**SUMMARY**

Mobile devices have become part of our everyday lives and can impact social interactions with friends and family. As digital technology continues to improve, it has become commonplace in most homes. Mobile devices are a source of quick and endless information while also connecting people all around the world [2]. Mobile devices have become essential for communication and coordination between family members as they allow for planning of activities and exchange of information from anywhere [26]. However, excessive use of mobile devices can have a negative impact on social interactions and diminishes the connection between friends [29].

In this study, we target mobile device usage in the home. By focusing on the home, we can understand the practices of people in a comfortable environment. Furthermore, by targeting the practices within the home, we can study how people act as a family when mobile device practices are exposed. To better understand mobile device usage in the home, we employ research through design and provocative design, and develop Tempus and frame it as a provotype. Tempus sparks reflection through provocation on mobile device usage within the home. Using the two approaches in conjunction may lead to subtle mobile device practices being noticed.

Diverging from previous work, which designs primarily for Android devices, Tempus exploits that mobile devices rely on the internet. Thus, Tempus is not platform-specific. Tempus lowers the network quality of all participating devices when a family member uses their mobile device when together with other family members. Participants can restore the network quality by doing a family activity and uploading a picture of this activity to Tempus. By collaborating on managing the network, the internet becomes a shared resource.

Tempus is deployed in a three-phase field study over four weeks with three families. In the first week, Tempus logs whenever a mobile device is used, both alone and together with other family members. In the second and third weeks, Tempus logs mobile device usage and controls the internet. In the fourth week, Tempus goes back to just logging mobile device usage.

Our findings show that the internet as a shared resource worked as a provocative approach, as it sparked reflection from the participants on their mobile device usage. Participants would consider if their mobile was important when the network quality worsened or when they were together with their family. Furthermore, the family members enjoyed spending time together as a way of regaining their network quality. While the family activities were mainly the same as before the study period, participants felt that more thought went into the activity, and more family members participated. Finally, by measuring the mobile device usage from the families before, during, and after Tempus was active, we could show the families how their mobile device practices had changed. The quantitative data showed that total mobile device usage had decreased significantly. While some of the participants had noticed some minor changes in mobile device practices, none had anticipated that usage decreased to such an extend. This suggests that the participants subconsciously changed their mobile device usage practices throughout the study without noticing.

We show that employing the internet as a shared resource can help researchers understand mobile device usage and spark reflections from the participants. We find that motivating the participants to spend time together, rather than only restricting access, positively affected their time together without their mobile devices. Lastly, we show how quantitative data can support both the interview and the qualitative data analysis. The quantitative data helped enrich the interview conversations, and we gained additional insight into the effects of Tempus.

# Exploring Mobile Device Non-Use in the Home by Making the Internet a Shared Resource

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## ABSTRACT

Mobile devices have become part of our everyday lives and can impact social interactions with friends and family. This paper explores provocative design and non-use to create reflections about when and how people use their mobile devices in the home. Diverging from previous work, which designs prototypes primarily for Android devices, we exploit that mobile devices rely on the internet. We study how people react when their internet becomes a shared resource by decreasing the network quality of the mobile devices whenever a person uses their device in a family setting. We design and deploy the Tempus provotype in a three-phase field study over four weeks with three families. Tempus logs mobile device use in the first week, controls the network quality in the second and third, and logs use again in the fourth week. We conclude that the internet as a shared resource can create reflections on mobile device usage.

### Author Keywords

Mobile device usage; non-use; research through design; provocative design; explorative field study.

## INTRODUCTION

As digital technology continues to improve, it has become commonplace in most homes. It is a source of quick and endless information while also connecting people all around the world [2]. Mobile devices have become important for communication and coordination between family members as they allow for planning of activities and exchange of information from anywhere [26]. However, excessive use of mobile devices can have a negative impact on social interactions and diminishes the connection between friends [29]. Mobile devices also influence how family members interact during social interactions. The use of mobile devices may improve the quality of social interactions between family members [27, 11]. Yet, the quality can also be reduced depending on how the devices are used and in which context [10]. Mobile devices' influence on the quality of social interactions is a wicked problem that is hard to narrow down, and it does not have a solution that accounts for every aspect.

Some of the main reasons why family members use their mobile devices in the home include checking notifications, looking up information, and boredom [27]. Checking the phone can be seen as problematic by other family members when it is not urgent. Mobile device notifications and other disturbances from mobile devices can contribute to family members being distracted, thereby negatively impacting social interactions [10].

Previous research in HCI has explored how mobile devices are used within the home and how to change behavior related to mobile device usage [5, 18]. The focus has been on alleviating some of the negative effects that may stem from using mobile devices during social interactions. A lot of the research relies on non-use to limit mobile device usage [5, 18, 19, 17, 20, 23]. These different forms of non-use include group-based intervention apps for limiting smartphone usage [20] and assistance apps to mitigate smartphone distractions [19]. A lot of the research looking to limit and understand mobile device usage only develops apps for Android [5, 18, 19, 17, 20, 23]. We consider this to be a gap in the research as other operating systems are also widely used. To differentiate from other research, we use the internet as a provocative resource, where the family members have to share a network that changes in quality. This leads us to the following research question:

*How does designing the internet as a shared resource affect mobile device usage in the home?* We make the internet a shared resource by monitoring the families' internet to detect mobile device activity, which we can do on any device with internet. When a family member uses their device while together with other family members, the network quality decreases for the entire family. Since family members can then impact each other's network quality, the internet becomes a shared resource as they now have to consider their own and others' ability to access the internet. We do this with the intention to spark reflections on mobile device usage and increase time spent together as a family without mobile devices.

To spark reflection on the participants' mobile device usage, we use provocative design. We create a provotype called Tempus to help create valuable insight and increase understanding of the families' mobile device usage. We use research through design to help us understand what problems exist in the families' current practices. We deploy Tempus in a four week field study at three different families to explore how designing the internet as a shared resource affects the families. The field study consists of three phases: The first week Tempus logs mobile device use, the second and third week Tempus controls and logs the network quality, and the fourth week Tempus logs mobile device use again. We do a qualitative analysis, supported by quantitative data, of the conducted interview from the field study. We then report on how the internet as a shared resource sparked reflection on mobile device use.

This paper follows the work from our previous semester, of which a summary can be found in Appendix A. In that project, we explored non-use of mobile devices through provocation and gossip. This paper builds on what we learned from the previous work, notably the need for a more provocative approach than gossip. Furthermore, we expand on the technical foundation that determines mobile device use from the previous semester.

This paper is structured as follows. First, we explore related work on mobile device usage, research through design, and provocative design. Then we present the design process of Tempus and its technical aspects. We continue by introducing our field study and the findings where we find that the internet as a shared resource made the participants reflect on their own and others' mobile device usage and reevaluate the time they spend together. We then discuss the implications of these findings, and lastly, we present future work and limitations.

## MOBILE DEVICE USAGE IN THE HOME

As digital technology advances and more devices become readily available, so does the amount of technology present in our homes. The ever-increasing number of features available on mobile devices encourages more use, which takes time away from other activities. Kawsar et al. [16] conducted a study where they investigate mobile device activities and where and when these activities take place in the home. The authors found that the participants use mobile devices for a wide array of daily activities. The study also found that with the increased number of devices available in the home, fewer disputes arise when deciding which family member has access to a device. This indicates a shift in the family context, as family members having access to their own devices can create moments of isolation in the home, as other family members are distracted by their mobile devices [16].

Other studies have shown that mobile device usage in the home mediates and shape interactions and relationships amongst family members. Oduor et al. [27] explored the frustrations and benefits of mobile device use in a social context within the home. They find that the main reasons for mobile device use in the home are checking notifications, looking up information, and boredom. The participants reported frustration when family members used their devices for non-urgent matters in a social context. Mobile device use was accepted when it was considered urgent. Furthermore, the participants reported that mobile device use could also be viewed as beneficial, for example, when looking up information relevant to the current social context in the home.

With the introduction of more mobile devices in the home, research has found that it can negatively influence social interactions [16, 27]. To study this problem, Ko et al. [18] developed the prototype "FamiLync", an app they used to explore limiting strategies and non-use in a family. FamiLync provides a way to view one's smartphone usage to increase social awareness of smartphone usage and encourages non-use by allowing the participant to set limiting goals. The authors found that FamiLync encourages the entire family to cooperate to limit smartphone use, motivating parents and children to continue participating. This research highlights that engaging the entire family leads to richer conversations about when and how to use mobile devices in the home.

### Mobile Device Usage and Quality of Social Interaction

Mobile devices are used in different scenarios, such as when the person is alone or is engaged in a social interaction. Using mobile devices during social interaction might not detract from the quality of the interaction [27, 11]. However, Dwyer et al. [10] showed that mobile device use during social interactions can be problematic. They found that using smartphones during face-to-face social interactions makes the participants feel distracted, and they report less enjoyment from the interaction. Furthermore, indirect negative side effects spawn from the distractions, such as boredom and worse mood. The study suggests that pauses in conversations may arise during extended social interactions, allowing time for smartphone use that can negatively impact the interaction. Other studies find that smartphone use during social interactions can cause less positive social impressions [36] and lower relationship satisfaction with a romantic partner [32]. These reported effects all stem from smartphones' distractions, suggesting that smartphones can be a distracting element that prevents people from fully engaging in social interactions [10].

Other studies have found that smartphones can also improve the quality of social interaction. Genç et al. [11] conducted three exploratory studies to understand smartphone usage during social interaction. They found that although smartphone usage can negatively impact the interaction, it may also improve the interaction. They also found that smartphones can enrich interactions as an interactive tool for people to engage with, for example, by taking pictures. The study found that interactions between people occurred more often and for a longer period of time in those situations.

### Non-Use

The use of technology is only one way to learn about interactions between people and technology. Non-use is another way of exploring how people interact with technology. By exploring ways and reasons for people not using technology, we can learn about interaction and how researchers can use non-use as a research tool [34]. In HCI, non-use is defined as not using computers, the internet, or as a form of resistance to technology [33].

