concept using the term *transparent technologies*, which are "so well fitted to, and integrated with, our own lives, biological capacities, and projects as to become (...) almost invisible in use" (Clark, 2004, p. 37). Additionally, a wide range of more concrete research and design studies have been inspired by Weiser and Brown's vision. We will address numerous such examples in this chapter, but we will first discuss a number of more critical standpoints towards the concept of calm technology.

4.3. Critical views

Although Weiser's ideas have been widely adopted, they have also been critically discussed. Weiser's (1991) discussion of the computer for the 21st century did not only address interactions with computing technology taking place in people's periphery of attention, it also argued how future ubiquitous computers could be aware of and adapt itself to their context. Much of the work that followed in Weiser's footsteps aimed to create such smart environments. In a critical stance towards Weiser's ideas, Rogers (2006) doubts the technical feasibility of such smart technologies, since despite the efforts of ubiquitous computing researchers, "their achievements are limited by the extent to which they have been able to program computers to act on behalf of humans" (Rogers, 2006, p. 418). She therefore suggests moving away from the aim of *calm* living in which technology proactively serves the user's needs, toward the aim of *engaged* living in which people proactively engage in interactions with technology. Similarly, Graves Peterson (2004) critiques the idea of unremarkable computing (Tolmie et al., 2002) for the domestic environment by proposing 'remarkable computing'. She argues that computing technologies for the home environment should not be 'invisible in use', but rather interactions with such technology should be motivating, surprising, playful and engaging.

Bell and Dourish (2007) argue that ubiquitous computing should no longer be viewed as a vision for the future, but that it is already here, albeit in a form slightly different from what Weiser anticipated. For example, they mention that "rather than being invisible or unobtrusive, ubicomp devices are highly present, visible, and branded" (Bell and Dourish, 2007, p. 412).

First, some of these critical remarks discuss the extent to which Weiser's (1991) vision has been achieved in terms of the required technologies. We agree with Rogers (2006) that the idea that computers could be aware of and anticipate their environment like people can, does not seem feasible in the near future. Despite that, we also agree with Bell and Dourish (2007) that much of Weiser's ideas have become reality; computing technology is truly all around us nowadays. Though, as also emphasized by Rogers (2006) and Bell and Dourish (2007), these modern technologies are not as 'calm' or 'invisible' as Weiser proposed. We believe however that this is not due to a potential lack of success in creating truly smart computers, we believe that it is caused by the interaction design of today's computing devices. As we observed in Chapter 3, peripheral perceptions and actions frequently take place in the everyday physical world, showing that the kind of interaction proposed by Weiser already takes place in non-technological settings. We therefore believe that whether or not technological developments have already reached, or will ever reach the level that Weiser envisioned, the interaction style proposed for calm technology will be feasible with technology of any level of sophistication. Furthermore, given the observation that indeed computing technology is all around us nowadays, we believe that enabling interactions to shift between center and periphery of attention is currently even more relevant compared to 15 years ago when calm technology was proposed.

Second, the critique discussed above proposes that interaction with technology should be engaging and inspiring rather than calm and unremarkable (Graves Petersen, 2004; Rogers, 2006). We agree that new technologies should not by definition go unseen and directly become mundane resources of everyday life, and that these technologies should allow for engaging, inspiring or playful episodes of interaction. With peripheral interaction, we therefore aim for interactions that can indeed be highly engaging and interesting when performed in the center of attention, while these interactions can also be unremarkable and routine-like when performed in the periphery. We therefore believe that peripheral interaction, similar to our understanding of calm technology which "engages both the center and periphery of our attention" (Weiser and Brown, 1997, p. 79), does not exclude engaging and playful experiences with computing technology, but leaves the option for both types of interaction open.

4.4. Awareness through peripheral perception

The vision of calm technology has inspired many other researchers in exploring similar concepts, which lead to a number of terms that describe related areas of research. These terms include *peripheral displays* (Matthews et al., 2004), *ambient information systems* (Pousman and Stasko, 2006), *ambient displays* (Mankoff et al., 2003), *ambient media* (Ishii and Ullmer, 1997) and *awareness systems* (Markopoulos, 2009). Most of these areas explore the design and evaluation of systems that are to present *perceptual* information in people's periphery of attention, in order to promote peripheral awareness of this information. These systems are thus examples of peripheral interaction design, aimed specifically at peripheral perception. These areas are usually motivated by the statement that displaying information through traditional methods of human-computer interaction (HCI) may cause people to be overburdened with information (Maes, 1994). We will further elaborate on these areas by discussing examples of both visual and auditory displays.

VISUAL DISPLAYS

Many examples of systems that display peripheral information do this via the visual modality. While the number of examples of such visual displays is larger than what we can address here, we now present some of these examples to give an idea of what is available in related work, also see Figure 4.1.

An early example of a calm technology design is the *Dangling String* (Weiser and Brown, 1997), a 'plastic spaghetti string' that hangs from the ceiling in an office context. The string is connected to a motor that spins based on the information sent through the Ethernet cable. If the network is busy, the motor spins fast and if the network is not busy it spins slowly. This way, the Dangling String subtly informs office workers of the network activity. Another well known example of a system that aims at providing peripheral awareness of background information is *Pinwheels* (Ishii et al., 2001), a large scale installations of pinwheels whose physical motion can represent various types of digital data, such as the activity of people in the room in which it is installed. Dahley et al. (1998) presented *water lamp*, which shows the heartbeat of a significant other as shadows of water ripples on the ceiling to promote a feeling of connectedness. With similar aims, *Motion Monitor* uses colored light to provide awareness of movements at remote locations (Matthews et al., 2004). Motion Monitor is presented as an example of a peripheral display, which “allows a person to be aware of information while she is attending to some other primary task or activity” (Matthews et al., 2004, p. 247). *SnowGlobe* (Visser et al., 2011) also aims to support social connectedness between two remote living rooms, through light changes on a physical artifact, and is presented as an example of an awareness system (Markopoulos, 2009). Another example of an awareness system is *Digital Family Portrait* (Mynatt et al., 2001), a digital photo frame which presents subtle information about elderly family members living elsewhere, to promote awareness of their day-to-day activities. *Portholes* (Dourish and Bly, 1992) is a visual display which promotes awareness of the activity of coworkers who are employed in different countries, by displaying images of colleagues who work on similar topics. Elaborating on the concept of

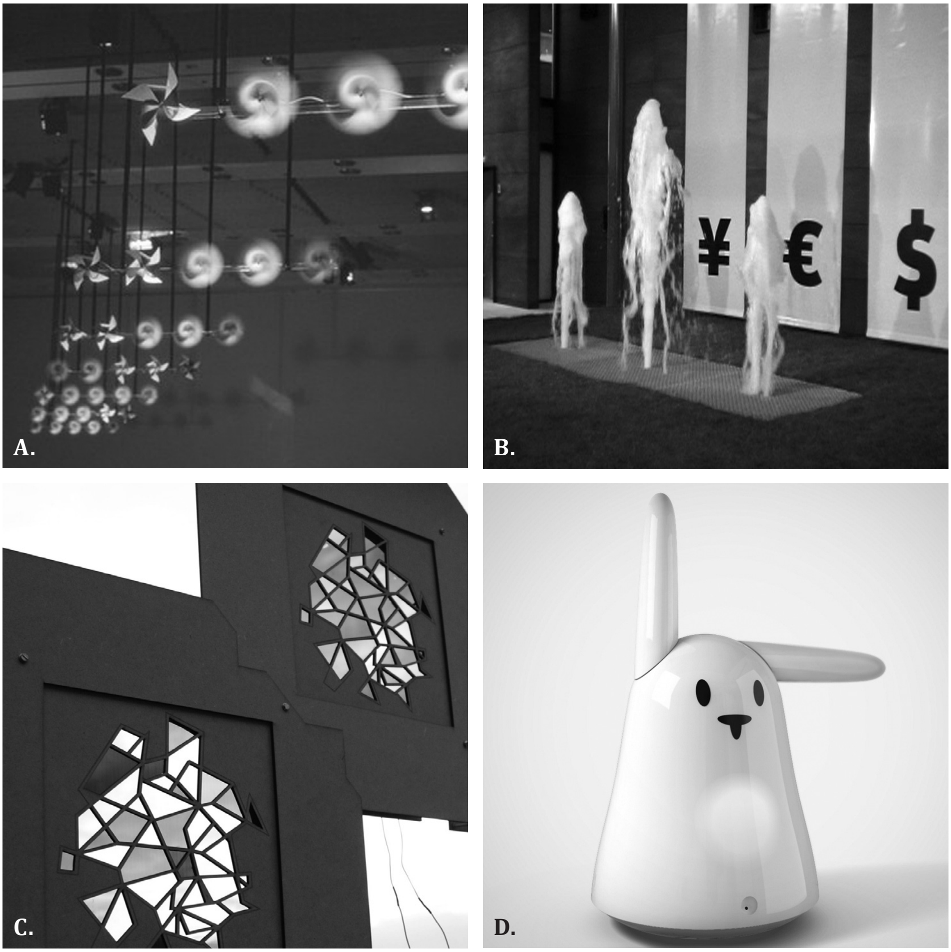


Figure 4.1. Images of related designs which display visual information for peripheral awareness: (A) Pinwheels, image source (Ishii et al., 2001); (B) Data Fountain, image source (Eggen and Mensvoort, 2009); (C) SpectroFlexia, image source (Mailvaganam and Bakker, 2013); (D) Karotz, image source (www.ykone.com).

peripheral information displays, Intille (2002) suggests to leverage the cognitive mechanism of *change blindness*, people's inability to detect seemingly obvious changes to a visual object. He suggests to display changes to information such that they are likely not detected by observers (e.g. displaying the change when the observer is looking at something else). This way, up-to-date information is available whenever a user wants to focus attention on it, without unnecessarily attracting attention. Though related, such displays are therefore not intended to be perceived in the periphery.

The *information percolator* (Heiner et al., 1999) is an example of an ambient display, which uses air bubbles to unobtrusively display background information which can be perceived in the periphery of attention. The aim of the information percolator is not only to have an informative function, but also to be decorative. This idea is also referred to as *informative art* (Redström et al., 2000) or *information decoration* (Eggen and Mensvoort, 2009). Another example of such a design is *Data Fountain* (Eggen and Mensvoort, 2009), a full size water fountain that displays the relative values of the dollar, euro and yen through the height of water jets. To those interested in the value of these currencies, Data Fountain will be informative, while to those who are not interested in this information, or even unaware of the fact that the fountain displays this information, the display will likely not overburden them with information but instead be perceived as decorative. Similarly, *SpectroFlexia* (Mailvaganam and Bakker, 2013), is a decorative interactive stained glass design which can display relevant information, such as availability of colleagues, by subtly changing the colors of its glass.

Apart from these research oriented examples, a number of commercial products also exist that aim to provide peripheral awareness of background information. The *Ambient Orb*[2], for example, is a light-emitting ball which can glow in different colors and, through these colors, display several types of digital information such as stock market trends, weather information or traffic congestions. The *Ambient Umbrella*[3] is an umbrella which handle lights up when rain is expected, in order to subtly remind people to take their umbrella on potentially rainy days. *Energy Joule*[2] is a device which glows in different colors, revealing changes in energy prices, while this and other energy related information can also be directly accessed through a display on the device. The subtle color changes aim to peripherally inform people of the best moment to use high consuming electronic devices. *Karotz*[4], formerly known as *Nabaztag*, is a rabbit shaped electronic artifact which can display all kinds of information from the internet through color change and movement of the rabbit ears.

[2] *http://www.ambientdevices.com, last accessed 25-04-2013*
[3] *http://www.postscapes.com, last accessed 25-04-2013*
[4] *http://www.karotz.com, last accessed 25-04-2013*

AUDITORY DISPLAYS

The above examples present peripheral information visually. However, we concluded in Chapter 3 that the auditory modality plays a major role in everyday (peripheral) perception. In Human-Computer Interaction in general, sound is used in many interactive systems, mainly for alerts, status indication, data exploration, and entertainment (Walker and Nees, 2009). This is typically implemented when users need to visually focus on something else and when immediate action is required. These sounds are therefore mostly designed to attract attention.

An area of research which more widely explores the use of audio in interactive systems studies *auditory display*. This research area "applies the ways we use sound in everyday life to the human/machine interface and extends these uses via technology" (Kramer, 1994, p. 1). Auditory displays do not only aim to leverage the qualities that sound is eyes-free and that it can be alerting, they also use other qualities of audio, such as the fact that it can be monitored in the background, that two auditory streams can be perceived and distinguished in parallel and that sound can be directional. Such qualities of audio have also been explored in the development of auditory displays that aim to present information in people's periphery of attention. Again, numerous examples of such designs are available, of which we will now discuss a few to provide an insight in this area of research.

The earlier mentioned *Dangling String* (Weiser and Brown, 1997), which spins a wire to display network activity in an office, is actually both a visual and auditory display since physical sounds are produced as the motor spins. This way, office workers can also gain awareness of the network activity without looking at the string. *AmbientROOM* (Ishii et al., 1998) uses ongoing soundscapes of bird and rain sounds to display information relevant for office workers, such as the number of unread emails or the value of a stock portfolio. Similarly, *Audio Aura* (Mynatt et al., 1998) uses background auditory cues to provide office workers with information such as the availability of colleagues. *SonicFinder* (Gaver, 1989) uses 'auditory icons' to convey information to computer users: when selecting a digital file, the sound of a hitting a physical object is played, revealing the type and size of the file through respectively the material and size of the object. Another design meant to support computer users is *ShareMon* (Cohen, 1993), an application that enables monitoring background file sharing events through audio. A more recent example is *Birds Whispering* (Eggen and Mensvoort, 2009), which conveys information about the activity in an office through bird sounds. *Holaire* (Eggen et al., 2008) is a design which plays a chord on a physical guitar to welcome people entering an office space, and to inform other office workers of people coming in.

A complex soundscape was explored with the *ARKola simulation* (Gaver et al., 1991): a simulated soft-drink factory that uses an ecology of auditory icons to indicate states and events of machines through rhythm and timber of everyday sounds. Participants use these sounds in their operation of the simulated factory in order to produce as many bottles as possible. Butz and Jung (2005) present a concept which unobtrusively notifies employees of shopping malls or museums of personal messages. Each employee selects a personal musical instrument which is added to ongoing background music whenever this person needs to be notified of an event such as phone-call. This way, only the involved person is made aware of the information while others may not even notice a difference in the music. Hermann et al. (2003) studied auditory weather reports broadcasted on the radio to provide listeners with awareness of the upcoming local weather. With similar aims, Schloss and Stammen (2008) created three art installations that make information about the current weather conditions audible in public indoor spaces.

Some examples also use sound localization to peripherally communicate information. *ONTRACK* (Jones et al., 2008) is a design which adapts music played on headphones to subtly direct pedestrians toward their preset destination; the direction which the music seems to originate from resembles the direction of the destination. *Chronoroom Clock* (Zoon et al., 2012) is an auditory display that subtly provides information about the current time based on the direction the audio is coming from. This directional audio is intended to become an unobtrusive part of the everyday environment such that it can support time related routines.

OUR CONTRIBUTION

As evident from the above examples, the idea of presenting information in people's periphery of attention has been widely explored in related literature. In Chapters 5 and 6, we further explore the use of audio to display unobtrusive information. While our early explorations are mainly meant to gain practical insights and experience in this area, we believe that the contribution of our later iterations to the above mentioned work is twofold. First, we explore the use of peripheral audio in the context of primary school classrooms, while most related work focuses on the home environment or on desktop-workers in an office context. Second, our scope of peripheral interaction is broader than only the perception of peripheral information, aiming also at potential physical interactions with technology that may take place in the periphery of attention. We aim to combine audio as a background information source with peripheral physical interaction. Although both peripheral perception and physical interaction have separately been explored in HCI literature, we are interested in a combination of the two in order to potentially leverage a wide range of human attention abilities in interaction with computers.

4.5. Physical peripheral interaction

The majority of related work aims at peripheral perception of background information. Recently however, a number of studies have been published that present concepts similar to our idea of physical peripheral interaction. In this section, we will first address *related terminology*, which describes similar but slightly different interaction styles. Following, we will discuss examples of *tangible and embodied interaction* that aim for interaction in people's periphery of attention.

RELATED TERMINOLOGY

In the area of HCI, a number of terms have been introduced that describe interaction styles similar to peripheral interaction.

Implicit Interaction

Implicit interaction is a term used to describe interactions with computing technology that take place outside the user's direct awareness. Schmidt (2000), for example, defines implicit human computer interaction as "an action, performed by the user that is not primarily aimed to interact with a computerized system but which such a system understands as input" (Schmidt, 2000, p. 192). Ju and Leifer (2011) illustrate this concept by the comparison of an automatic door and a door that is operated by a doorman. While an automatic door only flings wide open at the detection of a person in front of it, a doorman and a passerby are aware of each other's presence allowing more subtle interaction to take place. For example, the doorman will slightly open the door as a person walks by, indicating the possibility of entering the building, and close the door again after seeing that the person decided not to enter. When such actions are translated to interaction with interactive systems, they make up implicit interactions, which occur "without the explicit behest or awareness of the user" (Ju and Leifer, 2011, p. 72) and "outside of the user's notice or initiative" (Ju and Leifer, 2011, p. 80).

Although the ideas behind implicit interaction and peripheral interaction are similar, there is one major difference. Interactive systems that implement implicit interaction automatically sense the user's behavior, for example walking past a door, and interpret this as input. Such systems therefore act autonomously based on their awareness of the user's behavior and context. While there are several valuable application areas for such technology, it is our intention that peripheral interaction with computing technology is initiated by the user, be it with a low amount of mental resources.

Microinteraction

Another term that describes an interaction style similar to peripheral interaction, is *microinteraction*: "interactions with a device that take less than four seconds to initiate and complete” (Ashbrook, 2010, p. 1). Such interactions (also see Figure 4.2) aim to minimize interruptions by enabling users to quickly interact with a device and rapidly return to their other ongoing activities. An example of this interaction style is *PinchWatch* (Loclair et al., 2010) a wrist-worn device which recognizes gestures made with hand and fingers. Such gestures (for example sliding with one finger along another finger) can be performed during other activities and they can be interpreted as input by PinchWatch, e.g. to adjust the volume of a music player. Wolf et al. (2011) studied more particularly which hand and finger gestures, referred to as *microgestures*, could be suitable as microinteractions. Another design which seems similar to the idea of microinteraction is *Whack Gestures*, described as “inexact and inattentive interaction” (Hudson et al., 2010, p. 109). With Whack Gestures, a user can respond to a cue on their mobile phone or PDA by firmly striking the device, while it is still in his pocket.

The microinteractions presented in these examples seem highly relevant for peripheral interaction with computational devices. We could for example imagine that the gestural interactions studied by Wolf et al. (2011) could be applied in interactive systems that aim for peripheral interaction. However, the goal of microinteractions, enabling interactions with technology to be performed in an as short as possible timeframe, does not directly match with the goal of peripheral interaction. Peripheral interaction aims to fluently embed interactions in the user’s everyday routine. While short interaction durations may support this to happen, it does not necessarily seem to be a prerequisite. Interactions which take place in the periphery of attention are by definition performed with only few mental resources, while more mental resources are available in the center of attention. It is likely that peripheral activities may therefore take a longer period

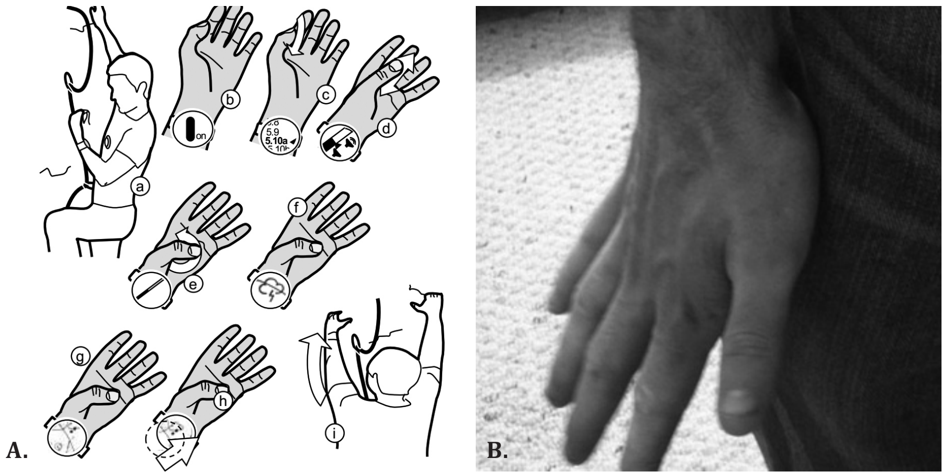


Figure 4.2. Illustrations of related work on microinteractions: PinchWatch (A), image source (Loclair et al., 2010); and Whack Gestures (B), image source (Hudson et al., 2010).

of time to be completed, compared to the same activities being undertaken in the center of attention. Therefore, we believe that aiming for minimal interaction duration could lead to valuable interaction styles, but should not be the main goal of peripheral interaction.

TANGIBLE AND EMBODIED INTERACTION

With computing technology playing an increasing role in everyday life, several HCI researchers have been inspired by interactions in the physical world to design interactions with the digital. Whereas peripheral interaction specifically draws inspiration from the way people use their attention abilities in daily life, the related area of tangible and embodied interaction is more broadly inspired by physical actions in the everyday world. Early research in this area focused on the development of *graspable user interfaces* (Fitzmaurice et al., 1995); physical artifacts called 'bricks' that could be used to directly manipulate digital data. Later work involved research on *tangible user interfaces* (Ullmer and Ishii, 2000), also referred to as *tangible interaction* (Hornecker and Buur, 2006; Mazalek and Hoven, 2009; Shaer and Hornecker, 2009); an interaction style that includes physical artifacts that both represent and enable the user to control digital data. *Embodied interaction* (Dourish, 2001) takes a broader stance by focusing on the "creation, manipulation, and sharing of meaning through engaged interaction with physical artifacts" (Dourish, 2001, p. 126), which can be realized by combining "tangible and social computing". Numerous examples of tangible and embodied interaction design are known in several different application areas such as entertainment (Boerdonk et al., 2009; Raffle et al., 2004), education (Antle et al., 2008; Zuckerman et al., 2005), musical performance (Jordà et al., 2007; Zigelbaum et al., 2006) and office work (Ullmer and Ishii, 1997), to name but a few. In line with the objectives of these designs, most of these interactions are designed to be in the user's center of attention.

Tangible interfaces and peripheral awareness

Some examples of interactive systems are known that combine peripheral monitoring of information with tangible interaction, also see Figure 4.3. The earlier mentioned *AmbientROOM* (Ishii et al., 1998) for example, which uses a background soundscape to convey information about emails or the stock market, also enables users to actively request this auditory information by opening a glass bottle that 'contains' it. *IrisBox* (Eggen et al., 2008) is a design with which users can physically indicate their availability. The design provides continuous background sounds representing the availability of friends or family members. Similarly, *Hangsters* (Peek et al., 2009) is a design that includes physical tokens as representations of instant messaging contacts. These tokens provide a visual peripheral display of the status of these contacts, but can also be manipulated to initiate a conversation or respond to a conversation request. Even though all these

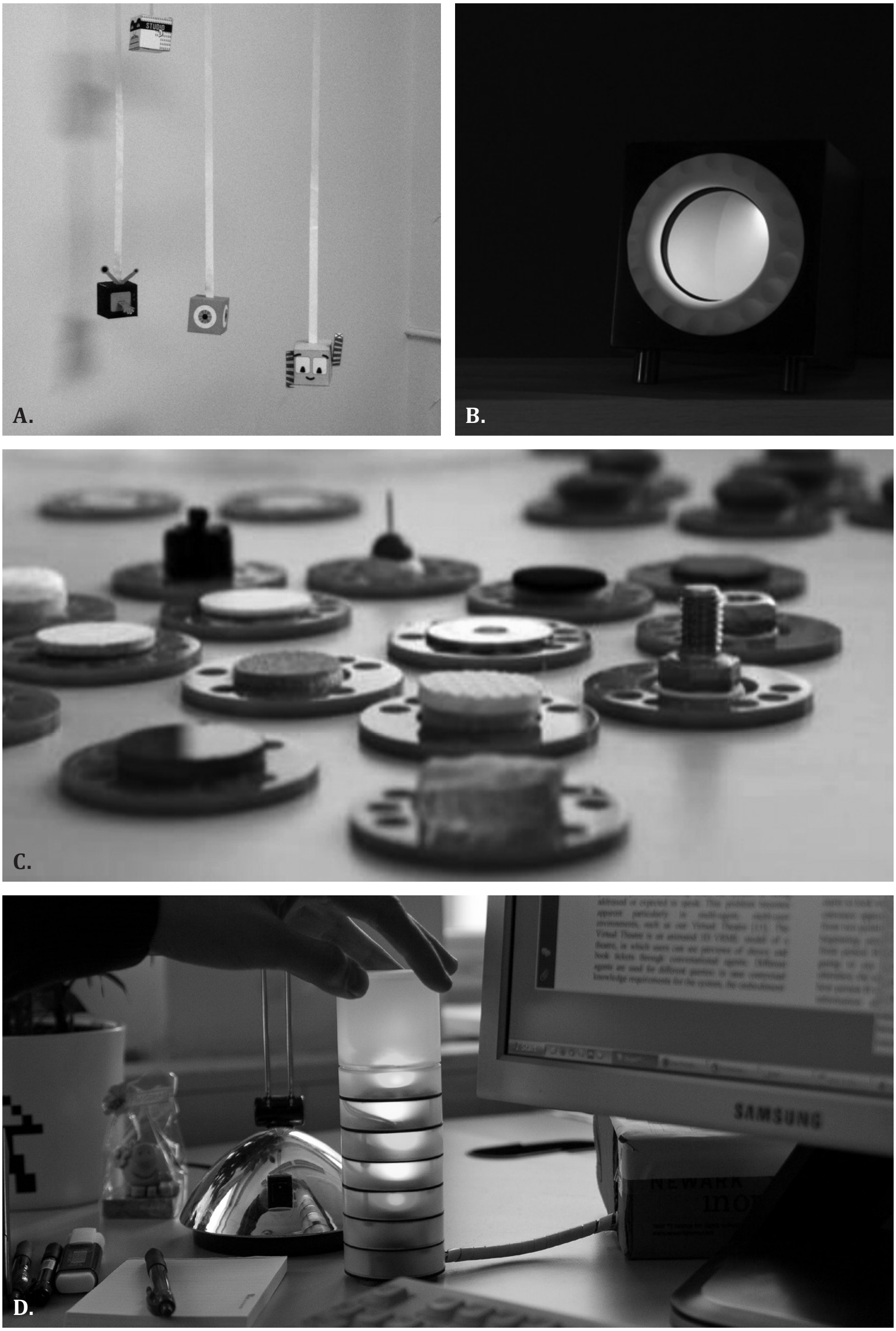


Figure 4.3. Images of tangible interfaces for peripheral awareness and peripheral interaction: Hangsters (A), image source (Peek et al., 2009); IrisBox (B), image source (Eggen et al., 2008); peripheral tangible interaction (C), image source (Edge and Blackwell, 2009); and StaTube (D), image source (Hausen et al., 2012).

designs could be monitored in the periphery, the physical interactions (requesting information, indicating your availability or initiating a conversation) are intended to take place in the user's center of attention.

Tangible interfaces for physical peripheral interaction

Additionally, a few examples of interactive systems are known that use tangible interfaces for physical peripheral interaction, also see Figure 4.3. The researchers who present these examples also use the term peripheral interaction to classify their designs. Different from our understanding of peripheral interaction, which involves both perception and physical interaction, the term is used in related work to address only physical interactions in the periphery of attention.

Edge and Blackwell (2009) use the term 'peripheral tangible interaction'. Their design consists of digitally-augmented physical tokens that can be manipulated on the side of the office workspace outside the visual focus. This allows office workers to track or update task progress in the periphery of attention. Olivera et al. (2011) also present a study on tangible interfaces for peripheral interaction. They illustrate peripheral interaction through the following scenario: a waitress in a coffee-bar arrives at a guest's table ready to refill an almost empty coffee-mug; to indicate he does not want a refill, the guest softly places his hand over the mug. This hand-over-the-mug action is brief and simple and can be performed while the guest continues reading his newspaper. Inspired by such actions, Olivera et al. studied physical six- or twelve-sides dice which could be rotated and place on one of their sides to select a certain system state, such as the user's social network availability status. Hausen and Butz (2011) also use the term peripheral interaction, and define it as a form of interaction that belongs to a secondary task, which is "simple and casual, not requiring precise actions, and thereby reduces the mental load caused by it to a minimum" (Hausen and Butz, 2011, p. 62). They also present a tangible interface for peripheral interaction, called *StaTube* (Hausen et al., 2012). StaTube can be physically manipulated to set and change the user's instant messaging status, while the status of contacts is subtly presented through colored light.

OUR CONTRIBUTION

Tangible and embodied interactions with computing technology have been widely explored in related literature. The idea of enabling such interactions to be performed in the periphery of attention seems to have gained interest of HCI researchers in recent years. However, only very few studies are available in this area. Our work therefore contributes by presenting concrete design examples (see Chapters 5 and 6) for the specific context of a primary school classroom, and by presenting elaborate evaluations of these designs.

4.6. Peripheral interaction in a classroom context

Most related examples of peripheral interactions were developed for desktop-workers. This has proven to be a valuable target group, since many relevant information streams are present in these people's digital environment. To extend the application area of peripheral interactions however, we are interested in exploring contexts in which the computer currently plays a less salient role. We chose to develop some of our designs (presented in Chapters 5 and 6) for the primary school classroom context, with the teacher as the main user of our designs.

The everyday routine of primary school teachers is usually characterized by a large number of small activities. Apart from their primary tasks such as explaining lessons to the class and giving instructions individually or in groups, several secondary tasks have to be performed as well. For example, teachers need to hand out assignments, monitor the children's progress, keep track of time, observe how the children are doing and prepare the next lesson. These secondary tasks usually have to be performed alongside primary tasks. In recent years, computing technologies have made their way into the classroom, many of which are now equipped with interactive whiteboards and (shared) desktop computers. These technologies are mainly meant to support the teacher's primary task of explaining the teaching material. Although some of the earlier mentioned secondary tasks could valuably be supported by technology, the technologies currently present in the classroom seem unsuitable since they require focused attention. We therefore believe that the target group of primary school teachers could benefit from peripheral interaction design.

RELATED CLASSROOM TECHNOLOGIES

A few related studies are known which explore peripheral interaction designs for the classroom context, also see Figure 4.4. These examples aim for peripheral *perception* of information rather than for peripheral *physical interaction*. While only a few concrete examples are known, learning and education is specifically mentioned as a promising application area for peripheral displays (Börner et al., 2011). *Subtle Stone* (Balaam et al., 2010), for example, allows high-school students to communicate their emotional state to the teacher, by changing the color of a tangible artifact. This information is communicated to the teacher on a personal screen, which could be seen as a peripheral information display. Hazlewood et al. (2011) used the earlier mentioned ambient orb[5] as a peripheral display during university student's instructions. The orb subtly presented students' feedback to the teacher through different colors. *Lantern* (Alavi et al., 2009) is a light-object located on university students' desks during instructions. Students can

[5] *http://www.ambientdevices.com, last accessed 25-04-2013*

Figure 4.4. Images of related classroom technologies: Lantern (A), image source (Alavi et al., 2009); Subtle Stone (B), image source (Balaam et al., 2010); and a large peripheral display for classrooms (C), image source (Lamberty et al., 2011).

manipulate Lantern to indicate which exercise they are working on or to call for help. Lamberty et al. (2011) explored the use of a large display in a primary school classroom while children were creating digital artworks. The display showed the ongoing work of all children in order to promote awareness of each other's artistic designs.

OUR CONTRIBUTION

As mentioned above, we believe that primary school teachers are a very promising target group for peripheral interaction. Since the aim of this thesis is to explore the concept of peripheral interaction, however, the activity of designing and evaluating interactive systems for this target group is merely a means rather than a goal in itself. Nevertheless, given the observation that only few related studies are known on peripheral interaction for classrooms, our work may contribute to the overall research area of classroom technologies by further exploring the potential of peripheral interaction for the classroom context.

4.7. Evaluation strategies

One of the important challenges raised by many authors in the field of interaction design for the periphery of attention is the evaluation of such designs. While numerous evaluation strategies are known in the area of HCI, these usually focus on the evaluation of tasks performed in the user's center of attention, and are therefore less suitable for evaluating peripheral interaction. We will now discuss evaluation strategies that have been applied in experiments on divided attention and peripheral interaction.

RELATED STRATEGIES

The literature on attention theory reviewed in Chapter 2, does not only provide insight in the human attention process, but also describes numerous experiments in which people's division of attentional resources is measured. One strategy applied is the dual-task methodology (Wickens and Hollands, 2000): participants are performing two tasks at once and their performance on these tasks is measured. For example, participants could be asked to operate a machine while also performing a *probe reaction task*, in which they have to respond to visual stimuli. The reaction time to these stimuli is used as a performance measure, and may indicate the mental effort required for the two tasks. An alternative approach is to determine the workload of an activity through physiological measures, such as heart rate variability or pupil diameter (Wickens and Hollands, 2000). These measures may reflect the resource demand of the activities being performed.

Next to experiments aimed to gain insight in the human attention process, several experiments have been described in related literature on the evaluation of peripheral interaction designs. Most of these experiments focused on displaying information in people's periphery of attention. A recent overview of applied evaluation techniques in such studies (Hazlewood et al., 2011) revealed that most peripheral displays are informally evaluated by having users interact with the design once or twice and assessing mainly the initial *enjoyment* of the display. A few more elaborate evaluations, as summarized by Hazlewood et al. (2011), focus on the *functionality* and *usability* of evaluated designs. With similar goals, a few specific evaluation techniques have been developed for displays of peripheral information. McCrickart et al. (2003) suggest to evaluate such displays based on three critical parameters: interruption, reaction and comprehension. Mankoff et al. (2003) have suggested an adaptation of the heuristic evaluation, aimed to look for usability problems with ambient displays, using a list of heuristics. CUEPD (Shami et al., 2005) is a method to find potential design improvements, by having users perform primary tasks while a peripheral display is available in the background. Matthews et al. (2007) specify five concrete evaluation criteria for peripheral displays, namely 'appeal', 'learnability', 'awareness', 'distraction' and 'effects of breakdowns'. They propose methods to evaluate each criterion separately, for example, they suggest to evaluate awareness through knowledge questions about the presented information and to evaluate distraction by measuring the overall duration and success of the primary task. These approaches are all intended to study peripheral interaction designs through controlled experiments in a laboratory setting. Although these evaluation strategies provide relevant insights, we find it problematic that they do not involve such designs being used during the everyday routine of the user.

Although the traditional approach to evaluate how users interact with technology is to observe them in a controlled, laboratory-style setting, the alternative approach of deploying (prototype versions of) designs in the real context of use for a period of time seems to be increasingly suggested in HCI literature (Brown et al., 2011; Rogers, 2011). Since the objective of peripheral interaction is to fluently integrate meaningful interactive systems in everyday life, this approach seems particularly suitable for designs that employ the periphery of attention, as also suggested in related literature (Pousman and Stasko, 2007). Hazlewood et al. (2011) for example suggest to evaluate ambient displays through field studies, or as they call it by deploying prototypes "in the wild". They propose to evaluate such studies by logging the number of times the system is used, by conducting interviews or by assessing the effects (e.g. by counting how many people take the stairs instead of the elevator as a result of installing ambient displays which promote using the stairs).

Insight 9. Interactive systems which aim to employ the periphery of attention and which aim to become a fluent part of the user's everyday routine, are best evaluated by deploying them in the context of use for a period of time.

Although field studies clearly enable designs to be used during the everyday routine, we are surprised that it is not common practice to evaluate whether or not interactions with a peripheral interaction design actually take place in the periphery of attention. Such an evaluation strategy may not directly be translatable to the effects of the design (e.g. when an interactive system is used in the periphery, it does not necessarily mean that it led to the desired effect). However, we see evaluating the extent to which a peripheral interaction design can be used in the periphery of attention as a first step toward finding evidence for the overall concept of peripheral interactions with technology.

