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Context-sensitive memory augmentation using recorded everyday life data

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Abstract

The recent rise of life-logging technologies and wearable computing gadgets allows the recording of data from our daily lives. Experiences make people what they are. The omnipresent tracking devices and their sensors experience the same things as their owners, thus creating e-memories and surrogate brains. Such life-logs or e-memories contain everything we can sense or our environment senses, like images, heart rates or locations. With this increase of digital personal data we explore challenges and solutions how to use this vast amount of data with the goal to support human memory. To do this, we used a user-centered approach. In the first step we conducted a series of focus groups and an online survey with the goal of understanding the requirements of life-logging tools. The results of the requirement analysis led to the development of a holistic concept of a digital life assistant. Our initial prototype leverages life-log data in form of a smart alarm clock, which provides an automatic morning briefing about the past and the upcoming day via audio and bedside projection. The prototype was finally evaluated in the field in a small-scale pilot study with the focus on the different presentation modes.

Kurzfassung

Die aktuelle Entwicklung von Life-Logging-Technologien und tragbaren Computern ermöglicht die Aufzeichnung von Daten aus dem täglichen Leben. Erfahrungen machen Menschen zu dem was sie sind. Die allgegenwärtigen Aufnahmegeräte erleben dasselbe, wie ihre Besitzer und schaffen damit elektronische Erinnerungen und einen stellvertretenden Verstand. Diese Life-Logs oder elektronischen Erinnerungen beinhalten alles was deren Besitzer oder deren Umgebungen wahrnehmen, wie z. B. Bilder, Herzfrequenzen oder Standorte. Mit diesem Anstieg von digitalen persönlichen Daten erforschen wir Herausforderungen und Lösungen, wie diese gewaltige Datenmenge nutzbar gemacht und das menschliche Gedächtnis unterstützt werden kann. Daher haben wir einen nutzerorientierten Ansatz gewählt. Im ersten Schritt haben wir eine Serie von Fokusgruppen und eine Online-Umfrage durchgeführt, um die Anforderungen von Life-Logging Werkzeugen zu verstehen. Das Ergebnis der Anforderungsanalyse führte zu der Entwicklung eines ganzheitlichen Konzepts eines digitalen persönlichen Assistentens. Unser initialer Prototyp macht sich Life-Logging-Daten in Form eines intelligenten Weckers zu Nutze. Der Assistent bereitet automatisiert ein morgendliches Briefing über die Vergangenheit und den bevorstehenden Tag vor und präsentiert dieses mittels Sprache und einer bettseitigen Projektion. Schließlich wurde der Prototyp im praktischen Einsatz in einer kleinen Pilotstudie mit dem Fokus auf die verschiedenen Präsentationsmodi untersucht.

Contents

List of Figures

List of Tables

1 Introduction

> In few decades there will be hardly industrial products in which computers are not interwoven.
>
> *(Karl Steinbuch, 1966)*

In today's society mobile devices are more important than a few years ago. Due to the ubiquity of smartphones and other mobile devices, a new technological era is beginning. The networking of sensors that gather different data penetrates all spheres of life faster than ever. Computers and sensors are integrated in everyday objects, such as bracelets, watches or glasses. These can exchange data via the Internet and blend into life [Gar13]. Thereby portable computers are getting more and more unobtrusive and our daily companions. They can record where the owner is or study habits of the owner. They act as an extended human memory and allow the user due to the constant recording of data to evoke at a later time memories. Because of the always-on mentality mobile devices are connected to other services and can set moments in a context. This change poses risks, but also benefits. With such smart objects undreamt-of possibilities emerge to enrich user's life. The possibility of gathering data in all spheres of life has the potential of another human evolution. Connecting and recording life in the first step allows doing advanced analyses. Beside this mega trend of connectivity there are a lot of benefits in different sectors like health or learning which are as well predicted mega trends[1]. Past experiences, habits and knowledge of the user can be analyzed to enable increased reflection. It is the birth of digital personal assistants that are therapists and cyber consultants. The assistants can enhance memory, help to manage the day or prevent medical incidents [Swa12a]. Gartner [Gar13] predicts that through 2020 the smart machine era will blossom with a proliferation of contextually aware, intelligent personal assistants.

Current technology evolves faster than biological human attributes. Thus, technology has to adapt to human and not vice versa. Intelligent devices have to live with us instead we live with them. With recent developments in automated capture technology and information retrieval there are great possibilities to assist human memory. People have to accept this change in thinking and learning. That is why we need a user-centered approach to generate true value for human. We are facing a time where data is ubiquitous. People are already generating and recording a lot of data in their lives, like communication or activities. But this information is often just gathered in the business context from big data-driven companies. We want to

[1] Megatrend Documentation website, http://www.megatrend-dokumentation.de/

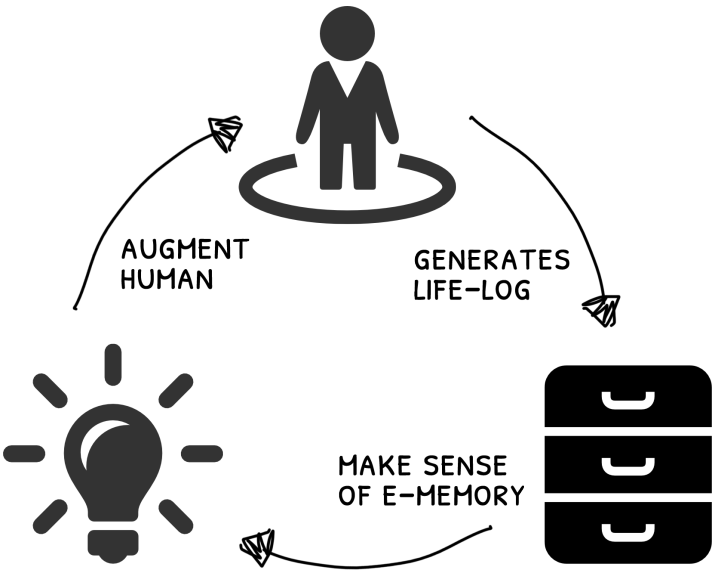


Figure 1.1: Abstract motivation of this work.

shift this disparity to the mainstream. We explore novel approaches and reliable future-proof memory solutions that hit the Zeitgeist and diffuse into the market. Our guiding research question is how software assistants can augment human memory in daily life. We achieve this in doing deep requirement analyses and implementing a prototype, that should proof a possible platform for personal assistants, that lead to the foreseen era of smart machines. Our abstract motivation is depicted in figure 1.1.

1.1 The Recall project

This thesis is part of the project *RECALL: Enhanced Human Memory* which has received funding from the European Union Seventh Framework Programme ([FP7/20072013]) under grant agreement no 612933. The aim of the project is to re-think and re-define the notion of memory augmentation with current technologies. Recall focuses to improve collecting, mining and presenting appropriate information to extend and enhance the human memory.

The project duration is 36 months and four institutions carry it out: Lancaster University (United Kingdom), University of Lugano (Switzerland), University of Essex (United Kingdom) and University of Stuttgart (Germany). Following the project plan, the project is divided into seven work packages: (1) Information collection, (2) Designing and developing an external memory display, (3) Privacy and Control, (4) Application of memory theory, (5) Quantitative analysis and evaluation of RECALL, (6) Dissemination and Exploitation and (7) Management.

Each university has a certain focus. The University of Stuttgart focuses on the second work package to select and present relevant information from the personal context streams.

Summed up the work of this thesis makes contribution to the Recall project as follows:

- identifies challenges and user's requirements for tools augmenting human memory through several requirement studies (focus groups, online surveys).
- explores convenient presentations of information in the morning.
- develops a software and hardware prototype as a platform, that automatically analyzes data and enhances memory retention.
- evaluates the proof of concept in the field and gains insights for future works.

1.2 Outline

The work is divided into following chapters:

Chapter 1 – Introduction: The current chapter motivates the work and discusses some major challenges, which arises when life-logging technologies are pushed to mainstream.

Chapter 2 – Background and Related Work: In the second chapter we discuss related work in the field of life-logging and we give the reader an overview about related fundamental topics.

Chapter 3 – Requirements Analysis: The third chapter focuses on the requirement analysis for possible applications augmenting human memory. We organized focus groups and an online survey to gain insights what people need in their lives.

Chapter 4 – Implementation: The fourth chapter explores the vision of a product and describes one prototype evolved from the previous requirement studies. The chapter describes requirements and hardware / software decisions for our proof of concept.

Chapter 5 – Evaluation: The fifth chapter shows the gained insights of the prototype through an evaluation in the field. We discuss the acquired feedback.

Chapter 6 – Conclusion The last chapter summarizes the results of our work and presents links for future works. Moreover, it illustrates a broader vision of possibilities recent and future technology can bring.

1.3 Conventions

We do not make a distinction between the terms *life-log* and *e-memory*. We use the terms interchangeable in this work. Both terms describe the digital preservation of experiences and meta information from a human being, whereas the term *bio-memory* or *human memory* refers to the biological human memory.

1.4 Challenges

This section deals with the emerging main challenges of life-logging applications, which are manifold. In 2012, Byrne at al. [BKJ12] identified from their point of view in the areas *practicalities of mobile device use*, *associated human factors* and *practicalities in the use of resulting data* challenges from engineering life-logging solutions. We want to share our perspective and add our thoughts to this discussion.

1.4.1 Data Fragmentation

In our data-driven world, personal data is scattered over different places and vendors. Humans use different services and leave their traces at various locations, like wearables, biosensors, smartphones or cloud-based services. To make use of all this data streams there is a need for convenient interfaces and independent data providers that aggregate different data sources. Human API[2] for example tries to fill this gap in the health area. But consumers and data vendors have different intentions and come into conflict. On the one side consumers want to keep their private data. On the other side vendors want to lock in the consumer into their own universe, because of the valuable user data. To overcome data fragmentation data has to be centralized again to some form of personal cloud — at least to a certain degree to do suitable analyses. Established data integration concepts within the enterprise context have to be transferred to the consumer area. Min et al. [MLY09] for example proposed Web Services. Gartner [Gar13] identifies the *Era of Personal Cloud* as a top ten strategic technology trend for 2014. Other mechanisms to not handing over the reins of data should also be considered.

[2]Human API website, http://humanapi.co/

1.4.2 Utilization

Sensors can collect a vast amount of data in one human life, but there is a lot of noise and negligible data. There is a famous quote from Paul K. Van Riper, a retired officer of the United States Marine Corps: "If you get too caught up in the production of information, you drown in the data." [Mal05, p. 144]. Hence, smart algorithms have to transform and utilize such big data to smart data. They have to filter, organize and connect information using data mining, machine learning and pattern recognition. Personal life-logs can be connected to create additional value. A simple example is to use the music taste of different people and recommend suitable music to the user. Almost every music service like *last.fm*[3] or *Spotify*[4] has a recommender system.

Moreover, the accuracy and quality of data differs. It is difficult to extract information from explicitly unstructured logged data. Algorithms have to judge the quality and compare different data sources, like implicitly captured activities at a certain time and place with the explicitly saved events in the calendar. There are already approaches to handle noise. Lee et al. [LE06] for example tried to filter background noise and identify the presence of speech in audio recordings from body-worn continuous recorders.

1.4.3 Reliability

In our fast-paced society technologies evolve, underlying data formats change or services crash. Backup strategies and replicas are needed. Moreover, data from life-logs have to be future-proof and should at least survive an entire human life like old Roman carved inscriptions in stones. A life-log has always to adapt and migrate itself to technological evolutions. Hence, standardizations, interoperability and migrations are essential fostering life-logging technologies.

Power consumption of battery-powered devices belongs to this challenge reliability as well. Smartphones get more and more features, but the available energy does not evolve as fast as features arising. This results in an energy gap. Current smartphone batteries last for about one day — sometimes even less depending on the usage. Then the users have to recharge the batteries again. But to get a universal surrogate memory, sensors have to assure to be always on. Recent developments try to bring charging possibilities to public places. With *Powermat*[5] users can wirelessly charge their devices at places where they are anyway like a bar while drinking.[6]

[3] last.fm website, http://www.last.fm/
[4] Spotify website, https://www.spotify.com/
[5] Powermat website, http://www.powermat.com/
[6] Video by Powermat: http://www.youtube.com/watch?v=aXbI36WdM4A

1.4.4 Data Protection

The life-logging trend gathers a lot of personal information. If wrong persons get this data they can abuse it. It is reasonable that a lot of people are suspicious of this trend. Especially in Germany the data protection is very strict compared to other countries like the USA. Institutions have to stick to laws and regulations when dealing with personal data. In Germany personal data is protected by the fundamental right to informational self-determination [KLH+12]. Concrete regulations can be found in the *German Teleservices Act*[7] and the *Federal Data Protection Act*[8]. The goal of the laws is to protect a person and not to harm the personal rights by dealing with personal data. The law is valid for non-public institutions like companies or clubs. So the law is applicable to institutions gathering, processing and utilizing personal data. But if the citizen does not use an external service and gathers data himself, then nobody will protect the citizen from himself. Furthermore, when gathering, processing or utilizing personal data there is a need for a signed declaration of consent from the affected persons. This could be a huge obstacle for the core of life-logging technologies. Users using for example an image-recording device have to ask their exposed environment in advance if they are authorized to shoot images from them. But this does not harmonize with the philosophy of implicitly recording life.

Knowledge is power. Therefore we need better methods protecting and encrypting personal data without sacrificing the ease of use. We need new approaches securing personal data. The logical next step is to come up with new locking mechanism like fingerprint, voice or iris scanner to conveniently, naturally protect and access information without men in the middle.