Studies in the HCI field have shown that families want to reduce mobile device usage by deploying strategies to limit it [27, 20, 19, 18]. Research has also shown that families want to spend family time together in which they share a sense of togetherness as this created more positive experiences [7]. In Oduor et al.'s [27] study, they also show several different strategies to limit mobile device usage and avoid conflicts caused by mobile device use in a social context. By studying the participants' strategies, they gain an understanding of the participants' perspectives on problems with mobile device usage. These strategies included but were not limited to: reducing the number of incoming notifications and content, describing what they were currently during on the mobile device, and simply placing the mobile device in a location that made it harder to notice the notifications. Another study that explores

how to limit mobile devices is the study conducted by Ko et al. [20]. Their prototype "NUGU", a smartphone app, explores how limiting smartphone usage together as a group can increase motivation by interacting with other group members. The authors found that people who use the group version of NUGU tend to do more diverse non-use activities, such as socializing or resting, as opposed to those who use the NUGU alone version. The group users also set longer limiting goals as they observe and learn from others in their group. Finally, the authors find that the group version participants have more motivation to set limiting goals, as they are motivated by the support of their family or friends, who also participate.

When reviewing the literature about problematic mobile device usage, we realized that many limit their study to only Android devices [5, 17, 18, 19, 20, 23, 24]. This is an understandable necessity, as the Android guidelines are less restrictive than Apple guidelines, since iOS does not give access to the operating systems' information and only allows for a program to run within its own environment [12]. As such, the previously mentioned studies were not possible for Apple products.

We have now explored mobile device usage in the home and how it might affect social interaction. Furthermore, we explored non-use of mobile devices. Mobile devices are important to coordination and communication between family members. However, they can also be distracting and impact social interactions negatively. It is a complex problem that does not have a solution that solves every aspect of the problem. Instead, it is necessary to understand mobile device usage and how it might affect social interactions. In the following section, we describe approaches for understanding and exploring such complex problem areas.

## RESEARCH THROUGH DESIGN

Understanding how people use their mobile devices in their homes, and in which context, is a complex task.

Research through Design (RtD) is used as a design approach in multiple research fields to explore and understand a problem area. In RtD, research is conducted by utilizing a designed artifact as a research tool to explore that area of interest. The design should draw out what is problematic or unknown about the current subject, rather than being a solution [35]. RtD often deals with wicked problems, which are unique problems that suffer from real-world constraints and which have no solution [31]. Problematic mobile device usage can be categorized as a wicked problem since it is both difficult to define and solve. There is no exact solution to this problem that solves all aspects. Problematic mobile device use depends on the context where it is used and how it is used. By utilizing RtD, researchers can develop an artifact to help explore and understand what is problematic about this wicked problem [6].

Previous research has used RtD to understand energy usage in people's homes. By utilizing RtD, these studies gain insights into how people think about their energy consumption by deploying designed artifacts in the participants' homes. For example, Katzeff et al. [15] studied households' electricity load balancing through their probe "Peacetime" to challenge the role of householders as energy managers. Peacetime prompts electricity non-use by providing peacetime periods during energy load peaks. By interviewing the participants on how they felt and interacted with these peacetime periods, the authors find that providing alternatives to energy practices can help decrease energy consumption. In another study utilizing RtD, Jensen et al. [14] used the concept of "hygge" to explore desirability and sustainability in smart homes. By designing the hygge probe, the authors find that designing for desirable atmospheres, such as intimacy, can lower electricity consumption from lightning in the home. While the study focuses on lighting, they state that designing for intimacy is worth studying in designing for non-use technology practices. To summarize, RtD can be a useful approach to gain insights on complex problems, and it can be used to create artifacts that help researchers understand what is problematic about current practices or what can be improved. As such, artifacts created through RtD are used as research tools rather than finalized products.

### Provocative Design

In recent years, RtD has branched into other areas, such as provocative design. Like RtD, provocative design explores wicked problems by creating provocative prototypes to question norms and beliefs of a concept [9]. Different approaches have been suggested to design for provocation. Bardzell et al. [1] propose designing provocative prototypes using three dimensions: conceptual, functional, and aesthetic. An example of how to design with these dimensions can be seen in the work by, Raptis et al. [30] develops the prototype "The box" to challenge energy-consuming practices in households. They use RtD and provocative design to create The box and challenge the idea that electricity is always available and cheap when the participants have to wash their clothes. Jensen et al. [13] found that The box generates strong reflections on the participants' energy consumption practices, to the point where they reflect beyond the prototype. The authors further argue that provocative prototypes must be deployed in the field to properly observe their impact. This argument agrees with the previously discussed theme of RtD benefiting from being deployed in the homes of participants.

Another provocative design approach suggested by Mogensen [25] is provotyping. Provotypes intend to expose experiences from current practices instead of focusing on how to improve them. Mogensen suggests that by provoking through concrete experience, provotypes can help create new practices based on current ones. Bruun et al. [5] use RtD and provocative design to develop the provotype "Pup-Lock". Pup-Lock challenges mobile device usage in the participants' homes by allowing family members to enforce a 30-minute lockdown of the participants' smartphones. They found that providing a visualization of time spent on the smartphone is not enough to reduce smartphone usage. Instead, they suggest that a change in expectation of smartphone use is required, as the participants must reflect on their use habits. By enforcing lockdown periods, Pup-Lock generates reflection from the participants. They state that provocative design is favorable as it pushes the participant to reflect by locking them out of their phones instead of simply notifying them about how much they use their devices. Through interviews with the participants about

how they used and thought of Pup-Lock, the authors gained valuable knowledge on smartphone usage. For example, during lockdowns, the participants noticed how they could give full attention to their family members, in contrast to when their smartphones were unlocked. A common theme from both the study of Raptis et al. [30], and Bruun et al. [5] are that the developed provocative artifact use unfamiliarity as part of the design. The box diverges from mainstream design by making the artifact a bulky box that looks retro and industrial. Pup-Lock integrates strangeness and defamiliarization as part of the design; hence the design becomes unfamiliar in the home, and the participants are more prone to reflect [3].

In summary, RtD and provocation can spark reflection on a subject by deploying a designed artifact in a field of study. With a properly designed artifact that is unfamiliar in its context, the reflection can go beyond the artifact's scope, creating more valuable insight and understanding of the area of interest.

## DESIGN PROCESS

As shown in the related work, the subject of understanding mobile device practices is complex [10, 11, 27]. In this study, we target mobile device usage in the home. By focusing on the home, we can understand the practices of people in a comfortable environment. Furthermore, by targeting the practices within the home, we can study how families respond when mobile device practices are exposed. Finally, by studying people in a group, such as a family, the participants are more likely to be motivated to participate and engage with the study [19, 20, 18].

To study mobile device usage in the home, we must consider where and how the usage practices can be problematic. We agree with previous research that not all mobile device usage is bad, but rather how and when mobile devices are used should be studied and reflected upon [11]. We target mobile device usage in a family setting, as we only intend to challenge mobile device practices when people are together rather than challenging general mobile device usage. We define a "family setting", as two or more family members together at home.

We develop Tempus, as a provotype, to better understand mobile device usage in the home through RtD and provocative design. We believe that using the two approaches in conjunction may lead to subtle, mobile device practices being noticed. Tempus challenges the mobile device practices in the home by provoking the participants in a setting where they otherwise feel relaxed and secure. We hope that this intrusion of the home sparks reflections and emotions from the participants.

As previously mentioned, many studies pertaining to mobile devices only consider devices using Android. Considering this gap in the research of mobile devices, we look for ways to target all mobile devices. We see that most mobile devices use the internet, which can be both monitored and hacked. We design Tempus to be provocative by controlling the network quality of mobile devices. Tempus takes inspiration from Man-in-the-middle attacks [37], which is when a third-party inserts a device in-between the network communication of two parties, such as a router and mobile device. The third party forwards the traffic from the router to the mobile device and vice-versa, meaning the router and mobile device are unaware of the third party. The third party can then read and control all network communication between the router and mobile device. Tempus works as a third-party between the router and mobile devices, which allows it to monitor and control network communication to and from the mobile devices. By not forwarding traffic to the mobile devices, Tempus can simulate bad internet quality.

### Conceptual Representation of Tempus

To show how we use the approaches of RtD and provocation, we create a conceptual representation of Tempus. Tempus achieves provocation by lowering the network quality for all participating devices on the network and using LEDs to represent the network quality. Due to technical limitations, described later in this section, Tempus only considers it a family setting when the participants are near Tempus, meaning whenever two or more participants are physically close to Tempus. To restore network quality, the family must engage in a family activity and upload a picture of the activity. We do this with the intent to make the family reflect on alternatives to using their mobile devices. The internet essentially becomes a shared resource, as such, the family must spend time together if they want to spend time on their mobile devices. We create user stories to help explain how a family member can worsen the network quality and how a family can restore the network quality. An example is provided in Figure 1.

We develop Tempus to provoke for non-use of mobile device usage when family members are together near Tempus. We facilitate this provocation by placing Tempus in the most frequented rooms of the participants' home, such as the living room or kitchen, essentially creating a non-use zone. Furthermore, Tempus introduces some uncertainty to the family members, as those outside the non-use zone are also affected when Tempus changes the network quality.

### Components of Tempus

Tempus consists of three parts: a physical design, a controlled WiFi, and a web interface.

The physical design is a wooden box with a LED display. We design the wooden box to look minimalistic and simple to fit into the participants' homes as part of the decoration. The LED display is a Micro:bit that consists of a 5x5 array of LEDs connected to a Raspberry Pi that runs the software of Tempus. The LED display represents the current network quality. When all 25 LEDs are turned on, it represents the best network quality, and for every fifth LED turned off, the network quality worsens. Tempus uses a switch, an access point, and a set of powerline adapters if no ethernet outlet is near the desired location of Tempus. The Raspberry Pi monitors the network traffic via the switch with port mirroring activated. The Raspberry Pi and the Micro:bit reside in the wooden box, while the access point and switch are hidden away. An example of Tempus is shown in Figure 2.