OUR CONTRIBUTION

Despite suggestions to evaluate designs in context of use and for a period of time, such field studies are not common for interactive systems that employ people's periphery of attention. Since we are interested in evaluating the integration of interactive technologies in the everyday routine, we have decided to follow Hazlewood et al.'s (2011) approach by deploying the designs we present in the coming two chapters in the context of use. Additionally, different from other approaches, we aim to assess if our designs can indeed be interacted with in people's periphery of attention. We therefore believe that an important contribution of our work lies in the presentation of and reflection on three evaluations performed in the context of use for a number of weeks (see Chapters 5 and 6).

4.8. Conclusions

In this chapter, we have discussed research and design work related to the area of peripheral interaction. We have addressed both related terminology and presented concrete examples of related designs. From this exercise, we concluded that most related work aims to present perceptual information in people's periphery of attention. A few recent studies are known which explore physical interfaces for peripheral interaction. We expect that by combining audio and physical interfaces for peripheral interaction, our work presents a novel approach aimed at leveraging a wide range of human attention abilities. Thereby, we intend to contribute to both the area of auditory display and the area of tangible and embodied interaction.

Additionally, we have motivated our choice to develop peripheral interactive systems for the target group of primary school teachers. While only few interactive systems for classroom settings aim to employ the teacher's periphery of attention, we believe this target group can particularly benefit from peripheral interaction. We therefore hope to contribute to research on classroom technologies.

Finally, we reviewed evaluation approaches for peripheral interaction. A few specific evaluation methods have been developed for peripheral displays, which are suitable for laboratory experiments. We believe however that peripheral interaction designs need to be deployed in the context of use for a longer period of time in order to assess their value in the user's everyday routine and to evaluate if such designs can be used in the periphery of attention. We therefore concluded that we will adopt the approach suggested in literature to conduct our evaluations through field studies.

5.

Exploring peripheral interaction designs

Abstract

This chapter presents two iterations of peripheral interaction design: the first meant to gain practical experience in peripheral interaction design and evaluation and the second more elaborately exploring designs in a primary school context. In the first iteration, three interactive demonstrators, AudioResponse, EntranceSounds and RainForecasts, that provide subtle auditory information, were implemented in an office for three weeks each. As a result of this exploration, we have seen that within such a period of time, sounds can start shifting from the center to the periphery of attention. The second iteration explored two interactive systems. CawClock makes selected time frames audible in order to provide teachers with awareness of time. NoteLet is designed to support the teacher in observing children's behavior, by enabling him or her to take pictures of the classroom through straightforward interactions on a bracelet. A qualitative, two-week exploration of both systems in a classroom revealed that the soundscapes of CawClock indeed shifted to the periphery of attention and supported the teacher's time awareness. The physical interactions with NoteLet did not shift to the periphery. However, the tangible aspects of NoteLet seemed to facilitate the interaction to be quick and simple, which may indicate that it could shift to the periphery with more practice.

This chapter is based on:

Bakker, S., Hoven, E. van den, and Eggen, B. (2010). Exploring Interactive Systems Using Peripheral Sounds. In Proceedings of HAID'10, Springer-Verlag, pp. 55–64.

Bakker, S., Van den Hoven, E., Eggen, B., and Overbeeke, K. (2012). Exploring peripheral interaction design for primary school teachers. In Proceedings of TEI'12, ACM Press, pp. 245–252.

5.1. Introduction to this chapter

Many interactions in the physical world take place in the background or *periphery* of attention and only shift to the *center* of attention when relevant or desired. Traditional methods of human computer interaction (e.g. screens, keyboards) typically require focused attention. With technology becoming ubiquitously present in everyday life, however, it will no longer be possible nor desired for all technology to be in the center of attention. In line with a number of related directions (Edge, 2008; Hausen et al., 2012; Pousman and Stasko, 2006; Weiser and Brown, 1997), we believe that leveraging human attention abilities in interaction design will support computing technology to better fit into everyday life. This may enable users to interact with technology in their periphery of attention while this interaction may also shift to the center when relevant. We call these types of interactions *peripheral interactions*.

In previous chapters, we have studied the concept of peripheral interaction by discussing psychological theories on human attention processes (Chapter 2), by analyzing qualitative examples of how people use their periphery of attention in everyday situations (Chapter 3), and by discussing related research and design work (Chapter 4). These studies revealed, among other things, that awareness of information present in the periphery is often gained through auditory perception (also see Insight 4 on Page 60). Furthermore, we found that many actions that require little or no attention are performed with the hands (also see Insight 5 on Page 60) and seem to involve physical tools or artifacts. We therefore expect that peripheral interactions with technology will benefit from using tangibles for physical interaction and/or audio to convey information.

In this chapter, we present two research-through-design iterations on peripheral interaction design, in which we aimed to put the insights gained in previous chapters into practice. The first iteration explored peripheral interaction designs which use audio that is to be perceived in the periphery of attention. Three demonstrators were developed and evaluated in an office context for three weeks each. In the second iteration, we developed two interactive systems for primary school teachers. CawClock was designed to provide time awareness by using soundscapes, which are to be perceived in the periphery of attention, to indicate the time passing through a timeframe that is selected by the teacher. NoteLet allowed teachers to mark moments which they wanted to remember later on, by taking a photo of the classroom. This was done through a straightforward interaction on a bracelet that could potentially be performed in the periphery. To evaluate the potential of these systems with respect to peripheral interaction, we placed prototypes of both systems in separate classrooms for two weeks. In this chapter, we describe the design and evaluation of the interactive systems of both iterations and present our findings regarding peripheral interaction in general.

5.2. First iteration: AudioResponse, EntranceSounds and RainForecasts

In this section, we present three working demonstrators, named AudioResponse, EntranceSounds and RainForecasts. Each demonstrator uses sound to convey information which may reside in the user's periphery of attention, while it may also be focused on in the center of attention when relevant. The main aim of this iteration was to gain practical experience in the design and (long-term) evaluation of auditory displays. We therefore chose to convey information that is known to be suitable for peripheral perception based on related work (also see Chapter 4 and in particular (Eggen and Mensvoort, 2009; Eggen et al., 2008; Hermann et al., 2003; Schloss and Stammen, 2008)). Our demonstrators should therefore not be seen as innovative products but as research tools. We implemented a diverse range of sounds and types of information, enabling us to compare different functionalities and sound designs. We have evaluated these demonstrators in three separate experiments to gain insights in how informative background sounds can play a role in interactive systems.

All three experiments took place in an open office in which twelve researchers work, including the author. Nine researchers actively participated in the experiments. These participants (4 female, 5 male, age 23 to 32) had diverse cultural backgrounds and none had extensive knowledge in audio related topics. Other than people entering, talking and working, PCs, lights humming, doors opening and closing, there were no significant sounds already present, e.g. there was no music playing. Footsteps were softened because of carpet on the floor. Each demonstrator ran separately in this office for three weeks continuously. At the start of each experiment, the participants received explanation about the working of the demonstrator. See Figure 5.1 for an impression of the location.

To evaluate the use of sound in these demonstrators, we gathered qualitative data regarding the experiences of the participants. All comments made by either participants or by visitors were carefully noted by the author during the experiments. Furthermore, after each period of three weeks, a group interview was conducted with 4 to 5 participants. In this section, we will describe the demonstrators and the analysis of the experiments and interviews.

5.2.1. AudioResponse

DESIGN

AudioResponse is a simple interactive system that plays a continuing soundscape of piano tones with semi-randomized pitch. The AudioResponse system constantly monitors the loudness (in decibel) of the sound registered by a microphone, located in the center of the room (see Figure 5.1). This loudness determines the amplitude

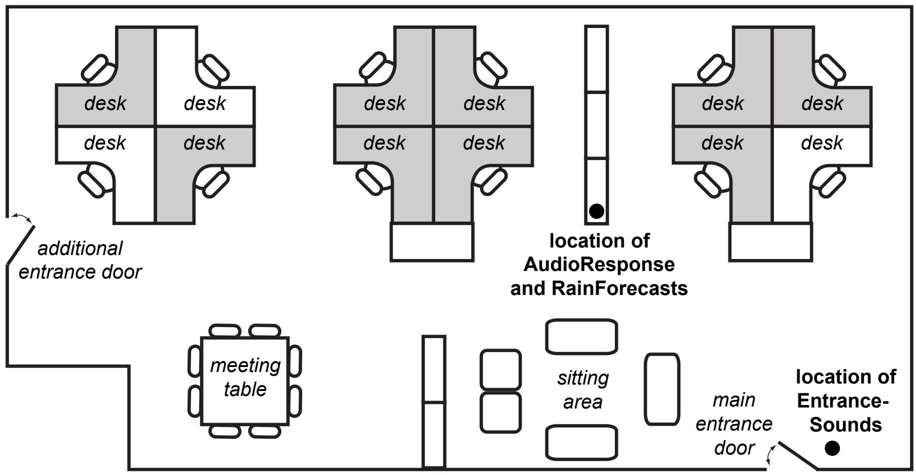


Figure 5.1. Lay-out of the open office used in the experiments, indicating the desks of our nine active participants in grey, and the location of the demonstrators.

of the piano tones; the higher the registered loudness, the larger the amplitude of the tones. The information communicated through this sound can provide awareness of the loudness of sounds the participants and their surroundings produce. This may provide awareness of 'what is going on around you' in a broad sense.

RESULTS

From reactions during the experiment and the group interview, we extracted 44 quotes regarding experiences with AudioResponse. These quotes were analyzed by the author. In this section we summarize our findings.

When the AudioResponse experiment ran in the office, four participants indicated that it made them aware of the loudness of certain everyday sounds. For example, a door in the hallway triggered a loud sonic response from the system, while the sound of this door was normally not experienced as very loud. Furthermore, two participants indicated that they felt that the system warned them when they were too loud, which also caused them to attempt working more quietly to avoid triggering the system.

All participants agreed that the system did not convey relevant information. However, some participants found the system 'fun' at certain moments, as it triggered laughing or conversation. Others experienced it as being annoying, because already disturbing sounds were enhanced to be even more disturbing. Regarding the piano sounds used in this design, the randomness of the pitch of tones caused some confusion, as some participants expected the pitch to be linked to certain information.

5.2.2. EntranceSounds

DESIGN

EntranceSounds is an interactive system located at the main entrance door of the open office (see Figure 5.1). A motion sensor located above the entrance registers if someone passes through the door (see Figure 5.2). Whenever a person is detected, a short piano chord is played. The pitch of the root of this chord indicates the number of people detected in the last hour. For example, if someone enters at 11.32h, the number of people registered between 10.32h and 11.32h is represented. Low pitch means that few people have passed and high pitch means that many people have passed. Since the EntranceSounds system does not register the direction in which people pass through the door, entering or leaving the room is not distinguished.

This system provides information about how busy the office was in the last hour, but also informs the people working in the office that someone is entering or leaving. The used door was always open during the experiment. As the office floor is covered with carpet, one will normally hardly hear someone entering or leaving.

RESULTS

The 39 quotes gathered regarding EntranceSounds were analyzed by the author. With the EntranceSounds system, there are clearly two types of users; people that

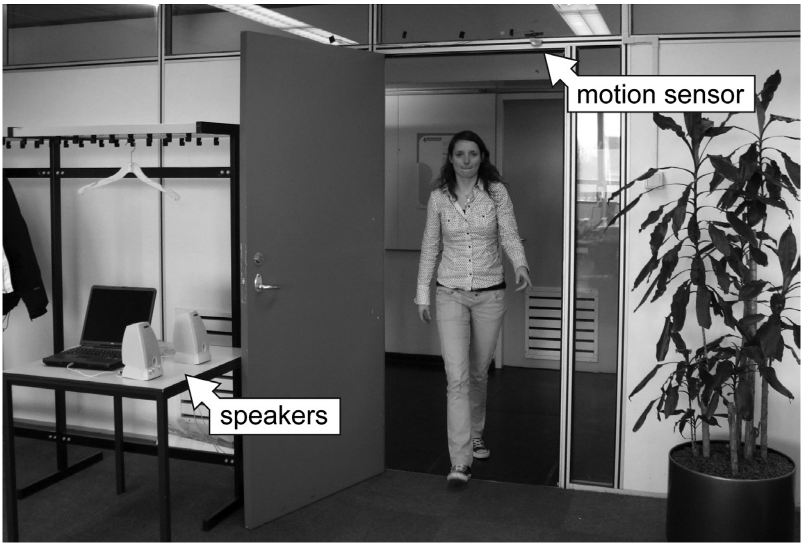


Figure 5.2. Picture of the EntranceSounds system, located at the main entrance of the open office.

enter or leave the room and thus trigger the sounds to be played (direct users) and people working in the open office hearing the sounds triggered by others (indirect users). Most indirect users noted that the system mainly informed them that someone is entering or leaving. This was not always experienced as relevant information, as many people can directly see the door, or are just not interested in this information unless the person entering comes to visit them. However, these participants also noted that it was easy to ignore the system and that they even experienced moments where someone had come to visit them, while they had not noticed the sound.

The information conveyed through the pitch of the chord was generally considered most useful by direct users; it made them realize that it was a busy hour in the office, or that “they had not been active enough”. When knowing the routines in this office, the information turned out to be rather useful in some cases. For example: one participant came in at 10.00h one morning and noticed that the sound was higher than expected, while the office was empty. This informed her that her colleagues must have gone for a coffee break. To indirect users however, the information about the number of people having entered or left did not turn out to be relevant; none of them felt the need to be informed of this each time someone passed the door. However, the sound was not experienced as annoying or disturbing by any of the participants.

All participants could clearly recognize the pitch changes when multiple people passed the door together. However, small differences were not noticed when the time in between two chords was bigger (say 5 minutes or more). This also became apparent from an experience of a participant who entered the office when the sound was much higher than normal, due to an event in the room. When this participant entered, she noted “this is not my sound, normally it always gives me the same sound, but now it is totally different”. Apparently, she usually did not notice pitch differences, even though small differences must have been present.

5.2.3. RainForecasts

DESIGN

The RainForecasts system provides audible information about the short-term rain forecasts for the city in which the experiment was held. Every half hour, the system presents the rain forecast for 30 minutes in the future, which may be relevant to users as it could influence their short term planning. The predictions are extracted from a real-time online weather forecast[6] in terms of an 8-point scale (0 meaning no precipitation and 7 meaning heavy thunderstorm). This value is represented by a specific auditory icon (Gaver, 1989), see Table 5.1, played in the

[6] *http://www.buienradar.nl, last accessed 25-04-2013*

center of the room. The sounds are selected to resemble the natural occurrence of each level precipitation, but also to be recognizable as such while presented out of context. This last consideration motivated our choice for drop sounds rather than recordings of actual rain, as short samples of such recordings played at an unexpected moment sound like white noise.

RESULTS

56 quotes gathered regarding the RainForecasts system were analyzed by the author. All participants agreed that they could easily recognize the rain forecast based on the sounds produced by the system. However, some participants felt that it was difficult to distinguish the different levels of rain when the sounds were played with 30-minute intervals. All participants agreed that the sound indicating 'no precipitation' was not distracting at all, whereas one participant indicated that the raindrop sounds were more distracting as they seemed louder than the no-rain sound. The participants indicated that they noticed the sounds less often towards the end of the three weeks of the experiment. Most participants mentioned that they did not hear it when working in concentration.

From the group interview, it became evident that the information conveyed by the RainForecasts system was not of equal relevance to all participants. Some were just not interested in the weather, while one participant, who traveled by bicycle, even based the time of going home on the weather. The information was therefore very relevant for this latter participant, who noted that it was exactly the information she needed: "The internet provides a lot of information, which makes it hard to find the specific information I need". Another participant however, wanted more detailed information (e.g. temperature) and preferred using the internet to look up forecasts.

Level of precipitation	Precipitation in mm per hour	Auditory icon
0	0	Bird sounds
1	< 1	Three rain drops
2	< 2	Four rain drops
3	< 5	Six rain drops
4	< 10	Eight rain drops
5	< 50	Mild thunder sound
6	< 100	Medium thunder sound
7	> 100	Heavy thunder sound

Table 5.1. Sound used in the RainForecasts system, indicating different levels of precipitation.

The participants also indicated that the system provided them with information other than the rain forecasts, namely the time. The system made a sound every half hour, which often resulted in reactions such as "did another half hour pass already? I must have been very focused!" Furthermore, some participants mentioned that the sound caught their attention more often at noon, which is the time of their usual lunch break. This indicates that the sound is more noticeable, or moves to the center of attention, when the conveyed information (time in this case) is more relevant.

5.2.4. Discussion of the first iteration

In the previous section, we have described the design and evaluation of three working demonstrators that use sound to communicate different kinds of background information in an office context. In this section, we will discuss the insights we gained regarding types of information and sound design suitable for such systems and regarding the perception of audible information.

TYPES OF INFORMATION CONVEYED BY THE DEMONSTRATORS

When comparing the three systems, all participants agreed that the RainForecasts system was most useful as they found the conveyed information most relevant. The AudioResponse system was considered least useful as the information provided was of no direct relevance to the participants. For this reason, some participants also experienced the AudioResponse system as being disturbing, while the other two systems did not disturb them. Interestingly, the volume of the AudioResponse sounds was not higher than that of the other sounds, and the used piano tones were similar to those used in the EntranceSounds system. This indicates, as could be expected and is also indicated in literature (Buxton et al., 1994), that the relevance of the information is related to the extent to which the sound representing it is experienced as disturbing.

> **Insight 10.** The extent to which audio is experienced as disturbing is related to the personal relevance of presented information.

Although the relevance of the audible information seems to be of importance, we have also seen that it is difficult to predict which information is relevant at which moment. For example, when one participant heard that many people had passed the door, she knew that her colleagues had gone for a coffee break. Another participant noticed the sounds of the RainForecasts system more clearly at 12.00h than at other times, as this indicated lunch time. The information that users take from such systems, is thus not always related to the information that is intended to be communicated. When and what information is relevant highly depends on the context and on the interests, state of mind and knowledge of the user. As multiple users are provided with the information at the same time, it can be relevant in one way to one user, in another way to another user and not at all to a third user. Peripheral perception of auditory information thus depends on highly personal factors, as we also concluded from the contextmapping study presented in Chapter 3 (see Insight 8 on Page 63). Therefore it seems important to deploy these kinds of auditory displays in everyday life settings for a period of time such that insight can be gained in their relevance for users and in their relation to the context in general.

When we look at the RainForecasts system, the conveyed information seemed relevant to many of the participants. However, some noted that the system did not provide enough information regarding the weather forecasts. For these participants, the information may have been too relevant to be conveyed in such 'limited' form. Although more sophisticated sound design could partly solve this (e.g. (Hermann et al., 2003)), it points out an interesting issue regarding the choice of information to be made audible. This information should be relevant, but in case it is and users require more detail, the interactive system should provide easy access to a layer of more detailed information. This way, general information can be monitored in the periphery via audio, and details can be examined in the center of attention when desired. The layer of details could be displayed through audio or by other means such as a visual display.

SOUND DESIGN

The presented demonstrators implemented three different sound designs and mappings. The AudioResponse used an continuing soundscape of piano tones, the EntranceSounds played short auditory cues when users passed through the door and the RainForecasts conveyed information through auditory icons every half hour.

The pitch changes as realized in the AudioResponse system were random and did therefore not convey any information, which caused confusion. The pitch differences in the EntranceSounds system however, revealed the number of people detected in the last hour. This has shown to be valuable at certain distinct moments. However, experiences with the EntranceSounds system have also shown that smaller pitch differences were not recognized, particularly when two tones were played with some time in between. The same issue was seen in the RainForecasts system, where participants found it hard to distinguish sounds indicating different levels of rain. If two sounds are not played successively, the differences between the sounds should therefore be clear enough to be perceived and remembered.

PERCEPTION OF AUDIBLE INFORMATION

All three experiments ran for three weeks successively, which enabled evaluation of how the perception of audible information changed over time. In each experiment, the sounds were perceived in the center of attention at the start. This means that the participants consciously heard them and often also reacted to them by looking at the demonstrator. However, in both the EntranceSounds and the RainForecasts experiments, we saw that the sounds shifted more to the periphery towards the end of the three weeks: they did not attract the participants' attention each time a sound was played. Getting used to the sounds thus seems required to enable them to shift to the periphery of attention. The sounds of the AudioResponse indicating above average loudness did not shift to the periphery but were always in the center of attention. This may be explained by the fact that many participants linked the information to themselves being loud, which annoyed them.

As mentioned before, we have seen that the information participants derived from the sounds was often different from what was intended by the design. For example, concluding that colleagues went for coffee based on the pitch of the chord in the EntranceSounds system. These kind of events occurred more often toward the end of the experiment period, even though the participants were informed about the meaning of the sounds at the start of the experiments. This may indicate that a learning period is needed to enable sounds to become integrated in the everyday routine, such that users can gain meaningful additional information from them. This also emphasizes the need long-term evaluations of peripheral interactive systems.

The results of the deployments of our three demonstrators reveal that the systems were most useful when the information conveyed by the sounds differed from what the user expected. This happened for example with the EntranceSounds system when the pitch was considerably higher due to an event in the office. In such cases, the sounds were clearly in the participants' center of attention and were experienced as relevant. However, this only occurred in a small number of cases. In most cases, the information conveyed by the sounds was as expected and did therefore not add to the knowledge of the participants. In fact, it is likely that in over 95% of the cases that a sound was played, no new information was conveyed. Though this may appear to be useless, it is exactly the intention of our designs. When comparing this to sounds in our physical environment, we see the same thing; when driving a car, the engine will sound as usual in most cases. Only in case of an unusual situation, the sounds will be different. This conveys new and relevant information and immediately shifts to the center of attention. When the sounds are only relevant in a low number of cases however, it is crucial to design them such that they only shift to the center of attention when required.

As we have seen, at times the sounds were in the periphery and at other times they were in the center of attention. Relating this to selective attention theory described in Chapter 2, we see that in most cases when sounds shifted from the periphery to the center related to *salience* (Knudsen, 2007). For example, when the rain sounds were experienced as louder than the no-rain sounds. However, sometimes participants attended to the system for other reasons. For example, when the RainForecasts sound at 12.00h attracted the attention more than the sounds at other moments, as it indicated lunch time. This could have been the result of *priming* (Treisman, 1964); the participant likely knew in the back of her mind that it was almost time for lunch, so stimuli indicating time may have been primed.

5.3. Second iteration: CawClock and NoteLet

In the first research-through-design iteration, we explored peripheral interaction designs which display auditory information in an office context. Apart from peripheral *perception*, however, we believe that interactive systems that are to become a part of the everyday routine could also benefit from interaction design that allows the user to *physically interact* with these designs in their periphery of attention. In the second iteration, which we discuss in the current section, we therefore explore both peripheral perception and physical peripheral interaction.

Most related examples of peripheral interactions, including our own demonstrators developed in the first iteration, were designed for offices (e.g. (Cohen, 1993; Eggen et al., 2008; Gaver, 1989; Hausen et al., 2012; Ishii et al., 1998)), which has proven to be a valuable target context since many relevant information streams are present. To extend the application area of peripheral interaction however, we are interested in exploring contexts in which the computer currently plays a less salient role.

We have focused our current study on teachers of the first grades of Dutch primary schools, who teach classes of 25 to 30 children of four to six years old. The first grades of primary school in the Netherlands are similar to what in other countries is known as preschool or kindergarten. Since the design-researchers who conducted this study have no practical experience in classroom contexts, two interviews with teachers and observations in a classroom were conducted to get a better understanding of the teacher's work and the classroom environment. This taught us that next to activities such as group talks, reading to the children and playing outdoors, a typical school day centers around the 'working lessons'. During a working lesson, which takes place twice a day, the children perform individual and group tasks such as role play, painting, language exercises and construction play. The teacher's work during a lesson consists of several tasks such as giving instructions, observing children's development, answering questions and stimulating learning. To perform this work, the teacher usually walks around the classroom, sits down with a child or stands on the side of the room to observe. See Figure 5.3 for an impression of a working lesson.

Since this iteration is a first attempt to design peripheral interactions for a classroom context, we felt there was a lot to learn about the setting and goals of our designs. We therefore decided to take an explorative approach to the design and evaluation process. After having obtained a better understanding of the everyday routine in primary school classrooms, a creative brainstorm session about peripheral interactions for this context was held in a group of design-researchers. Two designs were selected for further development; *CawClock*, which focuses on the perception of information in the periphery of attention, and *NoteLet*, which explores physical actions performed in the periphery. Early conceptual versions of these designs were discussed with a group of three primary school teachers to obtain feedback on the usefulness of these concepts in a classroom context. This feedback, which included practical suggestions about the size and visual appearance of the designs, was used as input for the finalization of the designs.

Figure 5.3. Impression of a working lesson in a first grade primary school classroom.

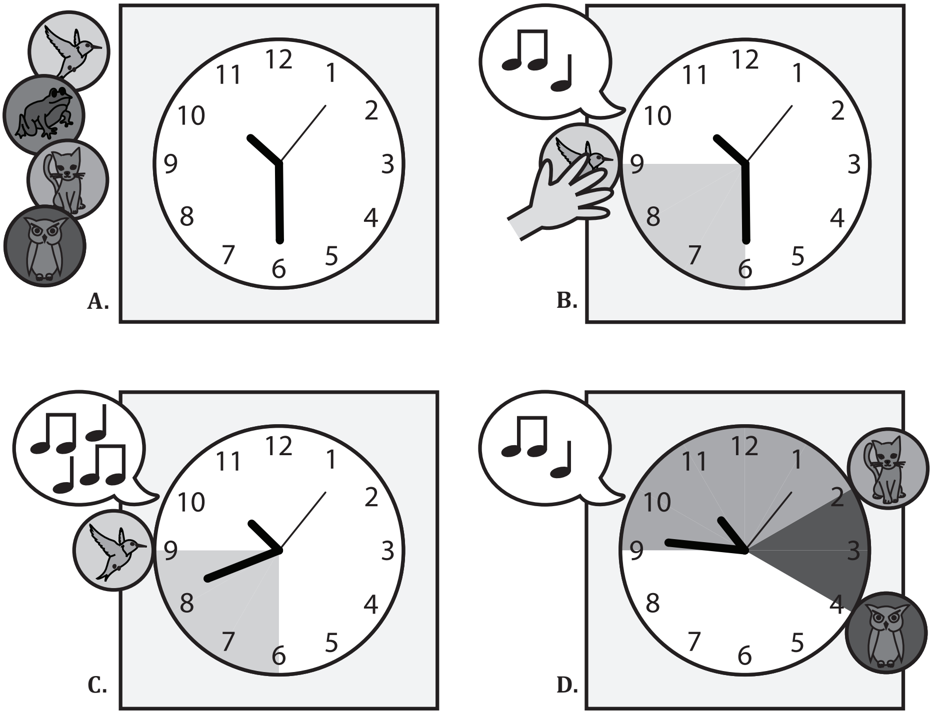


Figure 5.4. Illustration of CawClock; a clock with 4 tokens (A), a marked timeframe is represented by color and a soundscape of animal sounds (B), more animals are heard toward the end of the timeframe (C), multiple timeframes can succeed each other (D).

5.3.1. Peripheral interaction designs

CAWCLOCK

In the classrooms we visited, we saw that fixed routines are important during working lessons. Every lesson starts with 15 to 20 minutes of independent work; the children have to work on a single task and cannot ask the teacher for help. During the remaining 30 minutes, the children are allowed to choose a different task and may ask for help. At the end, 10 minutes are used for cleaning up. Since not all children know how to read the clock, or even have an understanding of how long 15 minutes are, the teacher uses expressions such a 'when the big hand is at the three, you can choose another task'. She frequently looks at the clock and reminds the children of the remaining time. This helps the teacher structure her time (e.g. all children need to be observed during independent work), but it also reminds the children of the current 'rules' and remaining time.

To support time awareness, we developed CawClock, see Figure 5.4. CawClock consists of a display that shows the time as a regular analog clock, and four tangible tokens, each with their own color and image of an animal on it (a cat, bird, frog or owl). The tokens can be used to mark a time-frame on the clock. For example, if at 10.30h the children must work independently until 10.45h, the teacher can place a token next to the 9 of the clock, where the big hand will be at 10.45h. The part of the clock between the 6 and the 9 (the current time and the end of the time-frame) will then be colored. While the big hand is inside the colored part of the clock, a background soundscape will be heard that corresponds to the animal on the token (i.e. cat-sounds, bird-sounds, frog-sounds or owl-sounds). Furthermore, the soundscape gradually changes; the number of animals heard increases toward the end of the timeframe, without increasing the volume of the audio. This way, the soundscape informs the teacher and children that the time-frame is ongoing and indicates how much time has approximately passed already.

The colored parts of CawClock are similar to those used in other educational time-keeping materials. The ColourClock[7] for example is a mechanical clock with fixed colored parts and one hand. Different from the ColourClock, CawClock has two hands, allowing it to be used as a regular analog clock. Moreover, the audio is designed to provide peripheral awareness of marked timeframes. The visual aspect of CawClock is not meant to be perceived in the periphery but can be used when detailed information is required. The tangible interaction used to mark time frames is designed to be in the center of attention; the teacher will consciously mark a timeframe and explain this to the children. The peripheral interaction intended with CawClock consists of the perception of soundscapes that represent timeframes.

To enable evaluation, we developed a fully functioning prototype of CawClock, see Figure 5.5 and the demo video[8]. This prototype used a TFT-screen and conductive magnetic connections to attach the tokens to the clock.

NOTELET

Among the many tasks of a teacher, an important one is to observe the children's abilities. This way, the teacher keeps track of the children's development over time, in areas such as motor skills, social skills and language. Observations are either done intentionally (the teacher sits down, observes particular children and particular behavior), or unintentionally (the teacher is performing another task but sees a child perform behavior that is worth making a note of). Examples of unintentional observations are seeing a child holding the pencil in a wrong way, or seeing a child collaborating well with another child. In case of unintentional observations, the teacher can walk to her desk to take a note or remember to take a note later. At the end of every few days, the teacher enters the notes into a digital system. As there is not much time for intentional observations, unintentional

[7] *http://www.colourclock.com, last accessed 25-04-2013*
[8] *http://vimeo.com/32092240, last accessed 25-04-2013*

Figure 5.5. CawClock prototype (A), the tokens (B), and CawClock situated in a classroom during the user exploration (C).

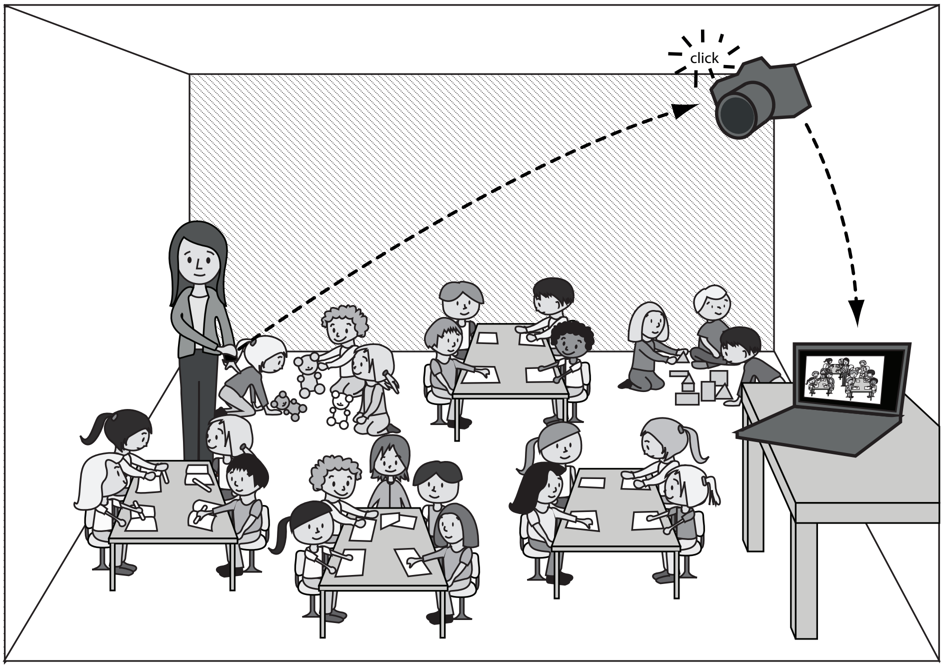


Figure 5.6. Illustration of NoteLet: a bracelet for taking pictures of the classroom.

observations play an important role in keeping track of development. These observations however, may distract the teacher from her current activity when a note needs to be made. On the other hand, remembering it by heart may not be sufficient.

To support unintentional observations, we have developed NoteLet, see Figures 5.6 and 5.7. This interactive system consists of a camera located in the corner of the classroom and a bracelet that the teacher can wear around the wrist. When the teacher squeezes her wrist, the camera will take a picture, which is stored with the date and time. On the back of the bracelet, the names of all children are listed. When the area next to a name is touched, not only a picture, but also the child's name is stored. To make it easy to find the right name, girls are listed on the right while boys are on the left, both in alphabetical order. Furthermore, the touch-sensitive areas are overlaid with patches of fabric; fabric with a smooth texture for children in first grade and fabric with a rough texture for children in second grade. This way, both location and tactile qualities of the touch sensitive areas may provide information about the connected child's name. The pictures can be used at the end of every few days when entering observations in the computer.

Taking pictures in case of unintentional but relevant observations is meant to replace the notes that are currently used. Although pictures may in some ways be less specific than notes, and do not capture everything (e.g. audio), we expect that

Figure 5.7. NoteLet prototype: manipulating the bracelet to take a picture without (A) or with (B) a name, and the webcam situated in a classroom during the user exploration (C).

when seeing a picture taken within the past days, a teacher will be able to recall her observation.

Since the system is wearable, the teacher does not have to change locations to use it. Taking pictures is intended to be a quick and straightforward action that can potentially be performed in the periphery of attention. Taking a picture without selecting a child's name is likely easier than selecting a name, but also leads to less detailed information. By incorporating both functionalities in our design, we hope to learn more about the value of each of these two options.

For the evaluation of this concept, we developed a working prototype, see Figure 5.7 and the demo video[9]. The bracelet uses simple touch-buttons and a ZigBee[10] module to communicate to a computer, which is connected to a 5 mega pixel camera mounted on the ceiling in the corner of the classroom.

5.3.2. User exploration

To learn more about the design and evaluation of peripheral interactions, we set up a user exploration with CawClock and NoteLet. As mentioned, we decided to take an explorative approach to the evaluation, rather than using a formal setup. We wanted to explore the value of our designs in the classroom setting (e.g. the purposes for which teachers may use them). Additionally, we wished to evaluate their suitability to blend into the everyday routine of the teacher. In line with these objectives, we found it important to evaluate our designs in the context of use and for a longer period of time. We installed each of the two prototypes in a separate classroom for two weeks. In these two weeks, the teachers used the prototypes for six school-days. The two classrooms were selected from the same school and the explorations ran simultaneously, to encourage discussion among the teachers about the designs.

Given the intended explorative nature of the evaluation, we gave the teachers open instructions. We demonstrated the prototypes and explained how they could be used, but explicitly pointed out that the teachers could use them in any way and for any purpose they wanted. By using this approach, borrowed from the Technology Probes method (Hutchinson et al., 2003), we hoped to learn more about the teachers' needs and desires and we hoped to gain inspiration for future peripheral interactions for this context. We did not inform the teachers of the intention of the designs being used in the periphery of attention; we expected that pointing out this may have the opposite effect.

To facilitate another study outside the scope of this thesis, we also developed a completely digital version of CawClock. The design was the same as the presented

[9] *http://vimeo.com/32202709, last accessed 25-04-2013*
[10] *http://digi.com, last accessed 25-04-2013*

tangible design, only the tokens were icons on screen that could be dragged to the clock using a mouse. This digital CawClock was use by a third teacher in the same school. Therefore, three teachers participated: one using the tangible CawClock, one using the digital CawClock and one using NoteLet.

To evaluate the use of our designs, we arranged an observation session in each participating classroom during a working lesson in the second week of deployment. During these 30 to 45 minute sessions, two researchers were present to take notes and a video was recorded for later analysis. At the end of the two week period, we conducted individual open interviews with each teacher and a group interview in which the teachers discussed their experiences among each other. The teacher who used the digital version of CawClock also participated in the group interview. His remarks about the audio design and the CawClock concept in general, have been taken into account in the findings we present in this chapter.

5.3.3. Findings and discussion

In this section, we will discuss the findings of our user exploration with CawClock and NoteLet.

CAWCLOCK

The teacher who experienced the (tangible) CawClock, used it every working lesson (9 times during the deployment) to indicate which rules applied at which moments and for how long. In each of these lessons, children had to work independently during the first 15 or 20 minutes of the lesson (indicated by one color on CawClock), while during the remaining time the children could ask questions (indicated by another color on CawClock). Furthermore, she used CawClock twice during the two week deployment to indicate when the children should be finished cleaning up, once to indicate the time available for lunch, and once to specify a timeframe in which they would play a game.