1.4.5 Privacy

We have to fundamentally rethink and redefine the term privacy. Recent developments show a shift towards transparent humans. Government and companies already surveil more and more public space like in public transport. On the other side people start to record themselves. With this sousveillance they are building a counterpart of recording instead of giving data only to organizations surveilling. Don Norman [Nor92, p. 72ff.] for example suggests a teddy bear as a recording device from the beginning of life. In this scenario, we have to solve the question, whether parents have the legitimation to decide for their children what to capture. Nowadays, most of the people start with life-logs in the middle of their lives. Thus life-logging technologies need an import service for data.

We can ask ourselves the question, whether anonymity and privacy is a phenomenon of the 21st century. Indigenous people in small villages also know everything what is going on in the village. Maybe it is time to think the other way round. Either the entire life should be

[7] German Teleservices Act, http://www.gesetze-im-internet.de/tmg/
[8] Federal Data Protection Act, http://www.gesetze-im-internet.de/bdsg_1990/

secret or everything should be public except of secrets. This transparency can foster human progress but also brings great danger to each individual. A solution could be something in between. Humans need some retreat area, but should also benefit publishing data. People should get the possibility to decide, whether they want to sacrifice private data to get some advantages from this technology. The entire challenge is highly complex and involves a lot of ethical questions. It seems like a bottomless pit, where the government has to draw new borders and guidelines.

1.4.6 Human Acceptance

The human factor plays an important role. Life-logging technologies have to generate true value for people to justify the persistence of life-logs. People often argue, that memory lapses are not per se bad. They can help to forget not important things to remember more efficient and to narrow and to focus the view. Forgetting is how to make sense of life and how to interpret life. This argumentation against e-memories is rather an argument for e-memories. The human memory needs to limit information in order to work. This was a great advantage in the evolution of mankind. But nowadays the human memory does not evolve as fast as technology does. When capturing an entire life people do not have to worry about forgetting. E-memories can help with amnesia, resulting from brain damage or dementia like Alzheimer. So, e-memories can be useful to forget to focus on living. E-memories should not necessarily remind people of everything they have experienced. Sometimes there are good reasons to explicitly forget. In 2008 Paul Connerton [Con08] described seven types of forgetting. *Prescriptive forgetting* is for example one type and important for the common good to forgive by forgetting. Knowledge and wisdom is abstracting and filtering experiences. In the first place the surrogate memory should augment the human memory. Hence, the surrogate memory needs to create similar mechanisms to protect the users from memories that could spawn bad chain of reactions. We need to find forms of digital amnesia like ephemeral messaging. According to Bianca Emmert [Emm13] technology evolves faster than human consciousness. The technological progress is more advanced than human comprehension and acceptance. Humans need to develop a consciousness to live and deal with such crucial data and make use of it in daily life. This can be achieved through educational advertising. For a successful introduction of life-logging technologies to mainstream we need to find ways to raise awareness in society.

2 Background and Related Work

> Just as the World Wide Web enabled an era of increased research, Total Recall will enable an era of increased reflection.
>
> *(Total Recall, p.135)*

The idea of augmenting memory is not new. Since early days, technology research has been trying to augment human memory. This chapter discusses fundamentals and related work. Furthermore, we take a closer look at commercially available products and describe the current state of the art.

2.1 Transhumanism

Collecting and reflecting information about oneself has a long history. This section gives a brief historical outline.

Richard Buckminster Fuller wrote a precise diary over his life with more than 140.000 papers and 1.700 hours of audio and video. From around 1920 until his death in 1983 he collected everything from his daily life, like sketches, bills or correspondence and made with meticulous precision notes about his daily routine. He called the scrapbook *Dymaxion Chronofile* [Fula, Fulb]. Nicholas Feltron[1] is a graphic designer from the USA. Since 2005, he annually publishes personal reports as books, which illustrates his everyday life data in various visually appealing styles. He recently launched an app called *Reporter*[2], which randomly prompts the user to answer a survey about the current moment.

However, former research started in 1945 with the *Memex*, a vision from Vannevar Bush [Bus45], in which a device holds records, communications and media as a complement to people's memory. This oft-cited paper *As We May Think* foresaw todays present. Vannevar Bush envisioned a memory aid that instantly brings personal information to the operator's fingertips.

[1] Nicholas Feltron website, http://feltron.com/
[2] Reporter website, http://www.reporter-app.com/

Later Lamming et al. [LF94, LBC+94] continued to improve computer-based support for human memory by building *Forget-me-not* — an automated memory collection system that logged activities, personal encounters, and communications. However, due to the technology available at that time, they were forced to compromise on the actual implementation. The prototype just worked in the laboratory context. They recognized that the challenges would arise in privacy, safety, reliability of data and speed of information retrieval. But the hardest challenge is to process the raw data and make it graspable for the users. The more a personal assistant knows about the user the merrier its potential value is.

More recent projects like *MyLifeBits*[3] [GBL+02, GBL06] or *iClips* [CJ10] tried to digitize people's entire lives as an e-memory beside the bio-memory. Their focus was to facilitate browsing and searching on demand in such archives [KBJ12]. The iCLIPS project recorded 20 months of PC, laptop, mobile phone and SenseCam activity of three participants. The project focused on the automated annotation and linking of multimedia items within life-log archives to facilitate more effective browsing and searching [KJ07]. The Microsoft Research project MyLifeBits was initiated by Gordon Bell. In 1998 he started to form the idea of life-logging. Gordon Bell wanted to get rid of his old papers and digitize his entire life. His idea was simple: "Record everything, keep everything.". The project should fulfill the aforementioned vision of Vannevar Bush's 1945 memex vision. Gordon Bell was the primary test subject in the project. In 2009, Gordon Bell needed about one gigabyte a month without audio and video. Jim Gemmel and Roger Lueder were the architects of the MyLifeBits software. They thought about how to organize this vast amount of life data. Beside the memory explorer they developed a screensaver that shows past memories. Memories are emotional, subjective and fallible. The so-called *foresight or hindsight bias* is an example how unreliable the memory is [KB05, Fis75]. In addition each access alters and can falsify the memory. Recalling past memories cause other memories to fade away and the recalled one becomes stronger. Often thinking back to a past holiday can narrow down the memories to some highlights [BP12]. Daniel L. Schacter [Sch99] classifies the memory's misdeeds into 7 basic sins: (1) transience, (2) absent-mindedness, (3) blocking, (4) misattribution, (5) suggestibility, (6) bias and (7) persistence. Thus, there is a need for a ground truth. Gordon Bell sees the e-memory as the ground truth and the bio-memory as metadata, which links the e-memory [Bel10]. In 2009, Gordon Bell and Jim Gemmel published a book called *Total Recall: How the E-Memory Revolution Will Change Everything* [BG09]. Later the book was renamed to *Your Life, Uploaded: The Digital Way to Better Memory, Health, and Productivity* [BG10]. In the book they summed up their gained insights and thoughts of this project. Gordon Bells sees four steps in the progression of digital immortality[BG10, p. 154ff.]. Firstly digitizing the entire life, secondly supplementing such data with more information, thirdly developing an avatar that responds like the underlying consciousness would and fourthly that the avatar learns and changes over time.

[3] Microsoft Research "MyLifeBits", http://mylifebits.com/

In 2010, Sellen et al. [SW10] criticized the approach of recording everything and demanded in the first step a human-centered approach to augment human memory. Developers should first identify and focus on useful data sources. Furthermore, the memory is a complex system and it should be clear, which cognitive process the tool supports. Moreover, memory augmentation tools should not be seen as substitution of the human memory, instead it should work in synergy. They also defined *Five Rs*, which such systems might support: (1) recollecting, (2) reminiscing, (3) retrieving, (4) reflecting and (5) remembering intentions. In this work we focus on reflecting and remembering intentions.

Nowadays, the basic idea of recording life is known under various buzzwords, like *Life-Logging*, *Quantified Self*, *Personal Informatics*, *Self-Tracking* or *Self-Surveillance*. We summarize these words as *transhumanism*. Transhumanism is a movement overcoming human limits and augmenting human with advanced science and technologies. We see life-logging and the quantified self movement as a subset of transhumanism. Both have recently received a lot of attention and became, because of the raise of applications, graspable for the mainstream. The so-called life-loggers would like to capture their entire lives and all sensory impressions. Members of the quantified self movement would like to measure themselves to gain insights and improve their lives. There are similarities to the field of *biofeedback* [SA03]. According to Swan [Swa13] the quantified self can be transformed into an extended exoself, which enables the development of new senses besides the ordinary senses. The quantified self movement wants to gather raw data and analyze correlations. There is a growing community, which is active in over 100 cities[4] worldwide to exchange best practices and lessons learned. On the quantified self website[5] there is a huge collection of tools to record life. There are for example many digital diaries or journal apps, like *Heyday*[6], *STEP*[7], *Saga*[8], *Argus*[9], *DayOne*[10], *Narrato*[11] or *Momento*[12]. Most of those diaries explicitly need inputs from the user. But some of them already try to implicitly and automatically collect information. Other apps, like *TicTrac*[13], *Quantid*[14], *addapp*[15] or *OptimizeMe*[16], try to track and aggregate multiple types of life data to learn how to improve it. Li et al. [LDF10] distinguish *uni-faceted* and *multi-faceted* systems. Uni-faceted systems limit the type of information, whereas multi-faceted systems collect multiple types of information allowing deeper insights. Furthermore, they proposed a

[4]Quantified Self Meetup website, http://quantified-self.meetup.com/
[5]Quantified Self Guide website, http://quantifiedself.com/guide/
[6]Heyday website, http://www.hey.co/
[7]STEP website, http://www.step.pe/
[8]Saga website, http://www.getsaga.com/
[9]Argus website, http://www.azumio.com/argus
[10]DayOne website, http://dayoneapp.com/
[11]Narrato website, https://www.narrato.co/
[12]Momento website, http://www.momentoapp.com/
[13]TicTrac website, https://www.tictrac.com/
[14]Quantid website, http://www.quantid.co/
[15]addapp website, https://addapp.io/
[16]OptimizeMe website, http://optimizeme-app.com/

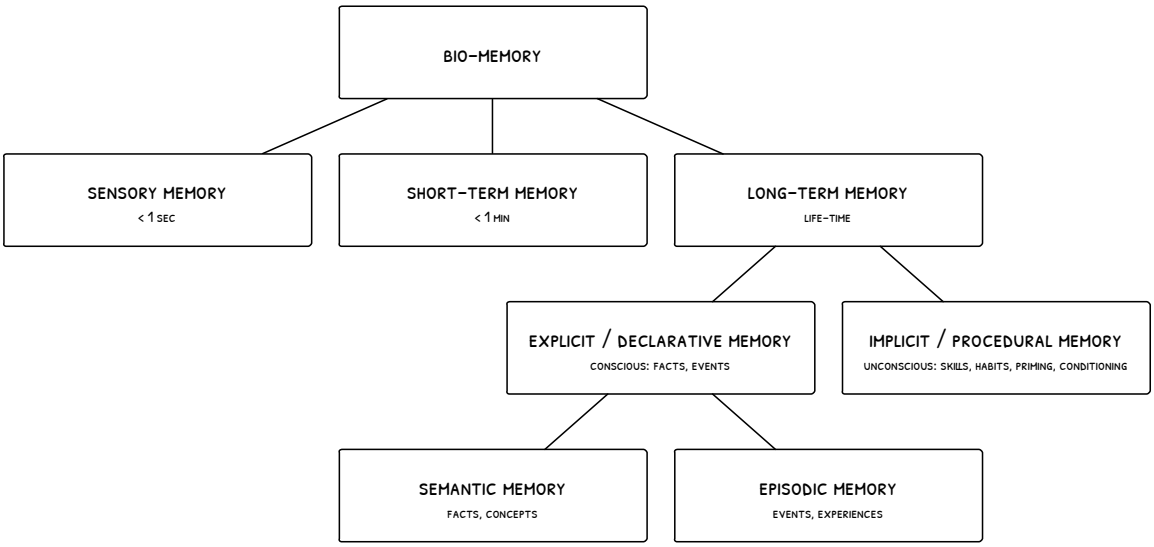


Figure 2.1: Classification of the bio-memory based on [BEAA09, p. 10].

stage-based model of personal informatics systems to make such systems better comparable. They defined five stages: preparation, collection, integration, reflection and action. After each stage there are barriers to overcome. These results can be useful during the development of new systems.

2.2 Bio-Memory Fundamentals

The human memory system is far more complex than the computer memory. The bio-memory is still one of the major research topics of interest within cognitive psychology and many mechanisms remain elusive. However, the bio-memory is a collection of various systems. In the following paragraphs we explain the basic concepts and models.

2.2.1 Memory Process

Hermann Ebbinghaus was a German psychologist and started the study of human memory. He discovered over 100 years ago a simple rule, that the amount learned is proportional to the amount of time spent learning. So, if the learning is doubled, then the information stored is doubled. This relationship is called *total time hypothesis* [BEAA09, p. 70]. The more neurons are fired the merrier people can remember things [KB03]. Anything that increases brain activity leads to a better encoding. The brain remembers just important information. This can be also

forced through simple repetition of information. However, there are different models how information is processed. Baddeley et al. [BEAA09] tried to summarize current research. The most common and simplest model is the multi store model from Atkinson and Shiffrin [AS68]. There are three stages of information processing: (1) encoding, (2) storage and (3) retrieval, which flows through different types of memory: (1) *sensory memory*, (2) *short-term memory* and (3) *long-term memory*. The model describes information flowing through the aforementioned states. First, information is perceived by sense organs and enters the sensory memory. The information is kept less than one second. Then the attended information enters the short-term memory. The capacity is about 7 ± 2 chunks [Mil56] and the information is kept less than a minute. Finally if the information is rehearsed it enters the long-term memory otherwise it is forgotten.