Tempus creates its own WiFi to control the network quality of mobile devices. When Tempus detects that a mobile device is used in a family setting, it lowers the network quality of

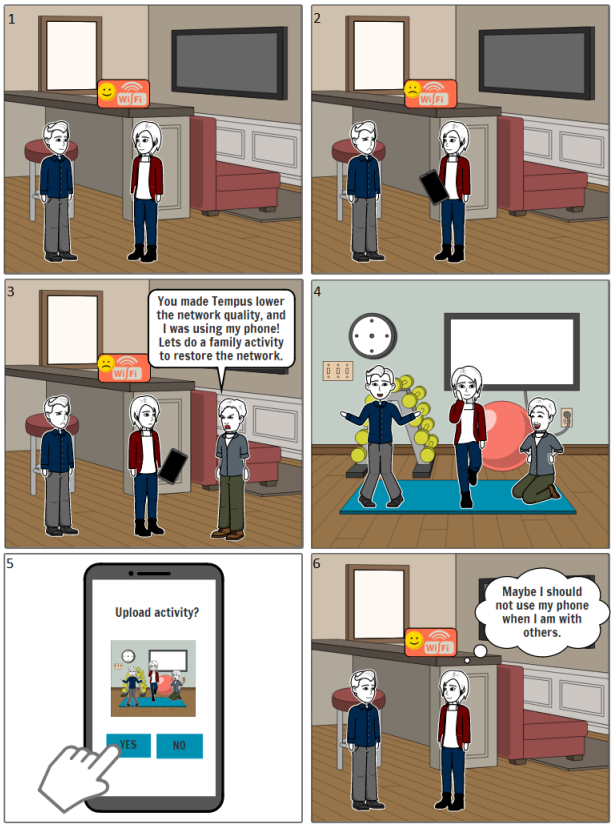


**Figure 1. 1) Two people are together, without their mobile devices, and Tempus is not affected. 2) One person uses their mobile device, so Tempus lowers the network quality for all devices. 3) A third person notices the bad network quality and complains to the original two people. 4) To restore the network quality, they do a family activity. 5) They upload a picture of the activity to Tempus. 6) Tempus restores the network, and the person is reconsidering whether they should use their mobile device during social interaction.**

the created WiFi. Tempus looks for mobile device use in one-minute intervals. If Tempus detects that a mobile device is used during this interval, it logs the usage and then does nothing for four minutes before another one-minute detection interval. This cycle continues indefinitely. Tempus does nothing for four minutes for two reasons. Firstly, it ensures that when a participant briefly interacts with their mobile device, the interaction is only counted as a single-use. Secondly, it ensures that the LEDs do not turn off too fast.

Because Tempus needs to determine a family setting automatically, we assume that the participants keep their mobile devices near them when at home. With this assumption, Tempus uses Bluetooth Received Signal Strength Indication (RSSI) to determine if a participant uses their mobile device in a family setting. Tempus considers it a family setting when the RSSI values of at least two devices are within a given threshold, which varies depending on the home. Tempus controls the network quality of participating mobile devices by blocking the internet traffic in short intervals. This blocking is achieved by rerouting all traffic to/from mobile devices through the Raspberry Pi and then not forwarding the traffic. When the network traffic is not being forwarded, the internet does not

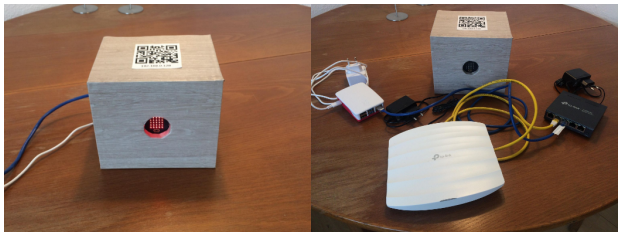

**Figure 2. Example of Tempus. Left picture shows Tempus with hardware hidden away, and the right picture shows Tempus with the Raspberry Pi, switch, and access point.**

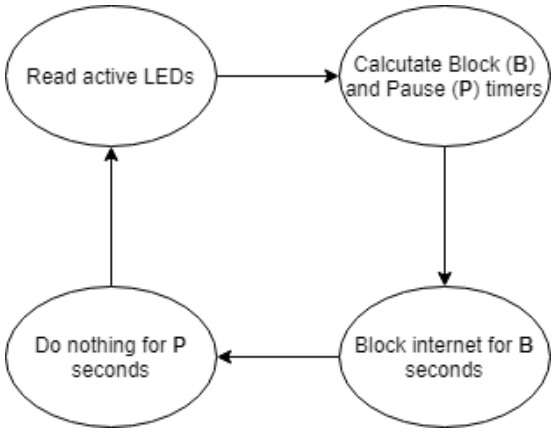


**Figure 3. Example of the network blocking process.**

work from the participants' perspective. Tempus blocks the internet longer and more often as the LEDs are turned off to represent a worsening of network quality. We refer to Whalen's paper [37] to get a quick overview of the area of network exploitation.

We use variables to determine how long and often the network should be blocked. To determine the values of these variables, we create six different levels of network quality represented by the LED display. The levels represent the experiences we want Tempus to provoke. Tempus should gradually get more provocative until the participants find the internet almost unusable. For the values to properly represent the intended experiences, we must consider the difference between loading a webpage and watching a video. When opening a webpage, a device loads the entire webpage once. When watching a video, the device continually receives data, which is stored in a buffer to ensure a smooth viewing experience. This buffer stores a few seconds of video that can be watched without internet access. If the internet is blocked regularly, for short durations, then loading a webpage is affected more than a video, as the video already has loaded the data. Instead, if the internet is blocked irregularly for long periods, then a video may not have enough data in the buffer. With this in mind, Tempus uses short blocks when there are many LEDs active, meaning websites are affected, while videos might not. When there are few LEDs active, the blocks are longer, and videos might stutter regularly.

We tested the six levels with our families and friends until we found values that corresponded to the intended experiences.

| Level | Intended experience |
|---|---|
| 5 | No change |
| 4 | I barely notice a slower network |
| 3 | I notice a slower network now and then |
| 2 | I often notice a slow network |
| 1 | I very often notice a slow network |
| 0 | I find the network almost unusable |

**Table 1. Levels of network quality and the experiences they should provoke.**

| Level | Active LEDs | Block time | Pause time |
|---|---|---|---|
| 5 | 21 - 25 | 0 | None |
| 4 | 16 - 20 | 5 - 10 | 180 - 240 |
| 3 | 11 - 15 | 10 - 20 | 150 - 210 |
| 2 | 5 - 10 | 10 - 25 | 120 - 180 |
| 1 | 1 - 4 | 15 - 35 | 100 - 160 |
| 0 | 0 | 20 - 45 | 90 - 150 |

**Table 2. Active LEDs, the corresponding level and the block and pause values (in seconds). The block and pause times represent the intervals for which Tempus blocks access to the internet and the subsequent pause before the next block.**

The different levels and their associated experiences are shown in Table 1. Tempus blocks network access for an amount of time corresponding to the active LEDs, represented in Figure 3. The time values corresponding to each network level are shown in Table 2. For example, if there are 14 active LEDs, then Tempus is at network quality level 3. Tempus then blocks the internet for 10 - 20 seconds. After Tempus has finished blocking the internet, it pauses for 150 - 210 seconds, meaning it does not block the internet during this time. After Tempus finishes its pause, it once again reads the number of active LEDs and blocks the internet according to the level.

The participants must upload a picture to a website to increase network quality. Tempus hosts the website on the local network, which means that it is always available even when network connectivity is blocked. The website provides two functionalities: the participants can upload a picture to increase network quality and see a gallery of uploaded pictures.

We decided to use pictures to show how mobile devices can enrich family time while also creating uncertainty about how and if Tempus verifies the pictures before restoring LEDs. Tempus does not verify whether the uploaded activity is a family activity; instead, it is left to the participants to decide what they consider a family activity. Tempus restores LEDs based on an algorithm when an image is uploaded. The algorithm introduces some uncertainty to Tempus as the number of LEDs restored is random to some degree. The algorithm considers the currently active LEDs, the title of the image they uploaded, and how many devices are near when the image is uploaded. On average, 10 - 13 LEDs are restored.

### Provocative Aspects of Tempus

When designing Tempus as a provotype, we must consider how it can challenge beliefs and provoke the participants to reflect on their current mobile device practices. However, Tempus should not be too provocative to the point of being rejected in the home. By making the internet a shared resource, each participant must reflect on how and when they use their device since using the device in a family setting decreases the network quality for everyone. Furthermore, we design Tempus to be visually provoking. We believe that the decreasing number of lit LEDs provides a sense of slowly degrading network quality. Since the LEDs are always active, it creates the illusion that the network quality is a constant factor. However, the change in network quality is only in effect when Tempus blocks the network. Another dilemma for the participants is how they upload an image of a family activity. The participants are only told that they must upload a picture of something they consider a family activity. Since a picture that depicts a family activity has to be uploaded, it may feel like Tempus is validating the pictures; however, this is not the case. The pictures uploaded are inserted into the front page gallery to create a picture diary where all family members can view them. This makes it so that if a participant "cheats" by uploading a picture that does not depict a family setting, they may worry about how Tempus and the other family members react.

In summary, deploying Tempus in a household introduces strangeness and uncertainty to the family members. Tempus' different components work together to provoke the participants to reflect on their mobile device habits.

## FIELD STUDY

To explore how the internet as a shared resource affected the participants' mobile device usage, we conducted a four week field study. The study was conducted in the participants' homes, where Tempus was placed in a room that the family frequented. The families were interviewed before and after the field study. We used the field study to explore the following: Firstly, how the participants reacted to Tempus lowering their network quality. Secondly, how the participants acted when Tempus encouraged them to do activities together. Finally, to explore the participants' reflections and challenges on the internet becoming a shared resource.

### Participants

Three families participated in the study. The families all lived in North Jutland and were recruited through our social network. All families had at least a 50 Mbps internet connection, which was more than enough for their usage. Thus, the families did not perceive the internet as a shared resource.