When marking timeframes, the teacher used the same token for the same activity every day, for example the cat to indicate independent work. The teacher mentioned that this way, the children automatically know what they are or are not allowed to do by listening to or looking at the clock. Although the teacher still announced the remaining time regularly, e.g. “look at the clock, we have 10 minutes left”, she also mentioned that she felt the children came to her less often than normal to ask if they could choose another task.

CawClock and the everyday routine

During the observations, the soundscapes of CawClock seemed to fit well in the classroom context. In the 45 minute video we recorded, of the 10 children that were in sight of the camera, only three looked up at the clock when hearing a sound, each about 4 to 5 times. Furthermore a couple of children imitated the sounds, but overall the soundscapes in the classroom did not seem to interfere with the everyday routine. This was also acknowledged by the teacher.

CawClock and the periphery of attention

Of the two teachers who used the two versions of CawClock, one indicated to be somewhat annoyed by the soundscapes. However, she also indicated that after a few days she got used to them, to a point that she did not notice that the sound had stopped. The other teacher was not annoyed by the audio and mentioned "I hear it, but I am not focused on it". During the observations, the audio also did not seem to attract the attention of the teachers much; only two instances were observed where a teacher looked at the clock when hearing a sound. This indicates that the soundscapes seem to have been in the teachers' periphery of attention at many moments.

CawClock's sound design

The teacher who used the tangible CawClock, frequently marked two successive timeframes; one for independent work and one for the rest of the lesson. She indicated that she always noticed the first timeframe ending as the cat-sounds would change to bird-sounds. In other words, the audio shifted to the center of attention at the transition of two timeframes. She also mentioned that the end of the second timeframe was less clear, as the audio simply stopped.

We also saw the audio shifting from the periphery to the center of attention at less relevant moments. It attracted the attention of one teacher when the sounds annoyed her. This particularly held for the cat and frog; the owl- and bird sounds were less distinct and easier to ignore. When discussing this in the group interview, we were surprised that the teachers mainly used words that are normally used for a telephone ringing, e.g. "maybe it should 'ring' less often". Although this way of thinking does not match our ideas of peripheral soundscapes, it is an understandable way of reasoning. Other commonly used devices (e.g. mobile phones or alarm clocks) use sound mainly to attract attention. Since we deliberately did not inform the teachers that our soundscapes were to be perceived peripherally, it may very well be the case that they thought they were expected to notice the sound every time it was played. This may have caused the experienced annoyance with some soundscapes. In hindsight, it may therefore have been better to explain that the sounds were intended as background soundscapes.

The intention of CawClock was to provide the teachers with peripheral awareness of time, by means of background soundscapes. The audio changed as a timeframe went by; more animals were to be heard closer to the end of the timeframe. Both teachers however indicated that this gradual change was not apparent to them. The audio therefore mainly provided awareness of the fact that a timeframe was still ongoing. To know how much time was left, they needed to look at the clock. Despite this, both teachers found the audio useful since they did not have to look at the clock to know that the timeframe had not ended; they were automatically informed through the audio.

One of the teachers mentioned that glancing at the CawClock supported time awareness. When looking at a normal clock, a glance was not enough for her to realize how much time was left until the end of the lesson; she had to remember which time she agreed upon, interpret the current time and so on. The color parts of CawClock however, gave her an immediate, clear overview of the time left. She found this useful when she needed to finish a task; glancing at the CawClock helped her to know if she was on schedule or not. This seems to confirm our earlier finding in the experiment with RainForecasts, in which we concluded that auditory displays that provide overall information in the periphery, could be extended by making detailed information readily accessible in the center of attention.

NOTELET

NoteLet was used in every working lesson; 9 times during the deployment. The teacher wore the bracelet during independent work (the first 15 to 20 minutes of the lesson), which is usually the moment she takes notes. At the end of independent work, she took the bracelet off. During the two weeks of the experiment, 58 pictures were taken; 6 or 7 pictures per lesson. The majority of these pictures (39 out of 58) included a specific child's name. The teacher indicated that she used the pictures with names in two different situations. First of all, she took a picture with name when a child did something she wanted to remember, such as sitting on a chair incorrectly. The second situation in which she took pictures with name, occurred when she remembered that a child had not been working well earlier on. At such a moment she took a picture with the name of that child, without looking at this child, to check if he or she worked better later in the lesson. According to the teacher, this enabled her to have 'extra eyes'. She preferred this over turning around to look at the child, which would distract her and might be intrusive for the observed child.

The option to take a picture without a name was used in 19 out of 58 cases. The teacher indicated that she used it to learn if she was aware of everything that was happening in her class; "you think you know everything, but with this picture you can see if that is really the case".

The teacher viewed the pictures at the end of each day. She did not enter observations in the computer; this was not needed during the exploration. However she indicated that it could be useful for that purpose. Furthermore, she noted that taking 6 to 7 pictures per lesson would be too much when using NoteLet for a longer period of time; it would simply take too much time to look at all these pictures after school hours. The two other teachers who participated in the group interview also imagined that this would be a problem. Although our research interest is mainly in the manipulation of the bracelet, this is of course important to take into account. The reason we used pictures was the amount of information they can contain, e.g. location, posture, activity. However, one of the teachers who did not use the NoteLet, commented "I would have to think 'When did I take this picture? Who was it about? Where is that child in the picture?', phew, that will take too much time". The fact that pictures contain a lot of information may thus be a disadvantage and pictures may therefore not be the right medium for every observation.

NoteLet and the everyday routine

The teacher indicated that the NoteLet was rather simple to use; she could quickly squeeze her wrist and finding the right name on the bracelet did not require too much effort, particularly because of the alphabetical order and the different fabrics that were used. When asked if taking a picture distracted her, the teacher said "It took a few seconds, I had to look at it to find the name but I was not completely distracted from my main task". Furthermore, she mentioned "It is useful as it is at hand, I do not have to go and write it down every time I see something". We therefore have the impression that, although looking at the pictures after school hours was too time-consuming, the interactions required to take pictures with NoteLet integrated well in the routine of the teacher.

NoteLet and the periphery of attention

During the observation, one picture was taken without a name, which required only a very brief look at the bracelet. However, the teacher consciously needed to look at the bracelet to find a name, as was also evident from the pictures taken with NoteLet in which the teacher was captured while she interacted with the bracelet (see Figure 5.8). The teacher mentioned "I did not know by heart where each name was, I used every name once or twice. If you use it more often, it will probably become a routine". Since conscious attention seemed needed to interact with the bracelet, it appears that it was not used peripherally during our exploration. We know from psychology theory (see Chapter 2) and from our contextmapping study (see Chapter 3) that mainly habituated activities are performed in the periphery of attention. The two weeks of our exploration were clearly not enough for the interactions with NoteLet to shift to the periphery; the teacher did not have automated knowledge of the location of the names on the bracelet. Squeezing the wrist to take a picture seemed to be a more straightforward interaction which may more easily shift to the periphery. However, our observations are too brief to confirm this.

Figure 5.8. Picture taken with NoteLet, of a child named John, by the participating teacher (visible in the foreground). The textbar at the top says "This picture is taken at 20-06-2011, at 13:38, of John".

Literature on habituation (Aarts and Dijksterhuis, 2000; Wood and Neal, 2007) discusses the link between habituated behavior and the goal of this behavior; behavior may become habitual (and thus potentially performed in the periphery of attention) when it has frequently been performed to successfully reach a relevant goal. As discussed above, the teacher who used NoteLet doubted whether or not she would find it worthwhile to look at the pictures after school hours, meaning that the goal for which she used NoteLet may not have been relevant to her. This could have contributed to difficulty of the interaction shifting to her periphery of attention. This confirms our earlier findings which state that activities can only become habituated when they serve a clear goal (see Insight 2 on Page 30) and that shifts to periphery of attention are often a result of highly personal factors (also see Insight 8 on Page 63).

NoteLet's interaction design

The design of NoteLet, which included alphabetical order of names and different fabrics to distinguish names, seemed to support the teacher in quickly finding the right name. However, the interaction did not shift to the periphery of attention during our exploration. This may raise the question if the activity of taking notes is suitable for peripheral interaction. Interactions with NoteLet started with (1) observing noteworthy behavior, followed by (2) finding the name on the bracelet and (3) pushing the corresponding button. The first of these three actions likely takes place in the center of attention; the teacher consciously decides to take a note of observed behavior. Although the other two actions did not take place in the periphery during our experiment, they required only a few seconds and seemed to fit in the teacher's everyday routine. We find this a promising finding and therefore expect that with a more sophisticated design (e.g. to prevent having to select among 28 individual buttons) and with more time to experience the design, similar interactions may be performed peripherally. Despite this, we do believe that the first action that is required for interaction with NoteLet, observing noteworthy behavior, is such a conscious act that it is highly unlikely that this part of the interaction is done peripherally. Although our peripheral interaction approach may make the act of taking a note easier and more embedded in the everyday routine compared to walking to your desk and writing it down, a part of this activity will always be performed in the center of attention. We must therefore conclude that interaction design which serves a purpose that inherently needs to be performed consciously could benefit from the peripheral interaction approach, but will unlikely become part of a completely peripheral activity.

Insight 11. Designs which serve purposes that inherently require conscious attention can benefit from peripheral interaction, but will unlikely become part of a completely peripheral activity.

5.4. General discussion on peripheral interaction

In this chapter, we have presented two research-through-design iterations: one exploring peripheral audio in an office context, and the other exploring peripheral interaction designs for primary school teachers. These latter two designs, CawClock and NoteLet, separately explored two types of peripheral interaction; the peripheral perception of (auditory) information on the one hand and physical interactions performed in the periphery on the other hand.

From the contextmapping study presented in Chapter 3, we concluded that audio is used in everyday life to facilitate awareness of information in the periphery (Insight 4 on Page 60). In our first iteration, we found that indeed participants perceived some of the sounds used in our designs in their periphery of attention. Also in the exploration with CawClock, the soundscapes shifted to the periphery of attention at certain moments. Although particular sound designs could be improved to make them more fitting for the context in which they are played, we have seen that indeed audio seems a suitable modality for peripheral perception. Participants in both iterations indicated that the audio enabled them to be aware of relevant information (e.g. they knew whether it has been a busy day in the office or they knew whether a time-frame on CawClock was still ongoing without having to look at the clock). Furthermore, in both iterations the audio shifted to the center of attention at certain relevant moments, which confirms our previous findings.

The physical actions required for NoteLet were not performed in the periphery of attention. Two weeks deployment may not have provided the teacher with enough experience to perform the interactions peripherally. Additionally, the goal for which teachers could use NoteLet did not seem relevant enough. This indicates that longer term studies are needed to evaluate if and how physical interactions (such as the manipulation of NoteLet) can shift to the periphery of attention. Furthermore, in a future design iteration, the teachers should be able to use the design for a personally relevant goal. This latter point is also discussed in literature on classroom technologies in general (Chen et al., 2009), which states that technology use in classrooms strongly depends on the teachers' goals with the technology.

In our contextmapping study, we saw that everyday physical objects and tools are often used in the periphery of attention (Insight 5 on Page 60), indicating that tangible interaction may be a suitable style for peripheral interaction design. Our NoteLet design is not a classical example of tangible interaction, which requires that physical artifacts can be used to *both* represent and control digital data (Ullmer and Ishii, 2000). However, the tangible aspects of NoteLet, such as the patches of fabric representing a child, seem to have made the interaction quick and straightforward. Although the interaction with the NoteLet prototype did not shift to the teacher's periphery of attention, the success of the tangible aspects of our design makes it interesting for us to further explore the use of tangible interaction in the periphery of attention.

NoteLet used a wearable bracelet design, which enabled it to be at hand any moment and seamed to facilitate the interaction to fit in the everyday routine. However, the teacher only wore the bracelet during specific parts of the working lessons and took it off afterwards. As a result, the interaction possibilities were only at hand at those moments. To some extent, the wearable aspect of the design may therefore have limited the use of NoteLet. It would be interesting to explore other types of interaction design in future iterations, which enable more flexible use.

Given the success of auditory perception as peripheral interaction and the potential of tangible interaction for this purpose, it would be interesting to think about combining the two. Auditory perception could potentially support tangible peripheral interaction, for example playing a short and subtle audio cue that represents a child, when going over a name on NoteLet. This could support finding names and may enable the teacher to not have to look at the bracelet. Since audio seems to shift to the periphery more easily than a physical action, such cues may support the action to shift to the periphery of attention. In Chapter 6, we further explore such interaction to learn more about this.

Most related work that aims at employing the periphery of attention is developed for the traditional office context, where the user is sitting behind a desktop computer most of the time. Based on our explorations with CawClock and NoteLet, we have experienced the classroom as a suitable environment for peripheral interactions. Computing technology has a lot of potential to support the teacher's tasks and activities. However, this is currently barely applied since traditional human computer interaction is less suitable (e.g. the teacher is not sitting behind a computer and needs to keep her eyes on the children). What we find particularly interesting about this context is that even though the main user frequently walks around, she stays within a confined space (the classroom). This opens up opportunities to integrate tangibles and other parts of a design into this environment, without having to confine it to a specific location such as a desk. We can for example imagine different tangibles or ambient information systems 'lying around' the room, available to be interacted with when desired. Such interactions will not only be suitable for classrooms, but can be generalized to similar situations in which a user walks around in a predefined space, such as a waiter in a restaurant or a nurse in a hospital.

5.5. Conclusions

In this chapter, we presented two research-through-design iterations on peripheral interaction. The first iteration focused entirely on peripheral perception of auditory information, while the second iteration explored both peripheral perception and peripheral physical interaction through two different designs. In the first iteration, three interactive demonstrators were implemented in an office environment for three weeks. This exploration revealed that the participants did perceive some of the sounds used in our designs in their periphery of attention, though getting used to the systems was required to achieve this. Furthermore, the kinds of information that participants picked up from the sounds differed depending on the context, interests and knowledge of the user, as well as on their experience with the system.

The second iteration involved two designs; CawClock aimed at providing peripheral awareness of time through background soundscapes, while NoteLet enabled taking photographs of moments that the teacher wanted to make a note of, through a simple and straightforward interaction on a bracelet. A two-week, qualitative user exploration showed that CawClock was valuable to monitor time and current 'rules' in the classroom, and that it fit in the classroom context. NoteLet was used regularly, but looking at the pictures after school appeared to be too time-consuming and therefore the interactions were not very relevant. We furthermore found that the auditory perception of CawClock indeed shifted to the periphery of attention at certain moments; the teachers heard the audio but did not have to focus their attention on it. The interactions needed for NoteLet did not shift to the periphery; two weeks appeared not enough to make this happen. The tangible aspects of the NoteLet supported the interaction to be quick, straightforward and at hand. Tangible interaction thus seems a promising interaction style to further explore for peripheral interaction design. In the next chapter, we will present the third design iteration in which we further explore peripheral interactions in classroom settings by using tangible artifacts in combination with background auditory feedback.

6.

Designing and deploying FireFlies

Abstract

This chapter presents our final iteration of peripheral interaction design. We present an open-ended interactive system called FireFlies, which aims to support secondary tasks of primary school teachers. FireFlies uses light-objects and audio as a (background) information displays, which can be manipulated by teachers through physical interaction. A working prototype of FireFlies was deployed in four classrooms for six weeks each. All teachers used FireFlies every day of the evaluation, primarily to communicate to the children in silence. The auditory display was less successful; the soundscapes were not experienced as informative and distracted teachers and children. The six participating teachers were able to physically interact with the FireFlies interactive artifact quickly and frequently without interrupting ongoing tasks. In the final weeks of the study, the teachers seemed able to easily shift their focus of attention between their main task and the interactive system. After the study had ended and the systems were removed from the schools, the teachers kept reaching for the devices and mentioned they missed FireFlies, which shows that during the experiment, it had successfully become part of their everyday routines.

This chapter is based on:

Bakker, S., Hoven, E. van den, and Eggen, B. (2012). FireFlies: Supporting Primary School Teachers through Open-Ended Interaction Design. In Proceedings of OzCHI'12, ACM Press, pp. 26-29.

Bakker, S., Hoven, E. van den, and Eggen, B. (2013). FireFlies: Physical Peripheral Interaction Design for the Everyday Routine of Primary School Teachers. In Proceedings of TEI'13, ACM Press, pp. 57-64.

Bakker, S., Hoven, E. van den, and Eggen, B. (2013). Evaluating Peripheral Interaction Design. Submitted to Human–Computer Interaction.

6.1. Introduction to this chapter

In contrast to traditional methods of HCI (e.g. keyboard and screen), which typically require the user's focused attention, interactions with the everyday world clearly shift between center and periphery of attention. Given that technology is becoming more pervasive in everyday life, we see a large added value in interactive systems that may similarly reside in the periphery of attention while shifting to the center only when relevant. This direction is pursued research areas of research, such as *calm technology* (Weiser and Brown, 1997), most of which aim at subtly presenting information to provide awareness through peripheral perception (Cohen, 1993; Eggen and Mensvoort, 2009; Ishii et al., 1998). However, given the observation that in everyday life, both perception and action can take place in the periphery, we have proposed to extend this area by designing not only for the *perceptual* periphery, but also to enable users to *interact* with the digital world in their periphery. We have named this direction *peripheral interaction*.

In previous chapters, we have defined the center and periphery of attention based on psychological theories (Chapter 2), explored how people perform everyday (non-technology enhanced) activities in their periphery of attention (Chapter 3) and reviewed related work (Chapter 4). Furthermore we discussed our first and second iteration on peripheral interaction, which included the design and evaluation of three demonstrators which provided subtly auditory information in an office context, and two interactive systems, CawClock and NoteLet, developed for a primary school context (Chapter 5). Although the results of these iterations were promising, it also revealed several potential improvements to both the designs and the evaluation setup.

In this chapter we present our third iteration, involving a newly developed peripheral interaction design, called *FireFlies*, which is based on the two earlier designs CawClock and NoteLet. Rather than separately exploring physical interaction and perception that may shift between the center and periphery of attention, FireFlies combines tangible interaction (Hornecker and Buur, 2006; Ullmer and Ishii, 2000) and audio to enable both peripheral physical interaction and peripheral perception. FireFlies is designed to support primary school teachers in peripherally performing and keeping track of secondary tasks, for example reminding children of the classroom rules, giving them turns and stimulating good behavior. Though developed for a user-driven purpose, the main intention of FireFlies is to study how interaction with technology can shift between the center and periphery of attention and thereby fluently blend into people's everyday routines, similar to the way in which interactions with the physical world are a part of routines. To reach this objective, we deployed FireFlies in four primary school classrooms, each time for a period of six weeks. This user study evaluated if the six teachers who worked with FireFlies, were able to physically interact with it in their periphery of attention, whether the audio could be valuable as a peripheral information source, and if the system as a whole blended in the everyday routine in the classroom. In this chapter, we will first discuss the design process in which we developed FireFlies, followed by a detailed presentation of the final design. In the second part of this chapter, we will present our user study and findings based on video-, interview- and questionnaire data obtained during the evaluation.

6.2. Third iteration: design of FireFlies

6.2.1. Design process

Only few interactive systems are known which support teachers by deploying their periphery of attention (see Chapter 4). Based on our previous iteration (presented in Chapter 5), and given the many activities teachers have to perform and the many information streams present in their everyday routines, it has become apparent that this target group could benefit from peripheral interaction design.

In our previous exploration of peripheral interaction, we developed and evaluated two interactive prototypes; CawClock and NoteLet. *CawClock* is a clock which used background nature- and animal-sounds to subtly display time-related information. In the evaluation of CawClock, the audio provided relevant information without attracting attention and therefore seemed a suitable medium for peripheral information display in classrooms. *NoteLet* explored physical peripheral interactions. NoteLet enabled teachers to take a picture of the classroom and store it on their computer along with a child's name, by touching a name on a bracelet. To easily select the right name, fabrics with different tactile qualities were used for children in different grades. Evaluation of NoteLet revealed that selecting a name was quick and simple and that the tangible aspects of the bracelet (e.g. the different fabrics) contributed to this. Though promising, interactions with NoteLet did not shift to the teacher's periphery of attention in the user exploration of two weeks. Additionally, teachers mentioned that looking at the pictures after school hours required too much time.

Building on our experience with CawClock and NoteLet, we were interested in developing an interactive system for primary school teachers which combined audio as a peripheral display of information with physical interaction designed to shift to the periphery of attention. A combination of peripheral perception and action would, in our view, enable a design to more fluently embed in the everyday routine of the teachers.

When evaluating NoteLet, the teachers did not see a major added value in using the design. It is unlikely that activities which are not relevant to a teacher will fluently become embedded in her everyday routine (also see Insight 8 on Page 63). In order to come to a relevant design for our target group, we conducted a creative workshop in which a primary school teacher, four experts on innovative educational technology development and two design-researchers participated. In this workshop (See Figure 6.1 for an impression), we introduced the concept of peripheral interaction and the participants brainstormed about tasks of teachers which could be supported by technology. These tasks were later discussed in groups to develop peripheral interaction concepts.

Resulting from this workshop we realized that mainly the small tasks that teachers do during teaching could be supported, for example dividing children in groups, counting the frequency of certain behavior or remembering to give a child instructions. We therefore decided that it would be interesting to develop an *open-ended* system that could be used for multiple goals, which would increase the likelihood that teachers can use it for a purpose that is personally relevant to them. This led to the development of FireFlies.

Figure 6.1. Pictures of a creative workshop on peripheral interaction for classrooms.

6.2.2. FireFlies

FireFlies is an open-ended design which can be used to support several secondary tasks of primary school teachers. The design consists of three separate parts: the light-objects, the soundscape and the teacher-tool. The *light-objects* (one for each child) are intended to be a visual (peripheral) display of information, while the *soundscape* provides generic peripheral information. We chose to present information in two modalities as the combination of a generic auditory display and a more detailed visual display was successful in our earlier CawClock design (see Chapter 5). The *teacher-tool* allows the teacher to manipulate the light-objects and to manipulate the soundscape through simple physical interactions which can potentially shift to the teacher's periphery of attention.

FIREFLIES LIGHT-OBJECTS

Each child has a small light-object on his desk, see Figure 6.2. This light-object can have one of four different colors: red, green, blue or yellow, or the light can be off. Each light-object is a small display that provides information to or about the child in question. Furthermore, all light-objects together form a visual display that is distributed over the classroom, providing information about the class as a whole.

FIREFLIES SOUNDSCAPE

While one or more light-objects are on, an ongoing background soundscape is played in the classroom. The soundscape is constructed of four specific nature-sounds, each connected to a color of the light-objects; bird-sounds (yellow), ocean-sounds (blue), cricket-sounds (green) and owl-sounds (red). The sound that is played depends on the current colors of the light-objects. When all of them are red, the soundscape consists only of owl-sounds. When some are red and some are green, both owl-sounds and cricket-sounds are played. When one light is then set to yellow, bird-sounds are added to the soundscape. The number of light-objects that have a certain color is represented in the frequency in which the corresponding sound is present in the soundscape; when only one light-object is blue, an occasional ocean sound is heard, whereas continuous ocean-sounds are heard when all light-objects are blue. The soundscape is meant to provide an overview of which colors are being used at the moment as well as approximately how many light-objects have those colors. As the soundscape is present in the background, it can be used to obtain general peripheral awareness of the current state of the FireFlies system without having to look at the light-objects themselves.

FIREFLIES TEACHER-TOOL

The teacher-tool is a device with which the teacher can set the colors of the light-objects or turn them off and thereby influence the soundscape, see Figure 6.3. The teacher first selects a color by moving the slider on the top of the tool to the intended color, or to the black area to turn the lights off. Each child is represented by a bead attached to a string on the bottom of the tool, see Figure 6.3. When squeezing one of these beads, the color of the light-object of that particular child is set to the selected color. The top part of the teacher-tool furthermore contains a button labeled 'everyone', which can be used to set all light-objects to the same color at once.

Although the basic functionality (selecting a child's name) of the teacher-tool is similar to the earlier NoteLet design, we decided to move away from the bracelet design. Evaluation revealed that the bracelet limited the use of the design; teachers only chose certain moments at which they put on the bracelet. The system was therefore not used often, as it was not as at hand. For a design to become part of the teacher's everyday routine, it must thus be flexible in use. The teacher-tool can be used while it lies on a table, while held in the hand or while worn on the

Figure 6.2. FireFlies light-object lit in different colors.

teacher's clothing using the clip on the back. This clip allows the teacher to easily carry the tool around the classroom without having to hold it continuously.

The interactions with the teacher-tool are intended to be quick and straightforward so that they can easily integrate in the everyday routine and potentially shift to the periphery of attention. To make sure that minimal attention is needed, NoteLet

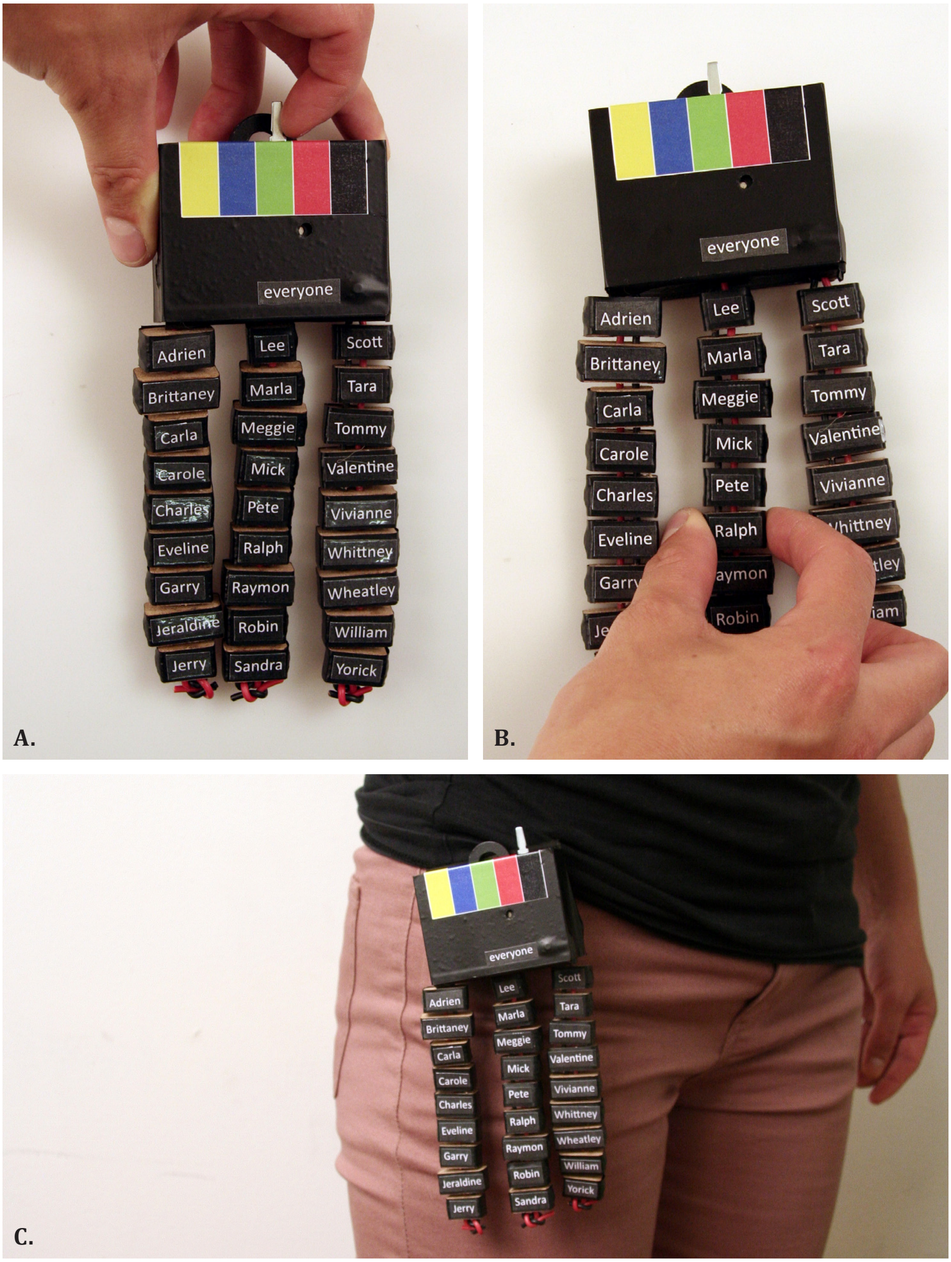


Figure 6.3. FireFlies teacher-tool: selecting a color (A), selecting a child's name (B) and clipped to the user's clothes (C).

used two kinds of fabric to enable distinguishing children in different grades. Although this made it easier to find a name, it did not enable distinguishing each individual child. On the teacher-tool we decided to differ the size of the beads relative to the length of the children's names. This way each individual child is represented by a unique bead-size. The beads are ordered alphabetically by first name. Since teachers likely have automated knowledge of the children's names, we expected that, after getting experienced with using the teacher-tool, feeling the size and location of the bead would allow them to easily select the right name.

To support quick interaction, the teacher-tool also includes audio feedback, played from an integrated speaker. When a color is selected, a short cue is played that corresponds to the soundscape's audio representing that color. Furthermore, when squeezing a bead, a short piano-tone is played. Each name is connected to a different pitch; low pitches for names in the beginning of the alphabet and higher tones for names at the end of the alphabet. A short cue of a low piano tone followed by a high piano tone is played when the button 'everyone' is used. Although these latter audio cues are played when the interaction has already affected the color of the light-objects, they may be useful for the teacher to check whether they selected the right name.

OPEN-ENDED DESIGN

FireFlies is developed as an open-ended design, meaning that the purpose for which it may be used is not defined, but can be chosen by teachers. They may use it to instruct children which exercise they have to do, to set a reminder to go to a certain child, to give compliments, etc. We thereby aimed to make sure that teachers would be able to use FireFlies for a personally relevant goal.

FIREFLIES INTERACTIVE PROTOTYPE

In order to perform an evaluation with FireFlies in a primary school, a fully functioning interactive prototype was developed. Both the teacher-tool and the light-objects operated on rechargeable batteries so that they could be used and located anywhere in the classroom. JeeNode[11] modules were used in both the teacher-tool and the light-objects to enable wireless communication and data processing. The soundscape was played from speakers located in the back of the room, such that the teachers could adjust the volume when desired. Also see the demo video[12] of the FireFlies prototype.

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[11] http://www.jeelabs.com, last accessed 25-04-2013
[12] http://vimeo.com/47002289, last accessed 25-04-2013

6.3. User evaluation approach

The aim of the study presented in this chapter is to explore the extent to which interaction with a specifically designed interactive system can shift between the center and periphery of attention, and blend in the user's everyday routine. We therefore conducted a user evaluation in which FireFlies was deployed in four different primary school classrooms, each for a period of six weeks. This would allow the intended target-group (primary school teachers) to extensively experience FireFlies during different classroom situations. The four participating classes were recruited from two different primary schools; two classes of the same school participated simultaneously, each with their own set of FireFlies. Other than the differences in children's names and thus sizes of the beads on the teacher-tool, these two sets of FireFlies were identical.

Of the four classes, two had a full-time teacher while two others were taught by two part-time teachers (e.g one working Mondays and Tuesdays and the other on Wednesdays, Thursdays and Fridays). This meant that in total six different teachers and 102 children worked with FireFlies for six weeks. Obviously, the full-time teachers used it during more schooldays compared to the part-time teachers. See Table 6.1 for an overview of the six female participants.

In the beginning of the six weeks, we gave the teachers the FireFlies prototype, explained how the teacher-tool could be manipulated and what the results of these interactions were on the light-objects and the soundscape. We furthermore explained that they could choose in which way and at which moments they would use the system, although we encouraged them to use it regularly, preferably at least once every day. Furthermore, we explained that they could adjust the volume of the soundscape as they wished. While they could also turn off the audio completely we encouraged them to leave it on as much as possible. Based on our earlier iteration with CawClock, we informed our participants that the soundscape was meant as a *background* information source.

<table>
<tr><th>Teach-er</th><th>Appoint-ment</th><th>Age</th><th>Teaching experience in years</th><th>School</th><th>Class</th><th>No. of students</th><th>Grade</th><th>Stu-dent age</th></tr>
<tr><td>P1</td><td>Full-time</td><td>26</td><td>3</td><td>A</td><td>1</td><td>25</td><td>4th</td><td>7 to 8</td></tr>
<tr><td>P2</td><td>Full-time</td><td>24</td><td>4</td><td>A</td><td>2</td><td>27</td><td>5th</td><td>8 to 9</td></tr>
<tr><td>P3</td><td>Part-time</td><td>51</td><td>23</td><td rowspan="2">B</td><td rowspan="2">3</td><td rowspan="2">27</td><td rowspan="2">3rd</td><td rowspan="2">6 to 7</td></tr>
<tr><td>P4</td><td>Part-time</td><td>26</td><td>3</td></tr>
<tr><td>P5</td><td>Part-time</td><td>46</td><td>16</td><td rowspan="2">B</td><td rowspan="2">4</td><td rowspan="2">23</td><td rowspan="2">4th</td><td rowspan="2">7 to 8</td></tr>
<tr><td>P6</td><td>Part-time</td><td>54</td><td>32</td></tr>
</table>

Table 6.1. Overview of the teachers participating in the FireFlies user study.

During the six week period, a researcher frequently visited the participating teachers before or after school hours to charge the prototypes' batteries and informally talk with the teachers about their experiences. We conducted two open *interviews* with each teacher; once in the third week and once in the sixth week of the study. Before this latter interview, we asked the teachers to fill in a *questionnaire* (see Appendix 2) about their interactions with FireFlies. Furthermore, we held 10-minute focus group interviews with the participating children in the sixth week of the study. Additionally, we recorded one hour of video each week, of every teacher using FireFlies, which we used for *observational analysis* on how teachers interacted with FireFlies.

Although both teachers and children were using FireFlies, we have chosen to focus our evaluation primarily on the teachers' interactions with the design. However, the children's perceptions of the light-objects and audio may also take place in their center or periphery of attention. We have decided not to evaluate this in our experiment for two reasons. First, the physical interactions with the teacher-tool were an important focus of this study. These interactions would (expectedly) only be executed by the teachers. Second, the analyses presented in Chapters 2 and 3, which lay the basis for our peripheral interaction designs and evaluations, focused on the attention abilities of adults. Such attention mechanisms may function differently for children, whose cognitive abilities are still under development, see for example (Lane and Pearson, 1982). In line with the studies presented in earlier chapters, we therefore focused our evaluation of FireFlies on the teachers' interactions with the design.

The different types of data collected in the study lead to findings with different levels of detail and abstraction. In the coming section, we will give a qualitative description of how the teachers and children were *using FireFlies in the classroom*. This description is based on qualitative interview results and functions as an introduction to the sections that follow. In these following sections, we discuss findings on whether or not the *physical interactions with FireFlies* were performed in the teacher's periphery of attention, and on if *auditory perceptions of FireFlies* took place in the periphery. Each of these two discussions first qualitatively describes how the relevant part of FireFlies was used by the teachers based on interview data, followed by a more detailed analysis of relevant quantitative data gathered from the questionnaire and observational analysis. Data analysis procedures are discussed in the three findings-sections.

6.4. Findings: using FireFlies in the classroom

In this section, we will illustrate how FireFlies was used in the participating classrooms, which is required to understand the later, more detailed analysis of whether FireFlies was used in the periphery of attention. The findings in this section are based on the data gathered through the different open interviews conducted with the participating teachers and children.