2.2.2 Types of Memories

There is not just one drawer where long-term memories are stored. There are different systems for different purposes like figure 2.1 shows [Squ92, Tul72].

Implicit / Procedural Memory The implicit or procedural memory is mainly responsible for knowing how to do things, like the skill to walk or ride a bike. This memory works in the unconsciousness. Thus, possible priming effects [SSP13, Bow12] also belongs to this part of memory.

Explicit / Declarative Memory The explicit or declarative memory can be further divided into the semantic and episodic memory. The *semantic memory* stores general knowledge about the world, like facts or concepts. The *episodic memory* encodes events or experiences occurring at a specific time in a specific place [BEAA09, p. 114]. The episodic memory allows mentally travelling through time, reliving past events and imagining the future [SC07]. The episodic memory includes the autobiographical memory. It evolves in childhood and forms the personality of a human. Psychologists from the Goethe University Frankfurt [KGK11] studied the autobiographical memory of children, when they have the ability to mimic actions, recognize the past or remember experiences. The research team explored different stages of developing an autobiographical memory. Furthermore, Parker et al. [PCM06] researched the memory of woman called Jill Price. She has a detailed autobiographical memory and is able to recall every day since she was fourteen years old. She remembers every good and bad detail of her life like it has just happened.

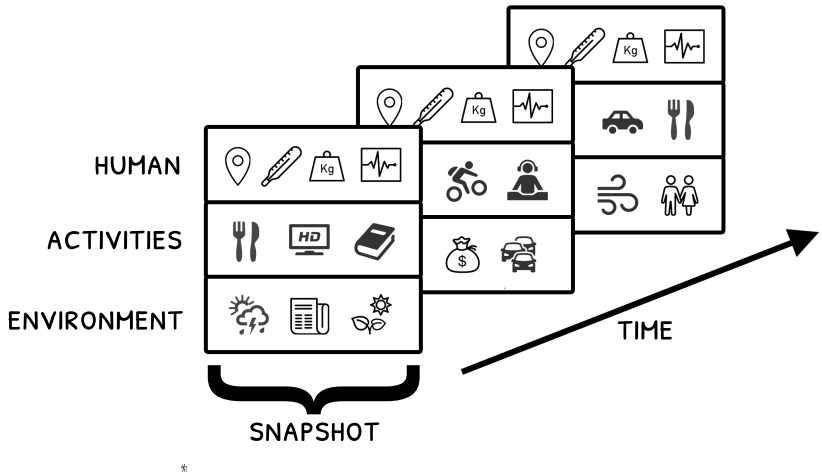


Figure 2.2: Categories of data sources and its chronological sequence.

2.3 Data Sources for e-memory

In the first place there is a need for hardware or sensors that record life data for the e-memory. Thus, it is necessary to define the term e-memory.

Definition 2.3.1
An e-memory or life-log digitally preserves moments and stores information about what a human and its directly exposed environment senses.

The world is filled with small computers. Some are at our homes, some are in our environment and some are with us. They populate every sphere and in 2008, the number of connected things exceeded the number of humans on earth [Swa12b]. In 1991, Mark Weiser [Wei91] called this vision *Ubiquitous Computung*. Mattern et al. [MF10] highlights the possibilities of this technological change. The *Internet of Things* stands for a vision, where the Internet is extended in real life and everyday things become part of it. Every "Thing" could be a possible data source for the e-memory. Thus, not just the human itself generates data. The entire environment generates data. We can think of the world as a central nervous system, which is interconnected.

A vast obstacle is how to capture e-memory data. There are two general ideas how to capture data. Either the user explicitly captures moments writing down notes / making pictures or sensors implicitly capture moments without assistance. We focused on the implicitly part and identified three categories (human, activities, environment) of data sources to better categorize existing solutions. First, the human itself generates for example physiological data like heart frequency, body temperature or body weight. Beside this health data we count location as well

as mind data, like emotions, to this category. Second, the human performs activities. But life is continuous and many activities are simultaneous or fade to each other. There are no concrete frames when an activity starts or ends. For example, a human can simultaneously read, eat and listen to the radio. Third, the environment generates data, which can be relevant to the e-memory. A combination of those categories with a timestamp creates a moment of a human's life. The smaller the interval of the snapshots the more precise is the image of experiences (see figure 2.2). However, to get an idea of the current hardware we present some vendors of the just described categories. More and more products appear and new startups rise, which are often funded by crowed funding platforms.

The environment, including other people, can generate data. This meta data from smart cities[17] or smart homes, like air quality, temperature, humidity, noise, light or pressure can belong to the e-memory. *WigWag*[18], *CubeSensors*[19], *SmartThings*[20] or *Nest*[21] are such devices for smart homes. Shaikh et al. [AMSMH08] build a system which uses environmental sound cues to automatically recognize activities. Moreover, there are even smart light bulbs, like *LIFX*[22] or *Philips hue*[23], that senses and can be remotely controlled. Even flowers can send their status through a Wi-Fi plant sensor[24] or toothbrushes[25] can collect brushing habits. But even intangible assets, like the current financial state, could be part of the e-memory.

In 2003, Aizawa et al. [ATKY04] started developing a life-logging system, which records brain waves, motion sensors, GPS, time data, data from the Internet, data from various applications and annotations by the user. Today smartphones are capable of providing most of such data. Therefore, Rawassizadeh et al. [RTWT13] proposed a generic mobile phone-based life-logging framework. Smartphones became feature-rich mobile devices and are by far the most promising device to track activities. People have their phones near them for all but up to two hours of their waking day and 25 % of smartphone users could not recall a time when their smartphone was not in reach [Lev13]. Moreover, smartphones are for many people the first and last technical device they interact with before waking up or going to sleep [CCI07]. Thus, Smartphones provide a powerful, ubiquitous and affordable platform to gather data. Researcher from the University of Bonn recently released an Android app called *Menthal*[26] [MBM+14]. The app tracks and observes user's usage and behavior on the smartphone in the background receiving data from thousands of people. Furthermore, the most common used software for activity

[17] Libelium website, http://www.libelium.com/
[18] WigWag website, http://wigwag.com/
[19] CubeSensors website, https://cubesensors.com/
[20] SmartThings website, http://www.smartthings.com/
[21] Nest website, https://nest.com/
[22] LIFX website, http://lifx.co/
[23] Philips Hue, http://meethue.com/
[24] Koubachi website, http://www.koubachi.com/
[25] Kolibree website, http://www.kolibree.com/
[26] Menthal website, https://menthal.org/

tracking are smartphone apps (*Moves*[27], *Runtastic*[28], *RunKeeper*[29], *Strava*[30]), because the cost of entry is low. Nevertheless, other wearables, which can be worn around the wrist, collars or belts and log activities, are gaining popularity. Good resources for available hardware can be found under http://devices.wolfram.com/ or https://bioniqhealth.com/. However, *Fitbit*[31], *Jawbone*[32], *Nike*[33], *Adidas*[34], *Misfit*[35] and *Kiwi*[36] are just some of the vendors. In the United States such wearables achieved mass-market penetration. Endevavour Partners [LM14] conducted an internet-based survey among two thousand of Americans. In September 2013, 10 % of people, which are older than 18 years owns an activity tracker. The younger age group around 25 to 34 primarily focuses on fitness optimization whereas the older age groups around 55 to 64 primarily focuses on improving health and extending their lives.

Some wearables not solely track activities. They also capture some human's health data or location data. *iHealth*[37], *Withings*[38], *Polar*[39], *Garmin*[40] or *Basis*[41] are some vendors, that offer capturing devices for such physiological data, like heart rate, perspiration or body weight. The most common neck-worn capture devices to record images are the *Microsoft SenseCam*[42] with its children *Vicon Revue*[43] and *Autographer*[44], and the 2013 published *Narrative Clip*[45]. They record what the user sees and where he is. Furthermore, Google is currently developing contact lenses, which measure the blood glucose level [OP14]. Current research topic is also to implicitly capture the current mood. Fukumoto et al. [FTT13] published a wearable smile/laughter recognition system to connect e-memories with emotions. Their mechanisms achieved an accuracy of 73 % or 94 % for detecting smile or laughter. Other research tried to detect and utilize emotions with skin conductivity, blood volume pressure, respiration or electromyogram [HP98, KJ09, KJ10b, KJ10a]. Doherty et al. [DS10] augmented personal e-memories with available web images, thus enriching the user's recalling experience.

[27] Moves website, http://www.moves-app.com/
[28] Runtastic website, https://www.runtastic.com/
[29] RunKeeper website, http://runkeeper.com/
[30] Strava website, http://www.strava.com/
[31] Fitbit website, https://www.fitbit.com/
[32] Jawbone website, https://jawbone.com/
[33] Nike+ website, http://nikeplus.nike.com
[34] Adidas miCoach website, https://micoach.adidas.com/
[35] Misfit website, http://www.misfitwearables.com/
[36] Kiwi website, http://kiwiwearables.com/
[37] iHealth website, http://ihealthlabs.com/
[38] Withings website, http://www.withings.com/
[39] Polar website, http://www.polar.com/
[40] Garmin website, http://www.garmin.com/
[41] Basis website, http://www.mybasis.com/
[42] SenseCam website, http://research.microsoft.com/sensecam/
[43] Vicon Revue website, http://www.viconrevue.com/
[44] Autographer website, http://www.autographer.com/
[45] Narrative website, http://getnarrative.com/

2.4 Context-Sensitive Systems

Context is what gives something a meaning. The advice to better take the bike to the office does not make sense, when already sitting and driving the car. Recorded data should be enriched with contextual data to create a meaningful e-memory. Rivera-Pelayo et al. [RPZMB12] defines context as "any information that can be used to characterize the situation of a tracked entity and that can aid the reflection process.". They distinguish three types of context: (1) social context, (2) spacial context and (3) historical context. This is similar to our aforementioned categories of data sources, which create a snapshot (see figure 2.2). In 2000, Brown et al. [**?**] discussed different types of context-aware applications and announced the rise of context-aware systems. With the support of today's technologies and e-memories this prediction comes true.

The term of *context-dependent memory* describes the effect of improved recall, if the context present at encoding and retrieval matches [BEAA09, p. 176]. Moreover, a negative mood fosters recalling more negative memories and vice versa. This is called *mood-congruent memory* [BEAA09, p. 178ff.]. In 1981, Brewer and Treyens [BEAA09, p. 131] conducted a study, where people had to recall objects from a room, where they have previously been inside. The participants recalled more schema consistent objects, regardless of whether the objects were present.

There are many applications in the domain of *Personal Information Management*, that support human to accomplish a certain task more efficiently, but most of them do not use contextual information [Jon07]. There are for example applications for note-taking to outsource memory information, like *Evernote*[46], *Microsoft OneNote*[47] or *Google Keep*[48].

Personal digital assistants should be aware of the user and assist its owner according to the current situation — in other words the current context. Rawassizadeh et al. [RTWT13] argued to distinguish life-logging tools and context-aware tools, because of several aspects, like long-term archiving or privacy. However, we think both kind of tools will merge. Therefore, the assistants should set the e-memory in context and make use of it. Researchers from the iClips project discovered, that contextual information improve recalling e-memories [KCFJ08, FKJ08, KBJ09]. Belimpasakis et al. [BRY09] built a life-logging system called *Experience Explorer*. Their aim was to separate the context and content collection mechanisms for a better scalability and extensibility. The focus was to process and to associate this content and context.

In most cases the recording wearables do not solely capture data. Most of the hardware manufacturers provide, on top of their hardware, software to view or analyze the logged data, yet without sufficient interfaces for third-party developers. Therefore, mainly big data-driven companies, which have access to a lot of user data, are able to create such holistic assistants

[46]Evernote website, http://evernote.com/
[47]Microsoft OneNote website, http://www.onenote.com/
[48]Google Keep website, https://drive.google.com/keep/

using contextual information. Nevertheless, Bradley J. Rhodes and Thad Starner developed the *Remembrance Agent* [RS96], a tool that proactively shows a list of documents which might be relevant to the user's current context. In comparison to the other approaches like "Forget-me-not", which mainly gather e-memories, the Remembrance Agent fosters the associative form of recall. The user does not need to exactly know what he is searching for. The tool proactively reminds the user of information. Google has in comparison to the Remembrance Agent a giant data basis to work with. Their *Google Mail People Widget*[49] is similar to the aforementioned Remembrance Agent. While writing e-mails it shows contextual information about the recipient. Another service called *Google Now*[50] tries to predict relevant information, like the current traffic or sports results and shows them. Another application, which is called *reQall Rover*[51] is a reference application to show the possibilities of their developed *reQall Personal Assistance Platform*. The assistant tries to figure out, what the user is going to do and proactively adapts its behavior according to the current context, whether the user is in a meeting, driving or sleeping. Then, it for example mutes incoming calls. Another smartphone app called *EasilyDo*[52] aggregates different sources and processes them to save the user some time. The assistant checks the traffic before the commute or warns of bad weather. Furthermore, there is another breed of evolving assistants, which uses natural language to communicate, like *Apple's Siri*[53] or *Speaktoit Assistant*[54]. They use at least location information to assist the user.