When selecting families, two criteria were considered. Firstly, the families had to live in North or Mid Jutland since we valued face-to-face interviews and the possibility to visit them if Tempus caused unintended problems. Secondly, to increase the chance of the family seeing the internet as a shared resource, the family had to have at least three members with a mobile device. The type or manufacturer of the family's mobile devices was irrelevant since Tempus was not platform-specific. Table 3 shows the anonymized name, age, and occupation for the participants in the three families

**Family A** consisted of two parents (Anna and Anton) and their son (Albert). All of them had smartphones, but Anna only used her iPad at home. They used their mobile devices for YouTube, podcasts, emails, calendars, internet browsing, etc. The parents both expressed that they used their mobile

| Family | Anonymised name | Age | Occupation |
|---|---|---|---|
| A | Anna | 52 | Housewife |
| | Anton | 51 | Program manager |
| | Albert | 24 | Student |
| B | Beate | 51 | Shop assistant |
| | Bob | 50 | Self employed |
| | Bella | 15 | Student |
| | Bailey | 12 | Student |
| C | Cecilie | 49 | Social and health Assistant |
| | Carsten | 51 | Danish military |
| | Clara | 19 | Student |

**Table 3. Participating families**


**Figure 4. Placement of Tempus in family A's home**

devices a lot. Albert did not live with his parents, but he lived nearby and visited 2-3 times a week; thus, the family partly fulfilled the second criteria for selecting families. Figure 4 shows Tempus' placement in family A's home. This placement meant that the participants were considered near Tempus when they were in the living room or near the dining table.

**Family B** consisted of two parents (Beate and Bob) and their two daughters (Bella and Bailey). All of them had smartphones, and Bailey also used an iPad. They used their devices for TikTok, Snapchat, Instagram, news, Facebook, etc. They all expressed that they used their smartphones a lot, and Beate stated that they use them too much. Figure 5 shows Tempus' placement in family B's home. Like Family A, the participants were considered near Tempus when they were in the living room, including the dining table.


**Figure 5. Placement of Tempus in family B's home**

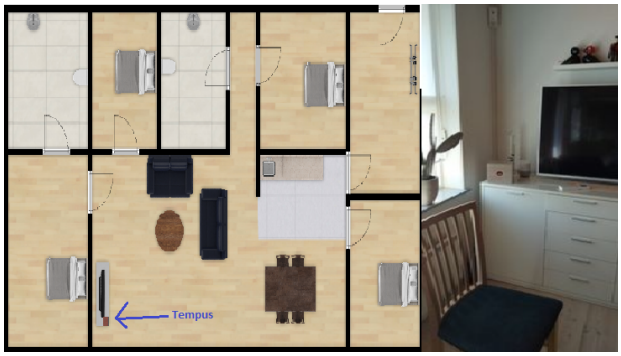


**Figure 6. Placement of Tempus in family C's home**

**Family C** consisted of two parents (Cecilie and Carsten) and their daughter (Clara). All of them had smartphones, and Cecilie regularly used an e-reader. We did not include the e-reader since, once downloaded, the books reside on the e-reader, making the network quality irrelevant. They used their devices for Facebook, Instagram, news, streaming, etc. Both parents expressed that they use their mobile devices a lot, especially when they have the day off. Figure 6 shows the placement of Tempus in family C's home. Due to the living room's layout, Tempus could only be placed near Clara's bedroom or the parent's bedroom. Because Tempus uses Bluetooth to determine nearby devices, Tempus would consider the devices residing in those rooms as nearby. Since Clara was more likely to be in her room alone, we placed Tempus near the parents' bedroom. This placement meant that the participants were considered near Tempus when they were in the living room, the parent's bedroom, or near the dining table.

### Study Design

When reviewing literature about non-use of mobile devices, we realized that many studies are limited to only qualitative or quantitative data [5, 17, 18, 19, 20, 23, 24]. Furthermore, only a few of these considered mobile device habits before and after the study. We believed that we could support the qualitative data gathered from interviews with quantitative data to compare mobile device usage before, during, and after the field study. As such, the field study consisted of three phases to facilitate this usage comparison:

1. A one week preliminary measurement phase to collect data about the participants' mobile device usage in the home. (pre-measurement)
2. A two week intervention phase, where Tempus controls the network and continues to log.
3. A one week measurement phase to collect data about mobile device usage after the participants experienced Tempus. (post-measurement)

We conducted semi-structured interviews before the deployment of Tempus. The purpose of the interviews was to get an initial understanding of the families' mobile device usage. Before the first measurement phase, the families were introduced to how Tempus worked. We disabled the families' WiFi and created a new WiFi with the same network name (SSID) and

password. Because the SSID and password were identical, the families' devices connected automatically. Thus, the family could use the internet like they always had, apart from the intended disruption caused by Tempus. We encouraged the families to contact us if they had any problems or concerns about Tempus and contacted them several times during the field study to ensure everything was working as intended.

Tempus controlled the network quality constantly for two weeks in the intervention phase, which meant that Tempus could affect the families' school or work life. We believed that interfering with work and school was too provocative. Anton and Bob seldomly used their mobile devices for work, and both stated that they would switch to 4G if necessary. The rest of the participants did not use their mobile devices for work or school.

#### *Measurement phases*

In the measurement phases, Tempus logged when the participants used their mobile devices in the home, either alone or together with other participants. The purpose of the pre-measurement phase was to gather data about the participants' mobile device usage before the intervention phase. In the post-measurement phase, Tempus gathered the same data after the intervention phase, which allowed us to explore and compare mobile device usage before, during, and after the intervention phase.

#### *Intervention phase*

Tempus controlled the network in the intervention phase and turned LEDs off when the family used mobile devices in a family setting. During this phase, Tempus logged when it turned an LED on or off. Logging data about the LEDs allowed us to deduce when the family wanted to restore the network quality, either because the internet was too slow or because of the number of unlit LEDs. Additionally, Tempus continued to log data about mobile device use, which facilitated comparison with the two measurement phases.

After the post-measurement phase, we conducted a final interview with all family members. We included both parents and children to encourage discussion among the family members. Two people conducted the interview: one to interview and one to help with follow-up questions or to clarify what was said. We created the interview guide using the information presented by Patton [28]. The interview guide focused on how the participants acted regarding their mobile device usage and the activities they had done. Furthermore, it focused on what the participants reflected on regarding their mobile device usage, both alone and together with the family. Finally, the interview guide also focused on how the participants reacted to the changing network quality and Tempus' changing LEDs.

Inspired by Kurze et al. [21], we extended the interview guide with the pictures taken by the family during the field study and graphs of the logged anonymous data. Kurze et al. studied how participants, both individually and collectively, try to make sense of presented anonymous sensory data. The authors call this behavior sensemaking. When we interviewed the family, we asked them if they wanted to share some of their pictures with us on a provided tablet. We asked the participants if they could tell us the stories behind the pictures that they found interesting, including why they did the activities and what the pictures showed. When showing the graphs, we firstly showed them graphs of each participant's individual mobile device usage in a family setting. We then asked them if they could make sense of these anonymous graphs. Following this, we showed them a graph of the family's total mobile device usage during a family setting, and shared the family's average mobile device usage during family settings for the three phases. By presenting the participants with pictures and graphs, we believed that the participants would engage in a sensemaking process similar to the findings of Kurze et al., and talk openly about their experiences and thoughts concerning when and why they had used their mobile devices.

All interviews were audio-recorded. The interview guide can be found in Appendix B. The gathered data consisted of 4 hours and 30 minutes of transcribed audio interviews, 56 activity pictures with titles, and 84 days of recorded logs. To analyze the gathered data, we used thematic coding with grounded theory, and emergent coding in NVivo [22]. Two of the authors read through the data individually before they started coding the data. The two coders separately coded the entire data set twice and then discussed the codes. By comparing the codes, categories were created, which resulted in six themes.

## FINDINGS

The collected data tells stories about each family throughout the study. The activity pictures present a rich view of what the families did when they put away their mobile devices. Family A uploaded 22 pictures of their family activities. The pictures mostly showed the activity rather than the faces of people involved in the activity, and the activities mainly consisted of walks. Family B uploaded 10 pictures of their family activities. All but one picture was centered around the children doing some activity. Family C uploaded 24 pictures of their family activities. These pictures mainly showed the family eating, for example, during breakfast or dinner. The pictures for each family is shown in Appendix D, E, and F, respectively.

In this section, we present the six themes identified from our four week field study. All the quotes have been translated from Danish to English. We describe how the internet being a shared resource affected the participants and sparked reflections on their own and other family members' mobile device usage. We finish by explaining how Tempus influenced the time the family spent without their mobile devices.

### Living with the Internet as a Shared Resource

The participants expressed how the network quality and the LEDs provoked them to see the internet as a shared resource. All participants expressed that the network quality provoked them, but there was a tendency to focus more on the LEDs. Maintaining Tempus' LEDs became a part of the families' everyday life. Carsten from family C stated that Tempus had a controlling effect on their daily lives.

> *"It has controlled much of my life for 14 days. Because I always look at it [Tempus], how much is there left [LEDs left]."*

Clara from family C described a situation where the number of lights started to decrease once her parents came home, suggesting that she was aware that her parents started using their mobile devices together, and as a result worsened the internet quality.

> *"I remember an evening where I was home alone. It was just my boyfriend and I, and when you came home, it [the LEDs] really started getting used."*

The participants clearly understood the relation between LEDs and network quality, but they often uploaded activities independently of their experiences with worse network quality. Carsten from family C said that the LEDs were something concrete and visual that affected them more than the internet.

> *"So it [the internet] has affected us, but what affects us the most is that you can see the dots [LEDs] and how much there is left. It has made an impact. And when you browse BT [Danish news site], ohh, now a dot disappeared just because I was looking. Such things come to mind."*

Carsten was not the only participant to relate the LEDs to the network quality. It was also the case in Family A and B where they never let the number of lit LEDs reach zero because they worried what would happen. As Anton put it *"Are you aware how dependent you are on the internet? Therefore it should not get all the way to zero."* Cecilie from Family C also described, how the LEDs were a central topic of conversation in her family. The LEDs were generally discussed a lot in all the families.

> *"We have been keeping an eye on it. It has been a very big topic of conversation."*

While there was a focus on the LEDs, the network quality also provoked the participants, which was especially evident in family A, as mentioned by Anton.

> *"But I quickly realized that if my internet... If the WiFi is slow, then I would have taken it straight to the garden and dug a hole for it."*

Only Anton expressed that Tempus' changing network quality provoked him to such an extend. Nevertheless, it made Anton sometimes put his smartphone away.