6.4.1. Analysis procedure of interview data

From the interview data, we mainly wanted to gain insight in how and when FireFlies was used, why the teachers chose to use it in that way, how they interacted with the design and the extent to which the teachers and children felt this fit in their routine. All interviews were recorded and transcribed verbatim. From these transcriptions, quotes were selected based on the above mentioned criteria. These quotes (668 in total) were analyzed using 'open coding' (Liamputtong and Ezzy, 2005) or 'conventional content analysis' (Hsieh and Shannon, 2005), meaning that no predefined coding scheme was used when clustering the quotes, but that

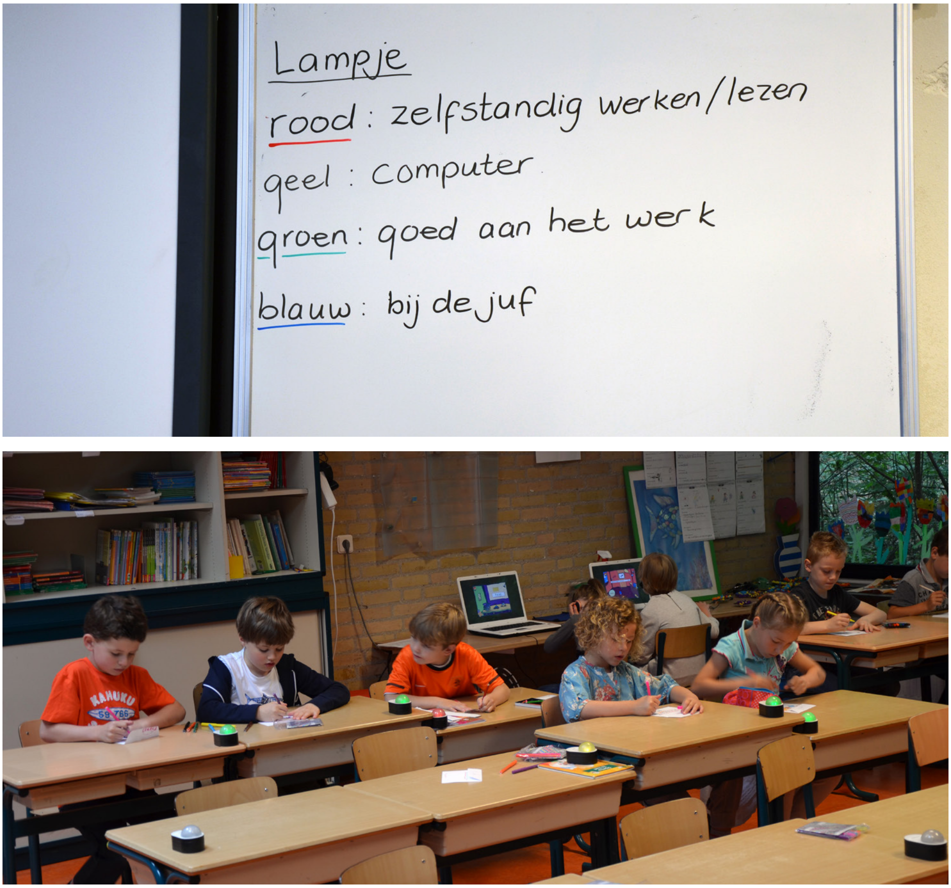

Figure 6.4. Impressions of how FireFlies was used in the participating classrooms. The top picture shows a whiteboard on which the meaning of each color is written (translated from Dutch: "Light, red: independent work, yellow: computer, green: working well, blue: come to the teacher).

meaningful clusters emerged during the analysis. This clustering was performed during a clustering session in which both the author and an independent researcher who was not involved in the study participated. The quotes were divided over the two researchers, who started creating their own clusters. During this process, the clusters of the individual researchers were compared and a final set of clusters was agreed upon. As a result of this clustering session, we found the clusters *visual perception of the light-objects*, *auditory perception*, *physical interaction with the teacher-tool*, *FireFlies design*, and *using FireFlies*. These clusters provided a detailed overview of the data. However, rather than presenting the results in each cluster separately, we will present our findings through four specific 'examples of use' extracted from these clusters. This way, we aim to provide a clear image of how FireFlies was used in the context of the classroom. Two of these examples, which provide insight in how the system was used as a whole, are presented in this section and two others, which focus particularly on *physical interaction* and *auditory perception*, are discussed in the next sections.

6.4.2. How FireFlies was used

As FireFlies is an open-ended design, the participants had to decide how they would use it. The part-time teachers (P3-P6) decided on this in discussion with their professional partner before the start of the deployment, whereas the full-time teachers (P1 and P2) discussed it with the children in class on the first day of the deployment. In all classrooms, a specific meaning was linked to each color; see Table 6.2 for an overview, and Figure 6.4 for an impression of how FireFlies was used.

Each participating teacher used FireFlies every working day during the six weeks of the study. In class 1, the light-objects were always on; the colors indicated a certain way of working and accompanying set of rules, one of which always applied. In the other classrooms, FireFlies was used in regular lessons, which

Class	Red	Green	Blue	Yellow
1	Work in silence	You can discuss	You are working well	Teacher is explaining
2	Work in silence	You are working well	Come to the teacher	Work on the computer
3	You are not working well	You are working well	It is your turn	Work on the computer
4	Work in silence	You can discuss	Come to the teacher	End of lesson, clean up

Table 6.2. Overview of the meanings of the colors of FireFlies in each participating classroom.

involved whole-class instructions, independent work and/or individual or group instructions. These lessons took place multiple times per day. In classrooms 2, 3 and 4, FireFlies was not used during group discussion, nor during creative lessons such as crafts, arts and music. We will now illustrate how the FireFlies light-objects were used by giving two usage examples. These examples are taken from the interview data, and are selected to give an impression of usage and to feed our discussion about FireFlies, rather than to provide an exhaustive overview of all the ways in which FireFlies was used during the study.

EXAMPLE OF USE 1: FIREFLIES AS A MEDIUM FOR COMMUNICATION

The children of classroom 1 are making a drawing during the arts lesson. All light-objects are green; the children are allowed to discuss. The lesson is about to end, they will continue with spelling. The teacher (P1) changes all light-objects to yellow: all children need to pay attention to her as she explains the lesson. After the explanation, all light-objects are turned red and the children start to work independently. The teacher sits in front of the room and observes if the children are doing well, for example if they are silent. She turns the light-objects of the children who are working well to blue, giving them a compliment. After ten minutes, she takes the teacher-tool and walks around the room to help children individually. Children who are doing well get a blue light, while the light-objects of children who are no longer working well are turned back to red. As the teacher passes a child with a blue light, she softly mentions 'you have a blue light, because you are working very silently, well done!'

In this example (see Figure 6.5 for a picture of this situation), the colors green, yellow and red are used to indicate what the children are (allowed) to do at that moment, e.g. 'you are allowed to discuss' or 'work in silence'. Similar to other participating classrooms, the meanings of red and green were chosen based on a method they used before working with FireFlies; a visual red or green traffic light on the whiteboard to indicate when the children were or were not allowed to discuss. Comparing to this traffic-light method, the teachers indicated that, with FireFlies, the children seemed more aware of the fact that they had to be silent when the red light was on. The teachers reasoned that this was caused by the fact that the light-object is a personal object, rather than one meant for the whole class; a red light, with their name on it, standing right in front of them, reminds the children continuously of the rules.

The fact that the light-objects are personal objects was also utilized by several teachers to differentiate between the children. For example, P5 frequently gave a group of children permission to work together while another group had to work in silence, which was not possible with the traffic light. The fact that FireFlies provides a personal display for each child was therefore seen as a major advantage of the design.

Figure 6.5. Picture taken during the deployment of FireFlies: all light-objects are set to yellow to indicate that the teacher is explaining the lesson.

As presented in the example, P1 used FireFlies to compliment children by giving them a blue light. Though other teachers used green for this purpose, this method was applied in other classrooms as well. The participating teachers mentioned they particularly liked the fact that this communication was done silently. Normally they would be hesitant to compliment children aloud during independent work, since that would break the silence. In classroom 3, the color green was used to give compliments, while they used red for the opposite purpose: as a warning when children were not working well. In this case we noticed that, although the children did not like getting a red light, they preferred it over being verbally warned. One girl mentioned "if the teacher says that I am not working well, I get very sad, but when the light says it to me, I change my behavior and I am not so sad".

After deciding on the meaning of the colors at the start of the user evaluation, only one teacher (P1) changed the meaning of one color in the first week of the user evaluation. After she realized that the initially chosen meaning of the color blue (used for children who were allowed to go to the toilet) did not have an added value, she decided to use it for compliments. Other than that, none of the teachers changed the meaning of the colors. We did see however that these meanings became more elaborate over time. For example, in classroom 1, yellow meant 'the teacher is explaining' and was initially used during whole-class teaching. In later weeks of the study however, the teacher also made individual light-objects yellow when children received individual instructions either at their own desks or at the teacher's desk. Similarly, in class 2, blue initially meant 'come to the teacher', while it was later used when the teacher was walking around the classroom to indicate which child she would visit next. In both cases, the original meaning of the colors blue and yellow did not really change, but simply expanded, for example from 'the teacher is explaining' to 'work with the teacher'. The children understood what they had to do from the context in which their light-object turned to blue or yellow.

EXAMPLE OF USE 2: FIREFLIES AS A DISTRIBUTED DISPLAY

A reading lesson is starting in classroom 3. At the start of the lesson all light-objects are off. The teacher sits in front of the room and points out which text they will read. She makes the light-object of one child blue and he/she reads one sentence aloud. After finishing the sentence, the teacher makes another light-object blue and this child reads the next sentence, and so forth. The light-objects of children who had their turn remain blue. By looking into the classroom, the teacher has an immediate overview of which children still need to get their turns. When all children have read, the teacher turns all light-objects off and starts again.

As evident from this example (also see Figure 6.6), using FireFlies to give turns was not only useful in communicating relevant information to the children, it also supported the teacher in knowing who already had their turns. This information is locally visualized as a distributed display in the classroom. The teacher does not need to keep track, the information is to some extent offloaded in the environment. We noticed a similar effect in situations where FireFlies was used to give compliments. P1 for example mentioned that at moments, she noticed that a group of children in the back of the room were not working well, they were chatting. But when looking into the room, she saw blue lights on their desks (they had received a compliment earlier in the lesson). This immediately reminded her to set these lights back to red and 'undo' the earlier compliment.

Figure 6.6. Picture taken during the deployment of FireFlies: the teacher gives the children turns to read sentences aloud by making their light-objects blue.

6.5. Findings: physical interactions with FireFlies

The main aim of the study described in this chapter is to evaluate whether FireFlies was used in the teachers' periphery of attention, and thereby integrated in the everyday routines in the participating classrooms. We address this in two separate findings sections, the current one discussing *physical interactions with FireFlies*, and the next discussing *auditory perceptions of FireFlies*. In the present section, we discuss our findings related to the teacher's physical interactions with the teacher-tool and particularly focus on whether these shifted to their periphery of attention. After providing and discussing an example of how the teachers-tool was used taken from the interview data, this section will present and discuss more detailed findings regarding peripheral interaction with the FireFlies teacher-tool.

EXAMPLE OF USE 3: USING THE TEACHER-TOOL

All light-objects in classroom 2 are red; the children are silently reading a book. The teacher stands in front of the room, the teacher-tool is clipped to her belt, and she turns all light-objects off while saying 'please take your mathematics books'. The children start working on their mathematics assignments. The teacher turns all light-objects to red and takes place at a table in front of the room meant to give instructions to a small group of children (the instruction table). She lays the teacher-tool on the table and makes two light-objects blue and three yellow. Two children then come to the instruction table and three others go sit at the computers. After giving instructions to these two children, she turns their lights back to red and makes two others blue. After all children had been at the instruction table, the teacher starts walking around the classroom, holding the teacher-tool in her hands. She helps children who need extra explanation and makes the light-objects of children who are working well green.

As evident from this example, teacher P2 used the teacher-tool in multiple ways and at different locations in the classroom. Most teachers, however, used it while sitting in front of the room. When operating the teacher-tool, it was held in the hands or lying on the table or the teacher's lap in the majority of cases. P2 operated the teacher-tool while attached to her belt, but only to set all light-objects to the same color at once, not to change individual light-objects. See Figure 6.7 for an impression of this scenario and Figure 6.8 for ways in which teachers used the teacher-tool.

None of the teachers had difficulty understanding how to operate the teacher-tool. Furthermore, all teachers indicated that, in the beginning of the study, it took them a while to find the right name on the tool. However, towards the end of the study, they indicated to automatically know approximately where each name was located; they quickly found most names. When discussing what had caused this interaction to become quicker, most teachers indicated that they had gotten used to it. Most teachers mentioned that particular names, e.g. those who needed to be called to the teacher a lot, could almost automatically be found as they were used frequently.

The beads of the teacher-tool, each representing one child, differed in size based on the length of the child's first name. The teachers indicated that this helped them mainly to find the names that were frequently used, or the names that were extraordinarily long or short. The majority of the names, however, were located through the alphabetical order in which they were listed.

When discussing the design of the teacher-tool, about half of the teachers indicated that they would have liked the names to be ordered in the way that the children are seated in the classroom. This would enable them to visually link the locations of the children in the room to their locations on the teacher-tool. They mentioned they are visually or spatially oriented and would prefer using that ability to operate the tool. Other teachers, however, indicated that they would not prefer this, as they would then need to 'relearn' how to use the teacher-tool after the locations of children's desks have changed, which happens around five times per year. These teachers indicated to have very good knowledge of the names of the children and preferred using this rather than location to find the names. It seems that there is no perfect interaction design of the teacher-tool which works best for all these six teachers. Peripheral interaction designs may therefore benefit from interaction design which can be adjusted by the user.

Insight 12. Peripheral interaction design could benefit from interfaces that can be personalized for or by individual users.

6.5.1. Mental effort required for interaction with the teacher-tool

An important aim of the study presented in this chapter, is to evaluate whether the teachers' physical interactions with the teacher-tool took place in their periphery of attention during the study, which may enable these interactions to blend into the teachers' everyday routines. As presented in Chapter 2, we see the center of attention as the one activity to which most mental resources are allocated, while the periphery contains all other potential activities. Since it is practically impossible to factually determine to which activity most mental resources are allocated during interaction in the context of use, we have focused our evaluation on events or behaviors that may indicate peripheral interaction with the teacher-tool. Now that we have illustrated how the teacher-tool was used, we will discuss these *indicators* for peripheral interaction in detail in this and the following subsections.

Figure 6.7. Picture taken during the deployment of FireFlies: the teacher has invited two children to the instruction table using blue lights (top), and complimented other children using green lights (bottom).

As stated in our earlier discussed Insight 1 (see Page 30), it is essential that activities that are to be performed in the periphery of attention require only few mental resources. Therefore, a first indicator for whether or not interactions with the teacher-tool shifted to the teacher's periphery of attention is the mental effort that teachers required to perform these interactions. We assessed this through both video observations and a questionnaire, which each teacher filled out in the final week of the evaluation. In this section we will discuss the questionnaire results, while the video observations are addressed in the next section.

Figure 6.8. Pictures taken during the deployment of FireFlies: different teachers carrying and interacting with the FireFlies teacher-tool.

The questionnaire aimed at evaluating the level of effort that teachers perceived to require for different physical interactions with the teacher-tool. In this questionnaire, we provided 10 examples of everyday actions that may be performed during lessons and 10 examples of interactions with the teacher-tool. The teachers were asked to rate how much effort they required to perform these (inter)actions. They indicated this by placing a cross on the visual Rating Scale Mental Effort (Zijlstra, 1993). Figure 6.9 shows this scale (translated from Dutch),

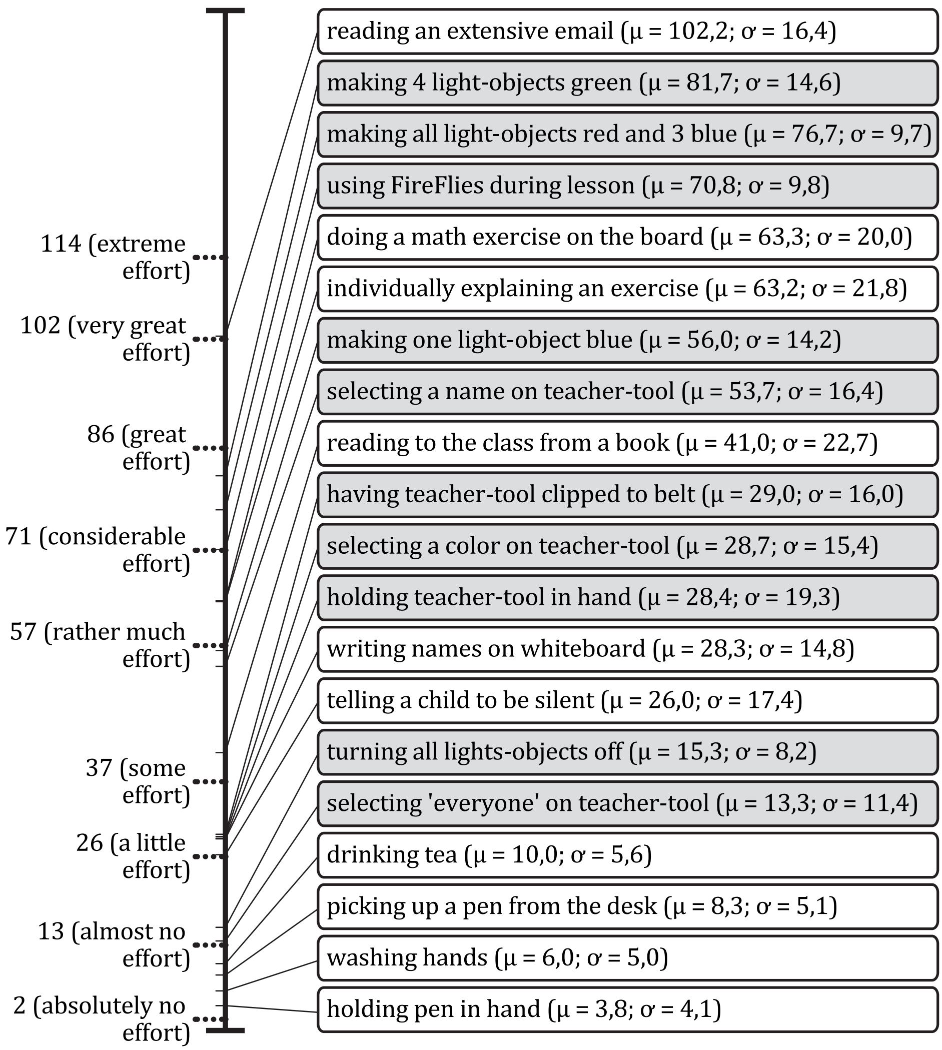

Figure 6.9. Rating Scale Mental Effort (Zijlstra, 1993) and the average results (μ) and deviation (σ) of our 6 participants, for 10 everyday work actions (white) and 10 interactions with the FireFlies teacher-tool (grey).

the example (inter)actions that were provided and the average results of our six participants. The questionnaire as we provided it to the participants can be seen in Appendix 2, "questionnaire part I: physical interaction".

As evident from Figure 6.9, single interactions with the teacher-tool, such as turning all light-objects off, selecting 'everyone' or selecting a color, were perceived to require little effort. The effort required for these activities seems comparable to the effort required to tell a child to be silent. The interactions needed to change the light of a single child, were perceived to require rather much effort. Based on the earlier discussed interview data, we may attribute this to the fact that it took some effort to locate the right bead. Although teachers reported to have automated knowledge of their pupils' names, they had to get used to the order in which the names were listed (alphabetical by first name).

More stacked interactions with the teacher-tool, such as changing the colors of four light-objects, were perceived to require considerable to great effort, comparable to the effort required to do a mathematics exercise on the whiteboard. Although the teachers were positive about the simplicity of the teacher-tool design, two of them mentioned that interaction would be quicker when the two actions required to change the color of a light-object (selecting a color and selecting a name) would be combined into one single action. For example the color may be selected directly on the bead representing a child.

Overall, Figure 6.9 gives the impression that the mental effort needed for an interaction with FireFlies complies with the effort required for the everyday activities that were included in the questionnaire. Stacked interactions require more cognitive processing (e.g. to find multiple names on the teacher-tool) compared to single interactions and thus more effort. Similarly the everyday activity of reading an extensive e-mail involves much cognitive processing, and thus very great effort. Doing or explaining an exercise seems to involve less thinking by the teacher; she has likely explained the same exercise numerous times. As the teacher may not have used all beads on the tool as often, the interaction of locating and selecting a number of beads may have required more effort.

From these questionnaire results we can conclude, even though selecting a child's name required rather much effort, at least some physical interactions with the FireFlies teacher-tool were perceived to require few mental resources. It therefore seems promising that these interactions may be performed in the periphery of attention.

6.5.2. Analysing observed interactions with the teacher-tool

Apart from the questionnaire data, in which the teachers reported the perceived mental effort required for physical interactions with the teacher-tool, we also captured video data. We used these data in a detailed analysis to find additional indicators for peripheral interactions with the teacher-tool.

DATA ANALYSIS PROCEDURE

One hour of video was recorded of each teacher, in each week during the user study. No researcher was present at the moment of recording. These videos were observed by the author, and all moments at which a teacher physically interacted with the teacher-tool were selected. The beginning and end of each interaction was marked, in order to identify its duration. The interactions were interpreted to start when the teacher grabbed or touched the teacher-tool, and the end of an interaction was marked when the teacher moved her hands away from the tool. In cases the teacher was holding the teacher-tool in her hand continuously, for example when walking around, we marked the start of the interaction when the teacher reached either for the slider, a name-bead or the button 'everyone'. In this case, the end of an interaction was interpreted as the moment that the hand with which the teacher interacted with the tool was moved away from the device. This entails that the interactions range from selecting a single name to setting a number of light-objects to one color and various lights to another color.

In total 497 interactions were found in the video data, see Table 6.3. As evident from Table 6.3, we were not able to record a video of each teacher in every week of the study. This was caused by absence of teachers, national holidays, irregular school schedules and sometimes the positioning of the camera. After all interactions were selected, and thereby a first impression of the context and conditions in which these interactions took place was gained, a coding scheme

Teacher \ Week	1	2	3	4	5	6	all
P1	18	22	x	5	17	x	62
P2	49	7	19	x	x	14	89
P3	51	8	26	x	35	13	133
P4	10	x	13	9	14	8	54
P5	15	14	x	17	x	30	76
P6	x	27	10	6	12	28	83
all	143	78	68	37	78	93	497

Table 6.3. The number of interactions with the teacher-tool, found in each one-hour video, recorded every week of each participating teacher, and the weeks in which no video was captured (indicate with 'x').

was constructed to offer more detailed insight in the data. This coding scheme included 3 categories, each consisting of a number of instances of behavior, see Table 6.4. For each interaction, one instance of each category was assigned to the interaction. In other words, each interaction was identified by the observer as a certain *interaction type*, performed with a certain degree of *visual focus* and *attentional focus*.

To assess the reliability of the coding scheme, a second observer coded 55 of the 497 recorded interactions with the teacher-tool. These 55 interactions included fragments from all participants and from different weeks of the study. To determine the extent to which the two coders agreed, we calculated Cohen's Kappa statistic, which provides the agreement between coders as a number between 0 and 1 (0 meaning no agreement and 1 meaning perfect agreement) (Siegel and Castellan, 1988). Table 6.4 presents the Kappa Coefficients for each category of our coding scheme. According to Landis and Koch (1977), the values we found can be interpreted as substantial agreement in the categories *interaction type* and *visual focus* and moderate agreement in the category *attentional focus*. The video observation results presented in the coming sections present only the findings of the first observer (the author).

Category	Instance of behavior	K
Interaction Type *(What is the teacher doing with the teacher-tool?)*	Selecting 1 name or 1 color or button 'everyone'	0,77
	Selecting 1 color and 1 name or button 'everyone'	
	Selecting multiple colors and/or multiple names or buttons	
	Unclear interaction type	
Visual focus *(How much of the interaction time is the teacher looking at the teacher-tool?)*	Constantly	0,68
	Most of the time	
	Most of the time not	
	Never	
	Unclear visual focus	
Attentional Focus *(Is the interaction performed during another task?)*	In between two other tasks	0,43
	During another task	
	Interrupts another task	
	Unclear attentional focus	

Table 6.4. Coding scheme used for video analysis and the level of agreement (Kappa Coefficient K) between the two coders, in each category of the coding scheme.

FREQUENCY OF OBSERVED INTERACTIONS WITH FIREFLIES

To gain insight in the extent to which interactions with the teacher-tool fit in the teachers' everyday routine, we have counted the number of interactions in each video we recorded, see Table 6.3. As evident from Table 6.3, the number of interactions per video differed considerably. Given the open-ended nature of the design, teachers could choose how often they used FireFlies, and clearly it was more often used in some lessons compared to others. The number of captured interactions also seems influenced by other factors however. Teachers were not always in sight of the camera when they interacted with the teacher-tool, for example when walking around the room. Also, the nature of some lessons enabled much more interactions compared to other lessons. For example, the video of teacher P2 was recorded each week during a mathematics lesson. During one lesson, P2 called each child to her desk individually for a quick knowledge-test, while in two other lessons, she called a group of children to her desk to work with them during the entire lesson. As P2 used FireFlies to call children to her desk, she interacted with the teacher-tool much more often in the first case than in the second. It is therefore important to note that the numbers in Table 6.3 should not be used to interpret longitudinal effects of the success or acceptance of FireFlies over the six weeks. Furthermore, it must be taken into account that the teachers knew they were being recorded, which may have encouraged them to use FireFlies more often than they normally would (also referred to as the 'Hawthorne effect' (Jones, 1992)).

Despite these limitations, it is clear from Table 6.3 that the teacher-tool was interacted with 5 to 51 times per hour, in the hours we recorded on video. This means that even in the video with the lowest number of interactions, the teacher operated the tool on average once every 12 minutes. In the other extreme, a teacher was able to interact with the teacher-tool almost once every minute on average. In some videos, the interactions indeed took place around once every five to ten minutes. In other videos, the interactions were less equally distributed over the recorded hour, but the frequency of interactions was higher in a shorter fragment of the recording. As all interactions took place during regular lessons, the frequency of recorded interactions seems to indicate that the teacher-tool could be used during the everyday routine of the teacher.

DURATION OF OBSERVED INTERACTIONS WITH FIREFLIES

As another potential indicator for the extent to which the teachers were able to interact with the teacher-tool as part of their everyday routine, we determined the duration of each interaction we captured on video. This duration largely depends on the type of interaction the teacher is performing. For example, selecting a single name likely takes less time than selecting a color and three names. We therefore included the category *interaction type* in our coding scheme, which distinguishes four types of interaction (see Table 6.4). Although more specific interaction types could potentially be distinguished, e.g. by differentiating 'selecting one name' from 'selecting the button everyone', it was not possible to make the coding scheme more specific, since the observers had to interpret these interaction types from videos taken from the back of the classrooms. The graph in Figure 6.10 shows the types of interactions that were coded, mapped to the average interaction duration. This graph shows that, as expected, the interactions that involved only one or two moves required less time compared to the interactions that required selecting multiple colors or names. This seems to comply with the earlier discussed questionnaire results, in which the teachers indicated that shorter interactions required less mental effort compared to interactions that involved multiple moves.

Figure 6.10 furthermore reveals that, on average, the interactions that required only one or two moves, took less than 5 seconds. Additional to our earlier finding that some teachers were able to frequently interact with the teacher-tool, we can now conclude that also many of the captured interactions were rather short in duration, which may increase the likelihood of these interactions shifting to the periphery of attention.

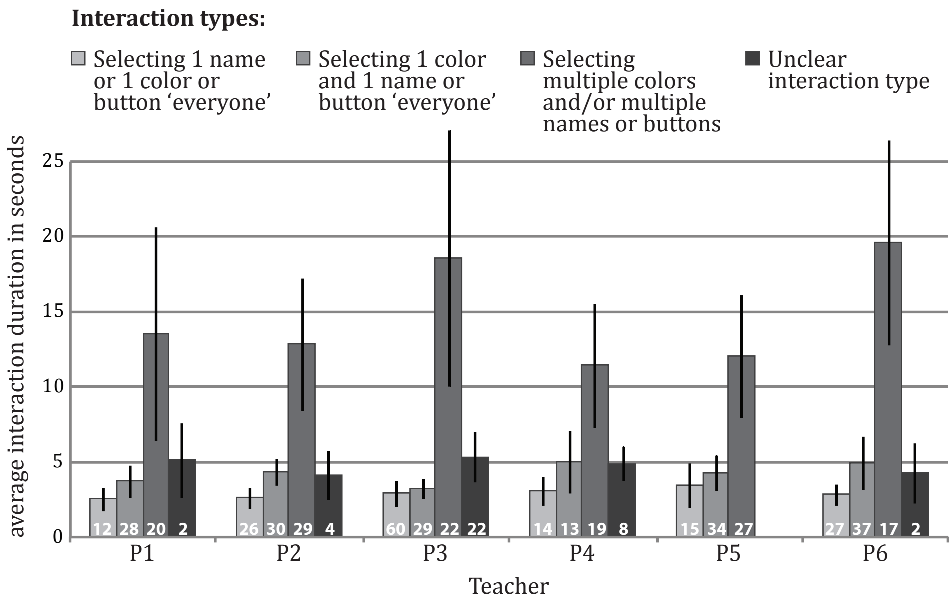

Figure 6.10. The average duration of interactions of each interaction type, for each participant. The white numbers reveal, for each participant, the numbers of interactions captured of each type.

As discussed in Chapter 2, we see the center of attention as the one activity to which most mental resources are allocated, and the periphery as all other potential activities. Activities can thus only shift to the periphery when another activity is performed simultaneously, that requires more mental resources (see Insight 1 on Page 30). We therefore evaluated whether teachers interacted with the teacher-tool while performing other tasks.

An observable phenomenon that may indicate if the teacher is doing another task, is whether or not she is looking at the teacher-tool during interaction. This was coded in the category *visual focus*, see Table 6.4. The instance *constantly* was used when the teacher did not take her eyes off the tool during the interaction. *Most of the time* indicated that the teacher at one or more moments looked away from the tool. *Most of the time not* was used to code interactions during which the teacher only sometimes looked at the device, and *never* indicated that the teacher never looked at it. Figure 6.11 presents the results of this category for each participant as the average duration of interactions. Table 6.5 shows the number of interactions captured of each level of visual focus.

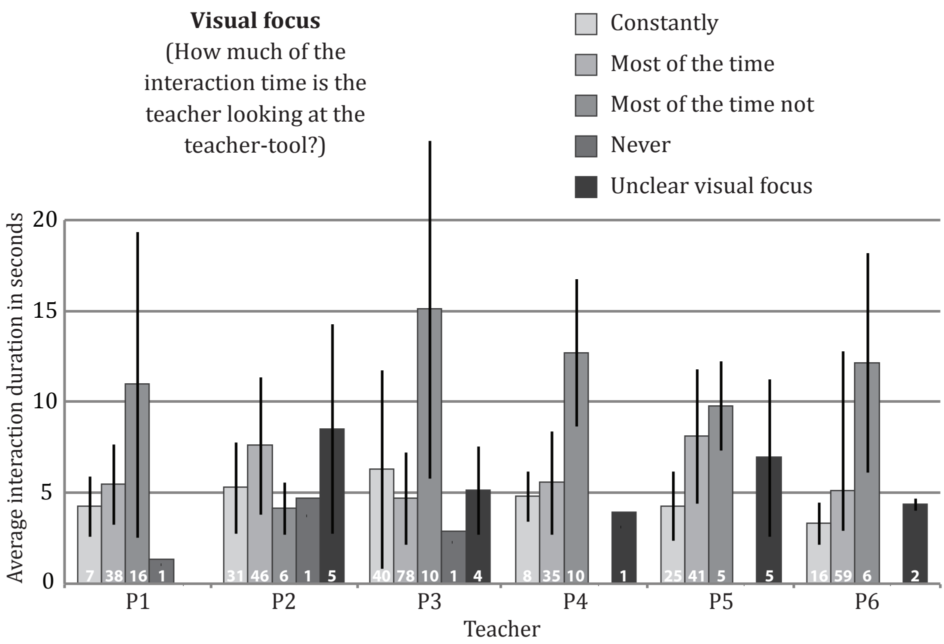

Figure 6.11. The average duration of interactions of each level of visual focus, for each participant. The white numbers reveal, for each participant, the numbers of interactions captured of each level of visual focus.

Teacher / Visual focus	P1	P2	P3	P4	P5	P6	all
Constantly	7	31	40	8	25	16	127
Most of the time	38	46	78	35	41	59	297
Most of the time not	16	6	10	10	5	6	53
Never	1	1	1	0	0	0	3
Unclear visual focus	0	5	4	1	5	2	17
all	62	89	133	54	76	83	497

Table 6.5. The total number of interactions of each level of visual focus, for each participant.

As evident from the Table 6.5, during the majority of the recorded interactions of all teachers, they were most of the time looking at the teacher-tool. In a number of cases, the teachers were most of the time *not* looking at it, and we even observed three cases in which the teacher never looked at the teacher-tool during interaction. Figure 6.11 indicates that, for many participants, the interactions in which they were most of the time *not* looking at the tool on average required the most time. The interactions in which the teachers were constantly looking at the tool, on average had the shortest duration. Overall, we must conclude that the teachers were able to interact with the teacher-tool without constantly looking at it, even though these interactions required more time on average.

To gain additional insight in whether or not the interactions with the teacher-tool took place during other tasks, we included the category *attentional focus* in our coding scheme (see Table 6.4). In this category, we observed if the teacher was clearly involved in another task, which continued after the end of the interaction. If this was not the case, for example when the teacher interacted with the tool in between two individual instruction sessions, the code *in between two other tasks* was used. When the teacher's primary task was the same before and after the interaction, it was interpreted whether the interaction clearly interrupted and disturbed this primary task, in which case the code *interrupts another task* was used. If the interaction did not seem to disturb the primary task, it was coded as *during another task*. As evident from the Kappa Coefficients in Table 6.4, the two coders only came to a moderate agreement in the category attentional focus, while a substantial agreement was reached in the other two categories. Both coders found the teachers' attentional focus most difficult to interpret from the videos. The number of interactions of each of these instances (coded by the author) is listed in Table 6.6.

Level of attentional focus \ Teacher	P1	P2	P3	P4	P5	P6	all
In between two other tasks	14	41	8	11	32	31	137
During another task	48	45	107	33	41	51	325
Interrupts another task	0	0	11	9	2	1	23
Unclear	0	3	7	1	1	0	12
all	62	89	133	54	76	83	497

Table 6.6. The total number of interactions of each level of attentional focus, for each participant.

As evident from Table 6.6, a clear majority of the interactions of all teachers were performed during another task, such as while giving individual instructions. The interactions that were performed in between two tasks, mostly seemed to take place in between two instruction sessions. In these cases, a child was walking back to his desk and the teacher used the teacher-tool to turn this child's light off and to make another child's light blue to call him to her desk. The fact that these interactions happened in between two tasks therefore does not seem to indicate that they were too demanding to be performed during another task, but simply that the situation in which they occurred was only suited for in-between interactions. Despite the moderate agreement between coders, the differences between the overall numbers in Table 6.6 seem large enough to at least conclude that many of the teachers' interactions occurred during other tasks.

As presented in Chapter 2, and Insight 1 on Page 30, (inter)actions can only shift to the periphery of attention when another task is being performed simultaneously. The results in the categories visual focus and attentional focus, seem to reveal that indeed the teachers were in many cases interacting with the teacher-tool while another task was ongoing. This means that, according to our understanding of the periphery of attention, in these cases either the interaction with the FireFlies teacher-tool or the teaching-related task must have been in the teacher's periphery of attention.

6.5.3. An observed example of physical peripheral interaction

As became clear from the above discussion of questionnaire results and formal video observation results, several interactions with the teacher-tool seem to comply with indicators of peripheral interaction, namely perceived mental effort, frequency of use, duration of interaction, and the possibility of being performed during another task. Though promising, these data do not prove that any of the interactions took place in the periphery of attention according to our model presented in Chapter 2. When looking at the videos we recorded, however, we observed a number of situations in which we do believe that the interaction with the teacher-tool shifted to the teachers' periphery of attention, particularly in the fifth and sixth week of the study. We will illustrate this by describing a specific example, taken from the video recorded in week five of teacher P4. The situation in this particular part of the video is as follows:

P4's class is working on a writing exercise. At the same time at the instruction table in front of the room, P4 is doing a reading exercise with four children who read words aloud simultaneously. During this reading exercise, the teacher is also paying attention to the rest of the class: she observes if they are working well, and gives compliments or warnings using green or red lights. While interacting with the teacher-tool, teacher P4 sometimes keeps reading the words of the reading-exercise aloud.

In this situation, the teacher has three activities: (1) the reading exercise, (2) observing the class and (3) interacting with the teacher-tool. Apart from these activities, she can potentially also do other activities, such as helping a child with his writing exercise, discussing an example of this exercise with the class, giving a child more reading material to practice, looking at the clock and checking her email. These latter activities might also be on her mind, while they are not performed. To discuss the teacher's activities in terms of whether they are central or peripheral, we present a hypothetical division of mental resources at four moments in the video connected to the above example, recorded of teacher P4 in a real classroom situation during our user evaluation, see Figure 6.12. The presented division of resources is estimated based on our informal observations of the video, and is intended to feed the discussion below rather than to provide conclusive insight in this teacher's resource division.