2.5 Summary and Discussion

Digitizing life and augmenting memory has a long history and the basic principle is known under various buzz words like life-logging, quantified self or personal informatics. Moreover, e-memory is a cross-cutting issue. Therefore, the topic around e-memory is interdisciplinary and involves various domains in psychology and computer science.

There is an implicit and explicit approach to record data. Implicit recordings offer more quantitative data, whereas explicit recordings offer more qualitative data. As we previously described there are already many available and evolving data sources that shift towards an implicit capture. Therefore, we want to focus on implicit data sources.

However, we want to build a holistic context-sensitive tool, that ties together findings from previous works and considers the requirements of a mainstream solution. Therefore we use a user-centered approach, like Sellen et al. [SW10] proposed, and conduct in the first step deep requirements analyses.

[49] Google Mail People Widget website, https://support.google.com/mail/answer/1251806?hl=en&ctx=mail
[50] Google Now website, http://www.google.com/landing/now/
[51] reQall website, http://www.reqall.com/
[52] EasilyDo website, https://www.easilydo.com/
[53] Apple Siri website, https://www.apple.com/ios/siri/
[54] Speaktoit Assistant website, http://www.speaktoit.com/

3 Requirements Analysis

What gets measured, gets managed.

(Peter Drucker)

With the ubiquity of smartphones and more recently wearable technologies, we have reached a point where pervasive technologies allow us to bring context-sensitive life-logging solutions into the mainstream. Taking advantage of this development we explore ways to summarize and present content to effectively support the human memory. The requirement studies should clarify the real human needs and requirements for our first prototype. By conducting a series of user studies we aimed to break down the set of features to an effective assembly of tools.

3.1 Focus Groups

To explore the possibilities of life-logging technologies and to better understand people's needs and concerns, we conducted *focus groups* [Smi11] to get a deeper qualitative understanding of the requirements for a mainstream solution.

3.1.1 Set-Up and Procedure

A focus group is a discussion with a group led by a moderator. The discussion in a focus group should inspire and influence other group members. By offering some food and beverages we tried to create a comfortable environment to foster creative thinking. We welcomed and introduced the participants into the research project and explained the goal of the study, the schedule and the rules — for example, there are no right or wrong answers and the answers stay anonymous. After this introduction the participants had to fill out the declaration of consent. Then we started with the discussion. In advance we prepared nine guiding questions with sub questions, which we used for the semi-structured interview and helped us to keep the golden thread. The nine questions were divided into three chapters (see table 3.1). We started with general questions concerning their memory and ended with questions about concrete methods and tools. The last question addresses general human concerns with this technology. After the discussion we explained further actions and thanked the participants. Each focus group lasted about 60 minutes. We made recordings with a dictation machine, which we later transcribed, categorized and analyzed. The focus groups were conducted in German. All

Topic	Question
Memory	What do you often forget? What are memories from your life, which you do not want to forget? What is important for you to remember in your daily routine? How do you temporally distinguish remarkable memories?
Methods and Tools	How is your approach to remember certain information? How and which tools do you use to recall memories? Do you have problems with these tools? What are innovative tools to augment human memory?
Concerns	What concerns do you have, if your entire life is recorded?

Table 3.1: Questions of the focus groups.

questions and results were translated to English. In the first run we assigned each statement to a superior, abstract category. Afterwards we pooled all statements with the same category together and interpreted them. Thereby, we followed the approach proposed by Mayring [May08].

3.1.2 Participants

In total there were 7 female and 12 male participants between 22 and 71 years (Mdn=25, M=29, SD=14). Nine participants were students, Nine participants were employed and one participant was retired. We organized three focus groups to compare and evaluate the different findings of each group. Each group had around six participants and different characteristics:

Technophilic Characters In the first group there were technophilic persons around 25 years. All group members were male and co-workers of a small education and training company teaching new media. The focus group took place in their familiar office after work.

Non-Technophilic Characters The second group consisted out of mixed non-technopilic people with any age and different professions. In this group there were five females and three males. This group should stand for the broad bulk of end consumers. The focus group took place at an apartment in the evening.

Different Memory Characters The third group were students from the university. All of the invited members had a special strategy of learning and a deeper understanding of the technological background. The focus group took place in the university in a conference room after lunch. (see figure 3.1)

Figure 3.1: Focus group in progress.

3.1.3 Results

There were no notable differences between the different focus groups. Therefore, we discuss all answers together — pooled together question by question.

3.1.3.1 1. Question: What do you often forget?

Tasks and Events The participants mainly forget personal tasks and events, which affect their daily life. Nobody instantly mentioned events, which are further in the past and important for their autobiographical memory. All answers are basically connected to the period around the present and future necessary for the daily life.

Nothing Interestingly in two groups two people instantly said that they do not forget anything. But later in the discussion they noticed that they however have some memory problems. It shows that they overestimated their memory and that they have a bad self-reflection of their memory.

3.1.3.2 2. Question: What are memories from your life, which you do not want to forget?

Later Recognition Some participants had difficulties to answer the question. Their point of view is that the brain shall decide if the memory is remarkable. They trust the inner mechanics and the oblivion of their brain. On the other side some participants do not know in the present if the moment is valuable in the future. Sometimes people just recognize in the future if the moment was important for their biography, for example the day when they first met their future wife or husband.

Memory Landmarks Another important outcome is that irregular and unique happenings that are distinguish from the daily routine are more important and thus are better remembered. Such drastic life events or extraordinary experiences are mainly connected to their social lives but also to global political incidents. This finding is consistent with the term of *memory landmarks* [Shu98, CJ09], which are of great personal importance.

Positive Events The participants mainly want to remember positive events with good emotions (marriages, holidays or births). This tendency to recall more pleasant memories than negative memories is called *positivity bias* [Sea83]. It increases over lifespan [CMC03]. However, they also answered some negative events (diseases, funerals, disasters), but it was not their first thought. Furthermore, bad memories remain longer in the memory — for example "if a person is mean to you, then you probably remembers it for a long time" (participant #1.3). One participant mentioned that "in sales you should not anger customers because it is difficult to get back their trust" (participant #1.1).

3.1.3.3 3. Question: What is important for you to remember in your daily routine?

Schedule For all participants it is important to remember what tasks they have to do and when they have to do tasks. It is important that they have a daily or weekly schedule on a paper or in their mind, which defines their rhythm of life.

Location of Objects In addition they want to remember where they have put objects. Some people often forget where they put their objects like their key, car or lighter.

Spontaneous Things Furthermore they want to remember spontaneous things occurring during the day like a good song in the radio while driving or good ideas while showering. Hence, there is some need for assistance in quickly saving things in all situations in life.

3.1.3.4 4. Question: How do you temporally distinguish remarkable memories?

Decay Drawing boundaries to temporally distinguish remarkable memories were difficult for the participants. They usually do not always think about what they have to remember. Usually people do not instantly forget everything. The encoded data just blurs and disappears in a fog. After a while they forget the details and just know the key points outstanding the fog like a lighthouse — for example, "if someone tells you joke, then you can probably remember the joke after a while, but not the exact wording" (participant #1.1).

3 Categories However, after a while the participants came up with three different categories. In the first category are memories that are necessary for daily tasks. In this working memory they keep information about a day or a week — for instance, what they have eaten or received and sent emails. In the second category are more structured memories, like the time for the weekly meeting in the job or names from fellow students. This information is longer encoded about months or even several years. The third category holds remarkable memories, which shapes the person and are important for the autobiographical memory or for the habitual social environment. Remarkable memories are similar to the answers in the second questions. The participants argued, that they usually do not forget this kind of important information.

3.1.3.5 5. Question: How is your approach to remember certain information?

Preprocess Information Most of the participants had similar learning approaches. Firstly, they preprocess the raw data by getting an overview, searching relevant information and writing summaries or cheat sheets with their own words. This helps to understand relations. After that they learn the written facts by heart through repetition or using mnemonics. However, after exams the factual knowledge is quickly vanished. This is called *bulimic learning*, whereby they quickly devour the facts and later regurgitate them [ZSP10].

Individual Strategy Each individual has developed to some degree an own strategy to remember. Two participants, for example, learn by talking with the wall or in the car. One participant even records the subject matter and afterwards plays back the audio recording.

Remember Paths A couple of participants do not want to remember everything by heart. It is sufficient for them to know where to search for the needed information. For them it is more important to understand correlations instead of factual knowledge.

Diary Just one participant mentioned a diary, although the participant does not use the diary to remember, but rather to process experiences while writing.

3.1.3.6 6. Question: How and which tools do you use to recall memories?

Stimuli The participants recall memories when they receive certain stimuli. These stimuli are triggered by human senses. The senses are generating emotions, which helps to remember. The more emotions are connected the better they can remember. Contextual cues trigger past memories. Some participants often remember things spontaneously when they do not directly think of it. They remember things when they, for example, walk by some remarkable points where they had their first kiss or a good friend died by a car accident.

Written Information The most common tool in recall is written information. Almost all participants use some kind of lists or calendars for important and faraway tasks or events. Other used tools are diaries, protocols of meetings, phone books, packing lists, shopping lists, Post-it notes, index cards, photo albums or videos. One participant even calls his text document as external brain clipboard. Although there are a lot of todo list apps in the app stores only less people use those apps daily. Some participants previously tried some todo or shopping list apps, but they were too complicated to use. Other participants were not aware of the technological possibilities nowadays, like location-based or time-based reminders. Most of the participants still use paper for reminders. Some persons schedule tasks on the previous day and check it off during the day.

Tangible Reminders Every participant uses some kind of tangible reminders. They physically prepare clothes for the next day or put objects somewhere (table, stairway, door), where they will stumble over it the next day. These reminders work because people compare their environment with their standard environment or schema (see chapter 2). If there is something different in comparison to their standard schema, they start to ask themselves questions. A classical example is to turn around the wristwatch. Another participant throws a book in the middle of the room as a memory aid, when he is to lazy to write a note.

Social Environment Another often-used memory aid is the social environment. People ask certain persons like wife, girlfriend or study group member for particular information or memories. Every focus group said, that they do not want to live in the past but look into the future, although most of them reminisce often during social events with friends. Everybody gladly tells stories from their past. Reminiscence is a pleasant activity.

Chain of Associations All participants can not directly access certain memories, but they argued that "there are always more memories than you can think of" (participant #1.2). They reconstruct and build a duplicate of the memory by swinging from one key frame to the next one like Tarzan the Ape Man — for example, to find a certain holiday they choose one key event and go from there back or forth in the chain of associations.

3.1.3.7 7. Question: Do you have problems with these tools?

Loosing and Distribution Participants have difficulties with the ease of loosing and the distribution of information. They have for example too many notes or regularly forget their shopping list. Moreover, tasks and calendar events are distributed over different places.

Design and Properties The design and properties have to be clear. Many apps miss this clarity. Another problem are bad physical properties like limited space on papers or possible disc corruptions.

Emotions It is difficult to save true emotions. In photos people often are forced to smile, but in general this does not reflect the right state of mind.

Laziness and Motivation The most important outcome is that humans are lazy and need motivation to use tools or to write something down. That is why we argue, that life-logging applications, where users have to explicitly and tediously log their data have no future for the mainstream. People prefer to use tools, which operate in the background or can be naturally used. They prefer telling something instead of writing. Hence, tools have to foster the motivation of usage. It is important to highlight the motivation by using and while using the tool. The users want a moment of success like striking out completed tasks on a paper or crumpling up the paper. They want a sense of achievement and an achievement system.

3.1.3.8 8. Question: What are innovative tools to augment human memory?

The participants came up with three different kinds of directions for a memory augmentation solution.

Future Guidance Firstly, participants stated that they would use the recorded life-log data, such as location or consumed food for future guidance. Participants stated that they would like to learn from their past, but they did not want just plain reports or statistics. Rather they preferred compressed or abstract reports and numbers that they could use to track improvements, in line with Peter Drucker's saying "What gets measured, gets managed.". Moreover, different data sources should be connected to get deeper and holistic insights into everyday activities. The data should be automatically evaluated to prepare advices like "Your wallet is almost empty. There's an ATM 50 meters away from you." or "Your fridge is running out of milk. There's an offer in the grocery you're going to pass in five minutes.".

Browse and Search The second direction is to browse and search the life-logs to extract certain information. Fading memories up to the point of forgetting is part of life. In some cases deliberate forgetting may be desired. Although every focus group said that they did not want to live in the past but look into the future, most of them reminiscence often

during social events with friends. Besides reminiscing and reliving the past, selected recall can be a reason for searching the past. Cases from the medical field involve dementia. To help avoiding information overload, people tend to outsource information and recall it later when needed, for example, when meeting new people at a conference, business cards are being exchanged. Information outsourced in this way can be accessed later in a dedicated search. Another idea discussed during the focus group involved the usage of recorded data as evidence for crimes: to prove a certain sequence of events, for example. Chen yielded similar results [CJ12]. The so-called *eyewitness testimony* [WMP06] has been found by psychologists extremely unreliable, yet judges and jurors tend to find such testimony highly believable.

Assistant Participants imagined a digital life assistant being able to help them throughout the day. One participant described it as "a kind of little goblin in your ear" (participant #3.3), which was capable of telling, for example, where lost objects were or what to do next. Information could be conveyed via speech, but other media should be available as well. This life assistant should be able to detect if a task was done or when it was time to remind users of open tasks. For example, proactive information could be given when certain shopping tours were due, as in: "you were going to cook pasta tonight. You should stop by the grocery store on the way home." In a reactive sense, the assistant could log conversations and automatically derive a summary of the topics discussed with eventual tasks that emerged.