> *"If the goal was to bother us so much that we put that trash [smartphone] away and started spending time on something else, then it succeeded."*

Similarly, the other participants said that if they experienced problems with the network quality, they often put their phones away and did something else. This was evident in family B, where Beate believed she had read more and that Bailey was more creative with finding activities to do without her phone.

> *"You [Bailey] became a bit more creative in the period, and it still holds. Doing something instead of using a phone. [...] But if I come down to her room now, then it is not the phone she sits with. [...] Now she started making many finger rings, and then the iPad runs a tutorial."*

Several participants were aware that they could avoid the varying network quality by switching to 4G, yet this rarely happened. The interviews showed that the participants only switched to 4G when they needed to do something they found important, such as opening NemID and ordering food for the family.

Tempus provoked the participants through the LEDs and by controlling the network quality, which in combination, made them feel like the internet was a shared resource.

#### Collaboration

The families saw maintaining the network quality as a joint project, and everyone took part in it. They regularly kept an eye on the LEDs, which made them upload pictures based on the remaining active LEDs. The fact that participants were aware of Tempus' LEDs suggests that they wanted to maintain the network quality even when they did not experience a worse network quality. Anton from family A compared looking at Tempus to watching the weather forecast or looking outside to see if it rains, referencing how checking for active LEDs became an everyday routine. Beate from family B even went as far as to compare it to an animal that needs feeding.

> *"Imagine if the internet went out, right? Imagine if they could not do anything on it [the internet]. Yeah, I do not know; it is probably like an animal that needs feeding."*

The strategies that the families adopted to maintain the network quality were somewhat different. The most obvious way to maintain it was to upload pictures when deemed necessary by the families. This strategy was used by all families but with different approaches. When family B saw that too many LEDs were missing, they did an activity and uploaded the pictures shortly after. In comparison, family A and C focused more on taking pictures whenever they did something together and uploading them when needed. Another approach was that families A and C would plan ahead. If the families knew that someone would be alone for some time, they would upload a picture so the person could use their mobile device without disturbances. Finally, family C thought a lot about not using their smartphones to conserve LEDs, as described by Carsten.

> *"I certainly had focus on it. I have not always taken... yeah, I have certainly thought about it many times - try to conserve the dots [LEDs] a little."*

The families' desire to maintain the LEDs made them pay attention to Tempus throughout their everyday life. The families also collaborated to keep the LEDs lit, using different strategies.

#### Reflections on Own Mobile Device Usage

All the families described how Tempus provoked them to reflect on their mobile device usage, both alone and together as a family. Furthermore, all participants believed they used their own mobile devices slightly less throughout the study. The participants said that they mainly reflected on their mobile device usage during the two week intervention phase, but some also reflected on it in the post-measurement phase. Only Cecilie said she reflected on her mobile device usage, because of Tempus, during the pre-measurement phase. In general, the participants did not see their mobile device usage as a problem. Nevertheless, Tempus made them reconsider if they

really needed to use their mobile devices or if they could just put them away and do something else. Cecilie from family C described this when she talked about how Tempus made her think.

> *"Yes, I think so. Also, how much time I spent on the phone. Then I thought arg [should I really do that]. Yes, I did that."*

Cecilie, in particular, got annoyed at herself when she realized how much time she had spent on her phone.

> *"But sometimes I think I sit and play games too often [on the phone]. I get so annoyed with myself afterward if I have spent much time on it because it is nothing. Then I have spent an hour on it, and then what? It is not something that makes you smarter."*

Family C was the family that used their mobile devices the most together during the study. Despite this, they were not annoyed by Tempus. Instead, they believed that the reflections Tempus sparked were good for them, as described by Carsten.

> *"But I think it has done something for us. I believe we have thought more about it [phone usage]. I believe that. Maybe not regarding activities, that is probably like usual, it has not changed our lives in 14 days. But regarding phones and using them, then I believe it has changed. At least you think more about it."*

The families mainly reconsidered the mobile device use when their use was unimportant. When the participants experienced bad network quality, they would consider if the task was important. If it were deemed unimportant, the participant would put away their device. In contrast, if the participants found the task important, such as reading work emails, they continued using their mobile devices. Anton from family A reflected on his phone usage when he described that he did not see his phone usage as a pastime, making him continue using his phone.

> *"I use my phone a lot. I do that already, and I do not experience it as a pastime. I believe it is much like education. I would call it that."*

Tempus made the participants reflect on their mobile device usage. As a result, some participants put away their mobile devices when they thought that the task was unimportant. Tempus even made some participants annoyed at themselves due to their usage. In contrast, other participants continued to use their mobile devices when they considered the task important.

#### Reflections on Other Family Members' Mobile Device Usage

Tempus did not only spark reflections on the participants' own mobile device usage but also their family's usage. The participants joked with each other about their mobile device usage and who was responsible for removing LEDs. Furthermore, some participants said that they believed the other family members used their mobile devices less than before the study. Beate from family B told a story where Bella and Bailey looked out the car windows during a family trip, whereas they would previously sit with their smartphones when the family drove somewhere.

> *"[...] You used to use it [smartphones] in the car. That time we drove to Tversted, it did not even come out of the pocket. You looked out the window for once."*

Similarly, Anna from family A noticed that Anton did not pull out his phone in situations where he used to before the study.

> *"[...] You [Anton] did not pull out your phone when we played games, or when we sat on a bench and such. You do not pull it out like you might have used to do. So I actually think so [believe Anton has used it less]."*

Family C joked a lot about each other's mobile device usage and who was responsible for lowering the network quality. During the interview, Clara and Carsten discussed who used their phone more during the evening, thereby removing LEDs.

> Clara: *"Yeah, you are also good at sitting and using your phones during the evening. I am not alone in that."*
> Carsten: *"Yeah, but there are some who are better than others."*

Family B also reflected on who was responsible for consuming the most LEDs. When asked whether they noticed which family member consumed more LEDs, Beate described how everyone except oneself was responsible for removing them.

> *"We knew that. It was everyone but oneself."*

The participants' joked about each other's mobile device overuse, and some believed that the other family members used their mobile devices less.

#### Subconscious Non-Use of Mobile Devices

Most of the participants believed that they used their mobile devices slightly less during the intervention phase, but none realized how much they had reduced their usage. The graphs in Figure 7 show the number of times Tempus identified mobile device use in a family setting for each day of the field study. The green columns represent the pre-measurement phase, the blue columns represent the intervention phase, and the red columns represent the post-measurement phase. Graphs for each mobile device use can be seen in Appendix C.

When we asked the families whether they had felt any difference in their mobile device usage after the pre-measurement phase, the answers were mixed. Family A thought they had used it almost the same amount, family B thought they had used it slightly less, and family C thought they had used it somewhat less. Despite this, when we mentioned the graphs, Cecilie jokingly responded with *"I feared that"*, suggesting that she was unsure if they had used it less.

Looking at the logs, it is clear that all families used their mobile devices much less during the intervention phase and slightly less in the post-measurement phase. When we asked family A if they could recognize the data in the graphs, Anton said: *"No, I would have thought that we used [smartphones] about the same amount in the blue period as we did in the green period"*. Nevertheless, the family went from using their mobile devices 34 times per day on average in the

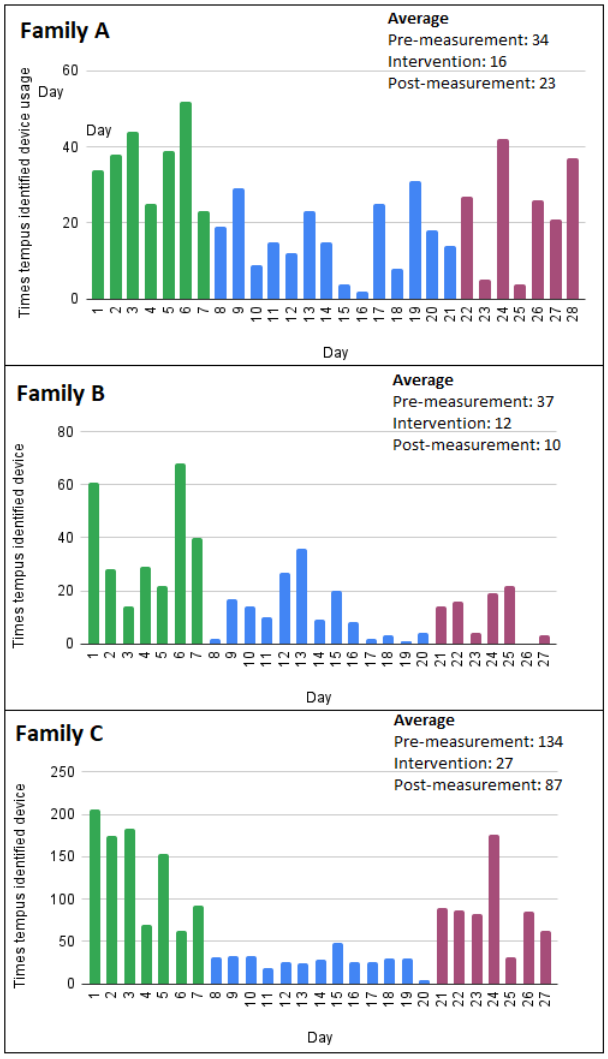


**Figure 7. The graphs show the accumulated number of times Tempus detected mobile device use in a family setting for each of the three families.**

pre-measurement phase to 16 times per day in the intervention phase.

Beate from family B described that she believed Bob worked less from home, which could be one reason for their reduced usage. However, Bob did not notice any difference himself.

> Beate: *"But I will say that you have worked less from home compared to what you used to, maybe."*
> Bob: *"I have said that I have not noticed that."*

Family C believed they used their mobile devices less, but they were surprised that they went from an average of 134 times per day in the pre-measurement phase to 27 times per day in the intervention phase. Another interesting observation from family C was that Cecilie believed she used her phone less in the pre-measurement phase than in the post-measurement phase. Cecilie stated that she reflected on her mobile device usage during the pre-measurement phase: *"There I also thought about it [not using the phone]. Because we also use it too much"*,

**Figure 8. Left: (Family A)** ***Still playing, who wins?*** **Right: (Family B)** ***Washing cloth***

whereas she said that she did not think about it during the post-measurement phase. Despite this, all participants in Family C used their mobile devices the same amount or less in the post-measurement phase compared to the pre-measurement phase, which suggests that Cecilie subconsciously thought about her mobile device usage in the post-measurement phase.

