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MASTER THESIS

DEDICATED AMBIENT DISPLAYS

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Abstract

The creation of Dedicated Ambient Displays (DADs) is a relatively new topic. A DAD is a device that displays a single value of information in the environment of the user. While some inquiries have been made, the best practices of designing such devices are not known. This study tries to add to that knowledge by designing two devices via a tinkering method and use an autoethnographic approach to evaluating them. The experience is then analysed to help in the development of a specification for a DAD toolbox.

Contents

Part I

Introduction

Chapter 1

Introduction

1.1 Introduction to this part

This section will explain the topic of this thesis, Dedicated Ambient Displays. The relevant concepts and state of the art will be discussed, after which hypotheses, research questions and goals of this project will be defined.

1.2 What are DADs

A Dedicated Ambient Display (DAD) is a physical object in our environment that displays a single piece of information from the internet. This is in contrast to many apps on a single device like a smartphone. As such they are a form of data physicalization.

A DAD can take any shape that is able to convey one datum (a single value) of data. This can range from a single bit of information to an entire aggregate number or numbers, as long as it represents one value. For example, whether or not someone on the internet is available for communication is a (single-bit) value. Values can also represent more abstract concepts such as moods, weather, financial information, etcetera.[16]

After earlier investigations of technological realization and conceptual design choices[23][13], this MSc project focusses on the experience through Dedicated Ambient Displays, their design and the process behind that.

1.3 Why are DADs potentially relevant?

We think DADs are interesting because:

- They can be characterized as a calm technology.
- They form a counterpoint to big data and/or web browsers everywhere.
- They adapt to the user.

1.4 Types of DAD

We postulate DADs can be subdivided in groups on two axes, according to the intended effects and intended audience.

1.4.1 Action requirement

- Informational DADs.
- Action invoking DADs.

The first group, informational DADs, are devices which intend to inform the user of something that requires no action. For example, a DAD that displays the amount of snowfall in your favourite skiing area. This information requires no direct action, even though an avid skier cares about it.

Action invoking DADs present information that requires an action from the user. This can be an action requiring immediate attention, or one that requires later attention. One can think of a DAD that displays when you should put your garbage bin next to the road so the garbage service can collect it (this happens on set days in the Netherlands). Or, a DAD that displays when you should water your plants. So, these DADs are in the background most of the time, coming to the foreground when needed.

An informational DAD is more likely to be ambient than an action invoking DAD. You need only consider the resentment people have for their alarm clocks (which require the action ”getting out of bed”) and the indifference they have to their wall clocks (which require no action) to see this.

1.4.2 Personality

- Group DADs.

- Personal DADs.

The group DADs audience is multiple people. It is intended to provide non-private information to an audience of multiple people. The data displayed can cover group activities (like the dangling string as described in the examples below), or otherwise only be relevant to the group it is intended for.

Group DADs can also display societal or global information. In this case, a DAD could be envisioned that displays a piece of data with the intent of inciting discussion. These DADs could be political statements, meant to effect societal change. However since it is more like a public art display, this type of DAD does not afford a lot of room for personalization.

The personal DAD displays a piece of data that is only meant for one person. Compared to the group DAD, this affords it a high degree of personalization possibility. It is a personal item, customizable to the users specific wishes and tastes.

1.5 Examples

The survey of DADs (called Single Value Devices) made by Mader et al.[16] contains a list of examples of these devices. A few have been reproduced here to illustrate the concept:

- The Dangling String[26] is an installation for an office environment. It consists of one and a half meter of plastic spaghetti hanging from the ceiling, mounted to a small electric motor. The motor is triggered by the activity on an Ethernet cable. A very busy network causes a madly whirling string with a characteristic noise; a quiet network causes only a small twitch every few seconds. Placed in an unused corner of a hallway, the long string is visible and audible from many offices without being obtrusive.

Figure 1.1: Dangling String

- Also for a working environment is the light installation of Gellersen et al. [8]. Posters of research projects on the corridor walls are illuminated by spotlights. The light intensity of each spot is determined by the number of hits on the corresponding project webpage over a period of time.

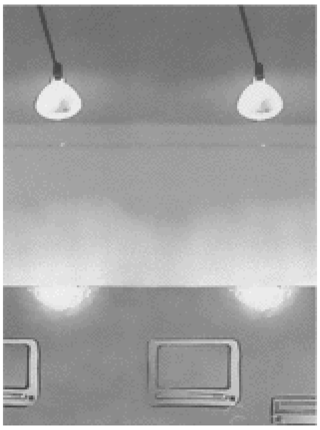

Figure 1.2: Ambient Lamps

These two are perfect (although old) examples of dedicated ambient displays. They display a single thing, do that in a way that allows a person to ignore it easily and at the same time allow for reading when wanted.

The current DADs are mostly prototypes, although some are for sale as a finished product. A few have been reproduced here:

- One such for sale product is the Ambient Orb[6]. It is a frosted glass ball with an RGB LED inside, able to connect wirelessly to the internet and display values such as windspeed, rainfall, traffic and stock prices.

Figure 1.3: Ambient Orb

- Another such product is the Power Aware Cord[1]. This is an extension cord on which strands of illuminating wire are wrapped helically. By alternating the light in the strands, an illusion of flow is created. The flowing effect increases in speed when more power is being used. This allows for someone to see their power use, and thus work to reduce it.

Figure 1.4: Power Aware Cord

- The last example we would like to show is the study by Occhialini, et al[18]. They used light to show peripheral information in working environments. Specifically an ambient display to help with time management during meetings by using beams of light.

Figure 1.5: Ambient meeting time manager

1.6 Concepts

1.6.1 Foreground/background model

The foreground/background model in telematics[5] is a model proposed for classifying systems according to where they are handled in human consciousness. For example, talking on the phone is a foreground task, it takes your focus. Hearing someone talk on the phone in the next room is a background task, it is easy to focus on something else (in the foreground) while still noticing the conversation taking place in the next room.

DADs should generally reside in the background, unless they need to come to the foreground for a specific purpose. This should allow for a more ”natural” perception of the information to occur. Since each device encapsulates one piece of information, there is (should be) no ambiguity what is being communicated when you interact with the device.

1.6.2 Calm Technology

A technology is calm when the interaction between it and the user is made to occur in the periphery of the user's attention (as opposed to the center of attention, like a desktop computer). In the increasingly connected world, we are in danger of focussing too much on our devices instead of other things. The ambient part of dedicated display indicates that DADs are supposed to be a calm technology as described by Weiser and Brown[26].

Phrased in the foreground/background model discussed above, a DAD should remain in the background unless the current information it displays require it to enter the foreground.

A device should not be so calm as to be invisible. The perceptibility of a DAD is expected to influence how noticeable it is. Depending on the goal of the DAD, this can vary in importance. For example in a coaching DAD (that helps the user adopt a new habit or break an old one), perceptibility is very important.

1.7 Hypotheses regarding concepts

1.7.1 Personal relevance

We expect customizability and the selection of ”personal” data (data the user cares about) by the user will help the device capture the users attention better when it is needed, without being intrusive.

1.7.2 Cockpit effect

The cockpit effect could arise when too many devices are in a users environment. Instead of offering a calm way to information, the environment would look like the cockpit of an aircraft – lots of gauges, lights, and displays. We expect that there is a limit to how many DADs can be present in an environment while still providing a calm way to offer information.

1.8 Design concepts

1.8.1 Designer as evaluator

The classical design approach is, in rough steps: A user need is given to a designer, who will turn it into a product which is then evaluated. This is not fine-grained enough. The step from user need to product is an iterative process (the specification phase in the design process) where evaluation and prototyping alternate in a cycle. This needs to be sped up for a field that is somewhat unknown like DADs.

Some parts of the design space are investigated, such as tools and hardware available. However, the overall design space is still unknown. Due to this we concluded that introducing test subjects at this juncture is premature. We do not even know if devices like this work, so we should examine that first. Therefore, it was chosen to have the designer as evaluator. This allows us to rapidly test prototypes and evaluate them, in a tinkering approach.

Secondly, since the designer of the DAD is also the user this should also increase the personal relevance of the device. The user can design their own data and display, instead of utilizing less relevant generic data sources and display solutions.

This approach of analyzing personal experience is similar to an autoethnographic study. Autoethnography is an introspective technique that examines the self as the object of research. For an overview of autoethnography, see Ellis, Adams and Bochner[7].

1.8.2 Autoethnographic study

Autoethnography has become an increasingly popular form of qualitative research, commonly used in the social sciences and humanities. It is a method of research where self-observation and reflexive investigation are used to address an issue.

The intent is to acknowledge the link between the personal and the cultural. The traditional scientific approach requires researchers to minimize their impact on the study, but this is not desirable or even possible when researching the self[25]. Instead, autoethnography puts the researchers subjectivity in the foreground.

Anderson[3] has proposed a definition of this type of study named analytical autoethnography. In this type of study a researcher who is a complete member of the group or social world that's researched, analyses the group or the interactions reflexively. As a method for social study it is not completely applicable to this type of study, since a DAD does not have to include a social world. However, the analysis is similar in the researcher's awareness of their connection to the research and their effects on it.

The researchers own feelings and experiences are incorporated in the study as valuable data. In this study, that data is used to rapidly iterate on DAD concepts to roughly and efficiently reduce the design space of the DAD.

This study differs from an analytic autoethnography in that there is no dialogue with informants beyond the self. This is normally done to get a complete and fair view of the social world under study. However, since this study contains a social world of one (the sole user of the DAD), it can not be included.

However, the findings from a qualitative study like autoethnography can be applied to a group of people who are similar to the designer in the aspect that they also care about the data selected. In other words, a bigger audience can be found for a good DAD.

If that audience agrees to a study, the results gathered from the autoethnographic approach can then be tested as hypotheses.

1.8.3 Tinkering

”Tinkering often has the reputation of playing around without plan” [12], however we argue that tinkering is a great way to explore an idea space. When the exact goal is unknown, the best option is to start working in the general direction of the goal, and see what challenges appear. In this context, the tinkering approach is a way of exploration, where the object of tinkering is not only the hardware but also concepts. Observations of the designer lead to improvements in this stage, where the designer is also observer and evaluator. Next to the exploration of the design space, goal of this stage is to identify conceptual flaws.

There is a similarity with the Scrum approach of software engineering, in which a team ”delivers products iteratively and incrementally, maximizing opportunities for feedback”[24]. Tinkering follows a similar methodology of iterative and incremental development, with the feedback being applied to improve the concept (the data), the design, and the implementation.

This study uses this tinkering approach, where through iterative refinement an increasingly clear picture of the design space and concepts is developed. This approach is also used in the design of the DADs themselves, as will be described in the parts concerning the DADs.

1.8.4 Toolbox

The DAD toolbox is a concept of all off-the-shelf technology, building blocks and methods that are available. This toolbox (not necessarily a literal toolbox) can then be used by a designer like one would use a box of building blocks – parts to be used. Items like Arduino's[1], various sensors, and cables are part of the toolbox, but so are things like 3D printing and laser cutting.

While initial inquiries have been made into the toolbox by Kolkmeier[13] and Smit[23], no complete toolbox exists.

Smit's work defined requirements for a toolbox that is based on (and extends) the Arduino microcontroller platform. It specifies properly documented example code, manuals, building blocks in categories (such as Power, Sensing, Communication, and Casing), and inspirational tools (examples of DADs, design practices).

Kolkmeier's work focussed on simplifying the procedures of connecting devices to the internet and communicating with/over the internet. A sort of DAD router-gateway was developed, a device that connects to the local network that DADs can then wirelessly connect to. The router handles internet communication and routes requests to remote DADs or data from web services.