3.1.3.9 9. Question: What concerns do you have, if your entire life is recorded?

Legacy Issues Participants are concerned about legacy issues and have fear of this technology change. After partying too much they are maybe embarrassed afterwards. Furthermore, they can easier forgive when they forget. When two persons had a dispute a year ago then it is good that it is dead and buried. But because of the digitization many things are preserved, especially things, which they knowingly suppressed, forgot or forgave. When they send a message to someone they have to keep in mind that the recipient can confront them sometime with it. This leads to a "noncommittal behavior" (participant #1.4). Sometimes it is good to talk something good. They do not want to know everything from their partner or children or sit in the retirement home and regret what they have not done. There is a reason why they forget a trauma or other things. Finishing off with memories and forgetting is self-protection. "The nebulous beautification of mist after processing death is important that after years it does not hurt that much anymore" (participant #3.6). Therefore, maybe the access to the e-memory should be restricted. The vast amount of recorded private and intimate data is for a couple of participants "totally scary" (participant #1.3). Legacy data can become a "digital boomerang" (participant #1.5) that can hit his sender anytime again.

Abuse The next concern is the abuse of personal data. Past memories can be an instrument of torture by replaying horrible memories over and over. Moreover, past memories can be altered and manipulated. The participants fear the loose of data protection and privacy that sooner or later someone like the government wants to access all the data. "30 years ago the population census in Germany caused a storm of protest, but nowadays it changed. A lot of people already expose their private data through shopping cards." (participant #2.6) The users should have the complete power over their private data not becoming a transparent human. "There are probably algorithms that non-independently decide what is important." (participant #3.1) This kind of filter or memory bubble can distort the worldview.

Value Proposition People need additional value and benefits in recording their lives. One participant does not regret, that he know almost nothing from his kindergarten anymore. Another one does not want to get reminded of thousands of old memories. From the childhood or holidays there are so many photos, but people rarely look at them. One participant argued, that a single life is not that eventful and meaningful and does not have to be preserved. People do not want to invest so much time in browsing and searching in the past.

Big Data Another major concern is the amount of recorded data and how to handle all of it. Big questions are where to save all the data, whether the data should be physically under the user's protection or whether the data should be outsourced to third-party supplier. In addition, people record much unnecessary data with much noise in it. They can not manually look at everything. They need automatically analyses and access methods. One possible solution is to adapt the sampling rate according to the context. Another big question is what happens with the e-memory after death, because there are a lot of private moments that nobody should ever see. We need some kind of digital cemetery and legal regulations. One participant recently had to dissolve its parent's house. The entire life and the collected belongings during life were quickly thrown away. Digital legacy can thus be easier archived.

3.1.4 Implications

With the help of the focus groups we gained some insights to come up with a first idea of a prototype, that leverages e-memories. In his work Gordon Bell [BG10] describes the kind of everyday data he logs and his interpretation of it. To bring applications like *MyLifeBits* to a mainstream community, we have to take into account that most people are far from being experts in handling such data. Hence, we have to introduce an extra abstraction layer, quite like a "black box". Bell suggests several methods and tools for people to be able to create their own life-logs, but most of his suggestions are too complex to be implemented by average users. The need for simplicity was stretched on numerous occasions during our focus groups. Complexity needs to be reduced to a minimum to make people adapt and successfully use

life-logging technology. Hence, we propose an implicit approach for collecting and making sense of everyday user data. We want to overcome the obstacle of data distribution and pool data in one device. The tool should be disguised as a bedside device, which also functions as an alarm clock. It should preprocess information and give the user a short briefing in the morning about the day, because the people often forget their daily schedule with tasks and events. Apart from the morning briefing it should guide the user during the day with short notifications based on the e-memory.

3.2 Online Survey

After gaining a first qualitative impression of users' needs we published an online survey to verify and extend the results from the focus groups. The results helped us to refine our first prototype concept.

3.2.1 Set-Up and Procedure

The survey was carried out online within two weeks from the 7th until 21st of March 2014. We wrote the questions in English and used *Google Forms*[1] (see appendix A). We promoted the survey through social media and various mailing lists from the university and a business concern.

The online survey was divided into three chapters: introduction to life-logging technologies with general questions about experiences so far, self-reflection, planning of the future and questions about the prototype and about the habits of the participants. The survey ended with questions about demographics like the age or employment, to find dependencies between demographics and the habits of the participants. At the end of each chapter, we allowed the participants to write any other comments to get the most out of the participation.

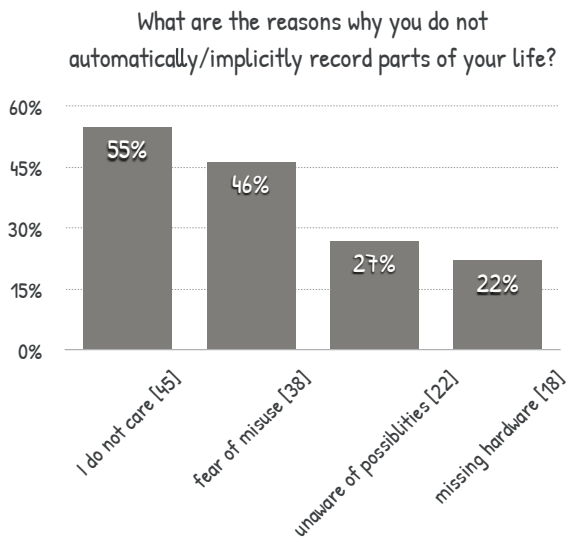
3.2.2 Participants

In total 125 participants, 77 males and 48 females completed the online survey. The average age of the participants was 27.98 (SD=8.06). The age ranged between 21 and 56. Among the participants were 66 students, 56 employees and 3 freelancers / self-employed persons. No unemployed persons participated in the survey. The analysis below offers new input according to our initial concept for a prototype.

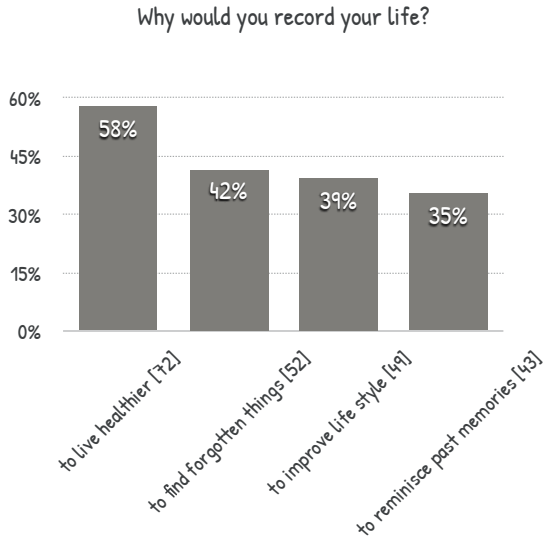
3.2.3 Results

In the following sections we describe the results from the different parts of the online survey. In some charts are numbers in squared brackets. Those are the absolute number of the parameter. Most of the questions allowed multiple answers. In those questions the percentage refers to the total amount of the analyzed group in the chart.

[1]Google Forms website, https://drive.google.com/forms/



(a) A lot of participants do not care about life-logging technologies.



(b) Health is most important for participants.

Figure 3.2: Reasons for and against life-logging.

3.2.3.1 Life-logging Technologies

We started our survey with a chapter about the general topic of implicit life-logging. In the first question we asked the participants, whether they already use apps / technologies, that automatically record parts of their lives. 34 % of the participants already use such technologies like *Runtastic* or *Moves*. However, the majority of 66 % do not use apps or devices so far. This is independent of gender and age.

The reason why 82 participants still do not use technologies to record parts of their life is crucial for further considerations (see figure 3.2a). 22 % do not have the right hardware. Hence, they do not have a smartphone or other capable tracking devices or they are satisfied with mobile phones with simple call and message functions. Therefore, only 18 out of 125 participants miss the hardware. Here, we can recognize, how much importance this issue has gained in recent years and how many are capable of recording their lives, yet not making use of it. Furthermore, the most mentioned reasons against recording are "I do not care" with 55 % and "fear of misuse" with 46 %. Participants with the reason "I do not care" do not know the advantages of using life-logging technologies yet. In times of NSA wiretapping scandals, the fear of misuse still exists. Nobody knows what happens with the recorded data and the sensitization for the correct use is not yet common. The following comment illustrates this frustration: "Problem is that you never for sure know which apps do record your personal data like location, activation... but in days of the NSA affairs this is nothing special any more" (participant #76). 27 % are unaware of the offered possibilities. Hence, we can conclude a

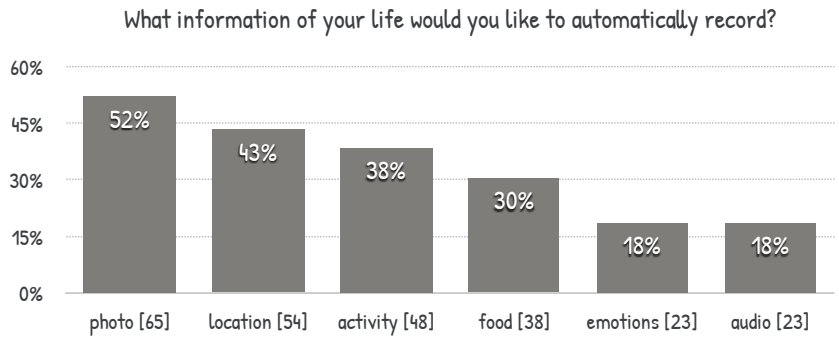
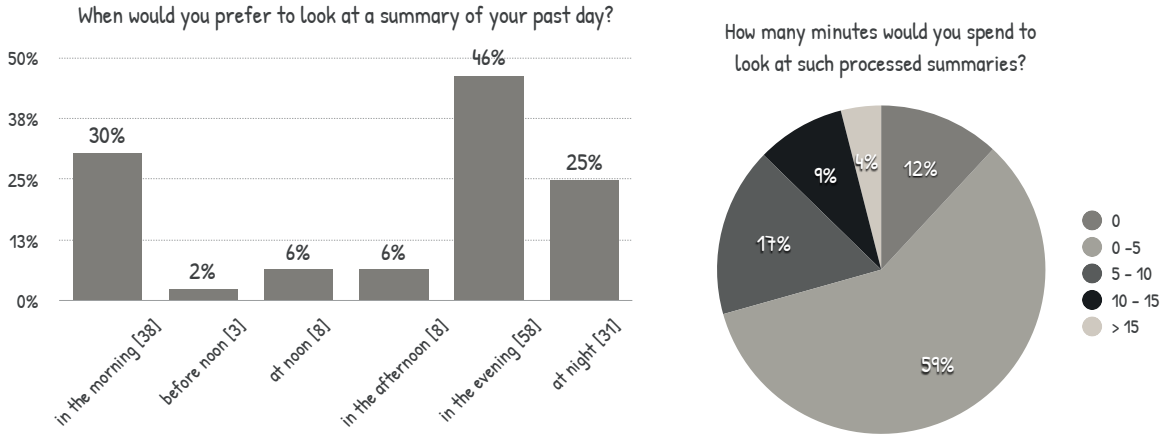


Figure 3.3: People want to record photos, their locations and their activities the most.

lack of awareness and familiarization with the topic. Other reasons for not using automatic life-logging technologies are: too complicated, too cumbersome, too much battery consumption, privacy or that the apps are not worth it yet. Many human concerns, which we identified during the focus groups, where touched in the additional comments again. Just to quote some of them:

- "Any kind of automatic recording of any part of my life is crucial for me and therefore I'm extremely conservative with such tools. [...] I do what ever is possible to minimise the risk of 'profiling'." (participant #82)
- "What would be the benefit of living the past?" (participant #101)
- "I prefer to care about the curriculum of my days on myself (in terms of actively using the synapses I have). In my opinion the long term costs of (too much) digital guidance is a decreasing ability to think in different ways, which will restrict an independent way of life. Too much guidance will be a harm to society." (participant #104)
- "You should think about data protection and privacy. People won't like to be monitored without asked before at every place (bathroom ...). And they want to be able to stop recording and delete data for sure." (participant #113)

The most important reason why people would record their life is to live healthier with 58 % (see figure 3.2b). Here, it is noticeable that the majority of participants, who currently do not use implicit life-logging technologies, would record their lives to live healthier, too. That shows the increasing understanding of health. People are more and more precautionary and want to proactively protect themselves against diseases. All other reasons are mentioned around 40 %, which shows the importance of all reasons. There is no difference considering the gender. Only seven participants answered that they would not record their life for any reason. However, one participant demanded a "tool that records stress levels and reasons for it [...] preventing or optimizing your daily routine to avoid or minimize stress" (participant #95).



(a) People want to look in the morning and evening at summaries of the past day.

(b) 59 % people would spend up to 5 minutes looking at summaries?

Figure 3.4: When and how long would people look at summaries?

In the next step we asked the participants what they would like to automatically record. The top answers were photo (52 %), location (43 %) and activity (38 %) (see figure 3.3). The visual aspect correlates with the fact, that 60 to 80 % of all perceived information depends on the visual system. The recording of what they eat is more nice to have, because only 30 % want to automatically record it. As another result the answers of the participants showed that recordings of emotional statuses and audio with less than 20 % are not yet important for them to record. However, especially emotions are important from the technical point of view to find memory landmarks in the e-memory.