Overall the participants' used their mobile devices far less during the intervention phase than they recalled, which indicates that Tempus subconsciously made the participants reluctant to use their mobile devices.

### Quality Time without Mobile Devices

The families all expressed very positive experiences with the family activities and stated that they did not use their mobile devices during the activities, apart from taking pictures. Although many of the activities were something that the families would typically do, they described how Tempus motivated them to do and participate in activities. Family A and B said that Tempus made them do new activities or activities they had not done for a long time, for example, playing board games, as seen in Figure 8 (left). Furthermore, family C described how Tempus made them more aware of doing activities together. The most common word in the participants' titles was "hygge", suggesting that the families enjoyed the activities. Examples are shown in Figure 9.

Families B and C faked activities once during the field study, which means that they uploaded a picture of an activity they did not do. However, both families put effort into taking a picture that looked like a family activity. For example, family B decided to put their hands on some already folded washing clothes and take a picture, shown in Figure 8 (right). When we asked the family how they felt uploading such a picture, the family said that it was something they enjoyed doing together.

> Bob: *"We had fun with it."*
> Beate: *"You had a lot of fun."*
> Bob: *"That was also something we did together."*

Similarly, family C put out a deck of cards on the table to display a game taking place. Thus, despite trying to fake the activity, the families did do something together, and they had much fun describing these fake activities.

All families described situations where a family member participated in an activity they normally would not have. Bob from family B said that the daughters came out of their rooms when the network quality was bad and that Bailey, specifically, often went to her parents and asked to do an activity.

**Figure 9. Left: (Family B) *Family hygge*. Right: (Family C) *Morning "hygge"***

> *"It is like a fire alarm. When the WiFi is bad, the children come out of their rooms"*

In family B, Tempus also affected the activities the children did with their guests. Beate described how Bailey and her friend had to do other things than being on the IPad because of the network quality.

> *"[...] When you are a guest, and the network does not work, then you are not on the internet either, and you do something else."*

Interestingly, the families positively described the activities, even those they only did to increase the network quality. Furthermore, the families' had fun with the activities and enjoyed spending some quality time as a family.

## DISCUSSION

This section discusses the implications of Tempus and how it relates to work within the HCI field and designing towards non-use. The field study aimed to explore whether the internet as a shared resource would affect the participants' mobile device usage and whether it provoked the participants to reflect on their mobile device usage.

### Internet as a Provocative Approach

Using the internet as a provocative approach was motivated by the previous work, which directly targeted Android devices [5, 17, 18, 19, 20, 23, 24]. Diverging from these studies, we targeted the infrastructure of mobile devices, namely their reliance on the internet.

The field study shows that changes in network quality can spark reflections on mobile device usage. However, the participants tended to focus more on the LEDs. We found that the participants would often observe Tempus' active LEDs to get an overview of the network quality, and it is evident that the LEDs made Tempus more provoking. One participant compared the LEDs to the WiFi symbol, and another stated that he could more easily comprehend the LEDs than the changes in network quality. Furthermore, the participants did not always experience the decreasing network quality since the internet was blocked in intervals. In contrast, the LEDs were always active, making it easier for the participants to determine the current network quality and see how much they had used their mobile devices.

Interestingly, the daughters from families B and C felt most provoked by the network quality. We believe this stems from the daughters spending more time in their rooms where they could not see the LEDs.

Previous research has used lockout mechanics to limit participants' mobile device usage and make them reflect on when to use their mobile devices. Tempus' showed a similar effect to the studies of Bruun et al. [5], Kim et al. [17], and Ko et al. [19], in that forcefully restricting participants from fully accessing their mobile devices can affect their mobile device usage. More specifically, we confirm that restricting mobile device use limits the subconscious habits of checking the mobile devices for short periods, such as checking notifications or scrolling through social media. A poor network quality showed to have a similar effect as the input tasks presented by Kim et al. [17], where a workload would make the participant reflect on why they would use their device. In the cases where usage was not deemed necessary, the participants would put away their devices. In our study, the participants would sometimes wait for the network quality to be restored. They would essentially weigh the cost-benefit between waiting for the network or putting the mobile device away. In summary, using the internet as a provocative approach proved to affect the participants' mobile device usage. However, a gradually decreasing internet quality can be hard to perceive for the participants. Hence a secondary provocation method is favorable, such as Tempus' LEDs. Furthermore, researchers can include many more potential devices, and thereby participants, in the study by designing prototypes that exploit the device's reliance on the internet, in contrast to developing platform-specific apps.

### Family Time without Mobile Devices

Mobile devices have been shown to increase tensions in homes when used in family settings. Blackwell et al. [4], Oduor et al. [27], and Bruun et al. [5] found that families want to reduce the interruptions stemming from technology when they are together. Notifications have been shown to distract people from the family activity, while natural lulls in the activity can create space for mobile device use [11]. We complement these previous findings by studying how the participants interacted with their mobile devices during the field study. All participating families indicated that mobile devices were not present during family activities, apart from taking pictures for Tempus. Some of the participants mentioned that they had intentions of reducing their mobile device usage before the study. They also mentioned that unspoken rules already existed for when mobile devices were not allowed. However, most participants stated that mobile device use during family activities felt wrong or counterintuitive. The few participants who used their mobile devices during these activities mentioned that it was because of work or similar important matters, similarly to the findings of Derks et al. [8]. While tensions showed at varying levels within the families, only family C mentioned that they would provoke each other about the usage. The family would joke about who had caused the LEDs on Tempus to disappear

and comment on family members using their mobile devices during dinner. Maintaining Tempus' network quality was seen as a joint task by all participating families, and taking pictures became part of their daily routine. We also found that the younger participants encouraged the family to do activities similarly to the findings of Ko et al. [18], for example, when Bailey and Bob faked the activity of folding clothes.

In summary, the families seemed to enjoy both their time without mobile devices and their time spent together. Thus, we see that motivating family members to spend time without mobile devices, rather than only restricting the usage, positively affects the time they spent together without their mobile devices.

### Quantitative Data to Support Qualitative Data

While many studies about non-use rely on quantitative or qualitative data, we included logged anonymous data about the participants' mobile device usage in the interview. Showing graphs of the participants' mobile device usage during the final interview proved to be a valuable inclusion. It drew out qualitative data that otherwise would not have come up during the interviews. This behavior confirms what Kurze et al. [21] found in their study on people's sensemaking from sensor data. Sensemaking includes presenting stories or using data as evidence for perceived behaviors. The same sensemaking occurred when our participants inspected the graphs. Despite the anonymous graphs, the participants started explaining outliers with stories and guessing whom the graphs belonged to. The graphs made the families talk among themselves and open up more, which led to data that we would not have gotten otherwise. The same occurred when we asked the family to show the pictures they took during the intervention phase. The participants talked about what the pictures showed and discussed their experience with the given activities. Thus, having something concrete that the families could relate to or directly speak about contributed to rich conversations that would not have happened otherwise.

When making sense of the graphs, most of the participants were surprised by the data presented to them. Most participants believed they used their mobile devices less during the intervention phase, but few expected a noticeable difference between the pre-and post-measurement phase. Some participants even mentioned that they thought they used their mobile devices more during the post-measurement phase since they were free from restrictions. As was shown in the graphs on Figure 7, the participants tended to use their mobile devices together a lot less during the intervention phase than during the pre-measurement phase. Although the mobile device usage increased after the intervention phase, it was significantly less than during the pre-measurement phase. Using two of the four weeks to gather measurement data has shown to be valuable for analyzing the qualitative data. Without the logs, we would not have found that the participants subconsciously used the mobile devices less. In summary, the quantitative data support the qualitative analysis, both in analyzing the data and conducting the interviews. In addition, presenting quantitative data to the participants can make them open up more in the interview and remember instances they might have forgotten to mention otherwise.

## FUTURE WORK AND LIMITATIONS

Based on the findings, we see the potential for further research using the internet as a shared resource for provocation towards non-use. By observing or controlling a network, future work can include any devices that require a network connection in the study, such as smart TVs or voice assistants. Future work might also explore a hard block of the network connection instead of disrupting the mobile devices' network connection in short intervals. Furthermore, we found that the families reacted positively to doing activities to restore the network quality for their mobile devices, which we can imagine being further expanded. Finally, using quantitative data to support the qualitative data proved helpful in analyzing mobile device habits. Only three families participated in the study, which causes some uncertainty with both the qualitative and quantitative data. Therefore, we suggest that future work include more families and increase the length of the three phases to increase the validity of the findings.

Some considerations must be mentioned in regards to the technical limitations of Tempus. Using Bluetooth RSSI to determine when two people are in a family setting can be inaccurate, as the signal strength can fluctuate heavily. Anton from family A noted how Tempus would remove LEDs when he used his phone alone. This was because Anna's tablet was recharging in the other room, where its RSSI value would sometimes exceed the threshold, which led Tempus to consider it a family setting. We recommend that future work requiring more accurate positions of mobile devices uses other means, such as WiFi positioning using triangulation. However, this requires additional hardware. Furthermore, Bob from family B mentioned how he would sometimes experience loss of internet access on the network, regardless of the number of active LEDs. Finally, future work that uses the participants' existing WiFi must consider its stability, as it can malfunction regardless of the prototype.

## CONCLUSION

In this study, we explored how the internet could be used as a shared resource to provoke towards non-use of mobile devices. By utilizing research through design, we developed the Tempus provotype to challenge current mobile device practices in the home. Tempus lowers the network quality of all participating devices whenever a family member uses their mobile device while together with other family members. Participants can restore the network quality by doing a family activity and uploading a picture of this activity to Tempus. The system is unique in that it exploits mobile devices' reliance on the internet to increase the variety of mobile devices that is possible to study. We deployed Tempus in a four week field study consisting of three phases with three families. During the first week, Tempus logged mobile device use. In the second and third weeks, Tempus provoked the participants while also logging. In the final week, Tempus once again logged mobile device use.