Figure 6.12.A shows the moment at which the teacher is explaining the reading exercise to the group of four children. Although this likely requires most of her mental resources, a few resources are probably allocated to keeping an eye on the class. At this moment she is not interacting with the teacher-tool, so no mental resources are allocated to interaction. Figure 6.12.B shows a later moment at which the teacher and four children are reading words aloud. The teacher is simultaneously looking into the room to observe the children, which might require more mental resources than the reading exercise. The next moment (Figure 6.12.C) the teacher looks for a name on the teacher-tool to give a compliment while still reading aloud. The interaction with the teacher-tool has now shifted to the center of attention. A moment later (Figure 6.12.D), the teacher is still reading aloud and looks at the list of words, while squeezing a bead to give a compliment. Interaction with the teacher-tool is now likely in the periphery of attention, while the reading exercise is back in the center.

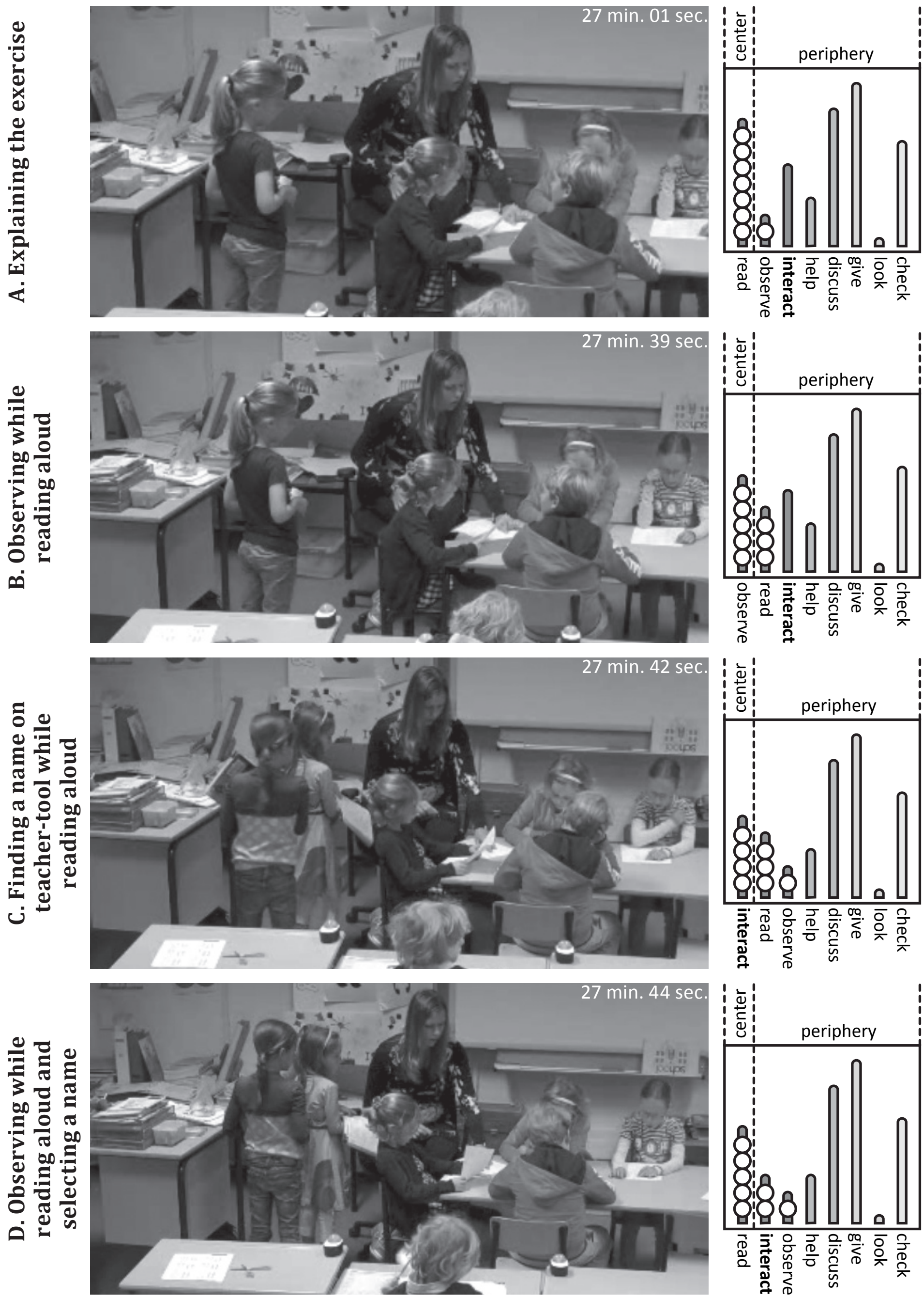

Figure 6.12. Screen shots from the video recorded of P4 in the fifth week of the study, while the FireFlies teacher-tool is on her lap, and for each screen shot the possible division of mental resources (also see Figure 2.5 on page 28) over the following activities: reading exercise (*read*), observing the class (*observe*), interacting with teacher-tool (*interact*), helping with writing exercise (*help*), discussing writing exercise (*discuss*), giving practice material (*give*), looking at the clock (*look*), and checking email (*check*).

In this example, the reading-exercise is clearly the teacher's main activity and will most of the time be in her center of attention. Observing the children seems a secondary task, which is most often in her periphery of attention, but may shift to the center when fewer resources are required for the reading exercise. Interacting with the teacher-tool also seems a secondary task, which may be in the center of attention when required (e.g. to find the right name), but may also be performed in the periphery (e.g. when selecting a name).

From this observed example it seems likely that P4 interacted with the teacher-tool in her periphery of attention. Similar examples were seen in the videos of other teachers. As mentioned before, in the interviews, the teachers stated that a main advantage of FireFlies was that it enabled them to communicate messages (e.g. compliments) in silence, and while working on another task. It therefore seems that it was relevant to the teachers to interact with the tool during other activities, which may have realized the interaction to shift to the periphery.

6.6. Findings: auditory perceptions of FireFlies

The study presented in this chapter, focused on evaluating whether interactions with our specifically developed peripheral interaction design FireFlies could shift to the periphery of attention and thereby fluently embed in the users' everyday routines. Interactions with FireFlies include both *physical interactions* and *auditory perceptions*. In our earlier iterations (see Chapter 5), one study focused entirely on auditory perceptions, while the other separately explored peripheral (physical) interaction and perception via two separate interactive systems; NoteLet and CawClock. From these early iterations, we concluded that the auditory perception of the soundscapes connected to our designs indeed shifted to the periphery of attention at moments, while the physical interactions with NoteLet did not. The main focus of the evaluation of FireFlies was therefore on the physical peripheral interactions with the FireFlies teacher-tool. However, the auditory part of FireFlies, which includes both the soundscapes played from speakers in the back of the classroom and the auditory feedback provided by the teacher-tool, have also been part of the analysis. In this section, we will first provide and discuss an example of how the soundscape was used taken from the interview data, after which we will present the results from our questionnaire and from informal video observations regarding auditory perception.

EXAMPLE OF USE 4: FIREFLIES AS AN AUDITORY DISPLAY

The children of classroom 4 are working on individual mathematics assignments. 10 children, who have strong mathematical skills, work on more advanced tasks and are allowed to work together. Their light-objects are therefore green, while the remaining *lights are red; those children work on their tasks in silence. The speakers in the back of the classroom play cricket and owl-sounds representing the green and red lights in the classroom. After a while, a child raises his hand to ask a question. The teacher sets the light-object of this child to blue and the child walks to the teacher and asks his question. Soft ocean-sounds are added to the soundscape. As the child walks back to his desk, another child raises his hand. The teacher makes his light-object blue, he walks to the teacher's desks and returns after his question is answered. A few minutes later, the teacher notices hearing ocean-sounds, and realizes the lights of the two children are still blue. She turns them back to red. At the end of the lesson, the teacher turns all light-objects to yellow. Bird-sounds are played and children realize it is time to clean up.*

While the teachers were rather positive about using the light-objects, the soundscape was applied much less often. Teachers could adjust the volume themselves and turn the speakers off in case they found it inappropriate. Although we encouraged them to try it out, P1, P2 and P4 used it only once in the beginning of the six weeks. They mentioned that they used FireFlies mostly when the class needed to work in silence, and that a soundscape would make it difficult to concentrate. Although P3 and P5 used it regularly, they had the same concerns and minimized the volume. They also mentioned that particularly the cricket-sound (connected to green) and the owl-sound (connected to red) were unsuitable because these were experienced as discreet, alerting sounds rather than ongoing background sounds. However, these two colors were used often during independent work. P3 and P5 mentioned that the ocean sounds connected to blue were suitable as a background sound as they provided a relaxing atmosphere. Blue however, was most often used alongside other colors, as a result of which multiple sounds were played simultaneously. Different from the other teachers, P6 was positive about the soundscapes and indicated that it had an added value by providing information to the children when they were focused visually on their work, and by creating a positive atmosphere in the classroom. For example, hearing the bird sounds firstly made children realize that the lesson had ended if they did not see the color change yet and secondly it provided a pleasant atmosphere which turned cleaning up into an enjoyable activity.

All teachers chose their way of using FireFlies based on the colors rather than based on the audio. Most teachers indicated that, if they were to choose, they would link the sounds and colors differently. They would prefer ocean-sounds to be linked to red, as the activity that is performed under the red light (working in silence) is better supported by the gentle background sound of the ocean, than by discreet owl-sounds. Insight 12 (see Page 133), which states that peripheral interaction design could benefit from interfaces that can be personalized for individual users, clearly does not only hold for physical interaction but also for peripheral information displays.

Apart from the soundscape, the teacher-tool also incorporated audio feedback to support interaction. Although the teachers said they understood that the audio feedback indicating the color selection could enable selecting it without looking, none of them actually applied this. Since they all looked at the design when operating it, they indicated that the sound did not have an added value to them.

6.6.1. Attention devoted to FireFlies audio

The sounds incorporated in the FireFlies system were intended to be perceived in the periphery of attention while they may also shift to the center when relevant. Apart from presenting how the audio was used, we are therefore interested in evaluating if the sounds were indeed perceived in the periphery and whether or not shifts to the center of attention occurred. We will discuss this by presenting questionnaire results (this subsection) and video data (the next subsection).

As part of the questionnaire conducted in the final week of the experiment, we were interested in obtaining subjective measures regarding whether or not the audio incorporated in FireFlies attracted the teacher's attention, and whether teachers found it informative. Similar to the earlier discussed part of the questionnaire that focused on physical interactions, we wanted to compare auditory perceptions of FireFlies to everyday auditory perceptions. We therefore gave each of the six participating teachers a list of 11 examples of auditory stimuli that can be perceived during school hours: 6 examples of everyday auditory stimuli and 5 examples of auditory stimuli of FireFlies. For each example, we asked the participants to indicate a) whether the sound attracted their attention, and b) whether they found it informative (if it provided them with relevant information). For both questions, they could select one of the following answers: 'always', 'usually', 'sometimes', 'usually not' and 'never'. Figure 6.13 shows the examples of auditory stimuli that were included in the questionnaire, and the average results of our 6 participants. The complete questionnaire also involved questions about visual perception, which are not addressed in this thesis, and can be found in Appendix 2 "questionnaire part II: perception".

As shown in Figure 6.13, the teachers reported that the short piano sounds played by the teacher-tool when selecting a name, or the button for 'everyone', sometimes attracted their attention. This can be compared to the beeps heard when pressing buttons on a copying machine, or the sound of a computer starting up. The audio of the soundscape and the short cues played when selecting a color on the teacher-tool, however, usually attracted their attention. This is comparable to the everyday sounds of two children chatting in class, and the sound of the school bell.

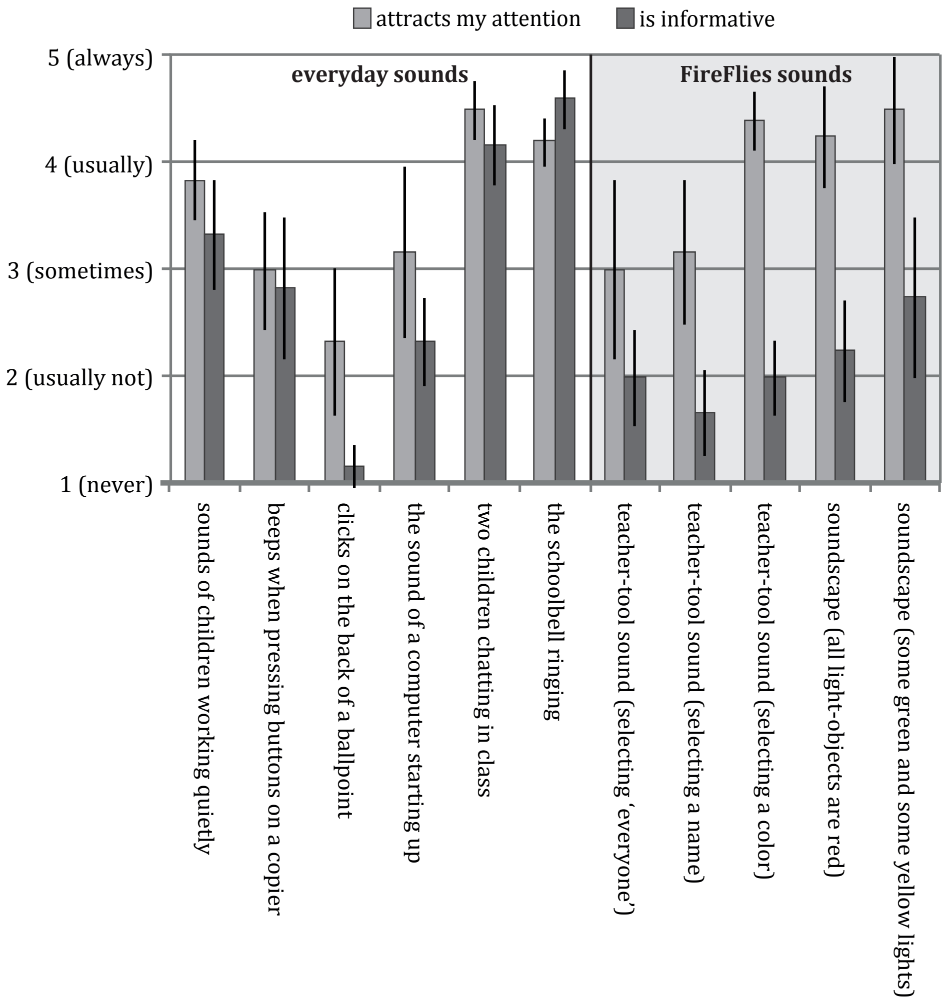

Figure 6.13. For six everyday sounds (left) and five FireFlies sounds (right), the average questionnaire outcomes of our six participants.

When looking at Figure 6.13, overall it becomes clear that the audio connected to FireFlies is less often considered to be informative compared to the everyday auditory stimuli included in the questionnaire. This finding seems in line with the interview data, which revealed that only one of the six participating teachers (P6) saw an added value in the soundscape of FireFlies: she argued that it provided a pleasant atmosphere, and that there were cases in which it was informative for herself (e.g. to realize that one of the light-objects was still blue while it should be red), and for the children (e.g. to realize that the lesson had ended when they had not seen the color change yet). In those cases, the audio may have shifted from the periphery to the center of attention because it became relevant. The other five teachers however, did not find the FireFlies sounds informative, as also revealed in the questionnaire. They reasoned that the soundscape only provided information about which colors are being used; they still needed to look at the light-objects to see which light-objects had which colors. For the same reason, these teachers did not find the audio relevant for the children. Although our intention with the soundscape was to provide overall (peripheral) information about the status of the light-objects without needing to look at them, this clearly worked out for only one of the six teachers.

In the interviews, all teachers except P6 furthermore argued that the audio distracted them and the children. The questionnaire results seem to reveal a similar finding; overall, teachers reported that the audio of particularly the soundscape very often attracted their attention. In other words, the audio shifted to their center of attention at inappropriate moments. The fact that the majority of teachers did not find the audio informative, may have caused some of the annoyance with it: audio that is not considered useful is more easily experienced as distracting or annoying compared to useful audio (also see Insight 10 on Page 96).

6.6.2. Observed distractions caused by FireFiles audio

Apart from questionnaire results, video observations could provide insight in whether the audio of FireFlies was perceived in the teachers' periphery of attention. The soundscape was turned on and audible 9 of the 27 one-hour videos we recorded in the participating classrooms during the study: in two videos of P3, one of P4, four of P5 and two of P6. Since the audio of the teacher-tool could not be turned off, it was present in all videos. While performing the formal video analysis of the teacher's physical interactions with the teacher-tool, we informally observed whether there were moments at which the teachers were clearly distracted or annoyed by the audio. This may be observed when they clearly look up after a more distinct sound was present in the soundscape. However, none of these events were observed in any of the 9 videos in which the soundscape was audible, nor did we observe any clear reactions to the audio of the teacher-tool. Even though many teachers indicated that they were distracted by particularly the soundscape, this was not evident from these informal observations.

Clearly, not all distractions or annoyances may lead to observable behavior such as looking up, so it seems likely that there may have been moments of distraction or annoyance which we were unable to observe. On the other hand, it may also have been the case that the teachers were unable to adequately report on their (peripheral) perceptions in the interviews or questionnaire. Perhaps only a part of the FireFlies sounds distracted and annoyed them, while another part of these sounds may not even have been noticed. The sounds that were experienced as annoying likely were the ones that the teachers remembered, and the other sounds could possibly not be recalled when discussing them in the interview or when filling in the questionnaire. Teacher P6, whose attention was at moments attracted to the audio in an informative (positive) way, may have recalled these events when discussing them. The results of the interviews and questionnaires do not seem clearly in line with our informal video observations.

6.7. Discussion

In this chapter, we presented the results of a six week deployment of FireFlies, a peripheral interaction design for primary schools, in four classrooms. In this section we will reflect on what we learned about *design for peripheral interaction*, and about *evaluating peripheral interaction*.

6.7.1. Design for peripheral interaction

FireFlies was developed as a peripheral interaction design; a system which is intended to be interacted with in the user's periphery of attention, and thereby blend into the everyday routine. The design builds on earlier explorations on peripheral interaction, one of which was also performed in the classroom context (see Chapter 5). In this section we will reflect on the design of FireFlies, on how successful we regard it as a peripheral interaction design, and what we can learn from our results regarding design for peripheral interaction in general.

OPEN-ENDED DESIGN OF FIREFLIES

One of the lessons learned from our earlier iterations is that the goal for which an interactive system is used should be personally relevant for the interaction to shift to the periphery of attention (see Insight 8 in Page 63). This did not seem to be the case for our earlier NoteLet design (see Chapter 5) and was the main reason for deciding to make FireFlies and open-ended design, meaning that it was up to the teachers to decide for which purpose they used it. As a result of the study with FireFlies, we noticed that teachers were rather enthusiastic about using FireFlies: they used it every day during the study. The design had an added value to them over their earlier ways of working. For example, it enabled them to communicate short messages (e.g. giving a compliment or a turn) to the children in silence. Additionally, the fact that the light-objects were personal devices was seen as a major advantage; it allowed setting different rules for different groups of children and, according to the teachers, it also seemed to encourage the children to follow these rules more compared to when using a sign intended for the class as a whole. Also, the light-objects functioned as a distributed display that enabled the teacher to offload knowledge in the environment to some extent. Although the usage differed among participants, we must conclude that all participants found a relevant purpose for using FireFlies. We believe this shows that the open-ended approach was successful and that one of the 'preconditions' for peripheral interaction, namely that it can be used for a personally relevant purpose, was met. Relatedly, we found that teachers were interested in adjusting the mapping between audio and color (e.g. connect ocean-sounds to red rather than to blue). Furthermore, it seemed that the interaction design of the teacher-tool might have been most suitable in one way for one teacher and in another way for another teacher. Enabling users to flexibly adjust such parameters of the design to their own liking could be an interesting approach to make peripheral interaction designs more open-ended. This could be an interesting direction for future research.

FIREFLIES AS A FLUENT PART OF THE EVERYDAY ROUTINE

The main aim of peripheral interaction is to enable interactive system to fluently blend in the user's everyday routine. From our interview- and video data, we concluded that FireFlies was used frequently, during other activities and for a relevant purpose, which seems to indicate that it indeed fit in the participants' everyday routines. When we asked the teachers to which extent they saw the system as a part of their everyday routine, a frequently heard reaction was that, particularly in the beginning of the study, they needed to consciously think about using FireFlies. One teacher for example mentioned *"I notice that, if I have not consciously thought about it for a while, sometimes I am calling children to my desk verbally and then think 'I could have done this with the light-object'"*. All teachers used FireFlies trying to replace previous ways of working, such as giving turns and compliments verbally. When they wanted to give a child a turn or compliment, they therefore automatically did this verbally without consciously thinking about it. In the sixth week of the study however, most teachers indicated that using FireFlies had in many cases become automatic. Due to absence of a teacher, one final interview took place in the week after the study, when FireFlies was no longer present. This teacher mentioned *"I sometimes think 'where are my light-objects', but then I realize they aren't here anymore"*. Other teachers indicated in the final interview that although they had to get used to using FireFlies rather than verbal messages, they now have to get used to verbal messages again. This seems to indicate that FireFlies indeed became a part of their routine.

An interesting insight here is that being able to perform an interaction quickly and easily, during another task, is not the only precondition for the interaction to become an automated part of the everyday routine. Clearly, the *cognitive action* (deciding to use the teacher-tool for a certain purpose) that precedes the *physical interaction* (actually interacting with it) should ideally be automated as well. This relates to theory on habituation (Aarts and Dijksterhuis, 2000; Wood and Neal, 2007), which states that habituated actions are strongly associated with their goals; whenever the goal is activated, the associated action will automatically and unconsciously be initiated. When an interaction is replacing an activity that is habituated, it takes time and experience to associate the goal (e.g. giving a child a turn) to the new (inter)action. It is not only required to learn to work with the new interactive system, it is also needed to 'unlearn' the known activity. Based on the statements our participants made in the interviews, we believe that in the case of FireFlies, using it for six weeks was enough for this habituation to happen.

Insight 13. When an interactive system is replacing an activity that is habituated, this activity must be 'unlearned' before the interactive system can become an automated part of the user's routine.

PHYSICAL PERIPHERAL INTERACTION: OPERATING THE FIREFLIES TEACHER-TOOL

One of the aspects of FireFlies was the teacher-tool; a physical interaction design which allows the teacher to change the colors of the light-objects and which is designed to be interacted with in the periphery of attention. As a result of our user study, we found several interactions with the tool that comply with indicators of peripheral interaction (e.g. requiring low mental effort, high frequency and short duration of interactions and being performed during other activities). We furthermore informally observed some interactions which clearly seemed to shift to the periphery of attention, as visualized in Figure 6.12. However, interactions which involved selecting a specific child's name seemed to require visual attention. In this section, we will discuss what we can learn from these findings regarding physical peripheral interaction in general.

To change the color of a light-object, the teachers first had to select a color and then press either the button labelled 'everyone', or select one name by squeezing one of the 23 to 27 beads attached to the teacher-tool. Selecting one name seemed to require more effort since the correct bead had to be located. However, all types of interactions could quickly and frequently be performed during other activities. In Figure 6.12, we separated the action 'finding a name on the teacher-tool' from 'selecting a name on the teacher-tool'. We observed that the teacher seemed to require a short moment of focused attention to find the name, while selecting this name seemed a peripheral interaction. While teachers indicated that some names could almost automatically be found (e.g. those that were often used, or those that were extraordinarily long or short), we did not find evidence to prove that locating the right name on the teacher-tool was done in the periphery of attention. As this results from a study in which six teachers used the teacher-tool for six weeks, we must conclude that it seems unlikely that the act of locating a child's name, while using the teacher-tool in the real context of a classroom and for a goal relevant in this context, could be done in the periphery of attention with reasonable amount of training. More generally speaking, selecting one of 23 to 27 options seems to require too much effort for it to be done peripherally, even if these 'options' are names that one is very familiar with or even has automated knowledge of.

Despite the fact that focused attention seemed needed to locate the right child's name, it took only a few seconds. Furthermore, the act of squeezing the bead with this name could be done in the periphery. Apart from the children's names, the FireFlies teacher-tool also has a button labeled 'everyone', which can be used to set all light-objects to the same color at once. Using this button does not require selecting one of many options. We did not differentiate the interaction 'selecting a child's name' from 'selecting the button everyone' in the formal video analysis, since it was often unclear in the videos which of these two interactions took place. In some specific observational examples however, such as *example of use 3*, the teacher did turn all lights to the same color without looking at the teacher-tool; it was attached to her belt. As could be expected, it seems as though the less complex interaction of selecting the button 'everyone' might be entirely performed in the periphery of attention.

Insight 14. Interactions with low complexity are more likely to become peripheral interactions compared to interactions with high complexity.

PHYSICAL PERIPHERAL INTERACTION: THE PURPOSES FOR WHICH FIREFLIES WAS USED

The interaction design of the FireFlies teacher-tool builds on the insights we gained by evaluating our earlier peripheral interaction design NoteLet (see Chapter 5). In our exploration with NoteLet, we realized that the occasion that may lead to interaction with NoteLet, namely observing a child's behavior that needs to be remembered, is an action that always requires conscious thought. Even though NoteLet may make the act of recording this observation easier, the complete activity (which includes observing a child's behavior and interacting with NoteLet) will likely never completely be performed in the periphery of attention. Since FireFlies is an open-ended design, the teachers could decide for which purpose they would use it. Similar to NoteLet, some of the purposes for which they used FireFlies also required conscious attention, such as observing if a child is behaving well and deserves a compliment. Other activities performed with FireFlies, such as sending a child to the computer, calling a child to the teacher's desk or giving the whole class permission to discuss, seem more routine activities which may not always require conscious thought. Compared to NoteLet, several occasions in which FireFlies was used therefore seem more suitable for peripheral interaction.

PERIPHERAL PERCEPTION: FIREFLIES SOUNDSCAPE

FireFlies used a soundscape, which provided continues background information about the current state of FireFlies. From our study, we concluded that one of the six participating teachers (P6) saw an added value in the soundscape: it informed her and the children of the current rules in the classroom and it provided a pleasant atmosphere. The other five teachers were not positive about the soundscape, they argued that it distracted and annoyed the children and themselves. Even though we encouraged them to decrease the volume rather than turn off the audio, three teachers completely turned it off after first use.

The FireFlies design builds on earlier work on peripheral interaction design, presented in Chapter 5, in which we concluded that the audio of *CawClock* was a suitable medium for background information display in classrooms. Although the audio design of FireFlies was largely based on that of CawClock, it was not suitable for most of the purposes for which FireFlies was used. One of the differences between the audio aspect of FireFlies and that of CawClock, is that the soundscapes of CawClock were more directly linked to the visual information in comparison to FireFlies. With CawClock, the teacher and children could understand from the audio which timeframe was ongoing and therefore which rules applied. Even though they needed to look at CawClock to specifically interpret how long the timeframe was already ongoing, the information provided by the audio was enough in many cases. With FireFlies, the same happened when teacher P6 set all lights to yellow to indicate that it was time to clean up: hearing the bird sounds was enough for children to understand what was expected of them. However, in cases in which not all light-objects were set to the same color (which happened most of the time), listening only was not enough to understand what the light-objects indicated. For example when hearing cricket and owl sounds, children in class 3 may know that some of them had received a compliment and others a warning, but they need to look at the light-objects to see who had received a compliment or warning. Though the teachers were positive about the light-objects and argued that they had an added value over traditional ways of working, the FireFlies soundscape was by most teachers seen as a valueless extra to the system. In comparison to CawClock, the information provided by the FireFlies soundscape was not detailed enough to be of value.

Another difference between CawClock and FireFlies, is the grades in which we deployed the designs; grade 1 and 2 for CawClock and grade 3 to 5 for FireFlies. We decided to deploy FireFlies in different grades based on our creative workshop with educational experts, who saw more opportunities for innovation in higher grades. During the deployment of FireFlies, we discovered that children who are 'working in silence' in earlier grades, are much less silent than those in higher grades, which makes background soundscapes more outstanding in higher grades. The soundscapes of FireFlies were therefore less suitable indeed.

Overall we conclude that the audio part of FireFlies was not very successful. Several improvements could be thought of and were also suggested by the participating teachers. For example, the sound design could better fit the auditory environment in the classroom, potentially by, rather than using animal- and nature sounds, using types of sounds that are more in line with the sounds that are already present. Additionally, the soundscape could stand out less when the volume at which it is played would automatically be adapted to the sounds already present in the class. This way, the soundscape does not become inappropriate at more silent moments. Furthermore, a major improvement could be made when the audio would be played locally by each light-object rather than from separate speakers in the back of the room. All these objects together would then form a distributed auditory display. The directional aspect of such sound design could make the information presented by it more meaningful (e.g. by revealing the location of children who got a turn or who received a compliment). Additionally, the volume would in this way be more equally distributed over the classroom. Though it was not feasible to add these functionalities to our current prototype, it would be an interesting improvement for a future research-through-design iteration.

THE COMBINATION OF PHYSICAL INTERACTION AND AUDIO

Apart from the soundscape, which was intended to provide information about the state of the light-objects in the user's periphery of attention, the teacher-tool also produced audio. When selecting a color on the tool, a short nature sound that resembles that color's soundscape was played. Also short piano tones of unique pitch were played when squeezing one of the beads representing a child's name. These cues were intended to be perceived in the periphery of attention and shift to the center when relevant. For example, when a teacher selects the color blue, she hears a short cue of ocean sounds and she knows she selected blue without having to focus her attention on the interaction. However if she would have heard bird-sounds, the audio may attract her attention and make her realize that she selected yellow instead of blue. She would then focus her attention on the interaction and correct the mistake. We therefore hoped that the audio of the teacher-tool could support the physical interaction with it to be performed in the periphery of attention, for example by enabling it to be performed without needing to look at the tool.

As presented in Figure 6.11, a large majority of physical interactions were performed while the teacher was at least some of the time looking at the teacher-tool. Only three observed interactions were performed while the teacher never looked at the tool. In the interviews, the teachers mentioned that the audio of the teacher-tool had no added value, they indicated that they looked at the tool to confirm they selected the right color or name rather than relying on the audio. A possible reason for this could be that the piano tones related to the children's names were played after the names had been selected, and thus after the light-objects changed colors. These sounds may thus not have been helpful in locating the right name, but could merely be used to recognize a mistake. However, none of the teacher's experienced a situation in which the audio informed them that a wrong color or name was selected. It therefore seems that the audio incorporated in the teacher-tool did not support the physical interactions to be performed more easily. However, it seems too soon to conclude that audio cannot support peripheral physical interactions in general, further research would be required to better explore this idea.

6.7.2. Evaluating peripheral interaction

Having deployed a peripheral interaction design in the intended context of use for six weeks, does not only allow us to extensively analyze whether our intentions with the design were met, it also enables us to reflect on our evaluation methodology. This section reflects on whether or not the evaluation methods we applied were suitable to evaluate peripheral interaction design. However, we will first addres some more practical discussion points related to conducting a long term study.

CONDUCTING A LONG TERM STUDY

The participating teachers worked with FireFlies for six weeks. Although, this study led to interesting new insights for our research on design for peripheral interaction, one may question whether these insights could also have been gained in a study of a shorter duration.

In the interviews, teachers reported that interactions with FireFlies became more automated over time. Furthermore, informal video observations resulted in examples, such as the one presented in Figure 6.12, which seem to indicate peripheral physical interaction with FireFlies. These examples were found in the videos of the last two weeks of the study. Qualitative results therefore seem to indicate that it was crucial to conduct a long-term study, to observe peripheral interaction development. The formal video observation data however, do not seem to clearly show longitudinal effects. For example, the duration and frequency of interactions did not clearly change over the course of the study, nor did the occurrence of any instance of behavior of our coding scheme. Instead most of these findings varied over the weeks. We see some potential reasons for the fact that no longitudinal effect was found in the formal video analysis. As mentioned earlier, the user study with FireFlies made us realize that the cognitive action of deciding to use the technology rather than the previously applied method to reach a certain goal needs to be automated before the interaction can blend into the everyday routine (Insight 13 on Page 154). In the first week of the study, the teachers were likely rather conscious about using FireFlies since it was newly introduced in their class. As a result, it seems unlikely that they often 'forgot' to use it. Possibly the fact that they knew they were being recorded, and that they knew they were part of an experiment (the 'Hawthorne effect' (Jones, 1992)), strengthened this effect. In later weeks, the teachers may have been less conscious about using FireFlies (it was less novel), but as the cognitive decision to use it was not habituated, they may often have automatically applied their known method rather than FireFlies. In the last weeks of the study, using FireFlies may have become automated in certain situations, as a result of which the teachers may have used it more often. This could explain why we informally observed indicators for peripheral interaction in the final weeks of the study, while a longitudinal effect was not evident from the video analysis. Additionally, we aimed to record a video at the same moment each week, but this was not always possible: teachers sometimes adjusted their schedule or special events occurred. Therefore the video data may have been too diverse to observe longitudinal effects. Summarizing, since we found indicators of habituations in the fifth and sixth week of the study, we believe that the indicators for peripheral interaction found in our study could not have been found in a study of shorter duration. We furthermore expect that showing longitudinal effects, with FireFlies or other peripheral interaction designs, is possible, but requires evaluations longer than our six weeks and less diversity in recording moments.

A general motive to perform longitudinal studies is to overcome the 'novelty effect' (Lippert, 2003): high levels of enthusiasm when a new technology is used for the first time. In the first week of the study, we observed this novelty effect particularly among the children, who were very engaged with their light-objects and, according to the teachers, easily 'obeyed' them. Toward the end of the study however, their enthusiasm decreased as FireFlies became more part of their routines. The children also reported that in the beginning they thought the light-objects were 'really cool' while at the end they were 'just normal'. Six weeks deployment was clearly enough to overcome the novelty effect; its influence on our results seems reduced to a minimum.

EVALUATING PHYSICAL PERIPHERAL INTERACTION

Though related work is available on the evaluation of technologies aimed to employ the periphery of attention, particularly evaluations of *physical* peripheral interaction are scarcely reported (also see Chapter 4). A few examples report interesting evaluations based on informal, anecdotal evidence. Since we aimed for a more structured approach, we now discuss lessons learned regarding this strategy.

In the formal video analysis of our study, all captured interactions with the teacher-tool were marked. Since FireFlies was designed to enable quick interaction, which may potentially shift to the periphery of attention, it seemed interesting to see if the duration of interactions with the teacher-tool decreased over time. This could indicate an increased level of automaticity over the weeks and is also a common evaluation strategy for *microinteractions* (Ashbrook, 2010; Wolf et al., 2011), an interaction style related to peripheral interaction (see Chapter 4). The average interaction duration did not decrease during the course of the evaluation for any of the participants however. Also, when separating the different types of interactions, no decrease in interaction duration was found. As an additional indicator for peripheral interaction, we coded the extent to which the teachers were looking at the teacher-tool during interaction. Interestingly, Figure 6.11 shows that interactions that took place when the teacher was most of the time *not* looking at the teacher-tool, required most time. This is an understandable finding since these interactions likely occurred when she was doing something else in the meantime. For example, P5 used the teacher-tool at the start of a lesson to allow a number of children to discuss. She did that while looking in the room to see which children could discuss, but also while explaining which exercise the children had to make. Interacting with the teacher-tool may therefore have taken more time compared to interactions that are not performed during another task. On the other hand, this interaction also seemed to show clear indicators of peripheral interaction. In hindsight, we therefore conclude that the duration of interactions does not seem to be a valuable means to assess whether they took place in the periphery of attention: a peripheral interaction is by definition performed with only few mental resources and therefore likely takes more time than when the same interaction would be performed in the center of attention.

Insight 15. Duration of an interaction is not a valuable means to assess whether the interaction took place in the periphery of attention.

Apart from interaction duration, we looked at the frequency of interaction, the extent to which interactions took place during other activities, and qualitatively described an observed example of an interaction which shows clear signs of being performed in the periphery of attention. Although none of these methods provide hard evidence that the interactions were performed peripherally, these methods did help us understand which interactions with FireFlies seemed suitable for peripheral interaction and which did not. An additional indicator for the success of FireFlies as a peripheral interaction design, was found when the prototypes were removed from the classrooms. Teachers indicated that they missed using it and that they sometimes even automatically reached for the teacher-tool while it was no longer present. Although this also does not prove that physical interactions with the teacher-tool were peripheral, it does provide evidence that a major goal of peripheral interaction, namely blending the interaction in the everyday routine, was met. We therefore see this as a potentially suitable means to assess peripheral interaction design.