It would be good to know if such a toolbox is a worthwhile addition to the field, and if so what would need to be added.

1.8.5 Justification of design method

There are many design methods. The tinkering design method applied in this project is used because it can rapidly identify and fix problems with a given design. The downside is that the end result can be somewhat haphazard. A more traditional design method like the waterfall model is too rigid in its reliance on sequential design. That is, in the waterfall model progress steadily flows one direction: first requirements are specified, a design is made, the design is then implemented and tested. For a device with many unknowns this is unsuitable.

This means the concept is final when the implementation design starts, where in the tinkering design method even the concept can be iterated upon.

1.9 Research Questions

The following research questions were defined:

Design steps Which generalizable design steps and patterns can we extract from designing DADs?

Toolbox Is a toolbox of DAD parts a worthwhile addition to the field? If yes, what can we add to it?

Designer as evaluator Is a designer as evaluator a valid way to develop DADs, and if so what are the limitations?

In addition to these research questions, additional ones will be formulated for each device. Those are reproduced in the sections on the two devices.

1.10 Goals of this project

The goals of this project are:

- Explore possibilities for DADs by taking on two cases.
- Contribute to toolbox development.
- Reflect on lessons learned to generalize to other DAD designs.

Each item will be explained further in the following sections.

[1] https://www.arduino.cc/

1.10.1 Explore possibilities for DADs by taking on two cases

We decided that the best course of action would be to develop two devices and investigate the process and the products. To generate concepts to eventually pick two devices, a brainstorm was used. Forty ideas were formulated in this brainstorm, which were then scored on five factors. The factors are *realisability*, *personal relevance*, *general relevance*, *frequency* and *originality*. The complete brainstorm list can be seen in appendix A.

Realisability is whether or not the device can be built in a short amount of time on a small budget.

Personal relevance evaluates if the device is relevant to the designer (i.e. the author of this report).

General relevance evaluates whether or not the device could be relevant to society as a whole (or at least a significant part of society). This differs from *personal relevance* in that things that are relevant to an individual are not necessarily relevant to society.

Frequency considers whether or not the thing to be displayed changes frequently enough to warrant using in this project. For example, current seat distribution across political parties in the Dutch Parliament is not an acceptable unit of information since it should only change once every four years.

Originality considers whether or not a device is a common idea.

Ideas that scored a pass in at least four of these five categories were considered further. The idea of water usage at a house (scoring pass on all five) was the first to be considered further. After iterating on it, the idea was changed and implemented as the Peace of Mind Flower described in Part II. The idea of a different take on an RSI prevention system (also scoring pass on all five factors) was chosen for the second device. This idea was changed in scope to include a novel way of attempting to measure RSI: an *electromyograph*.[2] This RSI prevention device is described in Part III.

1.10.2 Contribute to toolbox development

The concept of a DAD toolbox can be expanded and tested. By using items that could be toolbox and evaluating our experience, we can provide feedback on the usage and implementation of a toolbox.

1.10.3 Reflect on lessons learned to generalize to other DAD designs

After the design of any product, the design process can be evaluated and lessons learned can be extracted. The lessons learned from the two devices we developed might be generalizable to more DAD designs, which would help others not make the mistakes we might make.

1.10.4 Evaluate designer as evaluator

An important part of the process is using the designer as evaluator. We will evaluate the pros and cons of this method of design.

1.11 Conclusion to introduction

This concludes the introduction. The rest of the report will describe the two implemented devices, starting with the first device.

[2] In layman's terms known as a muscle tension sensor.

Part II

Device 1: Peace of Mind Flower

Chapter 2

Introduction

This part of the report describes the implementation and evaluation of a Peace of Mind flower, a device which can be used to assure next of kin of the wellbeing of a family member. The part will describe, in this chapter, the goals of the device and the research questions used. Chapter 3 will describe the technical implementation and physical design of the device. Chapter 4 will describe the evaluation of the device and the methods used.

2.1 Why a DAD?

The author's grandmother lives alone and her wellbeing is of some concern. There is a point in someone's life that they're no longer able to live alone any more, however it is desired to delay that as long as possible in accordance with their wishes.

Elderly persons with signs of dementia may be liable to reverse day-night rhythm (waking up at 3AM, going to bed at mid day). As a relative, the author would like to be reassured that she is still capable of living on her own. At the same time it is recognized that she is still her own person with a right to privacy. Any system should find a balance between those aspects.

Given the strong lean towards privacy, we think the limited information capacity of a DAD is very useful in this scenario.

2.2 Goals

The grandmother is the *subject* of the system. The *user* of the system is the grandmother's family. The goal of the system is to provide peace of mind to the user, by sensing the presence of the subject and matching behaviour to a ruleset to come to a conclusion of well-being of the subject. This conclusion is displayed in an ambient fashion to the user.

We hope that this will lead to an increased peace of mind in the user.

2.3 Research questions

The following device specific research questions have been defined:

Design What are the steps taken to design this device?

Peace of Mind Does this device provide a measure of peace of mind to the user?

- **Safety** Does this device afford an increased feeling of safety to the user?

- **Contact** Does this device cause increased contact between subject and user?

Chapter 3

Implementation

3.1 Technical overview

This device can be broken down into two broad parts. A measuring part, and a displaying part. These parts are geographically separated and communicate via the internet.

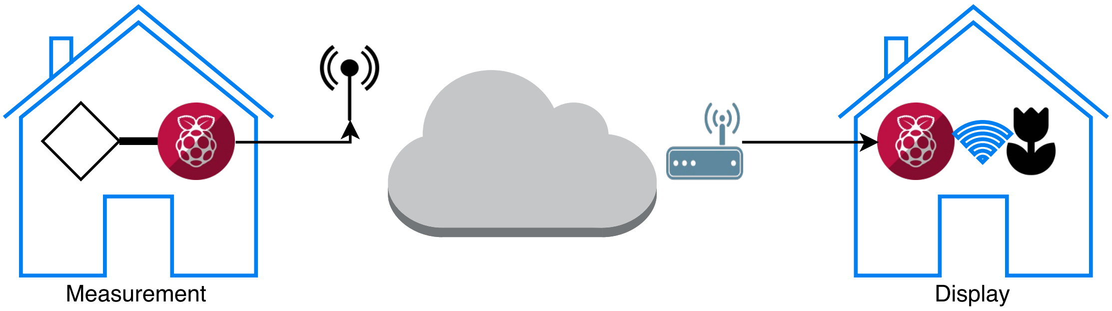

Figure 3.1: Device 1 design diagram

The measurement part consists of a measuring device (a Youless energy meter), a small computer (Raspberry Pi) and a 3G modem dongle (KPN 3G Dongel). This part is responsible for measuring the energy use, applying the processing to come to a conclusion. It is also responsible for keeping open an encrypted connection to the display and sending the conclusion.

The display part consists of another small computer (Raspberry Pi) to receive the connection from the measurement part and to send it along via WiFi to the microcontroller (Arduino Uno) with WiFi adapter (WiFly), which controls the display.

This setup was chosen due to practical constraints. In the following sections the choices made will be explained.

3.2 Measurement device selection

Different energy measurement options were considered. The devices were evaluated on:

1. Ease of installation.
2. Resolution of measurement.
3. Price.

Broadly speaking, there are four classes of energy measurement devices:

1. Plug-between meters, which are put between the plug of a device and the wall socket.
2. Energy company meters, which is reading the digital meter the energy company installed.
3. Clamp meters, which clamp around one core of a wire and measure magnetic fields.
4. Optical meters, which use a sticker to adhere to an old spinning-disk type meter.

The device chosen was a sensor that reads the spinning-disk meter that the energy company uses, called a Youless sensor. A more thorough examination can be found in Appendix B.

3.3 Measuring system setup

A Youless energy monitor is connected via Ethernet to a Raspberry Pi (RPi for short). This RPi is equipped with a 3G USB dongle which it uses to connect to the internet. The RPi also runs the Python code that collects and analyses the data.

Since the mobile internet provider uses Carrier Grade NAT or something like it (meaning we cannot initiate a connection from the internet), we have to let the RPi initiate the connection. The RPi connects via a secure shell (SSH) to another RPi and sets up an encrypted tunnel the data can traverse. A cleaner solution for this would be a VPN, but the automatic SSH setup serves for this prototype and was fast to implement. The measuring RPi also is in charge of keeping the SSH connection alive, restarting it when needed.

This setup was chosen because it is cheap and works even in homes that do not have a fixed internet connection (such as my grandmother's).

3.4 Disaggregation

Energy disaggregation is the act of taking an aggregated energy signal, such as this whole house energy meter, and breaking it down into individual appliances. It is sometimes called non-intrusive load monitoring [10]. A lot of work has been done in this field, but so far it only works on high resolution (multi-kilohertz) voltage and current analysis. Since we do not have access to voltage (V) or current (A), but only its combination for a specific duration ($V * A$ for x seconds, which is a slightly convoluted way of saying Joules or Watt-hours) at low resolution, these methods are not an option.[1]

Completely disaggregating this data is tricky without knowing exactly what kind of devices my grandmother has, and their actual (not stated on the sticker) power draw. However, we do not care about some of the devices in her house because they operate autonomously (such as central heating system or the refrigerator). This means the requirements can be relaxed somewhat.

The point of this disaggregation is to give some kind of indication that my grandmother is alive and well. Things that might indicate she is alive and well:

- Coffee maker or water cooker.
- Television.
- Washing machine and clothes drier.
- Lights.

Some of these are high drain loads and easy to measure (the coffee machine and water cooker use a lot of electricity, on the order of 1 to 2 kilowatt, as does the washing machine). The TV and lights use less electricity, and because they have similar power draw are harder to distinguish.

Some of these devices have a mostly fixed power draw. The water cooker and coffee maker draw a fixed amount of energy per second (Watt) until the water has heated up and the device switches off (and pumps the water through the coffee pad). The washing machine has a few distinct phases, heating water, normal cycle, spin cycle. The water heating phase and the spin-dry cycle probably use the most power of those.

The TV uses a mostly fixed amount of power until it is switched off (she has a cathode ray tube or CRT TV, which uses more power displaying a white image than a black one[2]).

Depending on the time of day and ambient light (due to time of year, cloud cover and the like), different combinations of lights might be on, making it harder to distinguish between lights and the TV.[3]

3.4.1 Distilling information

Distilling which device is on gives great information on the state of life of the resident of a house. Devices that are known to only change state on human input (like an electric kettle) must be triggered by the inhabitant of the house. From this information, a reasonably accurate picture of the lifestyle of a person can be made.

But, distilling which device is on is a hard problem, as stated in section 3.4. It should be possible to detect with high accuracy the use of high draw equipment, i.e. all the devices which heat things. The TV might be detectable because it uses a constant amount of power. The problem lies in when devices are switched on at the same time (that is, within the same measuring tick). When that happens, it is impossible to know which devices switched on.

So, a reasonable next step would be to only try to distil the information for a few devices of interest.

[1] If interested, the papers *Energy Disaggregation via Discriminative Sparse Coding*[14] and *Using hidden markov models for iterative non-intrusive appliance monitoring*[20] are interesting takes on the problem.

[2] http://www.scientificamerican.com/article/fact-or-fiction-black-is/

[3] Is that 120W load two 60W lightbulbs, or is that the 120W TV?

Distil for a few devices

Unique high-draw devices should be easy to detect. We can look for a 1450W spike in power use and assume with high confidence that it is the coffee maker (and not the lights and TV). Doing this we can define a few common use devices we can look for.

This can be expanded with a machine learning technique to include more devices. Parson, Ghosh, Wheal and Rogers tried this but got less than satisfactory results[20]. This method, however, requires high resolution data which is not available from the chosen monitor.