Our findings show that utilizing the internet as a shared resource worked as a provocative approach, as it sparked reflection from the participants on their mobile device usage. Participants would consider if their mobile device use was important when the network quality worsened or when they were together with their family. Furthermore, the family members enjoyed spending time together as a way of regaining their network quality. While the family activities were mainly the same as before the study, participants felt that more thought went into the activity, and more family members participated. Finally, by measuring the mobile device usage from the families before, during, and after Tempus was active, we could show the families how their mobile device practices had changed. The quantitative data showed that mobile device usage had decreased significantly. While some of the participants had noticed minor changes in mobile device practices, none had anticipated that their usage decreased to such an extend. This suggests that the participants subconsciously changed their mobile device usage practices throughout the study without noticing.

We have shown that employing the internet as a shared resource can help researchers understand mobile device usage and spark reflections from the participants. We found that motivating the participants to spend time together, rather than only restricting access, positively affected the time they spent together without their mobile devices. Lastly, we showed how quantitative data could support both the interview and the qualitative data analysis. The quantitative data helped enrich the interview conversations, and we gained additional insight into the effects of Tempus.

## ACKNOWLEDGMENTS

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## APPENDIX

### A. SUMMARY OF 9TH SEMESTER PROJECT

In the 9th semester, we studied how gossip could provoke non-use of smartphones. To explore how gossip worked as a provocative framework, we created the prototype "Gossiper" and evaluated it in a 1 week field evaluation. This summary describes the conceptualization of the used frameworks, how Gossiper worked, and the findings gathered from the field evaluation.

We created Gossiper using frameworks of provocative design and gossip. For provocative design, we considered the provocative dimensions suggested by Bardzell et al. [1], namely that interactive design can be aesthetically, conceptually, and functionally provocative. For the gossip framework, we had to understand how an interactive design could gossip. As such, much work went into conceptualizing gossip and creating criteria for how to create gossip. We defined gossip as *an informal evaluative talk about other individuals, where these are often absent.* Furthermore, for something to be considered gossip, it had to include the meta concepts *Intimacy*, *Social*, *Context*, and *Ambiguity*.

We developed Gossiper to listen for smartphone use on the provided network. When smartphone activity over a set threshold occurred, Gossiper would gossip about the person using their device. Gossiper is shown in the figures 10, 11, and 12. Gossiper consisted of a white box with two child toys on top. We painted the box white to mix in with the participating family's walls, and the two toys were a metaphor for two entities gossiping about the participants. In agreement with the participating family, Gossiper ran from 17:00 to 20:30 during weekdays and 14:30 to 21:30 during weekends.

#### Creating the Provotype

We found that provoking the participants through gossip did make the participants more attentive to their smartphone usage. However, we found that Gossiper needed some improvements moving forward.

- While gossip did make the participants reflect on their smartphone usage; it also decreased in effect. The participants noted that they were more aware of not using their smartphone at the start of the study than at the end.
- The provided network showed to be too unstable. Two participants disconnected from the network multiple times, meaning they were not gossiped about when they used their smartphones.
- Gossiper showed to gossip too much. When testing the threshold for determining the smartphone activity, we failed to notice that received Snapchat messages would cause Gossiper to gossip. Gossiper gossiped too often, to the point where it annoyed the participants rather than sparking reflections on smartphone usage.
- Gossiper did not correctly detect family setting. From the interview, we noted that the participants complained that Gossiper gossiped about them when they used their phones when putting the baby to sleep.

We concluded that gossip could be used as a provocative framework to encourage non-use of smartphones in a family setting. However, future work should consider the previously mentioned findings.

**Figure 10. Hardware outside box.**

**Figure 11. Hardware inside box.**

**Figure 12. Final provotype with hardware hidden inside box.**

**B. INTERVIEW GUIDE**

Huskeliste:

1. Sikre at vi må optage interview (og brug begge mobiler)
2. Sikre at de ved, at vi kalder prototypen for Tempus
3. Sikre at de ved, at der ikke er nogle rigtige eller forkerte svar. F.eks. hvis de føler at de har "snydt", så er det en korrekt måde at agere på, og så vil vi gerne vide det.
4. Sig at vi forventer at dette kommer til at tage 1½ time, måske op til 2 timer. Vi har planlagt en pause, men hvis i har brug for flere pauser, så siger i bare til.
5. Hvis i føler i allerede har svaret på et spørgsmål, må i gerne sige det.

**Struktur**

| **Spørgsmål** | **Follow-up pointers** |
|---|---|
| **Opvarmning** | |
| Hvordan har de sidste 4 uger været? | - Hvordan har det været at deltage? |
| Hvordan har i mærket at Tempus var aktiv? | |
| Hvis i skulle beskrive Tempus med 3 ord, hvilke ville i så bruge? | - hvorfor de ord? |
| **Aktivitet** | |
| Hvordan har I oplevet at skulle lave aktiviteter | |
| Hvilke aktiviteter har i lavet | Hvordan har I fundet inspiration til at lave aktiviteter<br><br>Har der været forskel på de aktiviteter I har lavet?<br><br>Har det været anderledes end de aktiviteter i normalt laver sammen<br><br>Har I brugt jeres mobil i disse aktiviteter |
| Hvem har bestemt hvilke aktiviteter I skulle lave | - hvorfor har du taget initiativ til det? |
| Vi sagde at i skulle ligge billeder af familieaktiviteter op. Hvad synes i der skulle til for det var en familieaktivitet? | |

| | |
|---|---|
| Spørg om vi må se nogle af deres billeder. Vælg 1 tilfældigt, og spørg om de vil snakke om et. | - Hvad lavede i på dette billede?<br><br>- Hvorfor denne aktivitet?<br><br>- Hvad var grunden til at i lavede denne aktivitet? |
| Overvejede i nogensinde at snyde med aktiviteterne? | - Hvis ja, kan i komme med nogle eksempler?<br><br>Hvordan havde i det med at ligge sådan et billede op? |

**Billeder**

| | |
|---|---|
| Har i set tilbage på de billeder som i har lagt op? | - hvorfor? |
| Hvordan har det været at skulle tage billeder af de aktiviteter i lavede? | Hvis alle aktiviteter er noget de har lavet sammen: Hvorfor har i ikke lagt et tilfældigt billede op? |
| Hvad gjorde i efter i havde lagt et billede op? | |

**Familietid (PAUSE)**

| | |
|---|---|
| Hvornår har i brugt tid sammen i løbet af eksperimentet? | Har eksperimentet ændret hvor meget tid i tilbringer sammen? |
| Hvordan vil I beskrive den tid i brugte sammen, når i ikke havde mobilerne i brug? | |
| Har det ændret noget i forhold til jeres forestilling om hvad man kan sammen som familie? | |

**Mobilbrug**

| | |
|---|---|
| Hvordan har jeres mobilforbrug været i løbet af eksperimentet? | |
| Har I tænkt mere over jeres mobilforbrug når i sammen? | Har i ændret nogle af jeres egne mobilvaner, når i er sammen?<br><br>Har I tænkt over andres mobilforbrug?<br><br>Har i bedt de andre om ikke at bruge mobilen?<br><br>Når I har brugt mobilen, hvad er den så blevet brugt til?<br><br>Mener i at i har brugt mobilerne mere eller mindre, når i er sammen med andre?<br><br>Vis grafer for TOGETHER.. Er de enige med det de ser? |

**Fysiske aspekt af Tempus**

| | |
|---|---|
| Hvordan forstår I Tempus' lys? | Hvordan har I lagt mærke til dem?<br><br>Hvornår har I lagt mærke til dem?<br><br>Hvor tit har i kigget på dem?<br><br>Hvordan har de påvirket jer? |
| Hvor mange lys var der som regel tændt, når i lagde et billede op? | |
| Ville i have placeret Tempus et andet sted? | - Hvor<br>- Hvorfor |
| Påvirkede Tempus jer i den første og sidste uge? Altså når Tempus ikke lyste. | Hvorfor / Hvordan? |

**Internet som en fælles ressource**

| | |
|---|---|
| Hvordan har I oplevet at internettet er blevet dårligere | Hvornår oplevede i det? |
| Hvordan var det at skulle lave noget i fællesskab for at få at øge kvaliteten? | |
| Har I følt at andres mobilbrug har forringet nettet? | Hvordan har det føltes? |
| Hvordan havde i det med at i forringede nettet når i brugte mobilen? (når i brugte mobilen sammen med andre) | |
| Har det forringede net skabt en snak/debat omkring mobilbrug? | |
| Har I forsøgt at lægge strategier for jeres mobilbrug under eksperimentet? | |

**Afslutning**

| | |
|---|---|
| Har i noget feedback som vi ikke har snakket om? | |
| Har i nogle spørgsmål? | (Hvis de spørger ind til hvad vi undersøger, så sig at det er det sidste vi svarer på, for ikke at farve andre eventuelle spørgsmål.) |