3.2.3.2 Self-Reflection (past)

The question, when people want to look at summaries of the day, shows that 46 % want to have a look at a summary in the evening and 30 % in the morning. Those answers are not dependent on the employment of the participants. The period before noon until afternoon is not relevant at all (see figure 3.4a). Hence, the morning or the evening is a good time to recapitulate the day, since the participants are at home and have time to settle down.

59 % of the participants would spend between 0.1 and 5 minutes to look at such processed summaries. The median is five minutes (M=5.81, SD=5.58) with a maximum of 30 minutes. 12 % do not want to spend time looking at summaries of the last day (see figure 3.4b). So, the general rule of thumb is around five minutes but could be longer if the provided information provides enough additional value.

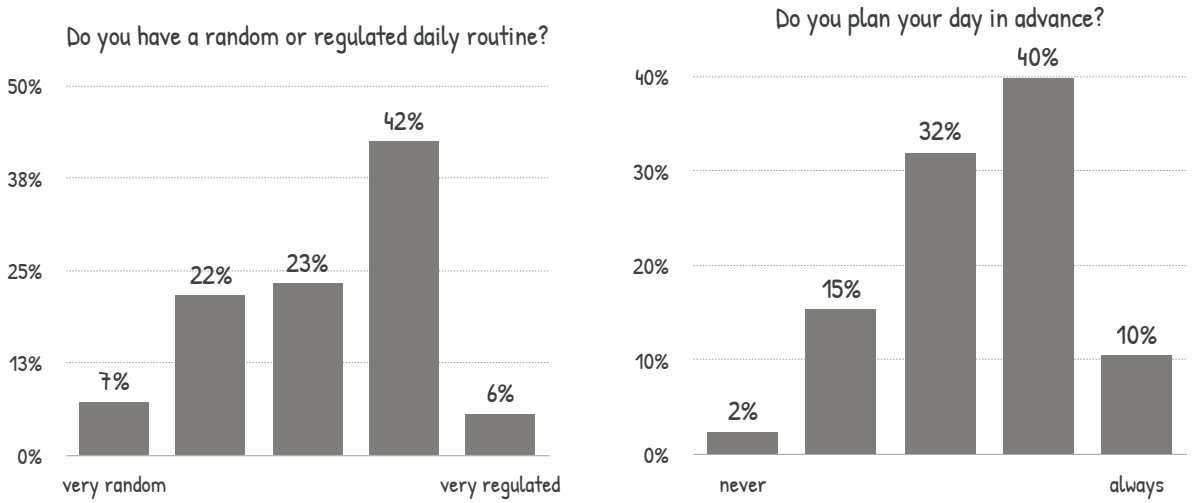


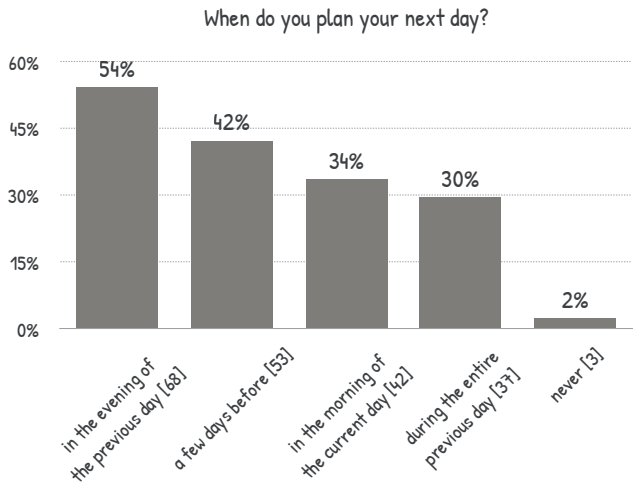
Figure 3.5: Most participants have a regulated day and plan their day in advance.

3.2.3.3 Planning (future)

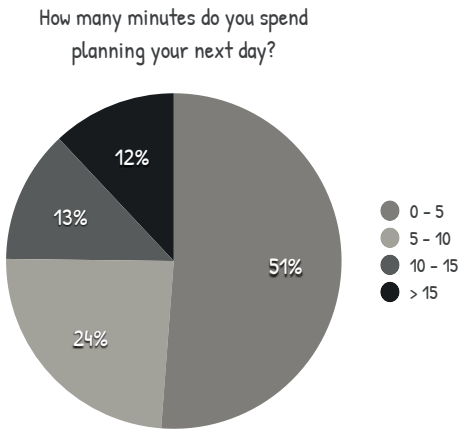
Next, we asked the participants, whether they have a regulated daily routine and whether they plan their day in advance. People, who plan their day in advance, are the interesting target group for our potential prototype. Thus, the result of these issues was of major importance. The majority of participants has a regular daily routine and plans their day in advance. 48 % have a regulated or very regulated daily routine and 29 % have a random or very random daily routine. (see figure 3.5). Moreover 51 % plan their day most of the time or always in advance and 2 % never plan their day in advance. 15 % plan their day most of the time not in advance. And the rest (32 %) responded to this question neither that they never plan their day in advance, nor that they always plan it. We can conclude, that in general there is a potential need to support people to plan their day in advance.

Just 7 out of 125 participants (6 %) plan their day only in the morning of the current day. All other participants (87 %) plan their day at least in the evening of the previous day (see figure 3.6a). For 7 % of the participants it depends on the upcoming activities, for example, "booking a washing machine happens a few days in advance, while social activities are mostly spontaneous or 1 day in advance" (participant #7). Some participants differentiate between business and private: "Business: This part of my life is really planned and 80 % of the dates are with a 2..14 days forerun. Private: The periodic dates are planned months in advance, as well as e.g. bank holidays, birthdays. smaller dates are planned from one day to the next or ad hoc." (participant #82)

51 % of the participants need at the maximum five minutes to plan their next day. The median is five minutes (M=10.17 , SD=11.97) (see figure 3.6b). Planning the future is a process



(a) Most people are planning in the evening their next day.



(b) Most people spend up to 5 minutes on planning their next day.

Figure 3.6: When people plan their day and what tools do they use?

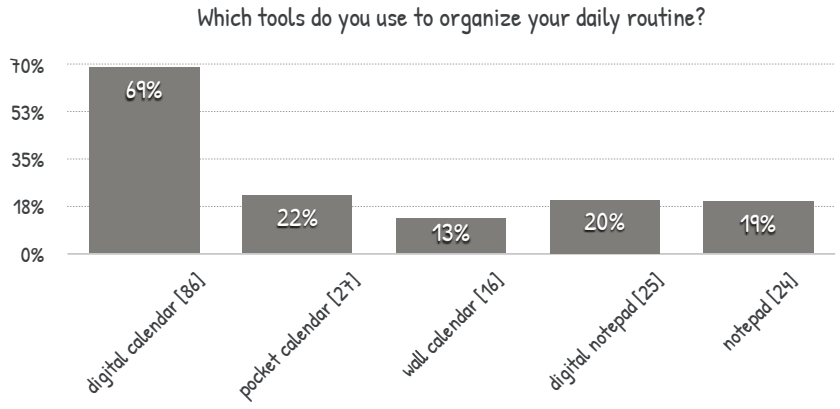


Figure 3.7: Most people use digital calendars to organize their daily routine.

which runs in the background while doing many other activities. Therefore, the test persons estimated the time they directly think about planning the next day.

For further considerations it is important, which tools the participants use to organize their daily routine. In times of digital media already 69 % organize their daily life with a digital calendar and just 22 % use a pocket calendar made of paper. The participants use digital notes and paper notes to a similar amount (see figure 3.7).

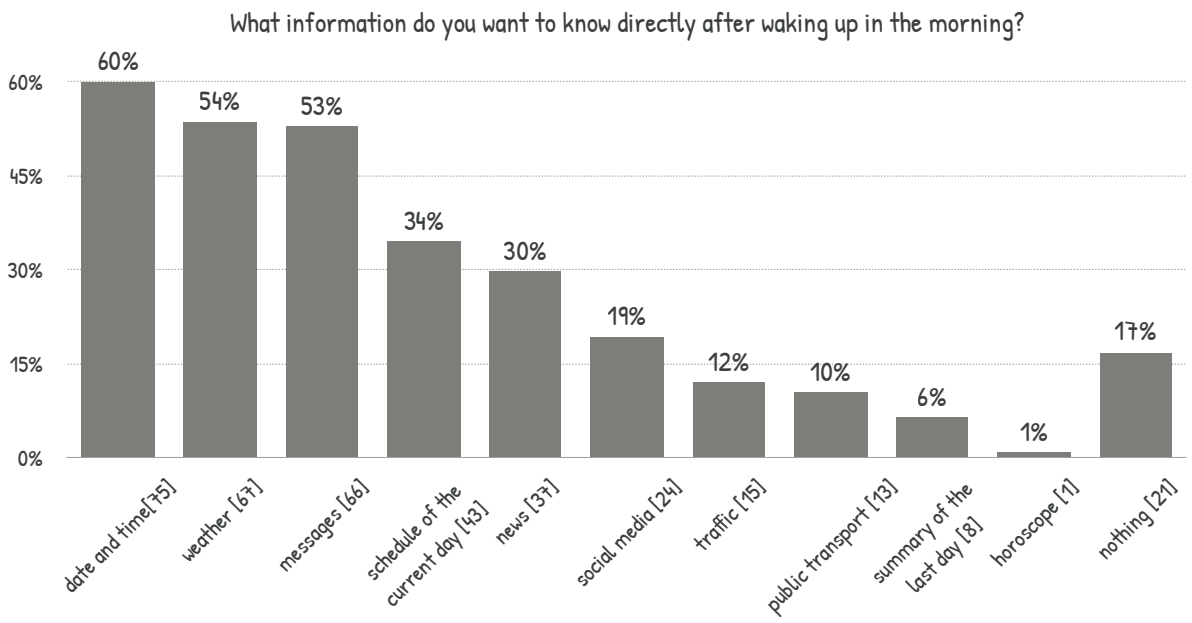


Figure 3.8: People would like to know the date and time, the weather and received messages directly after waking up.

3.2.3.4 Prototype

Usual alarm clocks wake up the majority of the participants (53 %). 14 % wake up on their own. All other possibilities like to wake up with the radio, with music, by persons or with light are with less than 10 % not very common, although there are studies [THE+04], which show evidence improving the wake up process with a dawn simulator. Hence, here is still room for improvements to support the wake up process.

Moreover, *Harris Interactive*[2], a market research firm, conducted an online survey [SOA13] about which app the participants check first in the morning. The study took place in the United States in August 2013 among 2000 adults. The most common checked apps are email (67%), weather (45 %), social media (40 %) and news (35 %). The participants in our online survey constituted similar results. Directly after waking up around 20 % want to get information about date and time, weather and messages (email, sms) (see figure 3.8). Just 17 % do not want to consume any information directly after waking up.

In the next question we asked, how information should be presented in the morning in bed. In digital times, almost everyone owns a smartphone or tablet. Therefore, it is reasonable, that 51 % prefer the presentation via smartphone or tablet in the morning. Although a projector is

[2]Harris Interactive website, [3]

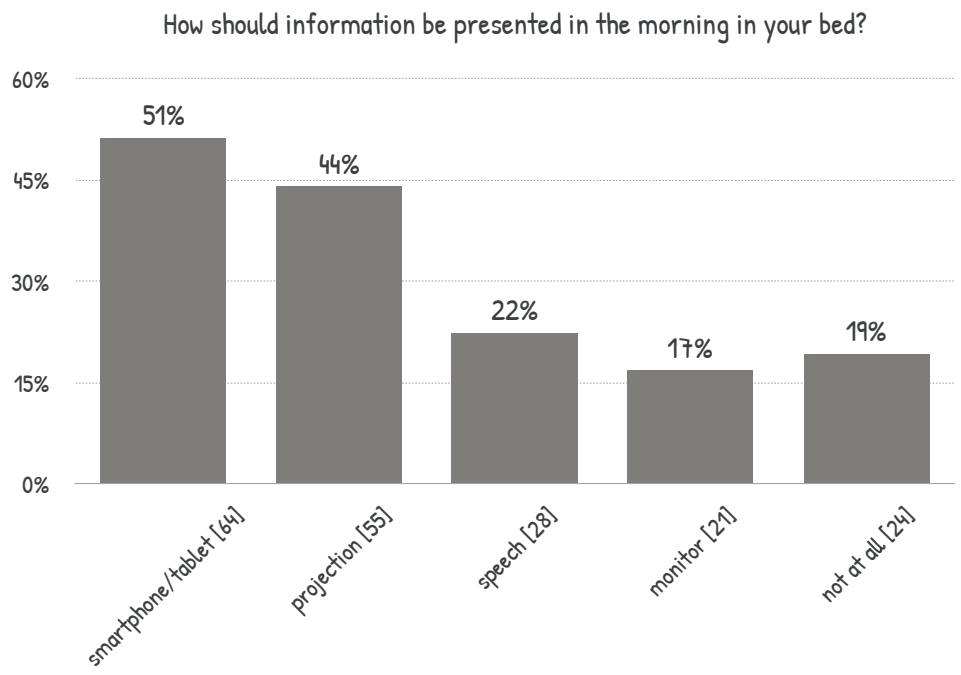


Figure 3.9: Most people like information to be presented on a smartphone/tablet or with a projection.

not a common consumer device, 44 % can imagine to consume information with a projector. Another form of providing information could be via an audio stream. With 22 % this option could be interesting in combination for example with a projector to explore new possibilities. However, 19 % do not want a presentation in the morning in their bed at all (see figure 3.9).