Insight 16. A possible means to evaluate if an (inter)action became a routine could be to assess the situation in the context in which the design was used for a period of time, after it has been removed from this context.

EVALUATING PERIPHERAL AUDITORY PERCEPTION

In our user study with FireFlies, we evaluated the soundscape through a questionnaire, interviews and informal video observation. We will now reflect on how appropriate these methods were for evaluating peripheral perception of audio.

As mentioned before, the sound design of the FireFlies soundscape was based on our earlier design CawClock. In the evaluation of CawClock, we conducted one live observation session in which we observed that the teacher barely looked up at the clock after hearing one of the sounds. Both this finding and the teachers' comments that they were able to ignore the audio, showed that the audio did not always attract the teachers' attention. We therefore concluded that the soundscapes of CawClock must have been in the teachers' periphery of attention at certain moments. Based on the interview with the teachers who used CawClock, we furthermore concluded that the audio shifted to the center of attention at moments when it became relevant (e.g. when one timeframe ended and another began). In the present study with FireFlies, we also did not observe the teachers looking up after hearing the soundscape. We also found an instance where the audio shifted to P6's center of attention because it became relevant (i.e. when she had forgotten to turn a blue light back to red). Other than that, the teachers gave us many examples of situations in which the audio shifted to their center of attention for less positive reasons, namely because it annoyed them. Although this also happened in a few cases with CawClock, the teacher who used CawClock indicated to have gotten used to the audio within a few days. This did not seem to have happened with FireFlies, potentially because the majority of participating teachers did not find the audio informative. Three teachers even completely turned off the audio after the first day. For the teachers who did use the soundscapes more often, we did not observe clear distractions. We therefore conclude that the soundscapes were likely in their periphery of attention at some moments. However, the shifts to the center happened mostly for inappropriate reasons.

Based on the above discussion, we must conclude that only observing whether users are clearly distracted by a soundscape does not seem a valuable means to assess peripheral perception. Although one may use this data as an indicator that audio did reside in the user's periphery of attention, there seems only an added value when the audio sometimes shifts to the center when it becomes relevant. Also it should not shift to the center for inappropriate reasons. Therefore, an evaluation of peripheral audio should involve an assessment of whether or not the audio is in the periphery of attention, as well as whether or not shifts to the center occur and for which reasons these shifts occur.

EVALUATING 'PERIPHERALNESS' VS. EVALUATING USER EXPERIENCE

As evident from both above discussions about the evaluation of physical interaction and auditory perception, it is clear that assessing whether or not the interaction took place in the periphery of attention seems challenging. First of all it is practically impossible to verify the division of a participant's mental resources while he or she is performing interactions in the real context of use. Secondly, even if it seems likely that an interaction took place in the periphery (e.g. because the perception of audio did not attract the participant's attention), this alone is not a valid indicator for the success of a design. In the case of auditory perception, we concluded that the audio must also shift to the center of attention and that these shifts should happen because the audio becomes relevant rather than because it is experienced as annoying. In case of physical interaction, we have seen that evaluating the extent to which a design becomes part of the everyday routine and can be used for a personally relevant goal, seems to say more about the success of the design than our finding that some of the interactions seem to have been in the periphery of attention. Although we did find indicators for interactions taking place in the periphery of attention, we must conclude that, in future evaluations of peripheral interaction, it seems more valuable to look at the intended effects of interaction (e.g. the intended user experience) rather than whether or not it actually was performed peripherally.

6.8. Conclusions

In this chapter we have presented FireFlies, an open-ended peripheral interaction design aimed to support primary school teachers in performing secondary tasks while teaching. FireFlies combines physical interaction and auditory feedback and can be seen as a research instrument or design intervention to study the concept of peripheral interaction design in context. An interactive prototype of FireFlies has been deployed in four different classrooms for six weeks each.

FireFlies was used by the participating teachers every school day during the study. All teachers found relevant uses for the system, even though the way they used it differed. FireFlies seemed beneficial as a visual information display to both children and teachers; it supported the teachers in silently communicating short messages to children and provided a personal information display for each child.

Teachers found the physical interactions with the FireFlies teacher-tool quick and easy, and were able to perform these interactions frequently during lessons, without interrupting ongoing tasks, and without needing to constantly look at the tool. Qualitative examples taken from videos recording in the final weeks of the study seem to indicate that indeed the interaction with the teacher-tool shifted to the periphery of attention at times. The audio aspect of the design was less successful: only one of the six participating teachers saw the soundscape as an added value, the others argued it distracted them and the children. We attribute this finding to the fact that the information provided by the audio was not detailed enough. To gain awareness of the relevant information regarding the state of FireFlies, it was required to look at the light-objects rather than listen to the soundscape only.

Though we have observed parts of the interactions with FireFlies shifting to the teachers' periphery of attention, we have also concluded that evaluating if an interaction is peripheral is challenging: this alone is not a suitable measure for the success of a peripheral interaction design. An important conclusion of the study described in this chapter therefore is that future evaluation of peripheral interaction could instead be focused on assessing other the effects of the design, such as its user experience.

The effects of FireFlies were evaluated qualitatively in our study, but lead to the most relevant insights. Interviews conducted with the six participating teachers showed us that using FireFlies replaced previous ways of working (e.g. giving turns verbally), which influenced the interaction blending into the everyday routine: the teachers automatically applied their known methods, and deciding to interact with the teacher-tool instead required extra conscious thought in the beginning of the study. It seemed however, that the decision to use FireFlies became automated toward the end of the study. Long-term deployment of peripheral interaction therefore was deemed essential to assess its effects. Teachers evidently needed time to incorporate the use of FireFlies in their everyday routines. However, the fact that they missed its functionality and sometimes automatically grabbed for the teacher-tool after the study had finished, indicates that using FireFlies became part of their everyday routines to some extent.

Section III
Reflection and generalization

Chapters 7 & 8

7.

Six considerations for peripheral interaction

Abstract

This chapter aims to revisit the insights we gained throughout the studies presented in this thesis, and to generalize them in order to discuss the contribution of our research to a larger body of work. We therefore present six considerations for peripheral interaction. These considerations are aimed for interaction design researchers and practitioners and may support them in anticipating and facilitating peripheral interaction with their designs. We believe that this can support interactive systems to fluently embed in, and become a meaningful part of people's everyday routines. Each consideration is grounded in examples from our own work and is elaborated by a number of explicit implications for design and evaluation.

This chapter is based on:

Bakker, S., Hoven, E. van den, and Eggen, B. (2013). Six considerations for peripheral interaction. Submitted to Personal and Ubiquitous Computing.

7.1. Introduction to this chapter

Computing technology is being integrated in numerous artifacts and environments. An increasing number of such everyday interactive systems will be available to be interacted with during our daily lives. Along with the opportunities that come with this development, we also see a challenge in fluently embedding these technologies in people's everyday routines. In this thesis, we have discussed the concept of *peripheral interaction* as a way to address this challenge. Peripheral interaction is inspired by the observation that many interactions with the physical world take place in people's periphery of attention, while they may also engage the center of attention when this is relevant or desired. For example, we are aware of what the weather is like, or we can drink coffee from a cup without conscious thought, while we may also intentionally look outside to see if it is raining, or intentionally sip from our cup to check if the temperature is right. These interactions are available to be undertaken in the periphery of attention, but can easily shift to the center of attention and back. We believe that interactive systems can be designed in such a way that they can similarly reside in people's periphery of attention, where they require no focused attention while being available to easily shift to the center of attention when this is relevant. This is what we aim to achieve with peripheral interaction.

The focus of this thesis so far has been on specifying, operationalizing and validating the concept of peripheral interaction. In doing so, we concluded from literature (Chapter 2) and we qualitatively observed (Chapter 3) that both everyday perceptions and physical actions can take place in the periphery of attention. We concluded in Chapter 4 that peripheral perception of digital information is widely explored in related work, while peripheral manipulations on interactive devices are only sparsely studied. In Chapters 5 and 6, we developed and evaluated interactive systems which presented auditory information that may be *perceived* in the periphery, and incorporated the possibility of *physical interaction* which may shift between the center and periphery of attention. These interactive systems should be considered research tools that we developed to validate our peripheral interaction approach. As a result of our studies, we found a number of qualitative examples, which showed that indeed physical interactions with our designs and auditory perceptions of stimuli produced by our designs seemed to take place in the periphery of attention. We believe that this is a promising finding, which supports our concept of peripheral interactions with technology.

The approach we have taken in earlier chapters of this thesis focused rather specifically on verifying the feasibility of peripheral interaction, and a large part of it involved the very specific target group of primary school teachers. Now that we have preliminary support for the feasibility of peripheral interaction by this specific target group, we set out to discuss the contribution of our research to a larger body of work. Given the increasing number of interactive systems that support everyday activities, the challenge of fluently embedding these in everyday life is highly relevant today. Having seen that interactions with technology could take place in the periphery of attention, we believe that our peripheral interaction approach may be beneficial for many everyday interactive systems. This approach may support researchers and practitioners in the area of interaction design in realizing that their designs may be interacted with in the user's periphery of attention and support them in anticipating and facilitating such peripheral interactions.

In this chapter we aim to generalize the insights we gained in our studies, in order to provide new insights in how peripheral interaction can be anticipated and facilitated through interaction design. We have therefore formulated the following six considerations for peripheral interaction.

Everyday interactions frequently shift between center and periphery

Everyday interactions depend on routine and context

Peripheral interaction is personal

Peripheral interaction requires both learning and unlearning

People are not aware of their periphery

Peripheral interaction is a means, not a goal

We will now clarify each consideration by illustrating it with insights we have gained in our studies and by discussing its implications for design and evaluation.

7.2. Consideration 1: Everyday interactions frequently shift between center and periphery

The intention of peripheral interaction is to enable everyday interactive systems to be available in the periphery of attention where they may easily shift to the center of attention and back. Such shifts are therefore an important aspect of peripheral interaction. The highly related concept of calm technology also describes this, by stating that "calm technology engages both the center and the periphery of our attention, and in fact moves back and forth between the two" (Weiser and Brown, 1997, p. 79). In the studies described in this thesis, which built on Weiser and Brown's vision, we gained more specific insights in how such shifts may take place, which we will elaborate on in this section.

CLARIFYING THIS CONSIDERATION

In the evaluations of the designs presented in Chapters 5 and 6, we found it valuable to split up the interactions into smaller stages of action when discussing whether they took place in the periphery of attention. This made us realize that a single interaction can shift from the center to periphery of attention and back, in between different stages of this interaction. We can explain this by discussing peripheral interaction in the light of Norman's action cycle (Norman, 1998), see Figure 7.1. Norman's action cycle is a frequently used model to describe interactions with technology (for example (Hartson, 2003; Vermeulen et al., 2013)), and it seems particularly suitable to describe peripheral interaction as well. In our view, peripheral interaction encompasses both action and perception, and Norman's action cycle clearly binds these two aspects of interaction in one comprehensive model.

How shifts may take place

According to Norman's action cycle, an action consists of seven stages. In order to discuss how interactions may shift between the center and periphery of attention, we will apply this model to example interactions with FireFlies, an interactive system for classrooms presented in Chapter 6. FireFlies consists of a *light-object* on each child's desk, an interactive device called the *teacher-tool* with which a teacher can change the colors of these light-objects, and a *soundscape* which presents the colors that are currently in use as a background information display. The teacher's physical interactions with the teacher-tool and the perceptions of the light-objects and the soundscape were intended to shift between the periphery and center of attention. In Figure 7.2, we present three example interactions with FireFlies, which are inspired by the teacher's interactions we observed in our

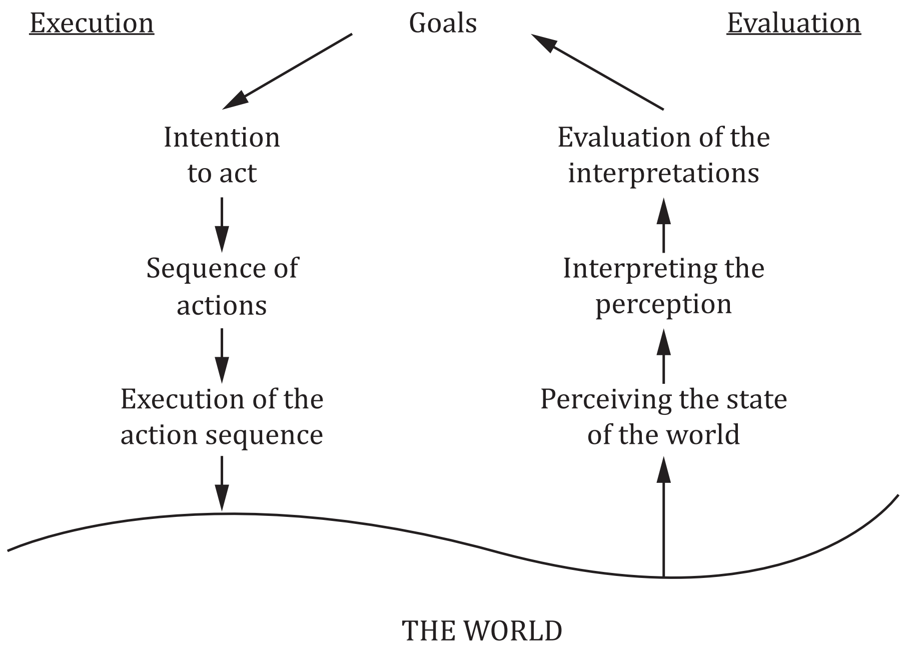

Figure 7.1. Norman's action cycle (Norman, 1998, p. 47).

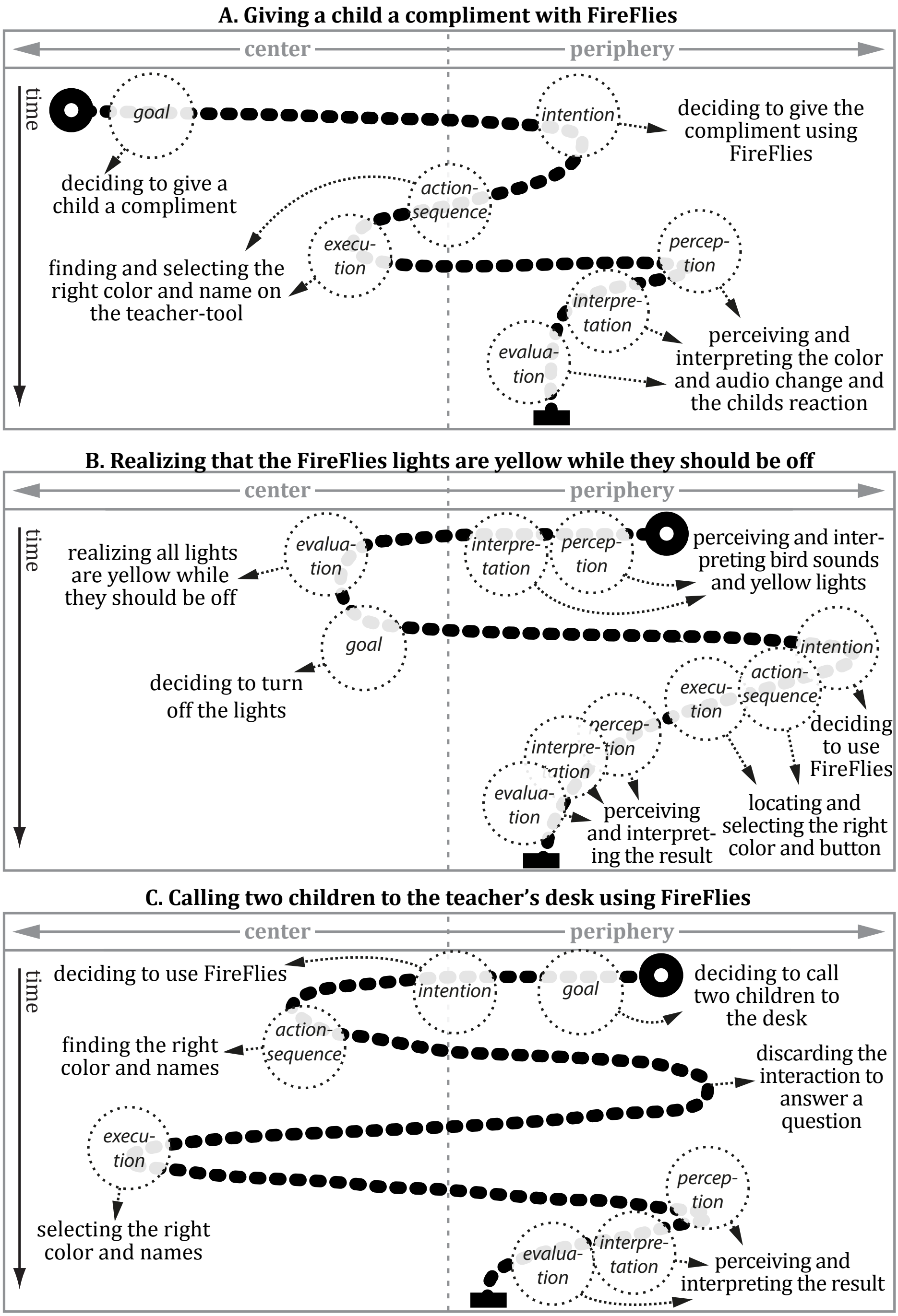

Figure 7.2. Three example interactions with FireFlies, and the way these examples may shift between the center and periphery of attention at different stages of Norman's action cycle (Norman, 1998). The start of each interaction is indicated by a black circle and the end by a short black bar. Stages of interaction are indicated by dotted circles and explained in text.

study presented in Chapter 6. For each example, Figure 7.2 illustrates the way it complies with Norman's action cycle and its potential shifts between center and periphery of attention. Though based on the results presented in Chapter 6, the illustrations in Figure 7.2 are hypothetical and intended to feed the discussion below rather than to provide an accurate and conclusive overview of how the participating teachers' interactions with FireFlies shifted between the center and periphery of attention.

Figure 7.2.A illustrates a situation in which the teacher uses FireFlies to give a child a compliment by making his light-object green. The interaction starts when the teacher observes that the child is working well and decides to give him a compliment. After forming this *goal*, the teacher forms the *intention* to use FireFlies to reach this goal. Next, the teacher specifies an *action-sequence* and *executes* this sequence: she grabs the teacher-tool, locates the color green, slides the color slider to this color, locates the correct child's name and selects this name by squeezing the bead on which it is printed. The teacher then *perceives* the result of her interaction: she hears the piano-tone that the teacher-tool plays as confirming feedback, she sees a green light on the child's desk, she hears cricket sounds which reveal that the color green is currently in use and she hears or sees the child's reaction to the compliment. The teacher can *interpret* from these perceptions that indeed the light turned green and *evaluate* that her goal of giving a compliment was reached. The other two examples in Figure 7.2 also illustrate interactions with FireFlies, which go through the same seven stages of action, be it in a slightly different manner. The interaction illustrated in Figure 7.2.B for example starts with a perception rather than by forming a goal and the example in Figure 7.2.C shows an interaction that is shortly interrupted by another activity.

As shown in Figure 7.2, some stages of interactions may take place in the periphery, while other stages can be in the center of attention. The interaction in Figure 7.2.A for example started in the center of attention when the teacher consciously decided to give a compliment, but shifted to the periphery of attention when deciding to do this with FireFlies: the teacher automatically grabbed the tool without actively deciding to do so. Later, it shifted to the center of attention to locate the correct child's name and back to the periphery when evaluating if the interaction was successful. As shown in this and the other examples in Figure 7.2, these shifts can happen quickly and frequently, between different stages of interactions. Even short interactions that may require only a few seconds can shift between center and periphery while the interaction is ongoing.

Why shifts may take place

As becomes clear from the examples presented in Figure 7.2, interactions do not only frequently shift between the center and periphery of attention, these shifts may also happen for various reasons. A number of reasons for such shifts are provided in the literature we reviewed in Chapter 2 and these also came forward in the studies presented in Chapters 3, 5 and 6. We will now discuss five of these reasons and illustrate them with examples of interactions with FireFlies. Although these five reasons are by no means exhaustive, they do provide an insight in why shifts may take place.

Habituation: A potential reason for activities shifting between the center and periphery of attention is habituation. This phenomenon is widely discussed in attention theories we addressed in Chapter 2, under terms such as *habit* (Aarts and Dijksterhuis, 2000; Wood and Neal, 2007) and *automaticity* (Wickens and Hollands, 2000; Wickens and McCarley, 2008), and we also observed it in the evaluations of our peripheral interaction designs. For example, on the first day of using FireFlies, one teacher indicated that she consciously needed to think about how to operate the teacher-tool (e.g. to first select the color and then a name). This action seemed to require conscious attention because it was not (yet) habituated, and therefore shifted to the center of attention. To use another term, the interactive system was not *ready-to-hand* (Heidegger, 1996), which, as we concluded in Insight 6 on Page 61, seems to be a prerequisite for interactions to take place in the periphery of attention. After using FireFlies a few times however, it seemed that all teachers knew how to operate the tool without requiring conscious thought: the execution stage of the interaction became habituated. In Chapter 6, we furthermore realized that the decision to use a new interactive system can become habituated. The interaction in Figure 7.2.A for example shifted to the periphery of attention when the teacher formed the intention to use FireFlies to reach the goal of complimenting a child. Alternatively, she could also have decided to give the compliment verbally. Some teachers participating in our study indicated that, although they planned to use FireFlies to give compliments, they often automatically gave a compliment verbally, without consciously thinking about it. However, after using FireFlies for a few weeks, they often automatically grabbed the teacher-tool in such situations and even attempted this when the system had been removed from their classroom. Clearly, the decision to use an interactive system needs to be habituated for it to require only few mental resources and take place in the periphery of attention, particularly when it replaces another activity that is already habituated, also see Insight 13 on Page 154. As the amount of resources required for such decisions may decrease over time, because it has been carried out more frequently, the intention stage of different interactions may be located at different distances from the center of attention, as also illustrated in Figure 7.2.

Difficulty: It seems that interactions can furthermore shift between periphery and center of attention because of the difficulty of the operation. This is addressed in attention theory as a common reason for an activity requiring focused attention (Wickens and Hollands, 2000; Wickens and McCarley, 2008) and we also observed it in our study with FireFlies (see Insight 14 on Page 155). For example, teachers who used FireFlies indicated that it was difficult to find the right child's name from the bunch of up to 27 names on the teacher-tool. They therefore required focused attention to do so, as also illustrated in Figure 7.2.A and 7.2.C. In the example of Figure 7.2.B however, the interaction to turn off all lights at once was less difficult as it did not require locating a child's name, and could therefore take place in the periphery of attention.

Significance: Another reason for interactions shifting between center and periphery of attention involves the significance of the interaction. An example of this is seen in Figure 7.2.B. The teacher in this example thought that the light-objects are off, but realized after hearing bird sounds in the soundscape and seeing yellow lights on the children's desks that she must have forgotten to turn the light-objects off. It attracted her attention because the information was, at that moment, of significant relevance to her: she needed to act upon it by turning the lights off. The interaction shifted to her center of attention, potentially as a result of *priming* (Treisman, 1964), a cognitive mechanism that increases the likelihood that perceptual stimuli are noticed when they are personally relevant to the perceiver. Phases of an interaction that involve physical actions may also shift from periphery to center of attention as a result of significance, such as when it is important that the interaction does not go wrong. For example, a teacher using FireFlies may consciously focus on selecting the right name or color with FireFlies, to avoid sending the wrong message to the wrong child. As shown in Figure 7.2.C, shifts from center to periphery of attention may also be caused by significance, when another activity is currently more important to the user and therefore occupies the center of attention. In this example, a child asked the teacher a question while the teacher was interacting with FireFlies. Since answering this question was momentarily more significant than performing the interaction, the teacher discarded the interaction with FireFlies and continued after the question had been answered.

Salience: Additionally, perceptions may shift between center and periphery of attention as a result of salience, which is named in attention theory as a common cause for perceptual stimuli attracting people's attention (Knudsen, 2007; Treisman, 1964). To give an example, children who were sitting close to the speakers which played the soundscape of FireFlies were sometimes distracted by the audio when a sudden, louder sound was heard. On the other hand, it seems that non-salient stimuli are often easy to ignore and may therefore shift to periphery of attention.

Affection: A last potential reason for interactions to shift from periphery to center of attention seems to be the affection a user may experience with an interaction. We first saw this in our context mapping study (see Chapter 3), in which we concluded that perceptions may attract the attention when they evoke either positive or negative emotions. We also found a few examples of this during an early research-through-design iteration described in Chapter 5. Some participants who used the EntranceSounds system, which generated a short auditory cue when people entered an office, walked in and out of the room a couple of times in a row to trigger the system just for fun. With the RainForecasts system, which used sound to indicate the weather forecasts, a participant mentioned that when hearing that the weather would be nice, she looked outside and seeing the nice weather made her happy. Different from these examples, the emotions related to an interaction may also be less positive. For example, some teachers who used FireFlies were annoyed by the soundscape and it therefore attracted their attention.

IMPLICATIONS FOR DESIGN

The above discussion reveals that interactions may shift between the periphery and the center of attention for various reasons. Although these reasons may seem unambiguous in our examples, most of these reasons do not stand on their own, but are highly related. For example, a stage of an interaction may be very significant or difficult, but performed so often that it is habituated and therefore possible in the periphery of attention. A sound may be very subtle and therefore not salient, but still attract the attention because the presented information is of significant relevance to the perceiver. On the other hand, the perception of a highly salient sound, such as a train passing, may be so habituated that a perceiver can easily ignore it. These reasons should therefore not directly be seen as prerequisites for peripheral interaction, but can be helpful in interaction design as we will discuss in this section.

When peripheral interaction is suitable

The potential reasons for shifts between center and periphery of attention discussed above could for example provide insight into the types of interactive systems which are suitable for peripheral interaction. For some systems, it seems undesirable that they shift to the periphery of attention. A fire alarm for example, seems *always* of such significant importance that it requires conscious attention. Similarly, interactions that should not go wrong, such as changing your password for an online service, are unsuitable to be performed in the periphery. Other interactions seem highly engaging most of the time, as a result of which a user likely chooses to focus his attention on it. For example, a very engaging computer game preferably seems to be played in the center rather than in the periphery of attention.

Different from these examples, most interactions will not always engage the user's center of attention. Think for example of systems that help you to keep track of relevant but not crucial information (e.g. the weather or the activities of friends and family), systems to support remembering upcoming agenda items and tasks (e.g. keeping a grocery list or remembering to call someone), or systems for everyday tasks at home, such as setting your alarm clock or controlling your lighting system. Interactions with such systems may at moments be very significant (e.g. when an important agenda item is coming up that cannot be forgotten) or engaging (e.g. when finding out that the weather will be beautiful on a day in which you planned to go on vacation), while in other cases, these interactions are relevant but not crucial. In these latter situations, such interactions are typically performed as a part of the *everyday routine*, and form an 'unremarkable' part of this routine (Tolmie et al., 2002). Such systems could, in our view, clearly benefit from peripheral interaction, and we describe such systems using the term 'everyday interactive systems'.

Suggestions for interaction design

The above identified reasons for shifts between center and periphery of attention may furthermore help anticipating how users may interact with (future) interactive systems. For example, designers and developers may ask themselves how difficult or significant the interactions with their design may be, whether the interaction is likely to become habituated or if a designed perceptual stimulus is salient. Additionally it could be considered if the reasons for which these shifts happen, match the goal of the interaction. For example, salience may be very appropriate for certain parts of interactive systems, such as an alert or reminder. However, interactions which are relevant but less urgent may better be supported by non-salient interactive systems. To determine when salient stimuli are appropriate in peripheral information displays, Matthews et al. (2004) present a useful toolkit that can support the design of displays that have multiple levels of urgency. Additionally, Vastenburg et al. (2009) present a model that informs designers of notification systems in determining a suitable moment of notification based on the urgency of the message.

The observation that interactions may quickly and frequently shift between the center and periphery of attention, also entails that interactions may be initiated at any moment, potentially in the periphery of attention. To support interactions with our FireFlies design to be easily initiated, we made sure they did not require any start-up time. For example, the soundscape played automatically and did not need to be actively requested by the user, and the interactive device did not need to be turned on before it could be used. Additionally, this partially motivated our choice of using audio rather than only visual elements. Since audio does not need to be looked at to be perceived, it can be heard whenever it is available. Furthermore, we found it important that our interactive device could be 'at hand' whenever the user wished to interact with it. Since primary school teachers often walk around the classroom during lessons, we decided to enable our design to be attached to the clothes of the teachers while they could also hold it in their hands. Of course many other options to make an interactive device available 'at hand' are possible. Interesting directions to achieve this could be wearable computing (Rhodes et al., 1999), mobile computing (Nakhimovsky et al., 2009), whole body interaction (England, 2011), gesture interaction (Wolf et al., 2011) or tangible gesture interaction (Hoven and Mazalek, 2011).

Apart from the idea that interactions should be available to be *initiated* any time, we have also seen in Figure 7.2.C, that interactions may easily be *discarded*, even when an interaction is unfinished. In this example, a child asked the teacher a question while the teacher was interacting with FireFlies. As a result, the teacher temporarily discarded the interaction with the teacher-tool to pick it up later. Although we did not directly anticipate this with our designs, they seemed to function relatively well in such situations; no settings were lost and no errors occurred when the interaction was discarded. We believe that the possibility of users discarding an interaction in the middle of it may be a relevant consideration for peripheral interaction design.

7.3. Consideration 2: Everyday interactions depend on routine and context

In the previous section, we have discussed how interactions shift back and forth between the center and periphery of attention, at different stages of these interactions. This gave an interesting detailed view on single interactions, but we also realize that interactions with everyday interactive systems do not stand on their own, but strongly depend on their context and the user's everyday routine.

CLARIFYING THIS CONSIDERATION

The main aim of peripheral interaction is to support everyday interactions with technology to meaningfully blend into the daily routine in a real world environment. In the everyday world, multiple activities are taking place at once. For example, a person walking to the train station may be talking on the phone, crossing the road, closing his jacket, and deciding what to eat tonight, while he also sees the traffic light turning red, hears the person on the phone sneezing, and sees another pedestrian running by to catch the train. This scenario seems chaotic but such 'chaos' seems common practice in many everyday situations. All these individual actions and perceptions can be described through the stages of Norman's action cycle. This means that, in everyday situations, numerous sequences of action are performed at the same time. Though the examples in Figure 7.2 each show only one line that represents an activity, in reality numerous lines are present which move criss-cross between center and periphery of attention.

The person in the previous scenario may shortly discard his phone conversation as a moment of focused attention is required to cross the road; he may try to find the buttons of his jacket to close it while listening to his conversational partner; he may form the intention of deciding what to eat tonight, but discard that activity after seeing the other person run and realizing that running is needed to catch the train. As this example illustrates, in real world situations, multiple activities are being performed at the same time, activities may start and end in the middle of the action cycle, stages of the cycle may completely be skipped or activities may be discarded at any stage of the cycle for a short or long period of time because other activities are currently more significant, engaging or salient. Humans are perfectly able to cope with such seemingly chaotic situations as a result of their attention abilities. Concluding, interactions with everyday interactive systems can be described in a step-by-step way, but they cannot be seen apart from the user's, sometimes chaotic, everyday contexts and routines.

IMPLICATIONS FOR DESIGN

When interactive systems are becoming embedded in the everyday routine, they can clearly not be seen apart from their context. The context may determine when and in which way a design is used and whether this can take place in the center or in the periphery of attention. In our study with FireFlies, we for example realized that many different classroom situations occur, such as whole-class instructions or individual instructions while the class is working independently. FireFlies was used differently in each situation. For example, most teachers barely used it during whole-class instructions because they wanted the children to concentrate on the whiteboard, while it was often used during individual instructions, for example to silently give compliments to children who were working well.

A detailed understanding of the context of use is important when designing or evaluating interactive systems that can facilitate peripheral interaction. This clearly holds not only for designs that specifically aim at peripheral interaction, but for any interactive system that is to become a part of the everyday context. This is widely supported in related literature, which for example states that a primary concern for ubiquitous computing research and practice is "the potential relationship between computation and the context in which it is embedded" (Dourish, 2004, p. 20). Several views have been published on what it means to understand context (Abowd et al., 1999; Oulasvirta et al., 2005; Schmidt et al., 1998). Additionally, more practical approaches on how to visualize and communicate context in a design process have been developed (Pedell and Vetere, 2005). These related studies suggest that understanding the context of use does not only mean having an image of the locations that are involved, but also includes understanding other contextual aspects such as the social context, the activities that are part of the everyday routine and the perceptual modalities that play a role.

To match our interaction design with the users' routine and context in the studies presented in this thesis, we found it helpful to take into account *multiple resource theory* (Wickens and McCarley, 2008), which describes how certain types of tasks are suitable to be performed simultaneously, while other tasks are not. For example, it is problematic to drive a car while reading a book, while it is possible to drive a car while the same book is being read to you. Such insights are valuable when designing interactions which may at moments shift to the periphery of attention. In the process of designing FireFlies, we for example realized that the teacher may want to have her eyes on the children most of the time. Therefore we altered the size of the beads that represent the children on the teacher-tool such that feeling the size of a bead revealed information about the length of the connected child's name, potentially enabling the teacher to operate the tool without looking at it.

Apart from these theoretical insights, we believe that an *iterative* design approach can be very beneficial to facilitate a fluent match between interaction design and context. Such an approach entails that earlier versions of a design are evaluated with users, in the intended context multiple times during the design process (Hoven et al., 2007; Hummels and Frens, 2008). We noticed the importance of this particularly in the sound design of FireFlies, which was based on our earlier design called CawClock. CawClock used animal sounds to present time related information in classrooms of the first and second grade of primary school. In these grades, children are four to six years old and regular lessons turned out to be rather noisy: children were walking around, moving things and talking to each other even though they were instructed to work silently. The soundscape played by CawClock seemed to fit in with these sounds: it could clearly be heard and the teacher and children could therefore extract information from it, but on the other hand it did not stand out or inappropriately attract the attention. This was different with FireFlies, which was deployed in grades three to five (children's ages six to nine). The children in these grades turned out to be much more silent during lessons. Even though the soundscape of FireFlies was similar to that of CawClock, the audio was much less appropriate in higher grades; it did not match well with the auditory environment, and therefore it stood out and attracted the attention too much. This could have been prevented by more extensively exploring the design in the context of use earlier in the design-process.

IMPLICATIONS FOR EVALUATION

The context and routine in which an interactive system is used highly influences how the user interacts with it, what its value is to the user and whether it can shift between the center and periphery of attention. Given that the aim of peripheral interaction is to embed interactive systems in the everyday routine, it seems evident such interactive systems are best evaluated by deploying them in the real context of use. This way, users can interact with them in an everyday life setting and the potential integration of the system into the routine can be experienced by the user and evaluated by the researcher. Although the traditional approach to evaluate how users interact with technology is to observe them in a controlled, laboratory-style setting, the approach to deploy designs 'in the wild' seems to be increasingly suggested in literature on interaction design in general (Rogers, 2011), and specifically for designs that are to employ the periphery of attention (Hazlewood et al., 2011; Pousman and Stasko, 2007).

In the studies we presented in Chapters 5 and 6, we also deployed our designs in the real context of use, and this approach indeed revealed insights that would likely not have been gained otherwise. This for example became clear in the deployment of the in Chapter 5 presented NoteLet design. This is an interactive bracelet which teachers could manipulate to take a picture of the classroom whenever they wanted to remember a child's behavior. Teachers could later view these pictures and take notes of the particular behaviors. As part of the iterative design process, we discussed an early concept of this design with three teachers, all of whom imagined that they could valuably apply it in their classroom. We deployed a prototype version of NoteLet in one of these teachers's classrooms and, after using it, the participating teacher realized that although it seemed valuable at first, the activity of looking at the pictures after school hours took too much time, and would therefore not fit in her routine as well as she had imagined. With FireFlies, presented in Chapter 6, we had an opposite experience. Of the nine teachers with whom we discussed an early concept of the design, four were hesitant about its potential usefulness. They had difficulty imagining for which purpose they would use it, and therefore they were unsure if it would be valuable to them. Three of these four teachers eventually used FireFlies in their classroom and all three found a relevant purpose for it and were able to integrate it in their routine. Though we realize that there is much in between discussing a conceptual version of a design with users and having them use it in their daily routines, these examples do show that crucial parts of the user experience may only become evident after it is deployed in the context of use for a period of time.