## C. MOBILE DEVICE USAGE GRAPHS

### Family A

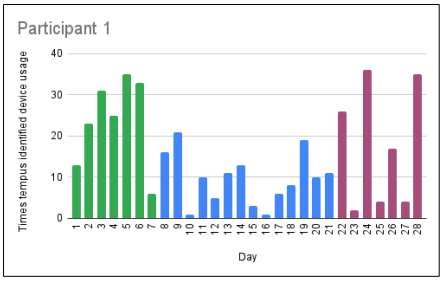


**Figure 13. Participant 1 (A)**

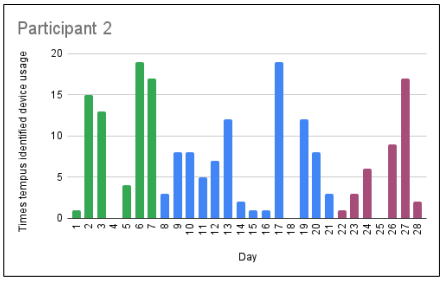


**Figure 14. Participant 2 (A)**

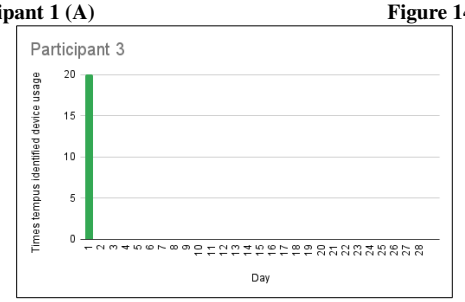


**Figure 15. Participant 3 (A)**

## Family B

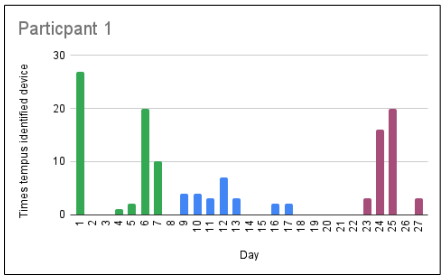


**Figure 16. Participant 1 (B)**

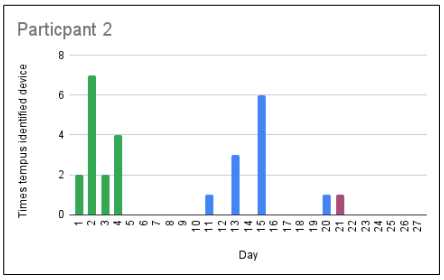


**Figure 17. Participant 2 (B)**

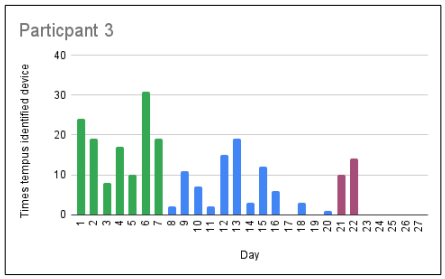


**Figure 18. Participant 3 (B)**

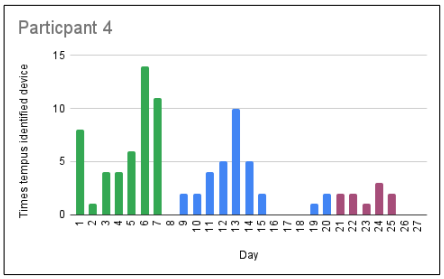


**Figure 19. Participant 4 (B)**

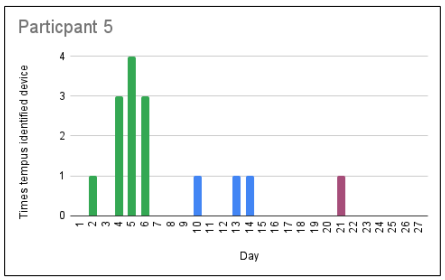


**Figure 20. Participant 5 (B)**

## Family C

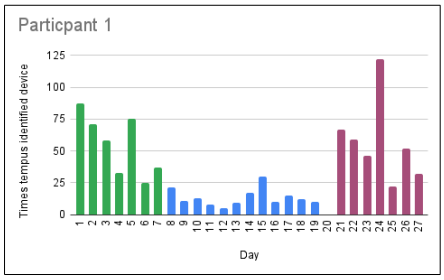


**Figure 21. Participant 1 (C)**

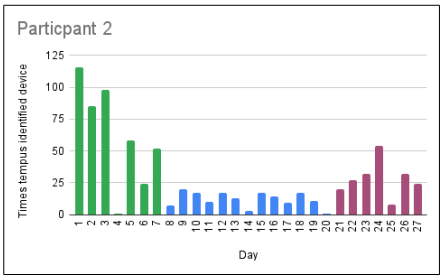


**Figure 22. Participant 2 (C)**

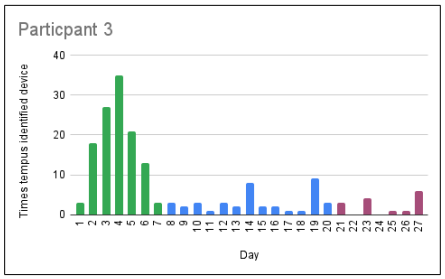


**Figure 23. Participant 3 (C)**

## D. FAMILY A PICTURES

Figure 24. Planke (Plank)

Figure 25. Ser Korpset sammen (watching Korpset together)

Figure 26. Aftengsmad og hyggesnak (Dinner and "hygge" talk)

Figure 27. Geo Guesser


Figure 28. Touche

Figure 29. Spiller stadig, hvem vinder? (Still playing, who wins?)

Figure 30. Ud i det blå (out in the blue)

Figure 31. Frisk luft inden aftensmad (fresh air before dinner)

Figure 32. Havearbejde (Gardenwork)

Figure 33. Hyggetur til havnen ("Hygge" trip to the harbor)

Figure 34. Skovtur (Out in the forest)

Figure 35. Eftermiddagskaffe i det fri (Afternoon coffe in the wild)


Figure 36. Deler en øl (Sharing a beer)

Figure 37. Kaffepause (Coffe break)

Figure 38. Østerådalen

Figure 39. Aftengåtur (Evening walk)

Figure 40. Aftensmad sammen (dinner together)

Figure 41. Gåtur (walk)

Figure 42. Bonderøven

Figure 43. Familien fra Bryggen


Figure 44. Vi er på vej til at købe ind sammen (We are on the way to shop together)

Figure 45. Eftermiddagshygge (afternoon "hygge")

## E. FAMILY B PICTURES

Figure 46. Vasketøj (Washing clothes)

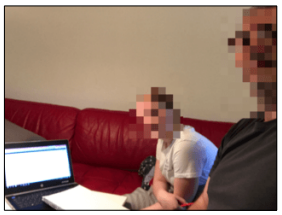

Figure 47. Lektier (Homework)

Figure 48. Hygge

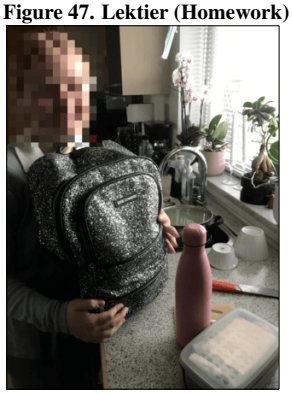

Figure 49. Madpakker (Lunch boxes)

Figure 50. Fælder træ (Woodcutting)

**Figure 51. Familie hygge (Family "hygge")**

**Figure 52. Morgen mad (Breakfast)**

**Figure 53. Madlavning (Cooking)**

**Figure 54. Tøse hygge (girl "hygge")**

**Figure 55. Ude at spise (Eating out)**

## F. FAMILY C PICTURES

**Figure 56. Klar til lækker middag (Ready for delicios dinner)**

**Figure 57. Spiser aftensmad (Eating dinner)**

**Figure 58. Laver morgenmad sammen (Creating breakfast together)**

**Figure 59. Dejlig gåtur i solskin (Lovely walk in the sunshine)**

**Figure 60. Leg med hundene (Playing with the dogs)**

**Figure 61. Ser film (watching a movie)**

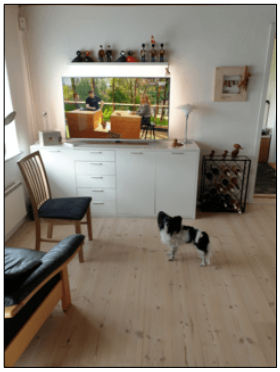

**Figure 62. Hygger med morgen tv ("Hygger" with morning tv)**

**Figure 63. Hygger efter aftensmaden ("Hygger" after dinner)**

**Figure 64. Hygge ved morgenmaden ("Hygge" at dinner)**

**Figure 65. Hygger efter aftensmaden ("Hygger" after dinner)**

**Figure 66. Ser fodbold (Watching football)**

**Figure 67. Hygger med varme hveder ("Hygger" with hot hveder)**

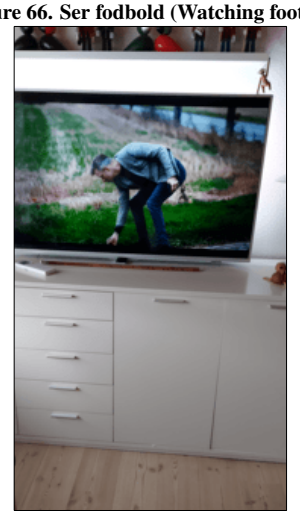

**Figure 68. Ser Sommerdahl (Watching Sommerdahl)**

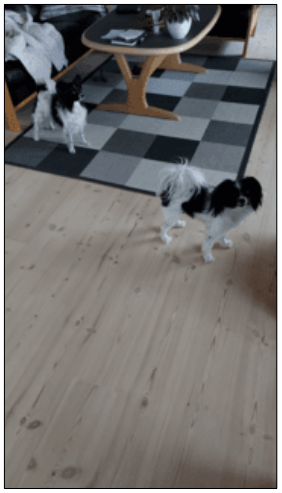

**Figure 69. Leger med hundene (Playing with the dogs)**

**Figure 70. Hygge med en god bog ("Hygge" with a good book)**

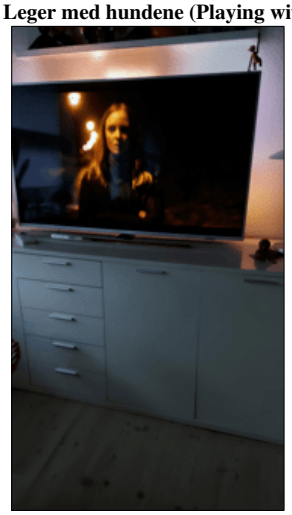

**Figure 71. Vi ser den som dræber (Watching the one who kills)**

**Figure 72. Fredags hygge (Friday hygge)**

**Figure 73. Vi ser legomaster (We're watching legomaster)**

**Figure 74. Vi ser formel 1 (We're watching formel 1)**

**Figure 75. Mens vi drikker te (t) (While we drink tea (t) )**

**Figure 76. Morgen hygge (morning "hygge")**

**Figure 77. Hygger med gaver til mors dag ("Hygger" with presents at mothers day)**

**Figure 78. Vi ser badehotellet (We're watching badehotellet)**

**Figure 79. Hygge med bog og the ("Hygge" with a book and tea)**