The question, whether the participants want to get guidance during the day via notifications showed that the majority (50 %) do not want to get any notifications during the day. 35 % want to get notifications and 13 % do not have an opinion about it. The participants, who do not have an opinion about it, do not use life-logging technologies so far. Furthermore, they stated, that they are unaware of the possibilities and fear about wrong usage. The acceptable amount of notifications is between 0 and 10000. But here one must note, that the participant who wants 10000 notifications commented, that he wants to get as many notifications as necessary and helpful. Other comments were: "Receive many information is helpful but too much will break you down" (participant #98) or "So the acceptable amount of notification depends on specifications of the individual day. Moreover an option to set a personal limit of notifications per day would be cool to adapt to life style patterns" (participant #12). On smartphones there are currently no detailed mechanisms how to handle the importance of notifications, although users differently value notifications from different categories [SSHD+14]. However, the median of the amount of notifications is three (M=4.50, SD=5.37). So, the participants

are willing to receive around three notifications each day. One participant demanded a system, that "stays quiet in the background but informs [...] about a critical status (e.g. you have moved only 2km the last 2 days! Go jogging or something!)" (participant #52).

3.2.4 Implications

The results of the focus group were a good possibility to get a first impression. The online survey was a continuation and more detailed view of the first impression gathered during the focus groups. In addition, significantly more people were interviewed and thus a larger sample and a more meaningful assessment were possible.

We expected that a continuous guidance with notifications would be more popular in the online survey, but the results were disillusioning. However, we think there is still a great potential in a continuous context-sensitive support during the day, but the people are just not aware of it. Therefore we just include it as an optional requirement for our prototype and focus on the morning assistant.

Now, we know how and what information people want to consume in the morning. We verified the most critical concerns and benefits and are now capable addressing them in our prototype. Keeping these results in mind we are capable to write a concept for our prototype.

3.3 Summary and Discussion

In this chapter we described our efforts to gain a deeper understanding of this broad topic and requirements for our prototype. We conducted three focus groups with 19 participants and one online survey with 125 participants. The focus groups helped us to get a first impression and understand what obstacles we are facing and we need to overcome. Now, we know the weak spots of memory recall in daily life and can conclude requirements to build a first prototype. The online survey provided mainly quantitative feedback and helped us to refine our prototype idea derived from the focus groups. We proved, that there is a lot of uncovered potential in leveraging e-memories.

We learned, that overcoming users' concerns regarding legacy issues, abuse, additional value or data handling is of high importance in order to create a mainstream application with personal data. Moreover, every person has its own style of personal managing. We have to further investigate, whether we find a common basis for this individuality. Furthermore, people have problems with the distribution of data and they complained about the lack of motivation of current systems. They are for example too lazy to explicitly record data. In addition, the participants showed us some directions for a digital life assistant. Therefore, our prototype should focus on the data aggregation and guidance. Most people are willing to reflect up to five minutes in the morning or in the evening e-memory summaries. Images, locations and

activities are most important. Moreover, 69 % of the participants use digital calendars to organize their daily routine and most of the participants would plan the next day up to five minutes in advance — in terms of directly thinking about it. Lastly, people would use life-logging technologies mainly to live healthier. Therefore, there is a great potential in preventive healthcare, which could be achieved through guidance and continuous monitoring.

4 Implementation

> Technology - and life, for that matter - has a trajectory. Things are happening whether you like them or not.
>
> *(Julien Smith, CEO of Breather)*

This chapter describes the translation of results from the requirement studies to the implementation of our prototype. We tied together findings from the field of cognitive psychology and memory research with the functionalities of the assistant. At first we present the basic concept and the vision of our prototype. Afterwards we describe the initial design with its limitations we had to make for our first evaluation and the actual implementation.

4.1 Concept

Based on the discussions in the focus groups, we created a concept for a first prototype for a holistic digital assistant, with the purpose of supporting people in their daily routine using mainly implicitly gathered life-log data or data, which is already there. The system should adapt and learn from its user and seamless integrate into daily life. The goal is to port the concept of business intelligence to life intelligence. Therefore, we call our prototype *L.I.S.A - Life Intelligence Software Assistant* and prospectively name the system as a whole *LISA*. The prototype should focus on the aggregation of data and not the gathering. The past should help to live in the present and form the future. The assistant saves time by preprocessing information, prepares people for the day and guides them. LISA strengthens their memory by drawing connections between old and upcoming memories putting the current or upcoming situation in context. Figure 4.1 shows the abstract concept of the assistant, which computing unit is at the user's home.

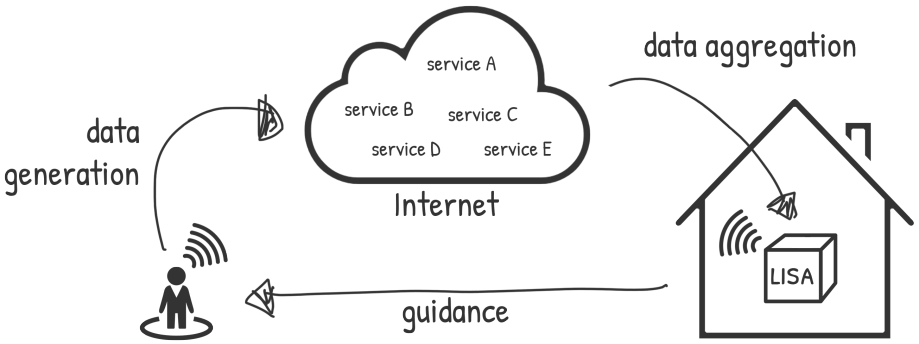


Figure 4.1: LISA aggregates data from different data sources, which the user is connected to. LISA utilizes data and gives the user guidance.

4.2 User Stories and Scenarios

In this section we describe and discuss the requirements of the system, which we will later cut down for our first evaluation cycle. We used the *RFC 2119*[1] to indicate the requirement level. *User stories* give each topic an overview over the requirement to guide the design.

4.2.1 Data Fragmentation

As a user, I want a local aggregation of my data from different data sources, to have the control over my own data and have them always at my fingertips.

To overcome the users' concern of abusing data, LISA must analyze the personal data in a save environment of the user. Therefore the system must be at the users' homes to protect their privacy. Initially LISA should make sense of the chaos, overcoming the distribution of data and aggregating different services to gain insights. LISA should find mechanisms to orchestrate data sources for an automated arrangement and management.

Existing assistants (see chapter 2), like *Siri* and *Google Now* just utilize their own data sources and therefore strive locking in the user. Our concept should allow more data independence through distributed data generation and locally data utilization, thus protecting the user's privacy.

[1] RFC 2119, http://www.ietf.org/rfc/rfc2119.txt

4.2.2 Guidance

As a user in the morning in bed and throughout the day, I want support for my daily routine, to improve my quality of life.

In 1979, Harvard MBA students were surveyed on their goals after graduation [McC86]. 84 % had no goals, 13 % had some goals and 3 % had clear written goals. 10 years later the 3 % earned 10 times and the 13 % earned twice as much as the 84 %. Another study [Mat11] from Gail Matthews shows, that people who wrote down their goals, shared this information with a friend and send weekly updates to that friend were on average 33 % more successful in accomplishing their goals. LISA should break down these insights to small achievable daily tasks [SER+11]. LISA must organize, structure and optimize the daily routine of the user. Tasks and events from different calendars should be combined into one stream. The user must plan the next day in advance by defining tasks/goals for the next day. The user should not define exactly when the task should be completed. The user should roughly note when the task should be completed — in the morning, in the afternoon or in the evening. Later omnipresent speech or activity pattern recognition may extent this and automatically adds goals or events to the schedule.

The overall goal of LISA is to improve the quality of life of her user. LISA should virtually guide people through the day and let them reminisce about similar past events that are connected to the current day. Moreover, LISA may find correlations, increase awareness and hook up into the habit formation process. LISA may reveal bad habits and recognize activities that lead to bad habits. She may try to help the user to change bad habits to good habits, motivating and inspiring the user to break those. LISA should give feedback to the user and be able to contact the user during the day with simple notifications to remind the user of contextual relevant information.

This guidance should be achieved in two steps. First, LISA must *detect demand for action*. In this step LISA must analyze the data with a rule-based system. In a future version LISA may interpret data with machine learning and data mining algorithms. In the second step LISA must *initiate actions*. If a defined condition comes true LISA must trigger an action. LISA must give the user feedback, thus triggering, inspiring, provoking and proactively calling to actions. This feedback, like being more active or eating less meat, should be thoughtful chosen to motivate the user and implant information into the user's subconscious minds. The user should get feedback with achievable small changes that lead to healthy habits.

4.2.3 Memory Prosthesis

As a user, I want to augment my bio-memory with the e-memory, to improve and optimize my daily routine.

LISA should enrich the user's bio-memory with the e-memory. Life-logging technologies enable to augment the bio-memory. As we learned from our requirement studies, people for example tend to forget their daily schedule and tasks. LISA should assist recalling such information through smart briefings.

According to the *encoding specificity principle* [BEAA09, p. 169][TT73] the more similar the cues available at retrieval are to the conditions present at encoding, the more effective the cues will be. Hence, LISA may use past experiences (images) or related information to build bridges to the past and get the users' mind into the right context for the day. If the user has fright of an upcoming event past similar contextual cues may help him gathering self-confidence and overcoming fears.

LISA must help recapitulate and relive the past day to consolidate memories. In the evening the user must reminisce the day checking off done schedule entries. This should trigger a positive emotion, because of the achievement. It should intensify consolidating memories, because sleep gives the body a chance to deal with everything that happened during the day. Furthermore, LISA must help remembering past events and improve memory recall making use of available past data. People for example rarely look daily at photo albums. LISA may process past events and display important one like irregular events with unusual locations, for example, in another city, many pictures or manually added calendar events [CJ09].

4.2.4 User Interaction

As a user, I want to naturally interact and communicate with LISA.

LISA must communicate with the user. There are two ways how LISA should communicate with the user. The device itself should be one communication instrument and the smartphone as daily companion may be the other one.

People spend a lot of their daily time in their bedrooms, yet there is not much technology. People often just have their smartphones at their beds. In 2013 the market research company IDC[2] conducted an online survey [Lev13] with over 7000 participants in the US, which had smartphones. Within the first 15 minutes after waking up 79 % reach for their smartphones. Among the younger participants it is even 10 % more. LISA must be located in the bedroom of the user and should wake up the user with convenient sounds or music to foster good mood and utilize some priming effects. LISA itself should talk to the user and present information

[2]International Data Corporation (IDC) website, https://www.idc.com/

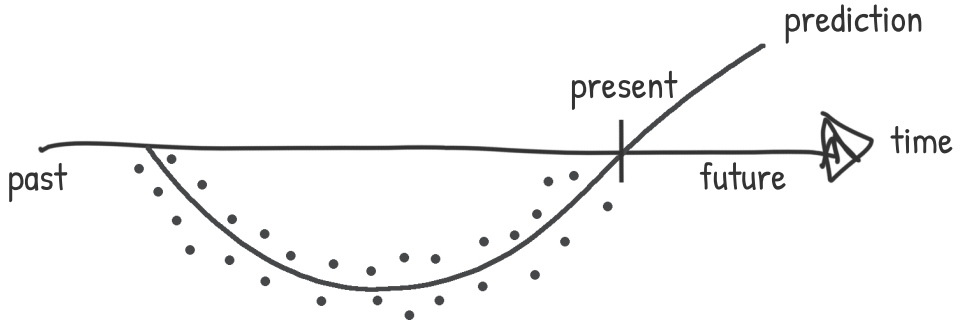


Figure 4.2: Prediction of user's behavior based on past data.

in an appealing way with a projector. LISA should give the user a visual and audial briefing of the day. The user must be able to set up the alarm in a configuration app for the next day. The alarm must automatically turn off after the wake up process. The dashboard must at least display date and time, the weather and other useful information for the day.

During the day LISA may communicate via notifications on the smartphone. For example, LISA may give feedback on the current activity status to achieve a set goal, like the walked distance. Furthermore, LISA may calculate the duration to the next event and remind the user when to leave to be just in time at the location of the event.

4.2.5 Early Warning System

As a user, I want LISA to always watch over me and communicate with me if something is bad or good, to protect myself.

Wearables lack of long-term engagement. One-third stops using the device after six months after receiving it [LM14]. We speculate, that at some point the directly readable value for the user is exhausted. Users are getting tired of simply consuming data in nice charts. We think it is the wrong approach to steadily grasp for engagement. Therefore LISA should work in the background and should not seek for attention. Instead LISA may be there like a guardian and help if it is necessary and otherwise be calm. If something gets out of control and does not fit to the usual behavioral pattern, then LISA may act as an early warning system and give the user feedback (see figure 4.2). Therefore, LISA must always be online and connected to the user.


(a) Prototype from the outside.


(b) Prototype from the inside.


(c) Prototype from the outside.

Figure 4.3: Hardware construction of the first prototype.

4.3 Design

Due to our user centric approach, we wanted to quickly push the first version of our proof of concept to the field. The ultimate goal of life-logging technologies is to gather the entire life, nevertheless we had to limit the data acquisition part of the system to few sources. We did not have equal access to information from the participants, which goes far back to the past. Thus, the scope of the prototype had to be simplified for the first evaluation. We focused on the initial platform setup and cut down the requirements to a morning assistant with the functionality of an alarm clock, that carefully wakes people up, recapitulate the last seven days and presents a briefing of the day. The system augments human memory by combining life-logging technologies with the creation of automatic summaries and daily teasers. The presentation is delivered via audio and a ceiling or wall projection.