In the end, we do not actually need to know which devices are on to provide an alive-and-well assessment of my grandmother, which we will describe in the next subsection.

Do not distil, use changes and history

By assuming changes in power draw are generally due to human activity, we can give an indication of well being by looking for those changes. Different time frames should have a different effect on the indication though; while turning everything on in the middle of the night does mean my grandmother is alive, it does not mean she is well. The downside of this are ”intelligent” devices, that switch themselves on and off when needed. For example, refrigerators don’t run the cooling system all the time. It is switched on when the contents of the refrigerator are too warm. This is a change in power draw, but it is not caused by human activity.

3.4.2 Rules system

It was decided to set up a simple rules system to generate fitness conditions. To facilitate this, one week of measurement data was combined with the weekly schedule of the participant. These rules are outlined here:

Morning There should be at least one use of the coffee machine in the morning to indicate waking up. This should occur between 6:30 and 10:00. The coffee machine uses approximately between 1000W and 1500W without interruptions.

Daily activity There should be a higher average power draw during the day. This would indicate lights or the TV being on, amongst other things. However, this is not a reliable measure. For example, during the summer time the lights and TV might be off because the weather in the garden is so nice.

Nightly (lack of) activity The nightly activity should be very low, with exception of activity that can be attributed to the washing machine or clothes dryer, which are on timers to run during the night when energy is cheaper.

More rules were considered, but were ultimately discarded. The discarded rules had the problem of not being universally applicable due to being only valid on certain days or measuring the results of actions someone or something else does for my grandmother.

3.4.3 Re-aggregating

The rules each provide an output, which is assigned a severity level in accordance with the daily plan. My grandmother makes either coffee or tea when she wakes up, so her not making a warm beverage is a cause for alarm. However, a lack of daily activity does not need to be cause for alarm. She might just be out of the house.

The system assigns each rule a proportional severity level which sum to 1. The system adds the severity levels for each rule that is unbroken, which is then converted to the percentage that the flower should close.

This way, ”breaking” one rule does close the flower somewhat, but not all the way. Only breaking all the rules makes the flower close completely.

3.5 Physical design

3.5.1 Display device design

For the display, a plastic flower-like object which can open and close its petals using a servo motor was chosen. This flower was designed by Jan Kolkmeier. The flower was equipped with an RGB LED in the pot so it can glow in colors. An Arduino with WiFly shield is used to control these functions. The flower was put into a terra cotta flower pot. The flower opens and closes by set amounts according to which rules are satisfied at the moment. This flower is pictured in 3.2.

Figure 3.2: Flower Pot DAD

The electrical design is reproduced in Figure 3.3. It includes an RGB LED for lighting, a photo-resistor so the lighting can be adjusted to ambient light and a servo to move the flower petals. Also pictured is the WiFly shield used for Wi-Fi communication.

3.5.2 Directionality of communication

The entire system is unidirectional. That is, there is no communication afforded by the system which does not go from the subject to the user. A bidirectional system would require teaching subject a new device which is impossible in this case. However unidirectional communication does not always have to be the right choice. In a situation where the subject is able to learn a new mode of communication, a bidirectional system might open up new possibilities.

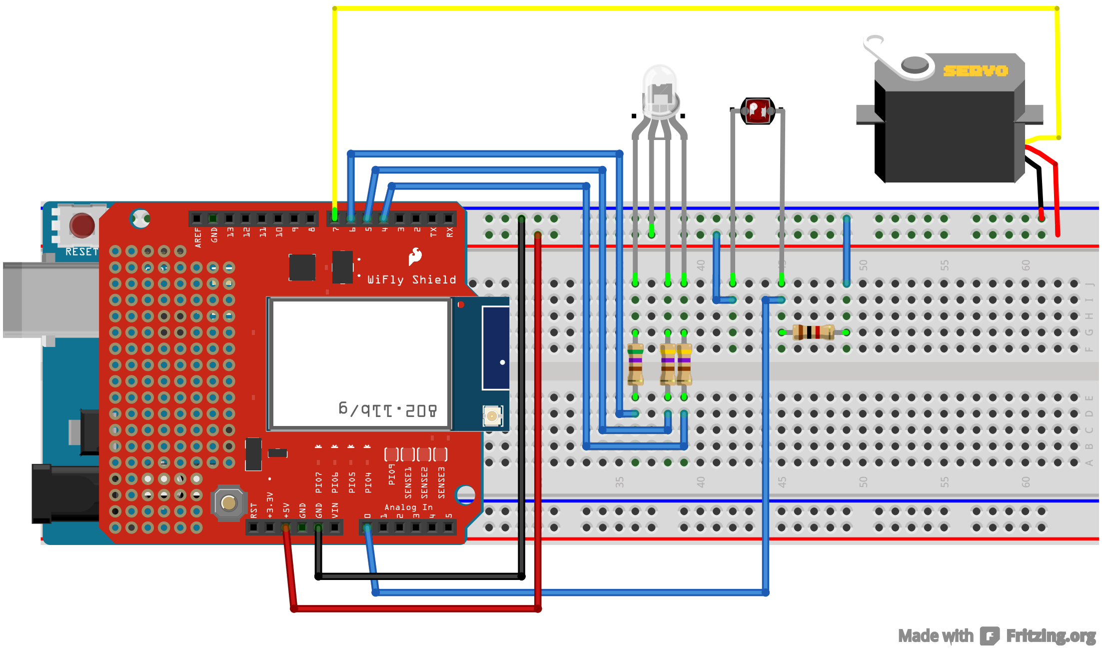

Figure 3.3: Breadboard layout flower

Chapter 4

Evaluation

4.1 Method

A diary study method like the one outlined by Rieman[21] was used. Three times per day a questionnaire form on the experiences with the device was completed by the author.

4.1.1 Questionnaire used in diary study

The questionnaire is reproduced in table 4.1.

Question 1 tries to measure the effectiveness of the DAD, which can be used to determine if the device is attracting enough attention but not be intrusive. That is, it can be used to measure if the dedicated ambient display actually is one. Questionnaire questions 2 through 7 try to find answers to the research questions. The numbers between the two extremes are a Likert scale[15].

The questionnaire was taken for 1 week before the device was operational, skipping the questions about the device itself (question 1(a) through 1(h) and question 3). Then, the questionnaire was taken for 1 week with the device active. This will allow us to measure the impact the device has.

1. What do you think about the device								
(a) Unhandy	1	2	3	4	5	6	7	Handy
(b) Irritating, disruptive	1	2	3	4	5	6	7	Pleasurable
(c) Hard to read	1	2	3	4	5	6	7	Easy to read
(d) Background while no attention required								
No	1	2	3	4	5	6	7	Yes
(e) Foreground while attention required								
No	1	2	3	4	5	6	7	Yes
(f) Ugly	1	2	3	4	5	6	7	Beautiful
(g) Unreliable	1	2	3	4	5	6	7	Reliable
(h) Do you think the device fits in your environment?								
No	1	2	3	4	5	6	7	Yes
2. How do you think your grandmother is doing?								
Bad	1	2	3	4	5	6	7	Good
3. Look at the device. How is your grandmother doing?								
Bad	1	2	3	4	5	6	7	Good
4. What feeling does thinking about your grandmother evoke?								
(a) Concern	1	2	3	4	5	6	7	Safe
(b) Sad	1	2	3	4	5	6	7	Happy
(c) Unconnected	1	2	3	4	5	6	7	Connected
5. Since the last time you answered this questions, how often have you thought about your grandmother?								
6. Since the last time you answered this questions, how often did you have contact with your grandmother?								
7. Since the last time you answered this questions, how often has your grandmother been the subject of conversation in the family?								

Table 4.1: Questionnaire

4.2 Questionnaire results

Two series of questionnaires were taken, described in section 4.1.1. One before the device was introduced, one after. The series that was taken before shall be used as a baseline to compare the device to. This will not apply to questions 1 and 3, which do not apply to a situation without the device. These device specific questions will be discussed after the next subsection.

4.2.1 Before and after

In this section the results of the questions that could be answered both before the device was introduced and after will be discussed. The results are displayed in table 4.2 on page 29.

Question	Before	After	Relative change
1(a) Handy		5,86	
1(b) Pleasurable		6,14	
1(c) Readability		6,57	
1(d) Background		6,52	
1(e) Foreground		4,86	
1(f) Beautiful		5,52	
1(g) Reliable		5,57	
1(h) Fits environment		5,95	
2 Blind view	5,50	6,05	
3 True view		6,19	
4(a) Safe	5,15	5,67	+10,0%
4(b) Happy	4,96	5,81	+17,1%
4(c) Connected	4,42	6,14	+38,9%
5 n Thoughts	0,69	0,48	-30,4%
6 n Contact	0,08	0,24	+200%
7 n Conversation	0,35	0,29	+17.1%

Table 4.2: Questionnaire results device 1, averaged

In relation to before the results after show an improvement to question 2 (How do you think your grandmother is doing?). A change in this question implies that the idea of well-being was updated. That is: a change here, positive or negative, implies that the device at least influenced the connection between examiner and subject.

Question 2 can also be compared to question 3 (Look at the device. How is your grandmother doing?), where a small improvement was noted. This implies that seeing the device gives a positive sense of safety or security.

Improvements were also noted in 4(a), 4(b) and 4(c) (all three are questions about what feelings occur when thinking about the grandmother), meaning the feelings asked about were more positive. This is expected given the small improvement seen in question 3.

A decline in the amount of times the grandmother was thought about (question 5) was observed. But, in improvement was seen in the amount of contact between grandson and grandmother (question 6). At first glance the decline in question 5 seems unintuitive, but can be explained by that a contact is always preceded by a thinking-about. Each instance of contact was only counted as a contact, not as a contact and a thinking-about. A second factor in this is that it is very hard to accurately keep track of one's thoughts. Not noticing thinking-about could be very common.

Question 7 (which is about how often the grandmother was the subject of conversation between the examiner and family), showed no change. This seems logical given the parameters of examination. Family were not notified when questionnaire surveys were taken. Since the grandmother was doing well during the survey, there was no apparent reason to talk more about her.

4.2.2 Device specific results

In this section, the answers to the device specific questions will be discussed. Since they are not comparable to a situation without a device, they will be considered as is. Within-group comparable questions (like the questions on foreground and background) will be discussed.

The device scored good on question 1(a) through 1(c) (it was handy, pleasurable and easy to read). This indicates that the chosen form of the device (flower in a pot, on a desk) was not wrong.

Strong results were also shown in the 1(d) (background when unneeded) question, but there was a poorer result in 1(e) (foreground when needed). This indicates that the device was unobtrusive when not needed, but was less good at grabbing attention when something did arise. That can partly be explained by the aim of DADs in general, they should not disturb the user with an alarm but notify them when they do happen to look at them. This does imply that safety-of-life medical systems or even systems like this where one wants a somewhat timely notification are less fit to be made into DADs.

Questions 1(f)(Is it beautiful?) and 1(h)(Does it fit the environment?) are very personal questions, more so than the others. The device did score high in these regards, but it has to be noted that other people might think it is very ugly or looks out of place. In this regard, a DAD is a very personal item.

The question on reliability (question 1(g)) shows a strong average score, with two outliers on days the system failed in some aspect. Knowing that the errors causing these failures had been fixed, the reliability score went back up the next day. However, a user who is not also the designer or operator of this system could have their trust in it irreparably damaged. From this, we deduced that it is very important for a system to include a sign-of-life signal. This sign-of-life signal will be discussed in the next section.