7.4. Consideration 3: Peripheral interaction is personal

In the previous sections, we have seen that everyday interactions frequently shift between the center and periphery of attention, that these shifts happen for various reasons such as significance or habituation, and that such interactions are strongly connected to the contexts and the routines which these are a part of. These aspects may clearly differ from person to person. Therefore, another important consideration is that peripheral interaction is highly personal. We already concluded this from our context mapping study in Chapter 3 (also see Insight 8 on Page 63), and we also noticed it in later studies.

CLARIFYING THIS CONSIDERATION

An example of the personal nature of peripheral interaction was observed in an early iteration with a design called EntranceSounds (see Chapter 5). This design played an auditory cue that represented the number of recent passers-by each time someone passed the door in an office space. An office worker who participated in the study came in one day at 10.00h, the usual time for coffee breaks, and heard that many people had passed the door while she saw that the office was empty. She concluded that her colleagues must have gone for coffee. This information could clearly only be extracted from the audio in that context and with knowledge of the particular everyday routine. In fact, another user in another context may have extracted completely different information from the same audio.

Another example was seen in the study with FireFlies. After the study, we asked the participating teachers about their suggestions for improvements to the teacher-tool design. These discussions revealed that some teachers would have liked the children's names to be listed in the same way the children were sitting in the classroom as they preferred this spatial orientation to easily find the right name. Other teachers however preferred an alphabetical order, which they found easier to remember.

Clearly, an interactive system may more easily become habituated, and therefore shift between periphery and center of attention, for one user compared to another user. This holds not only for the purpose for which an interactive system is to be used, but also the exact way the user interacts with it. This means that an interactive system may easily facilitate peripheral interaction for one user, while this will not as easily be achieved for another user. This provides a challenge for developers of everyday interactive systems that aim to facilitate peripheral interaction.

IMPLICATIONS FOR DESIGN

There may be many ways in which this challenge could be addressed. In our design of FireFlies, we aimed to address it by making FireFlies an *open-ended design*, which meant that the purpose for which teachers could use FireFlies was not predefined but could be chosen by the teachers. As a result, we indeed found that different teachers used FireFlies for different purposes, while most of them found it a valuable addition to their everyday routine. This seems to indicate a success of our open-ended approach. However, we also recognized that some teachers had difficulty integrating specific elements of the design into their everyday routine, such as the alphabetic order of the names on the teacher-tool and the use of audio in general, while this was easier for other teachers. Apart from an open-ended purpose, the design may therefore also have benefitted from an open-ended mapping between input and output (also see Insight 12 on Page 133). In other words, it would be relevant to enable interactions to be adaptable to the user as a means to facilitate peripheral interaction with everyday interactive systems.

A related issue, that applies mainly to information displays, is that the presented information may not be relevant for everyone who can perceive it. We noticed this with our RainForecasts design (see Chapter 5), which presented short-term weather forecasts through audio in an open office environment. This information was highly relevant for some office workers, one even based the time of going home on the weather, while others were genuinely not interested in the weather. Since the audio was played in an open office, these latter people also perceived it and were at moments annoyed by the audio as it had no value to them. To prevent such problems, Eggen and Mensvoort (2009) suggested the concept of *information decoration*, which aims to present information in a decorative way. This way, people to whom the information is not relevant, may still benefit of the design as it also serves a decorative function, such as by providing pleasant or relaxing background sounds. This direction seems particularly suitable in situations in which multiple potential users are involved, such as in public spaces.

7.5. Consideration 4: Peripheral interaction requires both learning and unlearning

Getting used to an interaction is important for it to become a peripheral interaction. As we recognized earlier in this chapter, interactions can shift to the periphery of attention when they are habituated. This however, entails that an interaction needs to be learned before it can potentially become a peripheral interaction, as also summarized in Insight 2 on Page 30.

CLARIFYING THIS CONSIDERATION

In our study with FireFlies, we observed that some elements of the design could quickly be learned and potentially become habituated, while this required more time for other elements. Most teachers for example rather quickly understood how they could manipulate the teacher-tool to change the colors of the light-objects. These color changes also influenced the soundscape, which represented each color that was in use through a specific nature-sound. Different from the interactions on the teacher-tool, the mapping between colors and sounds (e.g. yellow was connected to bird sounds and blue to ocean sounds) required some time to get used to: only after using it a couple of times, teachers were able to directly interpret that yellow lights were on when hearing bird-sounds. The learning process that seemed to require most time was related to the *decision* to use FireFlies for a certain purpose. Since the purpose for which most participants used FireFlies replaced a way of working which was already habituated, they found it difficult to get used to applying FireFlies rather than the habituated other activity. For example, when a teacher wanted to give a child a compliment, she often had already given it verbally before realizing that she could also have used FireFlies for that purpose. This example indicates that it may in many cases not only be required to *learn* to work with an interactive system, but also to *unlearn* another activity.

IMPLICATIONS FOR DESIGN

Before an interactive system can blend into an everyday routine, the user needs to get used to interacting with it. Our design CawClock, presented in Chapter 5, addressed this by involving *multiple levels of detail* in one information display. Though unintended, this aspect of CawClock seemed to support the process of getting used to it. CawClock combined the visual display of an analog clock on which colored timeframes could be shown, with a soundscape that represented which timeframe was ongoing and approximately for how long. The teacher who used CawClock for two weeks indicated that she could easily hear which timeframe was ongoing (each color was represented by a specific animal sound), but that she needed to look at the clock to find out how much time was left. Although the soundscape also indicated this through the number of animal sounds included, she had not been able to recognize this detail in the two week period. Although this may very well be due to lack of sophistication in the sound design, it may also show that two weeks was not enough to learn to recognize the subtle differences in the soundscape. If she would have used it longer than two weeks, she may eventually have learned to recognize these details in the soundscape.

Two things seem interesting in the above example. First, the combination of two modalities that display the same information could potentially have supported the learning process. Although the details of how much time was left could initially not be *heard*, the fact that it could easily be *seen* on the visual display may have helped the teacher in realizing how this information was presented by the audio. Second, the different levels of detail in the audio (the overall information of 'a timeframe is ongoing' versus the detailed information of 'the blue timeframe is almost finished') enabled the user to quickly apply the design without much learning time, while after a learning period, she may have been able to use the full potential of the audio. When such different levels of detail are implemented in a design, it is likely that people initially only use the overall information. However, while using the overall layer of information, the user may gradually start understanding the details as well and, little by little, learn to (automatically) recognize them. Although the details are this way not directly used, the process of learning how to use them also barely requires conscious effort. It therefore seems that a design with different levels of detail may support the process of learning how to interact with it.

IMPLICATIONS FOR EVALUATION

Given our observation that interactions need to be learned and that existing habits may need to be unlearned, it seems essential that everyday interactive systems are evaluated not only in the context of use but also for a longer period of time. With the upcoming ubiquity of computing technology, longitudinal evaluation strategies are becoming more common in human-computer interaction (HCI) research. Rogers (2011) for examples states "Whereas the burning question in HCI was once "How many participants do I need?" the hotly debated question is now "How long should my study run for?"" (Rogers, 2011, p. 58). A longitudinal approach to user evaluations is recommended specifically for systems that present information in people's periphery of attention (Hazlewood et al., 2011; Pousman and Stasko, 2007), and we also experienced it as vital in our research.

The studies presented in Chapters 5 and 6 all involved deployment of prototype versions of our design in the context of use for two to six weeks. The examples in which participants indeed seemed to interact with our designs in their periphery (e.g. the example illustrated in Figure 6.12 on Page 146) were gained mainly in the later weeks of deployment. Additionally, our observations that old habits may need to be unlearned or that interactive systems are strongly connected to their context would likely not have become evident in short term experiments. We furthermore noticed that our long term approach influenced the way participants treated our designs. For example, children were at first very enthusiastic about using FireFlies in their classroom, while in later weeks of the study, children mentioned that the presence of FireFlies was 'just normal'. Clearly, this 'novelty effect' (Lippert, 2003) was no longer evident in later weeks of the deployment and interactions with FireFlies were likely representative of how it would be used if FireFlies would be a regular part of their classroom.

Although everyday interactive systems seem best evaluated in long-term studies, this approach also has clear limitations. Such studies require tremendous time and effort, even if only a small number of participants is involved. While studies in which participants use a new design for a few hours or less seem unsuitable to evaluate the integration of the design in the user's routine, such studies can of course be suitable to reach other evaluation goals. For example, the usability of the design or the extent to which users can understand the mapping between visual and sound can also be concluded from studies with shorter duration. However, the main goal of peripheral interaction, embedding interactive systems in the everyday context and routine, can only be assessed in a long term study. The required duration of such studies seems to depend on many aspects, such as the number of times interaction takes place, the difficulty of an interaction and whether or not other activities need to be unlearned. In the six week deployment of FireFlies, we observed peripheral interactions in the fifth and sixth week of the evaluation. However, we did not find a clear longitudinal effect. For example, we did not find an evidently increasing number of peripheral interactions over the six weeks. Longer deployment would likely have been required to observe such effects. Nevertheless, our observation that some interactions with FireFlies can take place in the periphery of attention is a promising support for the feasibility of peripheral interaction. We believe that this and most other results presented in this thesis would not have been gained without deploying (prototypes of) interactive systems in the context of use for a longer period of time.

7.6. Consideration 5: People are not aware of their periphery

Activities that are performed in the periphery of attention, often take place outside conscious awareness. This entails that people are usually not aware of the things that take place in their periphery of attention. In fact, many people find it hard to grasp the idea that they are able to perceive information and perform actions in their periphery of attention. This may complicate the involvement of users in the design and evaluation process, which we also experienced in the studies with our peripheral interaction designs.

CLARIFYING THIS CONSIDERATION

A clear example of this problem resulted from our study with CawClock, see Chapter 5. After a two-week deployment of CawClock in a primary school, we discussed the design with the teachers who had used it. In their discussion of the soundscape, they made several remarks such as “the owl sound is too quiet, children may not always hear it” or “maybe it should ‘ring’ less often”. This discussion gave us the impression that they felt they had to pay attention to the clock every time it made a sound. They may very well have felt that way, since other interactive systems they commonly use, such as mobile phones and laptops, typically only use sound to attract the attention of the user, for example for reminders or alerts. The teachers may not have been aware of the fact that in their everyday lives, they perceive several sounds in their periphery of attention, such as the lights humming or people walking by. It could therefore have been hard for them to imagine that the soundscape of CawClock could also be perceived in that way. Clearly, more sophisticated sound design may have prevented some of these issues, however, this example also illustrates that people may be unaware of their ability to perceive and act in the periphery of attention. We even noticed that after people successfully experienced peripheral interaction, their awareness of it still seems limited. This clearly shows from an example of one of the teachers who had used FireFlies in her classroom for six weeks. This teacher sent us the following email (translated from Dutch) in the week after we had conducted the final interview and removed the system from her classroom:

"I would like to let you know that I really missed FireFlies in the last two days. Even though last week I thought, 'I am so busy, I am glad the experiment is over'. After all, it appears that you quickly get used to new things and that you also integrate them in your system."

Clearly, using FireFlies to some extent became a part of the routine of this teacher, even though she was not able to reason about that in the final interview. It only became clear to her after the system was removed from her routine.

IMPLICATIONS FOR DESIGN AND EVALUATION

The consideration that people have difficulty reasoning about what they (can) do in their periphery of attention, is important to take into account when involving users in the process of designing and evaluating an interactive system that aims to facilitate peripheral interaction. Clearly, asking people whether they think they would be able to interact with a design in their periphery of attention will unlikely lead to a valid answer. Even asking people if their interaction with a design took place in the periphery, after they have used it for a period of time, unlikely results in an accurate response. Alternative strategies for involving users should therefore be considered.

Several alternative strategies may be possible. In the contextmapping study presented in Chapter 3, we tried to address this issue by preceding the main part of the study with a sensitizing phase of one week, in which participants performed exercises at home to increase their awareness of their peripheral activities. In one of these exercises, participants were asked to record a ten-minute video of themselves while performing an everyday activity. They later viewed this video and wrote down which activities they performed as well as which other things they could hear and see in this video. This lead to some interesting remarks such as 'I did not know I fiddle with my hair that much'. In hindsight, this approach may also have been valuable in the evaluation of our peripheral interaction designs presented in Chapters 5 and 6. If we would have shown participants a video of themselves interacting with the design in their everyday routine, they may have been better able to reason about their own peripheral interactions.

In our studies reported in Chapters 5 and 6, we applied different forms of observation in addition to interviewing participants. The deployments of AudioResponse, EntranceSounds and RainForecasts (Chapter 5) took place in the open-office space in which the involved researcher was also located, who informally observed interactions with these systems. In the deployments of CawClock and NoteLet (Chapter 5), researchers were, at moments, present in the participating classrooms to observe the usage of the designs. During the study with FireFlies (Chapter 6), we captured videos which we used in a structured video analysis. Although these methods provided us with relevant insights, it also revealed that peripheral interaction is not easy to observe. For example, we coded whether or not participants were looking at the device during interaction, and whether their interactions were performed in parallel to other activities. Although these factors seem indicators of peripheral interaction, they provide no proof that indeed an observed interaction took place in the participant's periphery of attention. The observation that the interaction is performed simultaneous to another activity for example, only proves that one of these two activities is in the periphery, while it remains unclear if indeed the interaction was the peripheral activity.

A potential method to assess if a design became part of the user's routine appeared from the above email from a participant, in which she described realizing how much she had gotten used to FireFlies only after it was removed from her classroom. Although we did not intentionally apply this method, a strategy to assess the extent to which an everyday interactive system integrated into the everyday routines, could be to remove it from the participants' routines and interview them a few days later. We have also found an example in related work on auditory perception, in which a similar observation was made. This work studied the 'Sonic Finder' (Gaver, 1989), a design that played a short auditory cue each time a computer user selected a file or folder. This cue revealed the type and size of the file or folder through its timbre. Several people used the application for a while, but its value was only recognized after it was uninstalled from their computers.

IMPLICATIONS FOR RESEARCHERS AND PRACTITIONERS

The consideration that people have difficulty realizing what takes place in their periphery of attention, may not only apply to *users* of interactive systems, but it may too apply to their *designers*, *evaluators* and *developers*. This may hinder them in anticipating peripheral interaction with their design. To potentially overcome this problem, we performed a version of the above mentioned sensitizing exercise ourselves at the start of our design processes. The author located an audio recorder on her own dinner table and listened to the recording afterward. It turned out that numerous sounds were heard that she had not been aware of at the moment of recording it. As shown from the context mapping study, similar insights may be gained about everyday physical actions, when recording video. We believe it may be valuable for researchers and practitioners, who intent to facilitate peripheral interaction with their design, to apply this or other such methods on themselves in order to increase their awareness and understanding of their own periphery of attention.

7.7. Consideration 6: Peripheral interaction is a means, not a goal

The aim of peripheral interaction is to enable interactive systems to fluently and meaningfully embed in everyday routines and contexts. Inspired by Weiser and Brown (1997), and by many others who followed in their footsteps (Cohen, 1993; Heiner et al., 1999; Ishii et al., 1998; Matthews et al., 2004; Mynatt et al., 1998; Tolmie et al., 2002), we believe that this can be achieved when interactive systems are designed to be available for interaction in the periphery of attention, while they may also rapidly and frequently shift to the center of attention and back. Since the main focus of this thesis has been on specifying and evaluating how interactive systems can be used peripherally, it may seem that having interactions take place in the periphery of attention is, in itself, the goal of peripheral interaction. However, this is not the case: the *goal* is to meaningfully embed interactive systems in everyday life routines, while the approach to enable them to shift between the center and periphery of attention is a merely a *means* to achieve this goal.

CLARIFYING THIS CONSIDERATION

In our study with FireFlies, see Chapter 6, we concluded that the audio used in the design was not very successful: the teachers indicated that it distracted them and that it had no added value since the presented information was also available visually. However, from an informal analysis of nine one-hour video recordings of these teachers using FireFlies and the soundscape, we did not observe any moment in which the teacher clearly seemed distracted by the audio. It therefore seemed that, at least in some moments, the soundscape must have been in the teachers' periphery of attention. Despite this observation however, the soundsscape did not become a part of the user's routine. Evidently, only locating an interactive system in a user's periphery of attention does not necessarily cause it to become a part of this user's routine. For this to happen, it seems that the interactive system should also be meaningful to the user and, at moments, shift to the center of attention for a valid reason, such as when the interaction becomes relevant or engaging. In case of the FireFlies soundscape, perceptions shifted to the center of attention because of salience and annoyance and were therefore not meaningful. This emphasizes that interactions taking place in the periphery by itself does not directly lead to them becoming an integrated part of the everyday routine. Instead, this *goal* seems to be achieved through the *means* of enabling interactions to take place in the periphery of attention *as well as* shift to the center of attention for a valid reason.

IMPLICATIONS FOR EVALUATION

In our evaluations presented in Chapters 5 and 6, we realized that assessing whether or not an interaction took place in the periphery of attention is challenging. First of all it seems practically impossible to verify the division of a participant's mental resources while he or she is performing interactions in the real context of use. Secondly, even if qualitative findings indicate that an interaction took place in the periphery, this alone is no indicator for the success of a design. Evaluating the extent to which a design became part of the everyday routine and could be used for a personally relevant goal, seem to be more suitable indicators for success. We developed our designs as research tools to assess the feasibility of interaction in the periphery of attention. However, we must now conclude that in evaluations of everyday interactive systems that intend to facilitate peripheral interaction, it seems more valuable to look at the intended effects of interaction rather than whether or not it was actually performed peripherally. In other words, it seems more valuable to assess if the *goal* of integrated the design in the everyday routine was achieved, rather than whether the *means* of interactions taking place in the periphery was realized.

In our studies with FireFlies, we conducted a structured video analysis in which we observed specific indicators of peripheral interaction with FireFlies. For example, we evaluated the duration of interactions and observed whether or not participants looked at the design during interaction. Though this approach was useful to assess the feasibility of peripheral interaction with FireFlies, it did not provide us with much detailed information on the value of the design for the users. The way users experienced the design and the extent to which it fit in their everyday routine was assessed qualitatively through interviews and informal observation. Clearly, many other methods are available for evaluating the user experience of a design (Vermeeren et al., 2010), several of which are highly suitable for long term studies in the real context of use (e.g. (Larson and Csikszentmihalyi, 1983)). In earlier sections of this chapter, we have made a number of suggestions for evaluation of peripheral interaction, e.g. to evaluate it in the context of use, for a period of time and to look for alternative evaluation methods next to interviews. Extending this with the consideration that peripheral interaction is a means and not a goal, it seems most valuable to assess how users experience a design rather than whether their interactions took place in the periphery.

7.8. Conclusions

This thesis explores interactions with technology which reside in the periphery of attention, but shift to the center of attention when relevant or desired. In previous chapters, we aimed to validate if indeed interaction with technology could take place in people's periphery of attention. The goal of the present chapter was to generalize our results in order to support researchers and practitioners who work on the development of everyday interactive systems, in anticipating and facilitating peripheral interaction with their designs. We approached this by discussing six considerations for peripheral interaction.

In these discussions, we realized that everyday interactive systems can frequently shift between the center and periphery of attention, even between different stages of these interactions. These shifts can happen for various reasons such as *habituation*, *difficulty*, *significance*, *salience* and *affection*. We also recognized that everyday interactive systems cannot be seen apart from the routines and contexts in which they are used. This suggests that an iterative design process could be useful to support a fluent match between the design and its context, and that evaluations ideally take place in the context of use.

Our discussion furthermore made clear that peripheral interaction is personal. An interactive system may easily shift to the periphery of attention of one person, while this will not happen as easily for another person. Additionally, peripheral interaction seems to require both learning and unlearning. Interactions often shift to the periphery of attention once people have gotten used to them. This process of habituation sometimes also requires unlearning of activities that are already habituated. In our studies, we furthermore observed that people are usually not aware of what they (can) do in their periphery of attention. This may raise challenges when involving users in the design or evaluation process, and suggests that alternative evaluation methods should be explored next to conducting interviews.

Lastly, we felt it was important to emphasize that peripheral interaction is a means and not a goal. The goal of peripheral interaction is to fluently embed interactive systems in peoples everyday routines, so that they can be used whenever this is meaningful for the user but without inappropriately attracting the attention. We believe that our considerations can support researchers and practitioners in the area of interaction design to realize that their design may be used in their users' periphery of attention. Furthermore we hope that these considerations can support the anticipation and facilitation of such peripheral interactions with everyday interactive systems and thereby aid these systems in becoming a meaningful part of people's everyday routines.

8.
Conclusions

8.1. Introduction to this chapter

In the everyday world, computing technology is being integrated in numerous artifacts and environments. This development brings along many opportunities but also raises challenges. Particularly the challenge of fluently fitting new technologies into people's everyday routines has been addressed in several ways in human computer interaction (HCI) literature, advocating to look at the physical world for inspiration on how to design interactions with the digital world (Dourish, 2001; Ullmer and Ishii, 2000). One approach in doing so, called *calm technology* (Weiser and Brown, 1997), is inspired by the observation that many interactions with the physical world take place in the background or *periphery* of attention. For example, we are aware of all kinds of information (e.g. about the weather or the time), without consciously thinking about it. Additionally several physical actions such as tying your shoelaces, washing your hands or walking your usual route home, are performed without focused attention.

In contrast to traditional methods of HCI (e.g. keyboard and screen), which typically require the user's focused attention, interactions with the everyday world clearly shift between center and periphery of attention. Given that technology is becoming omnipresent in everyday life, we see a large added value in interactive systems that may similarly reside in the periphery of attention while shifting to the center when relevant for, or desired by the user. We believe that this approach will support computing technology to become a seamless and integrated part of everyday life routines. Most known related work focuses on subtly presenting information to provide awareness through peripheral *perception*. However, given the observation that in everyday life, *both perception and action* can take place in the periphery, we proposed to extend this area by designing not only for the perceptual periphery, but also to enable users to interact with the digital world in their periphery. We named this direction *peripheral interaction*.

In this thesis, we have explored the concept of peripheral interaction by adopting a research-through-design approach. We studied when and how everyday activities, which do not involve computing technology, take place in the periphery of attention (Chapters 2 and 3). Furthermore, we developed six interactive systems as research tools to explore peripheral interaction in a real-life context. Three early interactive systems were implemented in an office context and three further developed designs were deployed in a classroom context, each for a number of weeks (Chapters 5 and 6). These deployments aimed to assess the feasibility of perceptions of, and physical interactions with computing technology to take place in people's periphery of attention, and to evaluate the extent to which our designs integrated in the user's everyday routines. Drawing on the insights gained in our research-through-design studies, we formulated six considerations for peripheral interaction (Chapter 7), which can support researchers and practitioners in the area of interaction design in anticipating and facilitating peripheral interactions. In this chapter, we summarize our conclusions and discuss future research directions.

8.2. Research conclusions

The aim of the research presented in this thesis was to explore the concept of peripheral interactions with computing technology. More specifically, our work centered around four research questions. We will now separately address each research question and summarize and discuss the related conclusions.

WHEN AND UNDER WHICH CONDITIONS DO EVERYDAY PERCEPTIONS AND PHYSICAL ACTIONS TAKE PLACE IN PEOPLE'S PERIPHERY OF ATTENTION?

The concept of peripheral interaction is inspired by the way people perceive and interact with their everyday, non-technological environment. We were therefore interested in gaining a better understanding of how such everyday perceptions and actions take place and under which conditions they may be performed in the periphery of attention. We defined the *center* of attention as the one activity to which most mental resources are currently allocated, and the *periphery* of attention as all other potential activities (see Chapter 2). Therefore, we concluded that perceptions and actions can be performed in the periphery of attention, under the condition that another (central) activity is being performed simultaneously, which requires more, but not all mental resources.

Additionally, we found a number of factors that influence perceptions and actions shifting between the center and periphery of attention. For example, perceptual stimuli can shift from the periphery to the center of attention as a result of *salience*, e.g. when seeing a sudden flash of light, or as a result of *priming*, e.g. when hearing your name in a distant conversation (Chapter 2). Although most computing technologies use salient cues, such as alerting sounds, to attract people's attention, priming seems to occur more often than salience in everyday situations (Chapter 3). Therefore, we concluded that auditory information does not need to be louder or otherwise more distinctive when it becomes more relevant to the user. Everyday physical activities may shift to the periphery of attention once they have become *habituated*, which can occur when activities have frequently been performed in the past in a consistent context and to achieve the related goal in a satisfactory manner (Chapter 2). Such habituated activities are likely to be performed in the periphery of attention, particularly when the goal they serve is of *personal relevance* to the person performing them (Chapter 3).

Several perceptions of the everyday environment take place in the periphery of attention, many of which involve auditory perception (Chapter 3). The majority of everyday physical peripheral actions seem performed with the hands, most of which involve physical tools such as cutlery or a pen (Chapter 3). We therefore concluded that, when designing interactive systems inspired by people's peripheral interactions with the physical environment, relevant interaction styles to explore are *auditory display* (Kramer, 1994) and *embodied interaction* (Dourish, 2001) or *tangible interaction* (Ullmer and Ishii, 2000).

CAN INTERACTIVE SYSTEMS BE PERCEIVED AND PHYSICALLY INTERACTED WITH IN PEOPLE'S PERIPHERY OF ATTENTION?

Although peripheral perceptions and actions are common in everyday life, interactions with computing devices typically take place in the center of attention. Peripheral interaction intends to enable people to interact with such devices in their periphery of attention, while these may also shift to the center of attention when relevant or desired. Though numerous related studies aim to employ people's periphery of attention, no related work is known that evaluates if an interactive system can indeed be used in people's periphery of attention during their everyday routines (Chapter 4). In order to assess if people can perceive information from, and physically interact with computing technology in their periphery of attention, we evaluated a number of specifically designed interactive systems in the intended context of use. Three auditory displays were implemented in an office context and one auditory display (called *CawClock*), one physical interactive system (called *NoteLet*) and one design that combined audio and physical interaction (called *FireFlies*) were deployed in a classroom context.

The office workers who used our auditory displays (Chapter 5) consciously noticed most sounds on the first days of the deployment. However, once they had gotten used to the presence of the auditory displays, the audio did not always attract their attention, and was thus at moments in the periphery. Additionally, the office workers sometimes focused their attention on the auditory displays and were at those moments able to pick up useful information from them. We made similar observations in the deployment of CawClock (Chapter 5) in a primary school: participating teachers needed to get used to CawClock's sounds, but once this was achieved, they were able to hear the audio without having to focus their attention on it. Additionally, they could obtain meaningful information from CawClock's soundscape when focusing their attention on it. This was different however for the soundscape of FireFlies (Chapter 6), which used similar sound design as that of CawClock. Five of the six teachers who used FireFlies were not able to obtain meaningful information from the audio without looking at the design. As a result, the audio was considered distracting and did not shift to the participants' periphery of attention. Concluding, some of the auditory displays we explored in our studies were indeed perceived in the participants' periphery of attention. For this to happen, it was essential that the participants got accustomed to the presence of the auditory displays in their everyday environment and that these displays conveyed information that was meaningful to them.

We furthermore explored two physical interaction designs aimed to shift to the user's periphery of attention. NoteLet (Chapter 5) enabled primary school teachers to manipulate a bracelet in order to take a picture of the classroom. Although the participating teacher was able to do this quickly, a short moment of focused attention was required for interaction, and therefore these interactions took place in the center, rather than in the periphery of attention. The two week deployment of NoteLet appeared not enough to enable peripheral interaction. FireFlies (Chapter 6) used a physical device which teachers could manipulate to send basic messages to the children. This interaction indeed seemed possible in the periphery. For example, after five weeks of using FireFlies, a teacher was able to perform a simple interaction with FireFlies while she was reading aloud to a small group of children. Clearly, this interaction took place in the teacher's periphery of attention. More complex interactions with FireFlies however took place in the center of attention. We therefore concluded that simple physical interactions with computing technology can indeed take place in the periphery of attention, while a learning period is required to achieve this.

CAN INTERACTIVE SYSTEMS, WHICH ARE DESIGNED FOR PERIPHERAL INTERACTION, BECOME A SEAMLESS AND MEANINGFUL PART OF PEOPLE'S EVERYDAY ROUTINES?

The aim of peripheral interaction is to seamlessly integrate meaningful interactive systems into everyday life routines. Having found initial evidence for the feasibility of peripheral interaction is a promising step, but it is not the actual goal of peripheral interaction with computing technology. By deploying our earlier mentioned designs in the context of use for a number of weeks, we aimed to assess the extent to which these designs could become an integrated part of the everyday routines of our participants.

We deployed our three auditory displays in an office context for three weeks (Chapter 5). Participants could derive meaningful information from two of these systems, however, this information largely depended on the context and everyday routine of the specific user. Therefore, the systems seemed more integrated in the routine of one participant compared to another. Teachers who used CawClock (Chapter 5) found a meaningful use for the design and indicated that they did not need to adapt their routines to use it. Also, the soundscape seemed to fit well in the auditory environment in the classroom: it could clearly be perceived but did not inappropriately stand out. The soundscape of FireFlies (Chapter 6), on the other hand, did stand out and distracted the children and teachers, while most of them were not able to derive meaningful information from it. The FireFlies soundscape did not become a meaningful part of the everyday routine in the classroom. Concluding, some of the auditory displays we developed became a part of the participants' everyday routines, while this depended strongly on the extent to which they were meaningful to them.

The physical interaction design NoteLet (Chapter 5), was used regularly by the participating teacher, who did not have to deviate from her usual routine to take pictures using the bracelet. However, looking at the pictures she took with NoteLet after school hours turned out to be too time-consuming. Although, the physical interactions to take pictures seemed to fit in with the teacher's everyday activities, the goal of these interactions (reviewing the pictures later) did not seem valuable enough to fluently integrate the design as a whole in the teacher's routine. To ensure that teachers could use our FireFlies design (Chapter 6) for a valuable goal, we made it an *open-ended design*, entailing that teachers could choose for which purpose they would use it. All teachers who used FireFlies for six weeks found a relevant use for the system, which fit well in their existing routines. The physical interaction with FireFlies rather easily became an integrated part of the classroom context. This became particularly clear after the study had finished: the teachers indicated that they missed the functionality of FireFlies and sometimes automatically grabbed for it while it was no longer present. Therefore, physical interactive systems can become a fluent part of the everyday routine, while it is required that they are used for a meaningful purpose.

HOW CAN PERIPHERAL INTERACTION BE CHARACTERIZED AND WHAT SHOULD BE CONSIDERED WHEN DESIGNING AND EVALUATING PERIPHERAL INTERACTION?

Having concluded that peripheral interaction with computing technology is feasible and that such designs can become meaningful and integrated parts of a users' everyday routines, we set out to discuss how other researchers and practitioners in the area of HCI could benefit from our findings. Computers are becoming omnipresent in daily life and the number of computers in everyday environments will likely only increase in the near future. Since these computers are usually designed to be in the center of attention, they play an increasingly dominating role in everyday life. We consequently believe that the consideration that these computers do not always have to be interacted with in the center of attention, but that such interaction can also take place in the periphery, is currently highly relevant. We therefore aim to inform the area of HCI of the characteristics of and considerations relevant for peripheral interaction (Chapter 7) such that it can be anticipated and facilitated in future interaction design.

Concluding from our research-through-design studies (Chapters 3, 5 and 6), peripheral interaction is firstly characterized by *frequent shifts between center and periphery of attention*. These shifts can take place even within interactions of a short duration and happen for various reasons such as habituation, difficulty, significance, salience or affection. Interaction designers could anticipate shifts between the user's center and periphery of attention, by considering which of these reasons may apply to their designs. Secondly, peripheral interactions are strongly connected to the user's *routine and context*, they have a highly *personal* nature, and they *require both learning and unlearning*. Since these characteristics vary across people, it is essential to develop peripheral interaction designs iteratively, by involving users in multiple stages of the design process.

We believe it is vital to evaluate peripheral interaction in the context of use and over a period of time. However, when involving users in the design and evaluation process, it is important to realize that *people are not aware of their periphery*: it may be difficult for participants to reason about what takes place outside their conscious awareness. Therefore alternative evaluation approaches should be considered next to interviews. Finally, we emphasize that *peripheral interaction is a means, not a goal*. While one of our main research aims was to find evidence for interactions with technology taking place in the periphery, the goal of peripheral interaction in general is the integration of meaningful technology in everyday life. Evaluators of peripheral interaction should therefore carefully consider the aim of their evaluation. We can imagine that in many cases, assessing the integration of the studied design in the participant's everyday routine would be more relevant than finding out whether the design could be used completely in the periphery of attention.

8.3. Future directions

In the studies presented in this thesis, we observed that physical interactions with and perceptions of our specifically designed interactive systems could take place in the periphery of attention. These systems furthermore became a part of the user's everyday routine. Although these are promising findings, further research is needed to more extensively explore the potential of peripheral interaction. We now address three directions for future research.

EXPLORING APPLICATION AREAS FOR PERIPHERAL INTERACTION

The context of offices with desktop workers and the home environment are frequently explored application areas for designs that employ the periphery of attention (Chapter 4). We conducted studies in the classroom context (Chapters 5 and 6), and the interactive systems we developed were intended to support secondary tasks of primary school teachers. Apart from these contexts, several alternative application areas could be explored in which secondary tasks may be supported through peripheral interaction. We believe that peripheral interaction can be particularly beneficial for people whose main activities make it difficult for them to perform secondary tasks which involve interaction with technology. This also motivated our choice for the target group of primary school teachers: teachers have several secondary tasks that may meaningfully be supported by technology, but the currently available interactive systems (e.g. laptop computers) require focused attention and can therefore not be interacted with during the teachers' main activities (e.g. giving instructions). We believe that many other target groups could similarly benefit from peripheral interaction, such as athletes, drivers, commuters, travelers, nurses, physicians, waiters or shop-workers, to name but a few. Exploring how peripheral interaction could be useful and meaningful in several application areas would be an interesting future research direction.

Apart from such specific target groups, we believe that it is in general valuable for human computer interaction (HCI) researchers and practitioners to consider the possibility that people will interact with their designs not only in the center, but also in their periphery of attention, even when these designs are not specifically developed as peripheral interaction designs. We therefore see opportunities for future research not only in exploring which particular application areas could benefit from peripheral interaction, but also in exploring how HCI research and practice in general could benefit from the concept of peripheral interaction. We believe that more broadly exploring peripheral interaction by developing and deploying a wide range of design examples, in several contexts will be very helpful in gaining a more comprehensive understanding of when, how and why such applications may or may not be successful.

EXPLORING PERIPHERAL INTERACTION STYLES

Peripheral perceptions and actions in the everyday physical world often involve auditory perception and manipulations of physical artifacts (Chapter 3). In the design of the interactive systems we developed to explore peripheral interaction, we therefore implemented the interaction styles auditory display and physical interaction, and a combination of these two. While our designs may not comply entirely with the definitions of these interaction styles, we see lots of potential in further exploring these two areas to enable peripheral interaction. Particularly the combination of perception and action in the periphery of attention seems underexplored in related literature (Chapter 4) and our work only begins to explore the potential of this combination. As became clear from our deployments (Chapters 5 and 6), auditory displays seem to more easily shift to the periphery of attention compared to physical interaction. In a system that combines audio and physical interaction, the auditory perceptions can thus likely take place in the periphery before the physical interactions can. This could potentially support the physical interactions in shifting to the periphery as well. We performed an initial exploration of this with FireFlies (Chapter 6), which provided auditory feedback to physical interactions. However, this could be much more extensively studied by exploring what different roles perceptual stimuli could have in peripheral interaction design. For example one could distinguish feedforward and feedback (Djajadiningrat et al., 2002; Vermeulen et al., 2013), which could be provided in different layers of abstraction (Eggen et al., 1996). While the audio in the FireFlies interactive artifact was only presented as feedback (confirming which physical interaction the user has performed), feedforward (informing the user what the result of an interaction will be) could potentially support physical interaction in the periphery as well. For example, auditory feedforward may support users in performing the desired interaction without looking at the device. Additionally exploring a more natural and unified coupling (Wensveen et al., 2004) between interaction and feedback or feedforward could add to the ease with which such designs can integrate in the user's everyday routines. Studying designs which implement different kinds of auditory feedforward and feedback could provide valuable insights in how the interaction styles auditory display and physical interaction may influence and support each other.