4.3 Tinkering design process

As stated in the introduction, this device started out with the concept of measuring water use. After brainstorming (a design iteration) the concept was changed to electricity use. The idea then came up that this data can be used to make estimations of daily life patterns, after which the idea was formed to use that for a good purpose. The peace of mind datum was thus created.

The measurement part was implemented first. A solution for measuring was found, bought and tested. Then a display was made, connected over a local area network via WiFi. The next iteration was spent on forming end to end communication over the internet. The project was then installed and put into testing. The goal of this test was to measure energy use on site and create a viable rule set to generate a single value for the display. A second iteration was spent to investigate more accurate measurement options, for example using a Hidden Markov Model, but the idea quickly proved not viable due to the measurement system implemented.

The device was then evaluated with a diary study. After a while during the study, it became known that over longer periods of time the end to end communication would fail silently. This was solved by implementing auto-reconnect and giving a sign-of-life signal (and the results from the study so far were discarded). The signal was implemented as a LED illuminating the flower from below. After one night, it was discovered that a brightly glowing light at night was annoying, so a photo-resistor was introduced to lower the intensity of the LED in low light conditions.

This project would have been very hard to complete in a non-tinkering model. During the tinkering phase key knowledge was gained in areas that were unknown to the designer. This would make an a priori design in need of redesign when an issue was encountered. The concept of the device also changed in the initial iterations, which in a more traditional design model would mean a longer idea phase with research.

4.4 DAD design (toolbox)

Several items from the DAD Toolbox were used to create this device. Arduino, Raspberry Pi, servomotors and LEDs are possibly the most popular DAD toolbox items. However, the combination of these things proved to be harder than anticipated. A lot of time was spent writing and debugging interfacing logic to interconnect these devices. The setup described in Section 3.3 took a lot of trial and error to develop, especially the part involving the connection between the two halves of the system. This connection crosses the internet, which brings with it all kinds of possible failure modes that have to be handled gracefully.

The problem lies in the fact that while these items can be made to be interoperable, the DAD builder is tasked with making sure that this is done correctly, handling all edge cases.

A solution to this would be to create a literal toolbox of items that are guaranteed to work together. This could be compared to an integrated toolbox like LEGO Mindstorms However, part of the advantages of loose components is that the designer is able to create DADs in whatever form factor they choose. Due to the scope limiting nature of an integrated toolbox, it would also likely limit the possible devices that the toolbox can be used to create. Therefore we think it would not be in the best interest of the DAD toolbox to create a Mindstorms-esque integration. However, we do think that a software library that handles communication between DADs over the internet would be a very welcome addition.

This software library should handle the set-up, upkeep and tear-down of a uni- or bi-directional connection between two systems, gracefully handling things like network change (moving from WiFi to mobile data), devices running out of battery power or otherwise being unable to communicate (auto reconnect, and notify other end that connection has failed or re-established).

Since these requirements should not change much between different types of DAD, this is a prime area to create a reusable library for. The toolbox should then also include basic information on networking, but not go in depth in technical details.

4.5 Ethical evaluation

This device has quite a few ethical questions that need to be answered. Not only in the scope of this implementation, but also in the wider scope of these type of devices.

4.5.1 Who has access?

Energy use data can say a lot about a person: depending on the resolution of the data it can for example be used to determine if the person is at home, how many people live in the home, their level of religious observance, to what content the TV is displaying[9]. Thus this data should be considered private.

The measurement device we use has a very low resolution so we can not distil exactly which devices are on at any given time. Regardless, the information gathered is solid enough to provide a home/not-home assessment and this could be (mis-)used by third parties. For this reason, the Secure Shell protocol (SSH[1]) is used for all communication between the measurement setup and the display since this data travels over the internet.

Even though the communications channel has been secured against eavesdropping, it is still necessary to ask for permission to use private data under Dutch law.

Consent was given by my grandmother to measure her home energy use.

4.5.2 Expectations and behavioural freedom

In a more general sense, these types of devices can cause ethical issues. In a meeting with Dr. J. Soraker of the Department of Philosophy at the University of Twente[19], the following effects were identified.

Firstly, they can influence behaviours to fulfil expectations. That is, due to the subject knowing the device is installed that person might change their behaviour (sub-)consciously to match the perceived notion of what is expected of them. For example, making coffee when she is really not in the mood for it just to satisfy the device's rules.

The inverse of this effect can also come into play. A subject could decide to not do some task, because that will make the device give a warning and that in turn will make their loved ones call them. Care should be taken that this device does not replace human contact.

The point is that behaviour can be influenced in two directions:

- Doing things people otherwise would not do.
- Avoiding things they actually would like to do.

This effect can not be removed, but it should be considered in the design.

Secondly, the subject also has a right to privacy and it is reasonable to assume that a situation where this is needed can arise. My grandmother might be meeting someone she does not want her family to know. For example, a doctor's appointment should always be a private affair by default, where third parties are only notified of or invited to with the patient's consent.

Care should also be taken that such a system does not do more harm than good in the sense of habitual contact between the two parties. The family could feasibly replace visits and calls with this system, and both parties would be worse of for it. A device like this is also inherently unreliable, even if it does improve the feeling about the status of the elderly. This unreliability stems from the fact that the device is not measuring the well-being of the subject directly (which, if not impossible, is very hard). Therefore, it is possible for the device to signal all is well, while in reality something is wrong because it is invisible from the perspective of energy use.

Thirdly, this device is no solution for someone who is incapable of living alone. The improved feeling of well-being the device affords can be misused or misread (by family or care workers) to allow the elderly to live alone for too long. In other words, it should not be used as a substitute for personal contact or care.

4.5.3 Ethical recommendations

On further development, this device should include a privacy mode. Perhaps a button that signals all is well for the next few hours, and then times out. This can then also be used in the case where all is well, but the programmed expectations of the device are not met. This solves two problems. The aforementioned problem of privacy, and also a case where (if the subject knows about the expectations of the device) a false negative can occur. The downside to a privacy button is that a person with Alzheimer's will most likely not be able to learn about and remember the privacy mode on the device.

A participatory design process is also recommended. This is a process involving all stakeholders, so everyone knows what the device does and does not do. This, however, is hard when the subject is elderly and symptoms of dementia develop.

For the issues discussed above (less personal contact, misuse as a substitute for care) there is no technical solution. The issue has to be discussed with all stakeholders and made explicit.

[1] SSH encrypts data end-to-end.

Chapter 5

Conclusion

5.1 Research questions

This section answers the research questions posited in section 2.3. The findings are summarized based on the evaluation done on the project in section 4.

Design *What are the steps taken to design this device?* The design was done iteratively, with knowledge of previous iterations applied to following iterations. As an example, a sign-of-life signal was introduced in a later iteration due to the device failing silently in a previous iteration. This would have been very difficult to foresee, so the iterative design was an advantage for this project.

Peace of mind *Does this device provide a measure of peace of mind to the user?*
The device did provide some measure of peace of mind to the user, however this can not replace the peace of mind afforded by a (relatively low-tech) phone call or a visit.

Safety *Does this device afford an increased feeling of safety to the user?*
A small increase in safety was experienced. This small difference can be explained by the fact that the device does possess a certain latency. A sudden fall and not being able to get up (outside the scope of this project, but inside the scope of the worry) would be detected with a significant delay.

Contact *Does this device cause increased contact between subject and user?*
There was a doubling of the instances of contact (it was not measured if the duration of contact changed). This can partly be expected due to the project causing more contact outside of the scope of a DAD. That is, a different non-DAD project involving a loved one would likely also have increased the amount of contact. It is not known if the contact would decrease to original levels if the DAD was kept operational indefinitely.

5.2 Whole device

At first the device suffered from the prototype effect. The first iteration had to be reconnected to power daily to reinitialize the Wi-Fi connection, and confidence in the rules system was not complete.

Trust in the data is a very important part of this DAD. Reduced user trust degrades the DAD experience. Instead of a calm technology, the DAD becomes a worrisome technology, where the user experiences stress about the functional status of the device (Is it still working?). Or the user starts to ignore the device (I don't care if it's working or not). The first option makes the DAD not a calm technology, the second makes the device unable to come into the foreground of attention when required.

To remedy this, the device was updated to include a sign of life signal. A sign of life signal is some kind of status indicator that all is well with the device. This removes the doubt that the device is malfunctioning when it is in a given state for extended periods of time. This is especially important in the given case. One would hope their grandmother is well. However, the mere presence of this device made the author question his grandmother's well-being. That is, is she really doing well, or is the system malfunctioning somewhere? Instead of giving peace of mind, the flower on occasion gave the author more stress.

A recommendation pursuant to this experience is to make sure all networked devices include a sign of life signal. This signal could be implemented in similar fashion to a watchdog timer. This is a timer which shows a malfunction signal after a certain time. This timer should then be periodically reset by an other part of the system, travelling the same path as the normal data. If the data keeps coming in, the device is fine. If not, the watchdog timer will time out and show the error or reset the device. The designer should show the result of this watchdog/sign of life check to the user.

An iterative design and test-often design approach was found to be very helpful to developing this device. There are a lot of unknowns which can be corrected for in new iterations. This would have been harder in a classical design approach. The aforementioned sign of life signal was developed in an iteration due to experiences with previous iterations.

The concept of this device can be generalized to a larger group of people. Most of us, at some point, have someone we worry about. While the ideas of measuring electricity use and the display as a flower are in some degree personal, the concept itself can likely enjoy a bigger audience. The rise in use of smart electricity meters can open up opportunities for energy companies to allow others to analyse energy use data (with all the advantages and disadvantages that offers, see the ethical evaluation in 4.5). Done right (granting access to single devices only, revokability of access, privacy centric design), we think there would be a market for this concept.

Since the display needs only to show a 0 to 100% value, a lot of personalisation options are available for people who do not like plastic flowers. One can think of shining a (coloured) light on a memento of the loved one, for example.

5.3 Measurement subsystem

The measurement subsystem (a whole house electricity meter, described in section 3.2) was chosen due to the affordability and ease of install. However, more accurate measurements can be taken by appliance specific measurement. The implemented system suffered from having to disaggregate the measurement data and try to infer either a living pattern or what devices are on. This takes a lot of time to implement properly and should have been out of the scope of this research. Measuring a few appliances of interest gives a much more accurate result since irrelevant appliances (like the refrigerator) are automatically filtered out.

Part III

Device 2 RSI Prevention

Chapter 6

Introduction

This part of the report describes the implementation and evaluation of an RSI prevention device, which can be used to remind the user to adhere to a work rhythm that minimizes the chance of RSI. The part will describe, in this chapter, the goals of the device and the research questions used. Chapter 7 will describe the technical implementation and physical design of the device. Chapter 8 will describe the evaluation of the device and the methods used.

6.1 Why a DAD?

Computer work is a big part of many people's normal daily routine. Office workers, students, and gamers all spend long amounts of time interacting with a computer via mouse and keyboard. For a long time it has been known that this computer use can be a cause of RSI[4]. Henning et al.[11] and McLean et al.[17] found that 30 second breaks every 15-20 minutes throughout the day helped to improve worker well-being.

Existing rest-break software such as Workrave[1] use either a pop-up or outright lock the screen to remind the user to take a break. This can break the user's train of thought, reducing productivity. Using an ambient display to remind the user to take breaks might be desirable.

6.2 Goals

The system should remind the user, in an ambient fashion, to take work breaks after a certain amount of time.

It should not perform any action which draws immediate attention which could break the user's concentration on their task. Examples of that include: popping up a dialog window, locking the screen, or playing a sound.

6.2.1 Electromyography

Measuring mouse and keyboard input is an indirect measure of muscle use and does not measure all muscle use, so an *electromyograph* (EMG) system was used in addition to keystrokes and mouse movement.

Indications are that during continuous low-force contraction of muscles the same motor units are used repeatedly[22]. Or, as described by Lundberg[2]:

> Small, low-threshold motor units are recruited at low levels of contraction, before larger ones, and are kept activated until complete relaxation of the muscle. Long-lasting activation of these units may cause degenerative processes, damage and pain.

This implies that an EMG can be used to measure and prevent these effects.

This device can not take into account all of the issues that can arise from computer use, for those are too many and the scope of this device is too small. Factors that contribute to RSI symptoms that are not measured include posture or workspace set up such as desk height.

6.3 Research questions

The following device specific research questions have been defined:

[1] http://www.workrave.org/

[2] http://www.macses.ucsf.edu/research/allostatic/muscle.php retrieved March 6, 2017

Design What are the steps taken to design this device?

Duration Does this device help keep the correct duration of computer work?

Hindrance Does this device not hinder the user in their work?

Focus Does this device try to nudge the user's focus away from the screen?

Chapter 7

Implementation

7.1 Technical overview

This device measures the input device (mouse and keyboard) usage, and measures muscle tension via an *electromyograph* (EMG). An EMG is a system to measure electrical activity on the skin near the muscle (surface EMG) or in the muscle itself (intramuscular needle or wire EMG). Muscles contract by being subjected to electrical impulses from the nervous system, and those impulses are measurable. A surface EMG is non-invasive and thus does not require medical training to connect to the body.

7.1.1 EMG

A simple EMG system, the Advancer Technologies Muscle Sensor v3, was used to measure muscle activity. This device is a single-channel surface electromyograph, which works by measuring the electrical activity on the skin caused by tensing the muscle. It outputs an analogue signal which can be read with an Arduino's analogue input. To connect to the skin, foam hydrogel EMG/ECG snap on disposable electrodes were used.

To minimize electromagnetic interference, the cables to the electrodes were braided loosely so the ground wire is as close to the two measuring wires as possible. Even with this precaution, interference was still noticeable on occasion.

Two muscles were tried, the *extensor digitorum communis* (communal finger-stretcher muscle) and *flexor digitorum profundus* (deep finger-bender muscle). These muscles control the bending and stretching of the fingers (but not the thumb). Only one muscle can be measured at a time, and neither muscle show clear signs of increased tension when a feeling of exhaustion was created. The deep finger-bender muscle was chosen for measurement, for this is the muscle that is activated when the user clicks the mouse or types on the keyboard.

A system was devised where muscle activity spikes were detected. These were generated each time the difference between the current and previous measurements exceeded a certain limit.

This device has limitations. It smooths out EMG signals to provide an input a micro-controller can easily capture, which leads to decreased accuracy. The user manual shows how this is achieved[2]. It is outside the scope of this thesis to investigate further.

7.2 Input logging

An input logger was written to measure the keystrokes and mouse movements. It measures when the input devices are being used. It also collects the EMG data from the Arduino. This data indicates when the user is taking a break.

All input is captured and then sliced into 1 second pieces. If in a piece input above a threshold is measured, it counts as activity. Otherwise it is counted as rest. The threshold is only applied on larger mouse movements, so the mouse being pulled slightly by its cord does not count. The threshold is set at 10 pixels of on-screen movement of the cursor. The threshold value 10 was selected experimentally (by bumping the desk), and represents less than 1% of the shortest dimension of the monitor.

There is no threshold on keyboard use, i.e. all keystrokes are always counted.

7.3 Input aggregating

Depending on the study, different rules are proposed as to when a break should be taken. For the purposes of this project, the values proposed by McLean et al. were used[17]. These values are:

- Micro-breaks after 20 minutes of work.
- Micro-breaks last 30 seconds.

However, after initial evaluation it was found the 30 second break often occurred naturally. This resulted in the system never needing to alert the user to take a break. To remedy this, the break duration was set to 60 seconds. The rule system employed is a simple measure of activity and rest score and is outlined below:

- If activity is minimal (see 7.2), gain a rest point.
- If activity is severe, gain an activity point and set rest points to 0. Also add any accrued rest points to activity, so a very small rest does not count as a rest.
- A rest is suggested after an amount of activity points corresponding to 15 minutes of work are acquired.
- A rest is heavily suggested after an amount of activity points corresponding to 20 minutes of work are acquired.
- After a certain amount of rest points (60 seconds worth) are acquired, set activity and rest points to 0. Then update the score outlined below.

A score of activity duration was created to measure the influence of the program. When the user completes a rest, the score s (as described in the previous section) is calculated as following, where t is the amount of activity points:

$$s = \frac{\sum t^2}{\sum t}$$

The goal of this formula is to penalize lengths of activity that are too long. A lower score is better (units of work are the correct length or shorter). For example: user A and B both do 100 units of work. User A does it all at once, user B does 5 blocks of 20 units with breaks in between. User A receives a score of $100^2/100 = 100$, while user B receives a score of $5(20^2)/100 = 20$. Even though both users performed the same work, user B divided the workload better and received an appropriately better score.

7.4 Hardware

The device has been implemented using an Arduino Uno, an Advancer EMG module, two 9 Volt batteries and three 4N35 optocouplers.

Figure 7.1 shows the breadboard layout for this device.

7.4.1 Measurement setup

The EMG module used in this device outputs an analog signal between 0 and the input voltage which represents the electrical activity of the measured muscle. As an input, two 9 Volt batteries were used wired in a way to deliver -9V and 9V relative to neutral.

The Arduino sends the current EMG value to the controlling computer via USB at 20 updates per second.

7.5 Display

A digital picture frame was used to display photos chosen to convey a trinary status: All is well, you should consider stopping, stop as soon as possible. This device is pictured in image 7.2 on page 41. Via an Arduino and three 4N35 optocouplers[1] the buttons on the device (next picture, previous picture) can be pushed via software. Since this is not a high performance picture frame, care needs to be taken to give it enough time to load the next photo – button presses are ignored when it is loading in a photo. For photos that approximate the display resolution (about 840x400 pixels) a second of grace time is enough.

The same Arduino that takes the measurements is used to push the buttons. Care was taken to ensure that this did not impede the EMG measurement.

[1] An optocoupler or opto-isolator is a light emitting diode (LED) which operates a light sensitive transistor packaged as a single unit. By turning on the LED the transistor is activated. The two halves of the component are electrically isolated from eachother. It performs a similar function as a relay.

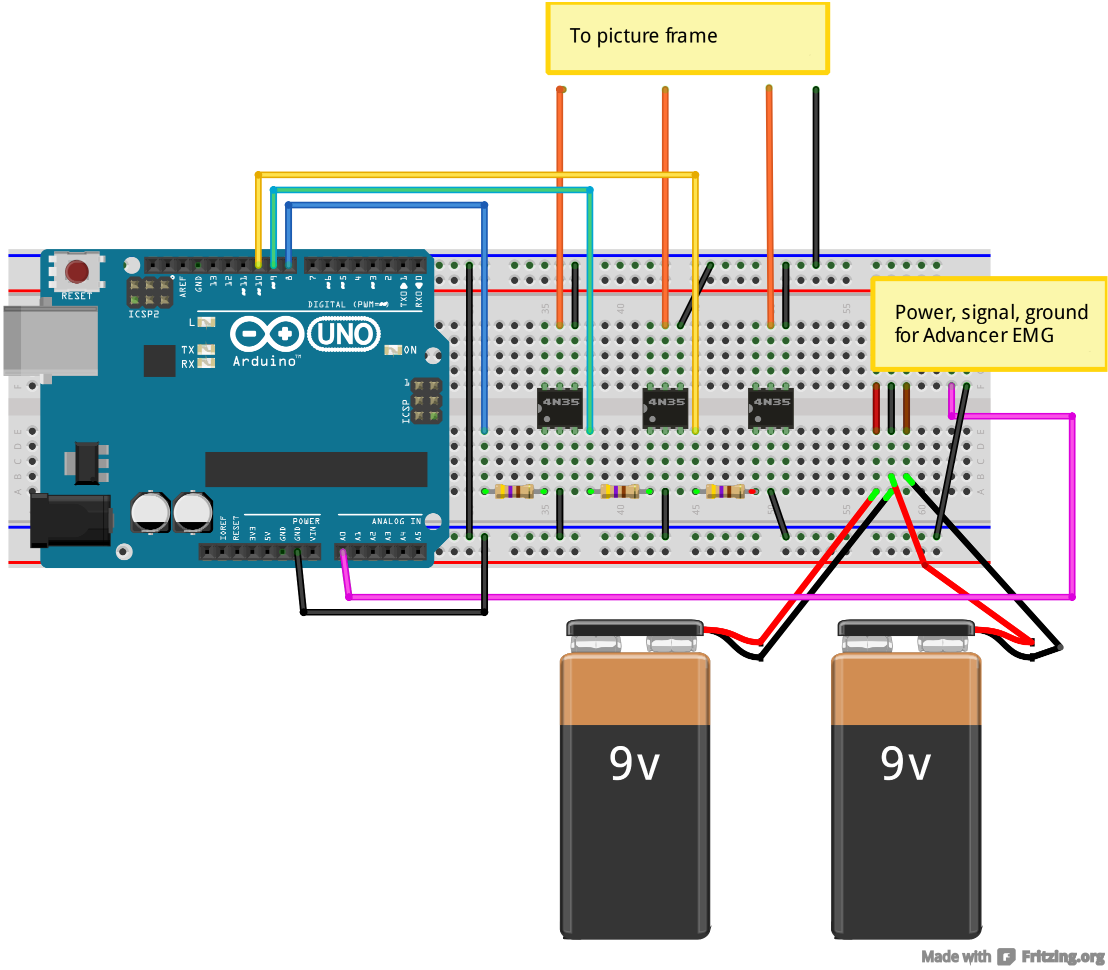

Figure 7.1: Breadboard layout RSI device

Figure 7.2: Digital picture frame

Chapter 8

Evaluation

8.1 Method

As with the Peace of Mind flower, a diary study was performed to evaluate the device. A questionnaire was developed, reproduced in table 8.1. The questionnaire is based on the one developed for the Peace of Mind flower.

8.1.1 Questionnaire used in diary study

1. What do you think about the device								
(a) Unhandy	1	2	3	4	5	6	7	Handy
(b) Irritating, disruptive	1	2	3	4	5	6	7	Pleasurable
(c) Hard to read	1	2	3	4	5	6	7	Easy to read
(d) Background when no attention required?								
No	1	2	3	4	5	6	7	Yes
(e) Foreground when attention required?								
No	1	2	3	4	5	6	7	Yes
(f) Ugly	1	2	3	4	5	6	7	Beautiful
(g) Unreliable	1	2	3	4	5	6	7	Reliable
(h) Do you think the device fits in your environment?								
No	1	2	3	4	5	6	7	Yes
2. Before work. How do you feel physically?								
Bad	1	2	3	4	5	6	7	Good
3. After work. How do you feel physically?								
Bad	1	2	3	4	5	6	7	Good
4. How long did you work?								
5. What kind of work did you do?								
6. How much effort would you say this costed?								
Very little	1	2	3	4	5	6	7	A lot

Table 8.1: Questionnaire

Question 1 (was also used as question 1 in the questionnaire for the Peace of Mind flower, see table 4.1) attempts to measure the effectiveness of the DAD. Question 2 through 6 attempt to get a subjective indication of the computer work done and how this influenced physical well-being.

Question 5 was included to control for different computer uses. The type of use was categorized in work and leisure use. Work use is programming and writing, leisure is browsing the web and playing games. It is presented in the results as a percentage of work use (the inverse being leisure use). Different activities have different input device patterns, and we cannot ensure that the computer is used the same way during those activities. This question provides insight in the proportionality of use categories.