While we saw potential in combining audio and physical interaction, peripheral interaction could clearly be supported through numerous interaction styles. For example, it would be interesting to explore tangible gesture interaction (Hoven and Mazalek, 2011), microgestures (Wolf et al., 2011) or wearable interaction (Rhodes et al., 1999) to enable physical interactions to shift to the periphery of attention. Apart from audio, other perceptual modalities such as haptic or visual feedback could be explored to present peripheral information. Additionally, we believe that a combination of multiple modalities (i.e. *multimodal interaction* (Oviatt, 2003)) to display information could enhance the process of learning to use and interpret a peripheral information display (also see Chapter 7). For example, an auditory display combined with a visual display of the same information may first primarily be looked at. While obtaining the visual information however, users also perceive the audio and will, potentially subconsciously, learn the mapping between sound and information. Over time, users of such systems should be able to obtain meaningful peripheral information by listening only. Future research would be needed to explore the value of various (multimodal) interaction styles for peripheral interaction. Again a range of design examples could be developed and explored in order to create a more comprehensive overview of the potential of different interaction styles.

Apart from exploring suitable interaction styles and modalities, another interesting direction for future research would be to explore how more open-ended and adaptable mappings between input and output could support peripheral interaction. As a result of the work presented in this thesis, we concluded that interactions can only successfully shift between center and periphery of attention when they are personally meaningful to the user. With our FireFlies design, we tried to achieve this by making it *open-ended*: the purpose of the design was not predetermined, such that the user could decide and thereby create the meaning of the design themselves. In our evaluation of FireFlies, we noticed that this open-ended design strategy could be taken much further to support peripheral interaction. For example, the interaction design of the FireFlies interactive artifact seemed suitable for one user, while another user would prefer a different lay-out and form of the design. It would therefore be interesting to explore if open-ended mappings between input and output (i.e. enabling users to adapt the interaction design to their liking) could support peripheral interaction. Potentially this would further enable users to define and create a personally relevant meaning of designs, which may enable such designs to more easily shift between the user's center and periphery of attention.

EXPLORING EVALUATION STRATEGIES

In this thesis we evaluated our designs by deploying them in the context of use for a number of weeks. We experienced this approach as vital to our research, and strongly believe that contextual and long-term deployment is required to evaluate the extent to which a design can become an integrated part of the user's contexts and routines. This evaluation goal furthermore seems highly relevant nowadays, for computing technologies are making their way into everyday life contexts. In our studies, we qualitatively evaluated this integration through interviews and observations, while formal video analysis strategies were applied to find indicators for peripheral interaction. An important direction for future research would be to explore different evaluation strategies that can be used in contextual and longitudinal studies. For example, video data could be used more extensively in such evaluations, perhaps as part of structured interviews with participants or in expert reviews. We could for example imagine that, in order to more formally evaluate if FireFlies became a part of the routine in the classroom, we could have asked an educational expert to assess this based on video recordings. Also, the idea of removing a design from the context to make participants realize whether or not it became a routine, could be further explored as a more formal evaluation strategy.

Although the interest in contextual studies is growing in HCI literature, the same literature also warns that such methods deserve further development. For example, it is important to consider what the role of the researchers is and how they potentially influence the participants' behavior (Brown et al., 2011; Johnson et al., 2012). Further research is required to better understand such factors and, in general, to create formal methods to conduct these types of evaluations so that they can become common practice in HCI research.

8.4. Concluding remarks

This thesis concludes that people can perceive information from and physically interact with computing technology in their periphery of attention, while such activities can shift to the center of attention when relevant for or desired by the user. This is a promising finding, as such types of interactions can support computing technologies in becoming a seamless and meaningful part of people's everyday routines, while enabling users to fully engage with them whenever they wish. With computers becoming omnipresent in everyday life, peripheral interaction is becoming increasingly relevant nowadays and we therefore challenge researchers and practitioners in the area of interaction design to consider how their current or future designs could anticipate and facilitate peripheral interaction. We hope that this thesis contributes to interaction design research and practice by providing insights in how human attention abilities can be leveraged in interaction design.

We started this thesis with a story of today's turbulent everyday life, in which all kinds of activities are performed simultaneously, and in which computing technology plays an important, but sometimes dominating role. We argued that by enabling computing technology to be available for interaction in the periphery while it may also be fully engaged with in the center of attention, such technology can become less dominating and more integrated in everyday routines, while still being meaningful for and initiated by users. Realizing that much more work is required to accomplish a change in the daily use of technology, we hope to have contributed to a future everyday life, which may be equally turbulent as today's life, but in which computing technologies form a meaningful, yet unobtrusive part of people's contexts and routines.

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Publications by Saskia Bakker

Journal articles

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Bakker, S., Hoven, E. van den, and Eggen, B. (2012). Acting by hand: Informing interaction design for the periphery of people's attention. *Interacting with Computers, 24*(3), pp. 119–130.

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Journal articles under review

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Bakker, S., Hoven, E. van den, and Eggen, B. (2013). Evaluating Peripheral Interaction Design. Submitted to *Human–Computer Interaction*.

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RELATED TO THIS THESIS

Bakker, S. (2011). Talking tangibles: design for peripheral interaction. In *Proceedings of the TEI'11 Conference on Tangible, Embedded, and Embodied Interaction* (TEI'11), pp. 427–428.

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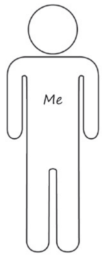
Appendix 1.

Exercises and materials used in the context mapping study

SENSITIZING EXERCISE 1 (originally A4 pages, in Dutch)

Opdracht 1.
Voor deze opdracht heeft u de bijgevoegde kookwekker nodig. Stel de kookwekker in op 30 minuten. Zorg dat de activiteiten die u de komende 30 minuten gaat doen onderbroken kunnen worden. Als het alarm afgaat, schrijf dan direct alle dingen op waarvan u weet dat ze in uw omgeving gaande zijn. Bijvoorbeeld, u weet dat uw partner de krant aan het lezen is, u weet dat de wasmachine aanstaat, u weet dat uw buren muziek aan hebben, etc. Probeer dit op te schrijven gebaseerd op wat u al weet, in plaats van doelgericht om u heen te kijken of te luisteren. Geef daarna op de linker pagina aan waar u in uw huis bent en wat u aan het doen was toen het alarm ging.

Wat er in mijn omgeving gaande is:



Ik deed deze opdracht op dag

tijd

Wat ik aan het doen was toen het alarm ging:

Waar ik was toen het alarm ging:

SENSITIZING EXERCISE 2 (originally A4 pages, in Dutch)

Opdracht 2.
Voor deze opdracht heeft u de bijgevoegde video camera nodig. Maak een video-opname van tenminste 10 minuten van uzelf, terwijl u een alledaagse activiteit in uw huis aan het doen bent. Denk bijvoorbeeld aan koken, lezen, werken, schoonmaken, TV kijken, een spel spelen, telefoneren, eten, etc. Probeer gewoon te doen wat u normaal ook doet, speel de activiteit niet na. Plaats de video camera op een vaste locatie vanwaar het meeste van uw activiteiten wordt opgenomen, het is niet erg als u voor uw activieit af en toe het beeld uit loopt. Zorg wel dat de afstand tussen u en de camera groot genoeg is zodat u helemaal in beeld kan zijn. Verander de locatie van de camera niet tijdens het opnemen. Als u 10 minuten heeft opgenomen, bekijk de video dan terug en luister en kijk aandachtig. Noteer wat u opvalt aan uw eigen handelingen en aan de dingen die in uw omgeving gebeuren. Geef ook aan wat u aan het doen was tijdens de opname. Als u wilt kunt u de bijgevoegde kookwekker gebruiken om u te herinneren aan het verstrijken van de 10 minuten.

Wat mij opviel tijdens het bekijken van de video:

Ik deed deze opdracht op dag

tijd

Wat mij opviel tijdens het bekijken van de video:

Wat ik aan het doen was tijdens de opname:

SENSITIZING EXERCISE 3 (originally A4 pages, in Dutch)

Opdracht 3.
Teken een simpele plattegrond van de kamers in uw huis waar u de meeste tijd doorbrengt. Op de linkerpagina ziet u een legenda. Geef op uw plattegrond locaties aan waar u alledaagse activiteiten uitvoert (dingen die u thuis regelmatig doet). Beschrijf deze activiteiten daarna in de legenda en beschrijf ook wat waarneemt als u op deze locatie bent. Dit kan te maken hebben met hetgeen dat u op deze locatie doet (bijvoorbeeld als u televisie kijkt hoort u het geluid van de televisie), maar denk vooral ook aan dingen die u hoort, ziet, voelt of ruikt die niets met uw huidige activiteit te maken hebben. Bijvoorbeeld als u televisie kijkt ziet u uw huisdier die rondloopt, hoort u het geluid van auto's die langsrijden of ruikt u dat uw buren aan het koken zijn.

Plattegrond

Ik deed deze opdracht op dag

tijd

Legenda

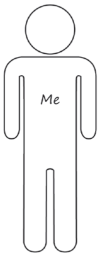
1. *wat ik op deze locatie doe:*
   Wat ik op deze locatie zie:
   Wat ik op deze locatie hoor:
   Wat ik op deze locatie ruik:
2. *wat ik op deze locatie doe:*
   Wat ik op deze locatie zie:
   Wat ik op deze locatie hoor:
   Wat ik op deze locatie ruik:
3. *wat ik op deze locatie doe:*
   Wat ik op deze locatie zie:
   Wat ik op deze locatie hoor:
   Wat ik op deze locatie ruik:
4. *wat ik op deze locatie doe:*
   Wat ik op deze locatie zie:
   Wat ik op deze locatie hoor:
   Wat ik op deze locatie ruik:

SENSITIZING EXERCISE 4 (originally A4 pages, in Dutch)

Opdracht 4.

Gedurende uw alledaagse bezigheden bent u voortdurend op de hoogte van allerlei informatie. Deze informatie is bijvoorbeeld in uw omgeving aanwezig is (bijvoorbeeld u weet wat voor weer het is als u buiten bent), of er is sprake van een bepaalde routine (bijvoorbeeld u weet dat uw partner aan het werk is omdat hij/zij op dit tijdstip altijd aan het werk is), of u heeft de informatie specifiek opgezocht (bijvoorbeeld u weet wat het laatste nieuws is omdat u een nieuwswebsite heeft bekeken), of er zijn andere oorzaken. Geef aan van welke informatie u momenteel allemaal op de hoogte bent en hoe dat komt.

Informatie waar ik nu van op de hoogte ben, en waarom of waardoor ik hiervan op de hoogte ben:



Ik deed deze opdracht op dag

tijd

Wat ik aan het doen was voordat ik aan de opdracht begon:

Waar ik de opdracht heb uitgevoerd:

SENSITIZING EXERCISE 5 (originally A4 pages, in Dutch)

Opdracht 5.
In ieder situatie, bij alles wat u doet, zal u dingen kunnen waarnemen (horen, zien, ruiken, voelen, etc.) die niets met uw huidige activiteit te maken hebben. Daarnaast zal u vaak handelingen doen die niets te maken hebben met uw huidige activiteit, die u doet zonder er bewust over na te denken. Denk bijvoorbeeld aan op uw horloge kijken, met uw vingers op tafel tikken, uw neus snuiten, etc. Probeer eens na te gaan welke handelingen u de afgelopen twee uur hebt gedaan naast uw hoofdactiviteit. Geef boven de tijdlijn aan welke hoofdactiviteiten u de afgelopen twee uur had en geef onder de tijdlijn aan welke andere handelingen u uitvoerde. Probeer ook aan te geven waarom u deze handeling uitvoerde.

Hoofdactiviteiten:

2 uur geleden —————————————————— *nu*

Andere handelingen:

Waarom ik deze handelingen deed:

Ik deed deze opdracht op dag

tijd

SENSITIZING EXERCISE 6 (originally A4 pages, in Dutch)

Opdracht 6.
Gedurende elke dag voert u thuis verschillende activiteiten en handelingen uit. Voor sommige van deze activiteite of handelingen heeft u veel aandacht nodig (bijvoorbeeld een ingewikkeld boek lezen), terwijl anderen weinig aandacht kosten (bijvoorbeeld uw veters strikken). Beantwoord de volgende open vragen.

Activiteiten of handelingen die veel van mijn aandacht kosten (geef ook aan waarom de activiteiten veel aandacht kosten):

Activiteiten of handelingen die weinig van mijn aandacht kosten (geef ook aan waarom de activiteiten veel aandacht kosten):

Activiteiten of handelingen die ik kan doen zonder dat ik er aandacht voor nodig heb (geef ook aan waarom de activiteiten zonder aandacht gedaan kunnen worden):

Ik deed deze opdracht op dag

tijd

Voordat ik aan deze opdracht begon, was het meeste van mijn aandacht gericht op:

Voordat ik aan deze opdracht begon, richtte ik minder aandacht op:

SCENARIO EXERCISE OF DISCUSSION PHASE (originally A3 page, in Dutch)

Wat er waar valt te nemen in mijn omgeving (ongeacht of ik dat ook bewust waarneem of niet), tijdens deze activiteit:

Handelingen die ik minder bewust of onbewust uitvoer tijdens deze activiteit (al dan niet in het belang van deze activiteit):

Hoofd-handelingen die ik bewust uitvoer tijdens deze activiteit:

Naam:

Alledaagse activiteit:

Appendix 2.

Questionnaire filled in by teachers after using FireFlies for 6 weeks

PART I: PHYSICAL INTERACTION (explanation and example, in Dutch)

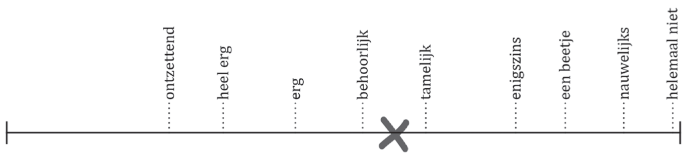
Bedankt voor je hulp bij mijn onderzoek!

Deze vragenlijst bestaat uit twee delen.

In het eerste deel van deze vragenlijst wordt je gevraagd om aan te geven hoe zeer je je moet concentreren om bepaalde activiteiten uit te voeren. Je geeft dit aan door een kruisje te zetten op een lijn, zie het voorbeeld hiernaast. Het zijn steeds activiteiten die je in de klas, tijdens een lesdag uitvoert. Ga iedere keer uit van je eigen ervaring met de activiteit.

VOOBEELD

Hoe zeer moet je je concentreren om een email te typen?



PART I: PHYSICAL INTERACTION (all questions, in Dutch)

Hoe zeer moet je je concentreren om ...

1. ... het knopje van ... in te drukken?
2. ... aan de klas een verhaal voor te lezen uit een boek?
3. ... je handen te wassen?
4. ... alle lampjes uit te zetten?
5. ... de lampjes van 4 kinderen op groen te zetten?
6. ... de kleur op het apparaat in te stellen op groen?
7. ... een uitgebreide email van een ouder te lezen?
8. ... een pen van je bureau te pakken?
9. ... een leerling te vertellen dat hij stil moet zijn?
10. ... het lampje van ... op blauw te zetten?
11. ... het apparaat aan je broekzak geklemd te hebben terwijl je rondloopt in de klas?
12. ... zes namen op het bord te schrijven?
13. ... de knop 'iedereen' in te drukken?
14. ... een slok van je thee te nemen?
15. ... een pen in je hand te houden terwijl je rondloopt door de klas?
16. ... het systeem met de lampjes te gebruiken, tijdens een les waarin je complimenten geeft door de lampjes te veranderen?
17. ... alle lampjes op rood te zetten en daarna de lampjes van 3 kinderen op blauw?
18. ... een leerling individueel uitleg te geven over een taal-opdracht?
19. ... een rekensom voor te doen op het bord?
20. ... het apparaat in je hand te houden terwijl je rondloopt in de klas?

PART II: PERCEPTION (explanation and example, in Dutch)

In het tweede deel van deze vragenlijst wordt je gevraagd hoe zeer bepaalde geluiden en visuele objecten in de klas je aandacht trekken en hoe informatief je ze vindt. Je geeft dit aan door een rondje donker te maken, zie het voorbeeld hiernaast. Ga weer uit van je eigen ervaringen met de geluiden en visuele objecten.

VOOBEELD

Geluid: Het geluid van een leerling die tijdens de les 'juf' roept.

Trekt dit geluid je aandacht? Merk je het geluid op?

- ○ Nooit
- ○ Meestal niet
- ○ Soms wel en soms niet
- ● Meestal wel
- ○ Altijd

Vind je dit geluid informatief? Geeft het geluid je nuttige informatie?

- ○ Nooit
- ○ Meestal niet
- ● Soms wel en soms niet
- ○ Meestal wel
- ○ Altijd

PART II: PERCEPTION (all questions, in Dutch)

Trekt dit geluid / visuele object je aandacht? Merk je het op?
Vind je dit geluid / visuele object informatief? Geeft het je nuttige informatie?

1. **Geluid**: De geluiden die je hoort wanneer de kinderen rustig aan het werk zijn tijdens de les.
2. **Geluid**: De piep-geluiden die je hoort wanneer je op een kopieer-apparaat iets intoetst.
3. **Geluid**: Het klik-geluid dat je hoort wanneer je het knopje op de achterkant van een pen indrukt om te gaan schrijven.
4. **Visueel**: De lampjes die allemaal op rood staan tijdens de les.
5. **Geluid**: Het geluid dat je hoort wanneer je de computer opstart.
6. **Geluid**: Het geluid dat je hoort wanneer je de knop 'iedereen' hebt ingedrukt op het apparaat.
7. **Geluid**: Het geluid van twee kinderen die in de klas aan het kletsen zijn tijdens de les.
8. **Visueel**: Een leerling loopt door de klas terwijl hij op zijn plaats zou moeten zitten tijdens de les.
9. **Geluid**: Het geluid dat je hoort wanneer je een naam hebt ingedrukt op het apparaat.
10. **Geluid**: Het geluid dat je hoort wanneer je groen hebt geselecteerd op het apparaat (een krekel-geluid).
11. **Visueel**: De lampjes die aan staan in verschillende kleuren tijdens de les (sommige kinderen werken samen en anderen werken zelfstandig).
12. **Visueel**: Een leerling heeft zijn hand opgestoken tijdens de les.
13. **Geluid**: Het geluid van de schoolbel die gaat aan het begin van de dag.
14. **Geluid**: Het geluid dat je hoort uit de boxen, wanneer alle lampjes op rood staan.
15. **Visueel**: Er ligt een verkeerd boek op de tafel van een leerling tijdens de les.
16. **Geluid**: Het geluid dat je hoort uit de boxen, wanneer een deel van de lampjes op groen staat en een deel op geel.

Summary

In everyday life we perform several perceptions and physical actions without focused attention. For example, we are aware of what the weather is like and we can wash our hands without actively thinking about it. These perceptions and actions take place in the *periphery* of attention, while they may easily shift to the *center* of attention when relevant. Computing technology is becoming increasingly present in our everyday routines. Interactions with these technologies usually require focused attention, which makes it challenging to fluently embed them in everyday life. Addressing this challenge, various researchers studied displays which subtly present information for peripheral *perception*. Moreover, a few recent studies explored *physical interaction* with technology to take place in the periphery. As both actions and perceptions shift between the center and periphery in everyday life, *both* perceptions of and interactions with technology could potentially take place in the periphery of attention.

This thesis proposes and explores *peripheral interaction*: interaction with computing technology which can take place in the periphery of attention and shift to the center of attention when relevant for or desired by the user. The goal of peripheral interaction is to fluently embed meaningful interactive systems into people's everyday routines. The specific aims of the research presented in this thesis are: (1) to study how everyday actions and perceptions are performed in the periphery of attention; (2) to explore if perceptions of and interactions with technology could take place in the periphery of attention; (3) to explore whether peripheral interaction designs can become a seamless part of people's everyday routines; and (4) to reflect on how peripheral interaction can be facilitated in everyday interactive systems.

Section I of this thesis analyses when and how everyday activities take place in the periphery of attention. Chapter 2 reviews attention theory and describes attention as the division of a finite amount of mental resources over potential activities. When requiring only few resources, multiple activities can be performed at once. The center of attention is therefore described as the one activity to which most mental resources are currently allocated and the periphery of attention as all other activities. An activity is thus performed in the periphery when another activity is being performed simultaneously, which requires more resources. Chapter 3 presents a contextmapping study aimed to gain extensive qualitative examples of everyday peripheral activities. This study reveals that audio plays a major role in peripheral perception, while most everyday peripheral actions are performed with the hands. We therefore decided to explore *auditory displays* to

enable peripheral perception of information, and *tangible interaction* for physical interaction with designs in the periphery of attention.

Section II addresses the design and evaluation of interactive systems developed for peripheral interaction. We adopt a research-through-design approach, in which both the act of designing and the act of evaluating designs in the context of use play an important role. The designs presented in this thesis aim to explore implications of theoretical knowledge in practice in order to yield new, generalized knowledge. Chapter 4 reviews related work, while Chapters 5 and 6 present and evaluate new peripheral interaction designs developed for primary school teachers. This target group was chosen because their everyday activities include numerous small tasks, which may be supported through peripheral interaction design in order to lighten the teachers' busy everyday routines.

The first two designs for teachers, *CawClock* and *NoteLet* (Chapter 5), were used in two classrooms for two weeks. This revealed that audio seemed a suitable modality for displaying peripheral information. Although the tangible interaction style seemed promising, two weeks was not enough for the physical interactions to shift to the teacher's periphery of attention. Furthermore, the primary school setting seemed suitable for peripheral interaction design. Chapter 6 presents a new design called *FireFlies*, which combines peripheral perception and interaction building on the results of the previous design iteration. FireFlies was used by six teachers for six weeks each. Analysis of video data reveals that teachers seemed able to shift their focus of attention between their main task and the interactive system. Additionally, qualitative data suggests that the design became a part of their everyday routines.

Section III discusses and generalizes the results presented in earlier chapters, and proposes six considerations for peripheral interaction in Chapter 7. This discussion reveals that everyday interactive systems can frequently shift between center and periphery of attention, even between different stages of interaction. Additionally, we recognize that everyday interactive systems cannot be seen apart from the routines and contexts in which they are used, suggesting that an iterative design process is needed to support a fluent match between design and context, and that evaluations ideally take place in the context of use for a longer period of time. Our discussion furthermore makes clear that whether an interaction can take place in the periphery differs from person to person and that peripheral interaction requires both learning and unlearning. Interactions often shift to the periphery of attention once people have gotten used to them, which also requires unlearning of activities that people are already used to. We furthermore recognize that people are usually not aware of what they (can) do in the periphery of attention. This may raise challenges when involving users in design or evaluation processes, and suggests that alternative evaluation methods should be explored next to conducting interviews.

This thesis concludes that people can perceive information from and physically interact with computing technology in the periphery of attention, while such activities can shift to the center of attention when relevant for or desired by the user. With such peripheral interactions, computing technologies could potentially become a seamless and meaningful part of people's everyday routines without inappropriately attracting attention. With computers becoming omnipresent in everyday life, peripheral interaction is becoming increasingly relevant nowadays. This thesis contributes to interaction design research and practice by providing insights in how peripheral interaction can be anticipated and facilitated.

Samenvatting

In het dagelijks leven hebben we niet altijd gerichte aandacht nodig om dingen waar te kunnen nemen of om fysieke handelingen uit te kunnen voeren. We zijn ons bijvoorbeeld als vanzelf bewust van de huidige weersomstandigheden, of we wassen onze handen zonder hier bewust over na te denken. Deze waarnemingen en handelingen vinden plaats in de *periferie* van onze aandacht. Ze kunnen echter ook naar het *middelpunt* van onze aandacht verschuiven als dit relevant of gewenst is.

Digitale technologie speelt een steeds belangrijkere rol in onze dagelijkse routines. Om met producten zoals mobiele telefoons en computers te interacteren hebben we doorgaans gerichte aandacht nodig. Dit maakt het uitdagend om de interactie vloeiend te integreren in de dagelijkse routines. Om deze uitdaging aan te pakken hebben verschillende onderzoekers de mogelijkheid bestudeerd om digitale informatie subtiel weer te geven, door gebruik te maken van perifere *waarneming*. Daarnaast richten enkele recente onderzoeken zich op *fysieke handelingen* met technologie die plaatsvinden in de periferie van de aandacht. Omdat zowel handelingen als waarnemingen in het dagelijks leven van het middelpunt naar de periferie van de aandacht kunnen verschuiven, zou *zowel* het waarnemen van, als het uitvoeren van fysieke handelingen met digitale technologie potentieel in de periferie kunnen plaatsvinden.

Dit proefschrift introduceert en onderzoekt *perifere interactie*: interactie met digitale technologie die plaatsvindt in de periferie van de aandacht maar die kan verschuiven naar het middelpunt van de aandacht wanneer dit relevant of gewenst is voor de gebruiker. Het doel van perifere interactie is het vloeiend integreren van betekenisvolle interactieve systemen in de alledaagse routines van mensen. De specifieke doelen van het onderzoek in dit proefschrift zijn (1) het bestuderen hoe alledaagse handelingen en waarnemingen plaatsvinden in de periferie van de aandacht, (2) het onderzoeken of mensen informatie kunnen waarnemen en fysieke handelingen kunnen uitvoeren met digitale technologie in de periferie van de aandacht, (3) het onderzoeken of interactieve systemen die ontworpen zijn voor perifere interactie vloeiend kunnen opgaan in dagelijkse routines, en (4) het reflecteren op hoe ontwerpers en onderzoekers perifere interactie kunnen faciliteren.

Deel I van dit proefschrift analyseert hoe en wanneer mensen alledaagse activiteiten ondernemen in de periferie van de aandacht. Hierbinnen worden in hoofdstuk 2 psychologische theorieën over aandacht besproken. Aandacht wordt beschreven als de verdeling van een eindige hoeveelheid mentale middelen over potentiële activiteiten. Wanneer activiteiten weinig middelen, en dus weinig aandacht, nodig hebben, dan kunnen we er meerdere tegelijk uitvoeren. Het middelpunt van de aandacht beschrijven we als de activiteit waarop op dit moment de meeste aandacht gericht is, en de periferie als alle overige activiteiten. Een activiteit kan dus uitgevoerd worden in de periferie wanneer er tegelijkertijd een andere activiteit wordt uitgevoerd die meer aandacht nodig heeft. Hoofdstuk 3 presenteert een 'contextmapping' onderzoek waarin een groot aantal kwalitatieve voorbeelden van alledaagse perifere activiteiten wordt geïdentificeerd. Dit onderzoek laat zien dat audio een grote rol speelt in perifere waarneming en dat de meeste alledaagse perifere handelingen met de handen worden uitgevoerd. Daarom besloten we om *auditory displays* te onderzoeken om perifere informatie weer te geven, en om *tangible interaction* te verkennen als interactiestijl voor fysieke interactie in de periferie.

Deel II van dit proefschrift richt zich op het ontwerp en de evaluatie van interactieve systemen voor perifere interactie. We gebruiken hierin een research-through-design aanpak, waarin zowel het ontwerpen van interactieve systemen als het evalueren van deze systemen in de gebruikscontext een belangrijke rol spelen. De ontwerpen die in dit proefschrift worden gepresenteerd zijn bedoeld om de implicaties van theoretische kennis in de praktijk te verkennen om zo nieuwe, gegeneraliseerde kennis op te doen. Hoofdstuk 4 geeft een overzicht van gerelateerd werk, en de Hoofdstukken 5 en 6 introduceren en evalueren nieuwe ontwerpen van interactieve systemen, die ontwikkeld zijn voor basisschoolleerkrachten. Deze doelgroep is gekozen omdat de alledaagse routine van leerkrachten bestaat uit vele kleine taken die mogelijk ondersteund kunnen worden via perifere interactie.

De eerste twee ontwerpen voor leerkrachten, *CawClock* en *NoteLet* (Hoofdstuk 5), zijn twee weken lang in twee basisschoolklassen gebruikt. Hieruit bleek dat audio een geschikte modaliteit lijkt voor perifere waarneming. Tangible interaction leek veelbelovend, maar twee weken was niet lang genoeg om de fysieke interactie met onze ontwerpen naar de periferie te verschuiven. Verder bleek de context van de basisschool geschikt voor het bestuderen en toepassen van perifere interactie. Hoofdstuk 6 introduceert een nieuw ontwerp, *FireFlies*, dat perifere perceptie combineert met perifere handelingen. Zes leerkrachten gebruikten FireFlies in hun klas, ieder gedurende zes weken. Uit een uitgebreide analyse van videodata kwam naar voren dat de leerkrachten in staat leken om hun aandacht te verschuiven tussen hun hoofdtaak en het interactieve systeem. Daarnaast bleek dat het systeem een onderdeel werd van de dagelijkse routine in de klas.

In Deel III van het proefschrift worden de bevindingen uit de eerdere hoofdstukken bediscussieerd en gegeneraliseerd en worden hieruit zes overwegingen afgeleid voor perifere interactie (Hoofdstuk 7). In deze discussie concluderen we dat alledaagse interactieve systemen makkelijk en regelmatig tussen het middelpunt en de periferie van de aandacht kunnen verschuiven, zelfs tussen verschillende stadia van interactie. Daarnaast stellen we dat alledaagse interactieve systemen niet los gezien kunnen worden van de routines en contexten waar zij onderdeel van zijn. Dit geeft aan dat een iteratieve ontwerpaanpak nodig is om het systeem te laten aansluiten bij de context, en dat evaluaties het beste plaats kunnen vinden in de gebruikscontext en voor een langere tijdsperiode. Onze discussie laat ook zien dat het van persoon tot persoon verschilt of een interactie plaats vindt in de periferie en dat zowel afleren als aanleren van gedrag nodig is voor perifere interactie. Interacties verschuiven vaak naar de periferie wanneer de gebruiker eraan gewend is geraakt, en nadat een eventuele andere handeling, waar de gebruiker al aan gewend was, is afgeleerd. We ontdekten bovendien dat mensen zich vaak niet bewust zijn van wat zij (kunnen) doen in de periferie. Dit maakt het moeilijk om gebruikers te betrekken in het ontwerp- en evaluatieproces. Naast het afnemen van interviews moeten alternatieve evaluatiemethoden onderzocht worden.

Dit proefschrift concludeert dat mensen informatie kunnen waarnemen van, en fysieke handelingen kunnen uitvoeren met, digitale technologie in de periferie van de aandacht, terwijl deze waarnemingen en handelingen ook naar het middelpunt van de aandacht kunnen verschuiven als dit relevant of gewenst is. Zulke perifere interacties kunnen ervoor zorgen dat technologie een geïntegreerd en betekenisvol deel kan vormen van de dagelijkse routine, zonder ongepast de aandacht te trekken. Aangezien computers steeds meer aanwezig zijn in het dagelijkse leven, is perifere interactie vandaag de dag een relevant onderwerp. Dit proefschrift draagt bij aan het (onderzoeks-)gebied van interactieontwerp door inzicht te geven in hoe perifere interactie kan worden geanticipeerd en gefaciliteerd.

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Colleagues in the UCE group, it has been a privilege to work among such interesting and diverse people. Thanks for all the fun moments! Industrial Design department, thank you for creating an inspiring environment in which I love to do research and to teach. All students who participated in 'design for the periphery' projects, thank you for your efforts! It was great to have the opportunity to work with you all, our discussions about peripheral interaction have been a valuable contribution to my research.

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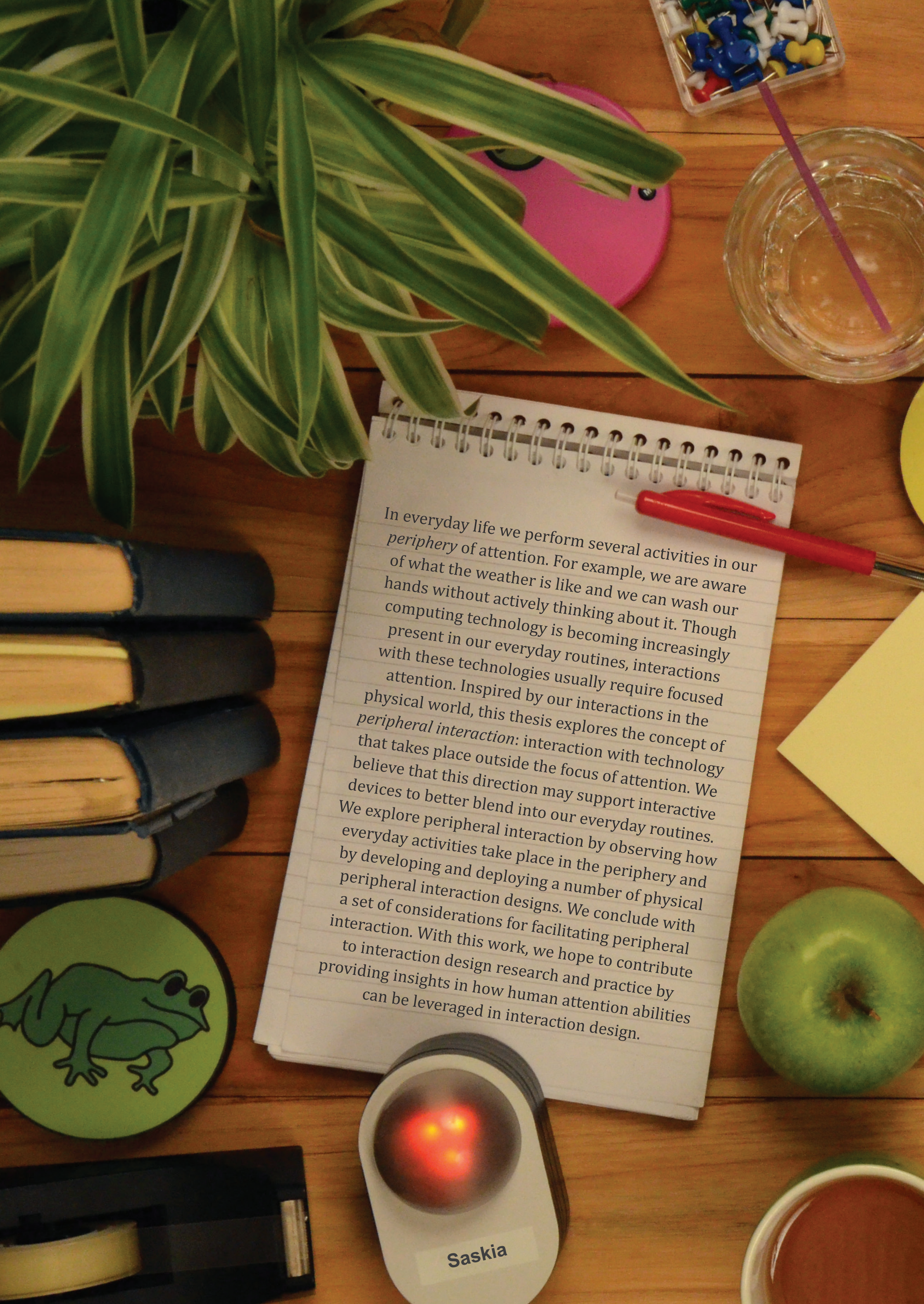
Curriculum Vitae

Saskia Bakker was born on the 13th of September 1983 in Deventer, the Netherlands. In 2001 she obtained her VWO-diploma at the Eckart College in Eindhoven. After a year of work and travel in Australia and New Zealand, she studied Industrial Design at the Eindhoven University of Technology. In 2009 she received her MSc diploma on a thesis entitled "Move | Learn | Explore", which was awarded the Gerrit van der Veer award for best Master thesis in the area of Human Computer Interaction in the Netherlands. Subsequently, she started her PhD research in the User Centred Engineering research group, at the Industrial Design department of the Eindhoven University of Technology. During her PhD, she was furthermore involved in education as a lecturer and coach. This dissertation is the result of her PhD research on the topic of "Design for Peripheral Interaction".


In everyday life we perform several activities in our *periphery* of attention. For example, we are aware of what the weather is like and we can wash our hands without actively thinking about it. Though computing technology is becoming increasingly present in our everyday routines, interactions with these technologies usually require focused attention. Inspired by our interactions in the physical world, this thesis explores the concept of *peripheral interaction*: interaction with technology that takes place outside the focus of attention. We believe that this direction may support interactive devices to better blend into our everyday routines. We explore peripheral interaction by observing how everyday activities take place in the periphery and by developing and deploying a number of physical peripheral interaction designs. We conclude with a set of considerations for facilitating peripheral interaction. With this work, we hope to contribute to interaction design research and practice by providing insights in how human attention abilities can be leveraged in interaction design.
Saskia