This questionnaire was taken before and after each consecutive work period, where a consecutive work period excludes breaks of 30 minutes or more (such as lunch). To be valid, a work period should span at least 30 minutes (note that this is a different measure than the suggested maximum activity time).

The device was tested in three phases. First phase is just the software running in the background (no EMG), to establish a baseline activity level. The second phase is the display and keystroke monitor, but no EMG. The third phase is the full system. This order was chosen because we expected the EMG leads to reduce user satisfaction in the device.

8.2 Questionnaire results

The results of the questionnaire are reproduced in table 8.2. Note that question 4, duration of work in minutes is reproduced here as a total and as an average. All the other questions are reproduced as averages only. Question 7 is not in the questionnaire proper, but is an answer taken from the log files of the application, and indicates the average amount of time worked in a single stretch. This differs from question 4 (duration) in that the duration is a computer use session, which can contain multiple stretches. Stretches are ended by being inactive on mouse and keyboard for 60 seconds.

Question	Baseline	No EMG	EMG
1(a) Handy		6,8	5,3
1(b) Pleasurable		6,8	5,2
1(c) Readability		6,9	7,0
1(d) Background		7,0	7,0
1(e) Foreground		6,7	7,0
1(f) Beautiful		5,9	6,2
1(g) Reliable		6,8	5,1
1(h) Fits environment		6,7	6,9
2 Before work	6,1	6,7	6,8
3 After work	4,8	5,8	6,1
4 Duration (total)	1065	985	990
4 Duration (average)	106,5	98,5	90
5 Type of work	66%	72%	69%
6 Perceived effort	2,5	2,3	1,7
7 Average stretch length (seconds)	1564	776	1128

Table 8.2: Questionnaire results device 2

8.2.1 Baseline, no EMG and EMG

The results show that the device in itself was well received. It stayed in the background all the time, only coming to the foreground of attention when needed. It fit the environment (a desk) and was considered handy (without the EMG).

The device was effective in reducing the length of stretches work units, from a baseline of 1564 to 776 seconds in the best case.

With the EMG, the device was received relatively poorly. The EMG leads were annoying and on occasion prevented a break from being counted due to a twitch or other muscle activity. This lead to longer periods of work due to giving up on pleasing the device's rules. That means, a 60 second break was taken but not registered and work was continued until a later time. However, the stretch length was still decreased compared to the baseline.

Due to the annoyance of the EMG system, on occasion the device was plainly ignored. That is, the user noticed the changed status of the device but did not care. This happened more often the longer the device was used.

8.3 Tinkering design process

The muscle sensor started out in the initial brainstorm session. On further brainstorming the idea was formed to include an EMG sensor to see if that would be a viable concept. The hope was that if it was, it could be used for all repetitive motion.

The first iteration was spent on creating the EMG measurement system. A solution for measuring this data compatible with an Arduino was found, bought and a measurement system was implemented. Since this data proved to be unreliable when the arm was placed on a desk, we asked an employee of the Roessingh Revalidation Center in the Netherlands who is responsible for their EMG systems and they indicated that this is likely unavoidable. A more accurate EMG system was borrowed from them to test, and the problem also occurred with that system. We could not borrow the system for an extended time, so the original EMG was used. It was decided to test the system in an additional phase, with and without the EMG system.

However, before the test phase was reached the display and input detection had to be implemented. The input detection was written first. Then an iteration was spent on connecting the EMG to the input detection. A rule set was implemented taking all data in to account. During tinkering with the rule system, it was found that the 30 second break initially chosen was too small, and it was doubled to 60 seconds.

At this point we had a working measurement system but no display. A picture frame was chosen because it is an item commonly found on a desk and provided ample opportunities for customization. It was connected via the same Arduino that measured the EMG signal. A few nice pictures were uploaded into the frame, and the system was operational.

As with the Peace of Mind Flower, this project benefited from the tinkering design process. The concept of the device was tweaked, and without experience with EMG systems the muscle pressure issue would not have been known. This process allowed the designer to adapt to the unknown elements of the product design.

8.4 DAD design (toolbox)

This device, like the peace of mind flower, uses several DAD toolbox items. An Arduino was used, in conjunction with an Arduino compatible EMG sensor. However, interoperating the digital photo frame with the Arduino required items that are not considered to be in the toolbox. Since the digital photo frame internally uses 12 Volt and Arduinos operate at the TTL logic voltage level (5 Volt), discrete components called optocouplers were used to connect the devices. Using these optocouplers requires a basic understanding of electrical circuits (they need a current limiting resistor or they will fail).

The toolbox should include knowledge on how to ”digitally” press buttons at a different voltage than the Arduino supports. This should include not only 12 Volt, but also the supported 5 Volt level at higher current, and possibly a safe way to switch mains (110 or 230 Volt) voltage.

The toolbox can not feasibly include data on all possible peripherals (such as the EMG sensor) that could be employed in a DAD. However, this does not mean that no attempt should be made to include a list of suggested devices in a range of categories, and how to approach connecting them.

This will require including a basic knowledge of electrical circuits in the DAD toolbox. This should include topics as:

- Voltage (and safety).
- AC and DC power.
- Small discrete components (resistors, capacitors, LEDs).
- Small scale power sources (such as batteries).
- Switching components (relays, optocouplers, transistors and triacs).

This does run the risk of the toolbox becoming a course on electrical circuit design. While a basic amount of knowledge can be included, care should be taken to ensure that this knowledge is presented in a practical manner. Referring to more in-depth information can be used to limit the scope of the contained knowledge.

8.5 Ethical evaluation

This device does not present many ethical hurdles in its current implementation. However, if this concept is to be expanded to a commercial product, the following ethical issues need to be handled.

8.5.1 Activity information

Muscle tension data can be considered medical data, and strict handling might be required by laws such as the GDPR[1]. Input device activity data can also be considered sensitive, as in that insurers or employers might use this data to provide incentives or punishments with regards to health. In general terms, data on bad habits might be used by employers or insurers to increase insurance premiums for individuals performing those bad habits.

[1] *General Data Protection Regulation*, a privacy law in the European Union.

8.5.2 Keylogger information

The nature of capturing keystrokes on a device means that all input is captured. A user typing in the password to his private email account or his online banking account is going to have his password essentially sniffed by the RSI prevention software. Care needs to be taken that the captured keystrokes are not saved in any way, nor that the software can be used as a vector by a bad-faith actor to compromise user accounts.

The implementation of the RSI program used for this thesis removes knowledge of what key was pressed as early as possible and only keeps the information that some key was pressed. For mouse cursor location, the absolute position was converted in distance travelled (in pixels) as early as possible. The log file is written in 1 second increments, with the values contained being the sum of activities in that period. Thus, the log file contains information of the type ”3 keys were pressed last second”. These factors ensure that a pattern of mouse movement and keystrokes can not be recreated from the application log file.

Chapter 9

Conclusion

9.1 Research questions

This section answers the research questions posited in section 6.3. The findings are summarized based on the evaluation done on the project in section 8.

Design *What are the steps taken to design this device?*
As with the Peace of Mind flower, an iterative design process was used. The capabilities of specific components (and the components themselves, even) were not known beforehand, the iterative design process allowed the design to adapt to the discoveries made.

Duration *Does this device help keep the correct duration of computer work?*
This device was very successful in reducing the length of stretches of computer work, as seen in the questionnaire results. However, the amount of perceived effort did not show the same magnitude of decrease.

A possible explanation could be that the chosen acceptable durations of work were wrong. An other explanation could be that the user already organically included breaks in using input devices.

Hindrance *Does this device not hinder the user in their work?*
The device is very non-intrusive, if we exclude the EMG. It is, in that sense, a very good DAD. With the EMG lead, the device was experienced as a lot more obtrusive and the calmness of the device diminished.

Focus *Does this device try to nudge the user's focus away from the screen?*
This device only takes focus when the photo being displayed changes. This is a rather abrupt change, and is noticeable in the corner of your eye. Outside of these state changes, the device was noticeable, but did not attract attention in a negative way.

9.2 Whole device

By testing only on a single user the impact of this device is hard to measure. RSI is a condition that develops over years of repetitive strain and the risk an individual is at depends on at least their posture and their natural tendency to take breaks. As stated before, the suggested 30 second break occurred by itself often enough (implying a correct work attitude) that the break needed to be increased to 60 seconds to have an impact on the work profile of the user.

However, a clear difference in length of work stretches was demonstrated, indicating that the device's suggestions were being followed. The device scored high marks in the factors that make a good DAD, staying in the background, but getting in the foreground when attention is required, in a non-annoying way.

The device itself performed well with the exception of the EMG part, which was unreliable in the quality of data and annoying the user. This diminished the satisfaction with the device, and the lesson learned here is that your device, above all, needs to be not annoying. The inclusion of the EMG was a case of over-engineering, adding a feature or option because it was possible, not because it was needed.

The iterative design process was very helpful due to the device being able to be broken up in smaller subsections. Using that, pieces of the final design could be made while others were still in the idea phase. The Java software for keystroke detection was written first, which was later upgraded with the capability to send data to the Arduino to control the picture frame and receive muscle tension data. Control software and hardware for the picture frame was then implemented, with finally the muscle tension meter being added.

The concept behind this device (RSI prevention) is a concept that is common enough that it entered the general vocabulary in at least the Netherlands, and probably in offices world wide. RSI prevention, aside from the obvious health benefits, also reduces the amount of sick days and will very likely increase overall productivity. Consider that a person can take 480 1-minute micro breaks for one sick day, and probably still come out ahead on productivity (as it is a break for the body, not for the mind).

The picture frame, as a very personalizable item allows for this implementation of the RSI prevention DAD to be used by other users with very easy modification (changing the pictures). This design is therefore very suitable to be applied to more users, since most people have pictures they like or they care about. This is not even considering the possibility of replacing the picture frame itself with some other display.

This does not mean that every computer should have a system like this attached. There are many computers that only see incidental use by a single user, and computers that are shared or public (libraries, flex desk workplaces) are a poor candidate to put personal photos on. This system's chosen display would also not work well with laptops due to the easy portability aspect of the laptop being degraded.

However, given the prevalence of computer work and RSI, we think it should not be hard to find a group of users who are interested in a device like this. The signal provided is discrete (currently ternary), so displays can take all kinds of forms from (but not limited to) photo frames to traffic lights and from chairs which buzz to automatic hourglasses.

9.3 EMG

The EMG used in this device ended up being too unreliable in detecting muscle activity. The input device data was more than sufficient to measure computer use and suggest breaks. Also, having the leads connected to the arm while working was occasionally seen as a hindrance reminding the user that the device was in use.

The EMG also caused frustration when it prevented a break from registering, and this caused the device to be seen as less reliable. This did not always happen, but it happened often enough to sour the experience.

For future devices we do not recommend the use of an EMG unless it can be made non-intrusive and unnoticeable. For example, the EMG might be integrated in a sleeve worn by the user. But on the whole, the EMG proved to be an unneeded addition to the device.

9.4 Display

The display used for this device performed very well. It stayed in the background, presenting information all the time, but not being intrusive or annoying. The swapping of pictures was noticeable, but did not become an annoyance. On several occasions, work was continued for a short amount of time while the device indicated a rest should be taken.

The picture frame is a nice addition to a desk (where a lot of people have pictures of things they like), so it fit the environment.

Part IV

Overall evaluation

9.5 Introduction

In this section we discuss the overall evaluation of the project, and the two subprojects (being the two devices made). The relevance of DADs will be discussed, along with the research questions. Then an overall discussion of the project and a conclusion will be given.

9.6 DAD relevance

In section 1.3 we listed some factors that make DADs relevant. In this section we evaluate those claims.

9.6.1 Calm technology

Both DADs developed show the characteristics of calm technology, where the interaction between the user and the device happens in the periphery of the user's attention. Both devices were unobtrusive when in use, allowing the user to receive the data displayed on their own terms.

In the case of the Peace of Mind Flower, the reliability of the system had a significant effect. The unreliable iteration of the device failed to be calm technology. When that was fixed, the device was very calm.

The RSI system's EMG sensor (the muscle sensor) also had a detrimental effect on calmness. The leads prevent the user from truly forgetting the device is there. You need to only stand up and walk away to be reminded of the leads that still connect you to the system. The version without the EMG was calm, it was just like any other digital photo frame that one might place on a desk.

9.6.2 Counterpoint to big data or browsers everywhere

Both devices could have easily implemented as a web app (and have been by others). This approach would not have made for an ambient display of data. The user of the browser would have to navigate to the page where the data is displayed, or a pop-up would have to be shown. The same would be true for a smartphone app. The notification would get mixed in with all the other notifications a modern smartphone throws at us every day.

A DAD allows you to pick data you are interested in and display it in a non-intrusive manner. This allows the user to absorb the information on their own terms, sometimes even in a background of attention way. This makes the DAD a good counterpoint in the delivery of information.

As an example, the RSI prevention device allowed the information to be displayed in a way that did not break the user's focus on their work. This was positively received by the user.

9.6.3 Adapt to the user

Both devices were adapted to the user. The flower could have easily been something else. It could have been a photograph in a frame that emitted light, or it could have been some other memento associated with the person being measured.

The RSI device was a picture frame. Outside of the obvious ability to choose the photos being displayed, an other user could have chosen to display the data as sound or music, or as a desk chair or mouse that vibrates when it is time to take a break.

These examples only consider the display part of the DAD. We can also conclude that through the method of brainstorming and tinkering design, the concept of DADs adapt to the data the user is interested in. If one can define a datum of interest, a DAD can likely be made. It is important to note that even the datum chosen can be tinkered with. In making the DAD the definition of the datum can be changed, possibly due to new points of view being discovered through tinkering with the design.

9.7 Hypotheses regarding concepts

Section 1.7 defined two hypotheses. While the scope of this project was too small to properly test these hypotheses, we can reflect on them based on our experiences.

9.7.1 Personal relevance

We expected that a customizable (in appearance) DAD would be better at capturing the user's attention when needed. Firstly, we think that people create a stronger bond with items they made themselves, especially with items that involve a creative aspect. The painter is proud of their painting. If someone bought a painting they can be proud of liking it, and proud of buying it but never proud of creating it.

We think the creative effort invested in making the item creates a stronger bond than merely buying the item. It should follow that the designer is proud of their DAD, given that it is also their creation.

While the case can be made that most of the software, hardware and concepts were created by someone else we do not think this diminishes the pride of creation. After all, the painter did not create the paint.

Therefore we think that the higher the amount of customizability, or rather the more creative effort the we can put into the DAD, the better we will be proud of the DAD and focus our attention on it.

Secondly, we noticed that the personal photos used in the RSI device on occasion evoked memories (and their associated emotions). This made the device nice to use and increased the bond with the device.

This effect is likely generalizable across a large portion of people. However the group of people who think they are not creative will probably dislike the process of creation. They may feel that they are running into the brick wall of the limits of imagination and form a negative opinion of their result.

Keeping this in mind, it would likely be best that customizability is allowed but not required in designing a DAD.

9.7.2 Cockpit effect

We expected that too many DADs in a single environment would be distracting due to information overload. While we could not test the limit, we can say that having two devices simultaneously did not create an information overload for the designer. However, we do expect there to be a limit (and possible diminishing returns leading up to it) to the amount of devices that can coexist in a space while still being calm. As a thought experiment take all the smartphone apps, websites and other digital services you use and place them in your living room (or office). There would be a cacophony of devices, each very calm but their cumulative presence would be too much.

A counter argument is that all those apps and websites are not too much currently. The difference is that a DAD is always somewhat present in the room. An unvisited website or unopened app is not as active in the background of your attention as a device (especially with its sign of life signal).

The exact number is a very subjective assessment. People differ in the amount of clutter they can ignore. For example, some people want a completely clean desk while others have stacks and stacks of items on theirs.

Generalizing out, there probably is a point where there are too many DADs in a space, but this will likely be different for every person. Combined with the point made above (in the personal relevance section) we propose keeping the amount of DADs in simultaneous use per user low.

9.8 Research questions

The general research questions will be answered here. For the device specific research questions, see the chapters on the devices. The research question is repeated in italics.

9.8.1 Design steps

Which generalizable design steps and patterns can we extract from designing DADs?

After an initial personal brainstorm which resulted in a list of ideas which were evaluated on fitness, the most promising ideas were extracted. These were proposed to the project supervisor and were refined in a discussion/brainstorm session. Both ideas were formulated from a perspective of ”what data do we want to display” first and ”how do we display it” later.

Both devices did end up being modifications of existing concepts, with the flower device being of the presence detection class of devices, and the RSI display being a hardware version of anti-RSI software.

The devices are also similar in the aspect of being easily divided in separate parts, which were then connected. The following patterns were observed:

- Subprojects can be seen as somewhat discrete projects.
- Lessons learned from subprojects can be applied to other subprojects.
- Subprojects can be tested independently, making it easier to identify the location of possible bugs.
- It is acceptable (or even good!) to start with an incomplete idea.

The design was performed iteratively, due to the tinkering approach. That is, small parts were built, refined, coupled with other parts and refined some more. Lessons learned from one part could immediately be applied to itself or other parts. A design from the start would have made that impossible.

This iterative approach and compartmentalized nature of the subprojects also allowed the designer to start implementing without a complete picture of the final product. That is, the RSI device was partly implemented before the picture frame was chosen as a display. This allows for a very flexible design process.

When the designer is not a professional (or is otherwise still a stranger to the applicable fields, like electrical engineering or software development), this approach is very suitable. This is because the design method allows for the gained knowledge to be immediately reapplied to the rest of the project. This can increase the quality of the final work. If DADs as a concept want to be embraced by the wider public, it should not exclude anyone who is not already moderately proficient in the technical matters required. Learning by doing is a way to avoid that.

One could argue that acquiring expert knowledge from an authority in the field would yield the same result. That is, asking an expert if something is possible, or how something is done would also achieve the same results. However, there are some downsides to that approach. One is that expert knowledge could exist but be unavailable to the designer, an other is that quite a few expert answers come down to try it yourself.

To illustrate that, let us imagine what types of answer one could get:

- No, it is not possible, we tried that.
- It is probably not possible, but try it.
- I don't know.
- It is probably possible, try it.
- It is possible, here is an example.

The middle three answers give a similar result: You should try it to find out. Only the fifth shows you a way to solve the problem. Only the first shows that the approach under consideration is not viable[1]. While this appears a pessimistic view of expert knowledge, this is only due to discussing the downsides and not the upsides.

Generalizable design advice that was extracted from the devices is:

- The sign of life signal for devices requiring connectivity.
- The danger of over-engineering.
- The ethical implications of personal data.

These can be generalized even further to reliability, non-annoyance and non-creepiness. A good DAD needs to be reliable. An unreliable DAD will be ignored after a time, just like a stopped clock will.

It also needs to be not annoying. If it steals attention too much, it is unable to be a calm technology and possibly be removed as a distraction.

The muscle sensor wire was considered an instance of over-engineering. It was unneeded to perform the function of the DAD. However, this view is personal. People who are more interested in biometrics might find this data very interesting and would be willing to accept the trade off. Generalizable from the incident remains that there is a limit to what a user finds acceptable annoyance for a given convenience – a trade off which should be kept in mind.

When designing a DAD to display personal data care should be taken that this datum is appropriate to display (and measure), because not many people enjoy being watched or feeling like their privacy is jeopardized. A privacy mode could provide a solution.

In general the designer should keep in mind: "Just because you can does not mean you should."

9.8.2 Toolbox

Is a toolbox of DAD parts a worthwhile addition to the field? If yes, what can we add to it?

A toolbox of DAD parts would be a great addition to the field. However, this recommendation differs from the one Smit[23] made, which said that the toolbox should contain specific parts (such as an AA battery holder, a relay, a light).

That would make the toolbox not unlike a box of Lego Mindstorms, a collection of parts guaranteed to fit together. Our recommendation differs from theirs. Firstly, it would not be feasible to include all possible parts, or provide detailed instructions on how to connect them while guaranteeing interoperability. As an example, the two DADs developed for this project both used items not in Smit's suggested toolbox (namely: electricity sensors, EMGs, optocouplers, digital photo frames).

[1] Even with a resolute no, the argument can be made that experts have thought things to be impossible that later turned out to be possible, and it might thus be worthwhile to try it again. As an example, Lord Kelvin stated at the Australian Institute of Physics in 1895 that heavier-than-air flying machines are impossible.

Secondly, we feel that having a defined set of items could limit the imagination to those items. This will likely harm personalization and data options, by constraining the user to the items in the toolbox.

Therefore, the toolbox should also contain a list of part types, an example (or two) of such a part, and explain the concepts required to connect them. In such a way, it should present itself more as a source of inspiration than a box of objects limiting the user to just those items.

Outside of parts suggestions, it should also include ideas, or solutions to common problems. Communicating over the internet has a few inherent pitfalls that can be solved by the toolbox. One of these pitfalls we encountered, the silent failure of a remote connection.

How to connect different types of hardware is also an idea that should be handled by the toolbox. But instead of only including specific instructions per part on how to connect it to a micro-controller, it should also include generalized instructions so that similar parts can be used instead.

However, this toolbox should not become a course on software or electrical circuit design, however it could provide the user with the confidence to seek additional knowledge in those fields. This does not mean, though, that this information should not be included, but it should be kept limited in scope with references to more in-depth material for the curious.

The DAD toolbox should be used during the brainstorm phase, where it can inspire the designer with items and concepts they did not know of. This could be one of its main strengths, but care should be taken that it does not become a sandbox that limits the development of ideas outside the sandbox. That means the concept of the DAD should not be hindered by an item not being in the toolbox.

9.8.3 Designer as evaluator

Is a designer as evaluator a valid way to develop DADs, and if so what are the limitations?

The designer as evaluator method is a valid way to design DADs. This method allows for a depth of design that is harder to reach than designing for someone else. The user of the DAD knows their requirements the best, so having the user build their own DAD means the intended purpose of the DAD will match the actual purpose of the DAD. The afforded depth of design means that very personal DADs can be created, the data shown tailored to your exact need, the form factor of the display chosen by you.

With this autoethnographic method, patterns of design can be extracted that will appeal to people with similar interests as the designer. Simply put, an user group can likely be found that also appreciates the design concept.

Qualitative data like the above is where this approach is most suited. This method also presents a fun way to learn about software and electrical circuits, possibly getting people interested in those fields.

Testing on yourself is important because the building of DADs (or indeed anything) can result in bugs or unforeseen consequences being introduced. The loss of connectivity the flower DAD suffered would be a fatal flaw were it to be tested on someone other than the designer (who could anticipate the failure). For any other user, the DAD would likely instantly be disregarded due to unreliability and be ignored from there on. When a DAD can automatically recover from a fault state or otherwise not need user intervention, it is mature enough to deploy to more users. A group study can then be held.

This method is also very quick. Any lessons learned can be immediately used and a new iteration can be started to evaluate them. In this project errors in the design were detected during an evaluation period and immediately rectified. This would have delayed a study with a different evaluator for much longer.

The speed of this method is very useful when the design space of the DAD is not narrowed down yet. New ideas can be very quickly evaluated compared to a model with an external evaluator.

The concept also has some drawbacks. It is very hard to create DADs for which you are not the target audience. While this is somewhat self-evident (it's hard to imagine being someone you are not), it does warrant stating. These class of DADs (for which the designer is not the target user) would be harder to test on yourself.

The other downside is that any quantitative results (such as from a questionnaire) should probably be considered anecdotal. While they likely accurately map the feelings of a specific user, these experiences are not guaranteed to be applicable to a larger group.

However, this is not a reason to discard these findings out of hand. The lessons learned on a sample size of one can be carefully considered for generalisation. This is in some cases almost self-evident (probably no one likes unreliable devices) but can also be hard or downright impossible to generalize (I like this anti-RSI DAD, so all computer users will).

This approach is very viable for designing DADs, if the downsides are kept in mind when handling quantitative data generated.

9.9 Discussion

The DAD is a niche but valuable addition to the field of personal electronics. It shows great promise as a device that bridges the gap between classical low-attention devices (such as clocks) and a modern day smart-phone or computer.

As a data physicalization device they are not new, but are a rare concept that are more often artistic displays than an useful data visualization method. The fountain that rises with stock price or the lights that illuminate searched-for articles are more novelties which incite discussion than a good way to convey accurate data.

This is where the main strength of those DADs lie, in our opinion. Starting conversations about the data displayed – not accurately describing the data. As a tool for art and discussion about the topics of today. An artistic DAD indicating the current air quality would likely be a better conversation starter about atmospheric soot particles than a graph showing the same data, even though the graph is a better conveyor of information.

This thesis focussed on personal DADs. These are not meant to incite discussion, but as a tool for reaching a personal goal. Personal DADs were chosen for this project to test the designer as evaluator method and the estimation that DADs as a field was partly uncharted territory. The personal DADs implemented were both successful, with the RSI DAD being the better device.

Which brings us to the drawbacks of this type of approach. Since the design was tested on the designer, the conclusions can not be universally applied to a group of people – it is personal. Lessons learned can (and have) been extracted from the experience, which can be extrapolated to a group of similar users. Care should be taken to not apply these lessons to a group of people without careful consideration of that group and the individual that provided the lessons learned. The findings are, however, useful starting points for further group studies.

As discussed above, the answers to the research questions indicate that DADs are a worthwhile field of inquiry. They are expected to show promise in getting people excited in technology by posing it as a creative field, instead of a purely technical one.

9.10 Suggested further work

The split between personal DADs and non-personal DADs presents two avenues for further study. The personal DAD can help with self examination (what do I really want to know), self-expression and personal goals and motives.

The personal DAD can be tested on suitability for a group of similar users. Would there be a market for a peace of mind flower? Given that it is separable in data gathering and display parts, would that market accept the product as is or would they want to create their own display? Does the group have similar findings to the individual?

In short, it would be interesting to see if the autoethnographic evaluation of design produces reproducible results.

The question of how many DADs is too many (the cockpit effect) could also be an area of further study.

The group or art display DAD can be a way to start conversations between strangers like only art can. It shows promise as a way to make people connect and express their views on issues. If and how this happens could be an interesting avenue of study.

9.11 Conclusion

This work examined dedicated ambient displays (*DADs*) in the context of personal use and their effect on the designer. The designer also functioned as evaluator of the technology, because it was not certain DADs were ready for group studies.

The DADs built were a Peace of Mind Flower, and an RSI Prevention device. The Peace of Mind Flower consists of an electricity meter installed at the house of a loved one, and a dedicated ambient plastic flower that opens (or stays open) when all is well with the loved one, and closes when abnormal electricity use is detected (possibly warranting a visit).

The RSI Prevention device consists of a digital picture frame, hacked to be controllable via an Arduino, a bit of Java code to register keypresses and mouse cursor movement, and an muscle tension sensor to see if that would be a benefit to the system. The photo in the frame goes from good to bad the longer the user is working without a break, and will reset to good when a break is taken. This way the user is reminded gently to take regular breaks while not locking the screen or breaking the flow (a complaint with RSI software that locks the screen or displays pop-ups).

All in all the tested DADs were successful, however the flower suffered internet connection issues at the beginning (later remedied), and the RSI device's muscle tension sensor proved to provide data that was too unreliable to use and the sensor was found to be annoying. Other than that, both devices performed well.

The work was completed with a *designer as evaluator* approach, which allowed rapid iteration. This was seen as a great help in the process. The downside to this approach is that the data collected is not applicable to a group without careful consideration. A *tinkering* approach was used to implement the devices, which was positively evaluated.

List of Figures

List of Tables

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Part V

Appendices

Appendix A

Brainstorm

The following ideas were developed in a brainstorm of possible devices. These ideas were then evaluated on five measures. Those measures are realisability *R*, personal relevance *P*, general relevance *G*, frequency *F* and originality *O*. Refer back to section 1.10.1 for explanation of these measures. The entries are in no particular order.

Idea	R	P	G	F	O
Web series: Notification when a web series I follow puts a new episode on-line.	X	X	X	X	
Forum: Notification on new posts on my Scouting groups forum.	X	X		X	
Email: Notification on important email (but not spam or mailing lists).	X	X	X	X	
Beverages: Notification on beverages at Scouting nearing depletion.	X	X	X		X
Sun: Warning for sun near horizon (take sunglasses with on the road).	X	X	X		X
Hearing aids: Notification for my grandmother if she's not wearing her hearing aids.	X		X	X	X
Hygrometer: Notification the air is too dry for the natural wood floor. Could also include an air quality sensor, prompting you to open a window.	X	X	X		X
Bank account: Notification on nearing a negative balance on your day-to-day account.		X	X		X
Maintenance: Notification when maintenance on vehicles is needed.	X		X		X
Fuel: Notification on driving inefficiently.			X	X	
Wasting energy: Notification on devices that are on unnecessarily, or simply on total energy use.	X	X	X	X	
Air filter: Notification that it's time to change the filters in the air circulating system at home (needs to be changed twice per year).	X	X			X
Sun blinds: Notification you need to lower the blinds.	X	X	X	X	
Water level: System that checks the water level in the fountain.	X	X			
Water usage: System that monitors water usage at my grandmother, who lives alone.	X	X	X	X	X
Heating: Notification on not turning off the heater when leaving.	X	X	X		X
Together: Notification on activities that are done together, like drinking coffee or dinner.	X	X	X	X	
Brushing teeth: Indication correct duration of brushing teeth (too long is bad too).	X	X	X	X	
Bath thermometer: Colour indication on correct bath-water temperature.	X	X	X	X	
Shower time: Notification on showering too long.	X	X	X	X	X
Watering: Notification when it is time to water plants.	X	X	X	X	X
Drying laundry: Notification that air dried laundry is dry.	X	X	X		X
Laundry done: Notification laundry is done so it can be dried.	X	X	X	X	
Appointment: Notification it is time to leave for an appointment.	X	X	X	X	
Lint filter: Notification that the lint filter in the dryer should be cleaned.	X	X	X		
Sport: Some type of athletic activity indicator.	X	X	X	X	
RSI: Warning when RSI symptoms can be developed. There's software for this, but it is not liked because it tends to steal focus and lock the screen.	X	X	X	X	X
Bed time: A bed time warning system. I tend to read too long in bed.	X	X	X	X	X
Epilepsy: A friend of a friend suffered from epilepsy. A system to warn others when an attack is imminent or occurring.			X		X
Groceries: A system that keeps track of what groceries you need and notifies you when it's enough to make the trip worth it.	X	X	X	X	X
Medicine: Pill box that reminds you to take medicine.	X		X	X	
Continued on next page					

Table A.1 – continued from previous page

Idea	R	P	G	F	O
Nutrition: A system that tracks food intake and indicates if you are eating all the necessary nutrients.	X		X	X	X
Deadline: A system that tracks deadlines and shows the proximity of the nearest.	X	X	X		X
Best by: A system that shows which items in your pantry and fridge are nearest to their ”best by” (or, ”use by”) date.	X	X	X	X	
Trash: System that notifies you to place a bin by the roadside for collection.	X	X	X		X
Solar index: System that indicates the amount of UV radiation expected for today (so you know when to use sunscreen).	X	X	X		X
Human Development Index: A system that shows socio-economic factors like the Human Development Index or Gross Domestic Product. Could also be something like a thing that glows in the colour of the parties who do the best in the polls leading up to an election.	X	X	X		X
Capacity: Remaining capacity in some kind of storage medium, like an e-mail account, cloud storage, local hard drives.	X	X	X		X
Bandwidth: Thing to show the usage of an internet connection.	X	X	X		

Table A.1: Brainstorm results

Appendix B

Energy measurement device

These are the energy measurement options that were considered for this project. The options described are types of device, not a specific item or brand. Each type is briefly explained in the following subsections.

Type	Measures	Ease of install	Price
Plug-between	Per Device	Easy	€ 100 each
Energy company	Whole house/Per Device	Outsourced	€ 200
Clamp meter	Per Group/Per Device	Hard	€ 100 each
Optical meter	Whole House	Easy	€ 80

Table B.1: Energy Meters

B.1 Plug-between meters

Plug-between meters, like the Kill-A-Watt plug between the appliance and the wall socket and give a reading on the power consumed. These can then be provided with a data transmitter to retrieve the data. A popular one is the Tweet-A-Watt by Adafruit for $90. Every appliance measured would require one of these devices, adding a lot of cost. They would also be visible in the living environment, plugged between the wall and the appliances.

B.2 Energy company meters

These meters replace the old style spinning disk meters with a digital one. These digital meters can report the power used to the power company, which can then set up a service for a user. Different power companies price these meters differently, some are € 200 while others come free. These devices are not visible in the living environment, but do require a licensed electrician to install. Some even provide plug-between meters that report to the same service so users can measure appliances of interest.

B.3 Clamp meters

A clamp meter uses the magnetic flux of alternating currents to measure the current in a conductor. Simply put, a clamp meter is placed around a conductor and reads out the AC current in that conductor. As with the plug-between meter, this clamp meter can then be provided with a data transmitter. The problem with these meters is when you pass multiple conductors through the clamp: The resulting data is the vector sum of all the currents flowing. In the Netherlands, power enters the home in a thick 2 or 3-phase wire, a clamp meter placed around this cable would likely measure exactly nothing, because the vector sum of the current entering and leaving the house should be zero.[1] To counteract this, one would need to open up this cable and measure the three individual conductors. This is highly dangerous and illegal, so this option was ruled out.

One could open up the individual groups of power inside the home (which are the outputs of the different fuses in the fuse box), which is legal, and can give you a per-group insight into power use. There are also commercial clamp meters which act like plug-between meters. This, however, is labor intensive and requires one to destroy the safety tubing the wires are in.

[1] Disregarding any leaks to ground, which should trip the ground fault current interrupter.

B.4 Optical recognition

The power meter in question has a spinning disk (375 revolutions per kWh) and a analog readout of numbers in kWh. The Youless LS110 uses an optical sensor to detect the black mark on the spinning disk, which represents 1/375th of a kWh. This data can then be read via a Ethernet connection in the JSON[2] format. This method is non-invasive to the power system of the house (it optically reads a measurement device already installed) and not visible in the living environment. However, in contrast to the plug-between meters, it gives us a readout of the entire household power use instead of per appliance.

Since the optical meter is the safest, easiest and cheapest solution, it was chosen. Youless was chosen because they are a Dutch company (no import hassles), and their meter supports Ethernet, making it easy to connect to a Raspberry Pi credit-card computer.

[2] JavaScript Object Notation, http://json.org/