4.4 Hardware

The system consists of a speaker and a projection component, which are integrated in a single box as enclosure. For the first prototype, we developed a web app, which runs on a Raspberry Pi inside of that box. Connected to a pocket projector and a power outlet, the box is used as a bedside device. The base components of the system consist in detail of:

4.4.1 Raspberry Pi

The Raspberry Pi (Model B) is a credit-card sized single-board computer and the heart of the system. It has an 8 GB SD card with the Debian-derived operating system Raspbian (Wheezy). The memory is 512 MB and the CPU has 700 MHz. We decided to use a Raspberry Pi over a smartphone or tablet, because the aggregated data should stay in a safe environment at home and create some kind of personal information hub.

4.4.2 Edimax EW-7811Un

The Raspberry Pi has only an Ethernet connection. Due to the high probability that the users do not have a wired Internet connection in their bedrooms, we had to set up a wireless connection with the wireless usb adapter from Edimax. We configured it that it automatically connects to the user's network while booting and that it does not go into standby after a while.

4.4.3 Philips PicoPix 3410

The Philips PicoPix is a LED pocket projector with a native resolution of 854 x 480 Pixel. It has a brightness up to 100 lumen, which is sufficient in the morning, when it is dark in the bedroom. The projector was put onto a mini tripod to set up the projection surface. The projector has a lot of features like an integrated media player. However, it does not automatically detect the connected image source or wake up, when a device is connected. For this reason we had to simulate the supplied remote control and built an interface with infrared.

4.4.4 USB Infrared Toy v2

For better reliability we chose to buy the USB Infrared Toy v2 from Dangerous Prototypes[3] instead of soldering diodes ourselves. To control the projector with the infrared tool we used the library *LIRC*[4] (Linux Infrared Remote Control). It is a library to decode and encode infrared signals.

4.4.5 Logitech Z120

In the first place we tried the multimedia speaker Z50[5] from Logitech, but the sound card of the Raspberry Pi could not adjust the sound volume very well. Thus, we bought the Logitech Z120[6] stereo speakers allowing the user to control the volume directly at the speaker with a volume control button. The total RMS power of the speakers are 1.2 watts.

[3]USB Infrared Toy website, http://dangerousprototypes.com/docs/USB_Infrared_Toy
[4]LIRC website, http://www.lirc.org/
[5]Logitech Z50 website, http://www.logitech.com/product/multimedia-speaker-z50
[6]Logitech Z120 website, http://www.logitech.com/product/stereo-speakers-z120

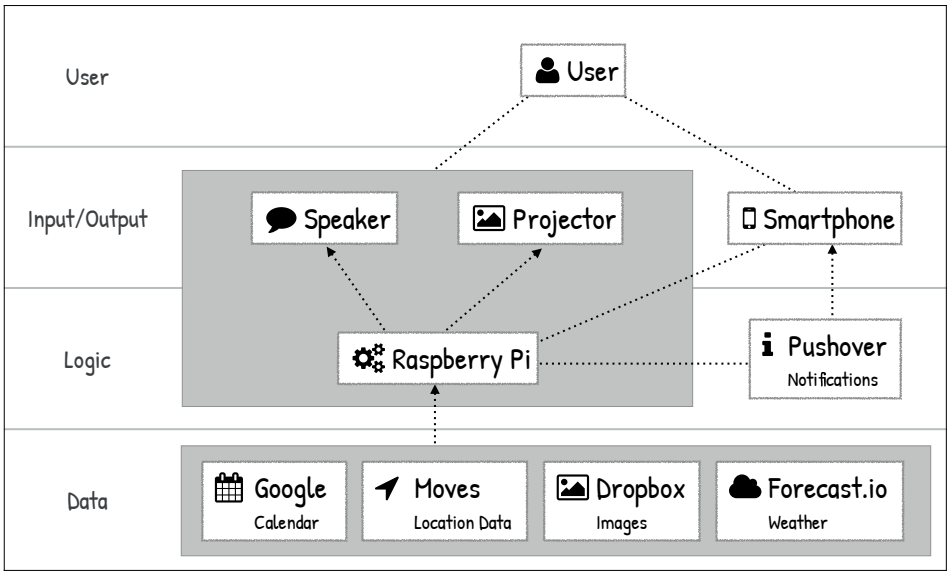


Figure 4.4: Basic architecture.

4.4.6 Wooden Box

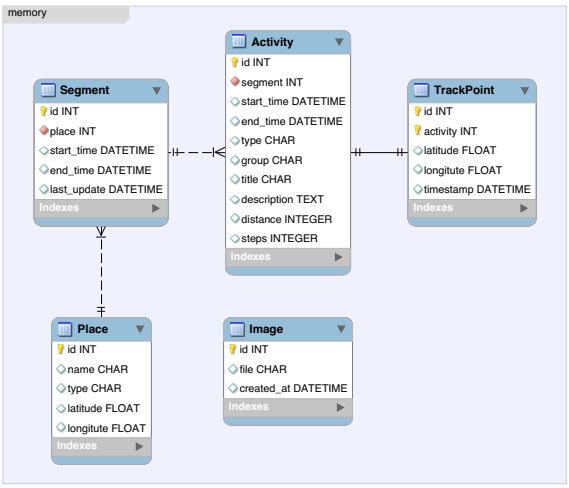
To hide most of the hardware we constructed and timbered a wooden box with the dimensions of 15 x 25 x 32 cm (height, width, length). The box is covered with a lid that has one hole in the middle for the cables for the projector. On the side we drilled a hole for the power supply (a triple socket) and optionally a network cable. At the front side we sawed two holes for the speakers. Figure 4.3 shows the final composition of the hardware.

4.5 Software

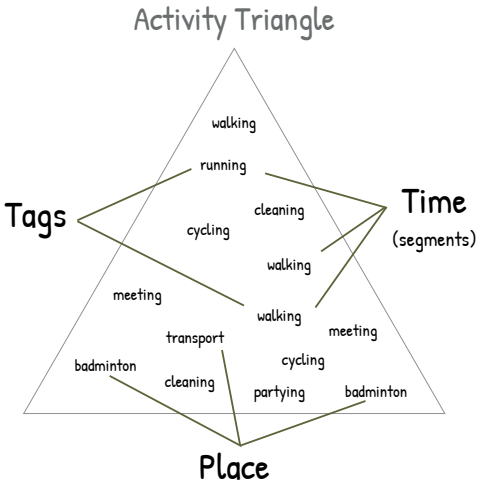
Our entire software runs on the Raspberry Pi with the operation system Raspbian (Wheezy). The following sections give an overview over the first software version and its deployment on the Raspberry Pi.

4.5.1 Architecture

The basic architecture and its interaction are outlined in figure 4.4. The user can communicate with LISA with the smartphone or the device itself. Furthermore, LISA can send push notifications to the smartphone. LISA mainly uses images, calendar, location and weather data.



(a) Simplified data model of memory app.



(b) Activity triangle how to search in the e-memory.

Figure 4.5: Data organization in LISA.

The software was designed as a web application written in *Python*[7] using Django[8] as the main framework. Django is a high-level framework, which encourages a rapid prototyping. Django provides a database-abstraction API for creating, retrieving, updating and deleting objects. As a database backend we used the relational database management system *SQLite*[9], which is easier to set up and can be better embedded compared to other databases like *MySQL*[10]. For our use case with few users and no high concurrency the SQLite database backend was sufficient.

We divided the Django project into two apps — *config* and *memory*. The users can access the configuration app with their smartphones. The memory app is used to store data and retrieve data with the projector again. The underlying conceptual data model of the e-memory is activity oriented (see figure 4.5a). All data, like images or location data, are attached to activities, which are clustered into time-based segments. The data model should be able to describe the *4W1H* questions (when, where, who, what and how). The usual search mechanism for a specific activity is to use time, place or tags, like it is presented in the *Activity Triangle* in figure 4.5b.

[7]Python website, https://www.python.org/
[8]Django website, https://www.djangoproject.com/
[9]SQLite website, https://sqlite.org/
[10]MySQL website, http://www.mysql.com/

4.5.2 Deployment

For easier portability and deployment we used *virtualenv*[11] to create an isolated Python environment. Virtualenv is basically a tool that installs dependencies with a certain version to a local directory. Globally updated libraries could break the application. Such side effects are addressed and avoided with virtualenv. Moreover, we created a Makefile to conveniently set up and run/stop/restart the application in the development or production environment. In the production environment we used *uWSGI*[12] as application server. For other jobs we created some shell scripts, which are executed by cronjobs. The server for example automatically starts when the Raspberry Pi boots and the script opens the browser *Chromium* with the dashboard. If LISA's boot process was successful, then she gives the user feedback through an audio snippet. To install fixes or updates every night the software automatically updates itself if there are commits on the deployment branch of the Git repository.

Initially we implemented a notification service that should remind the user according to defined rules (see figure 4.6). But LISA does not use it in the first prototype to communicate with the user. Instead she pushes system status information to the administrator. We used *Pushover*[13] as simple push notification provider for multiple platforms like iOS, Android or desktop. Furthermore, if an error occurs LISA sends emails to the administrator allowing him to proactively take action. For the email service we used *Mailtrap.io*[14]. For maintenance and configuration in-depth we can remotely control LISA and connect via *SSH (Secure Shell)* or *VNC (Virtual Network Computing)* to the Raspberry Pi.

4.5.3 Configuration App

With the *Configuration App* the user can configure the system. For our design we evaluated the predominant three types of mobile apps — first, the development of a *native app*, which just runs on the selected platform and second, the development of a *web app*. This is basically a website, which uses plain JavaScript, HTML and CSS. The third option is a combination of the previous two types. These types are called *hybrid apps*. Web apps are trans-compiled to native apps with frameworks like *Adobe PhoneGap*[15] or *Appcelerator Titanium*[16]. We decided to implement the configuration app as a plain web app that is optimized for mobile devices. The advantage of this type is the rapid prototyping and bypassing vendor lock-ins.

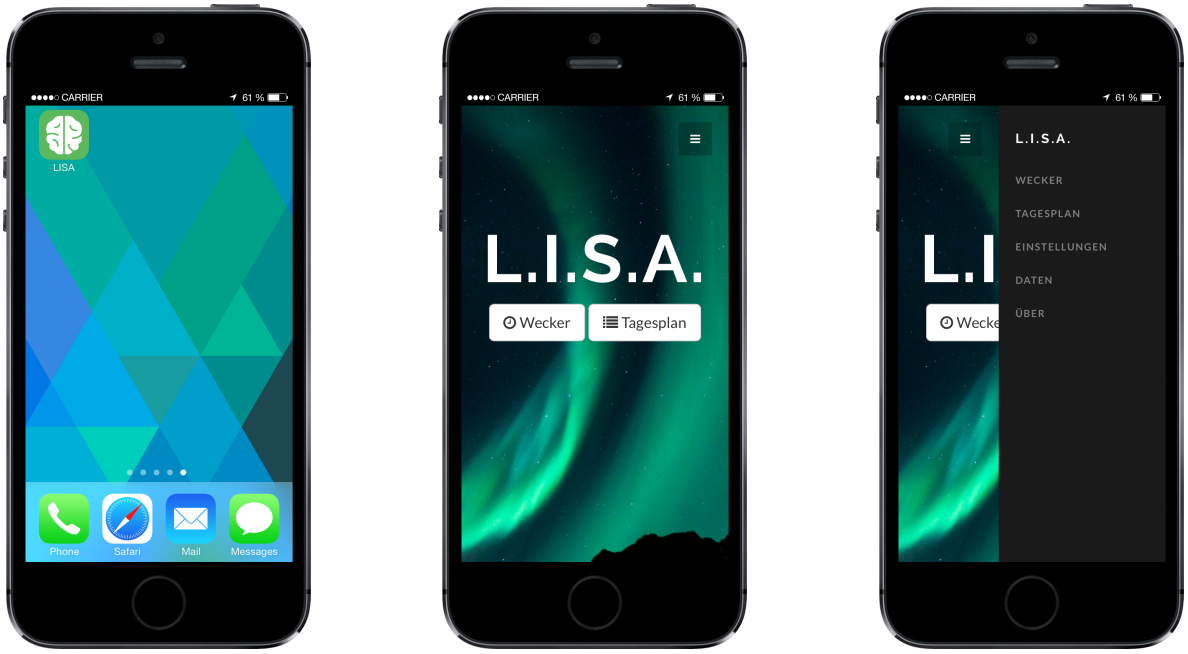
[11] Virtualenv website, http://www.virtualenv.org/
[12] uWSGI website, http://projects.unbit.it/uwsgi/
[13] Pushover website, https://pushover.net/
[14] Mailtrap.io website, https://mailtrap.io/
[15] Adobe PhoneGap website, http://phonegap.com/
[16] Appcelerator Titanium website, http://www.appcelerator.com/titanium/

Figure 4.6: Possible notifications on the smartphone.

For the graphical user interface we used the front-end framework *Bootstrap*[17] to create a responsive web app. The web app can be accessed in the local network, where LISA is installed. LISA uses *Bonjour* allowing other devices to conveniently find her under the network address: `http://lisa.local/`. Figure 4.7 and 4.8 show some screenshots of the app and explain its different purposes.

A human life with its generated data is highly complex. While creating ambitious tools we have to keep in mind what data we can use. For our prototype we decided to first integrate mainly three different data sources. For location data we used *Moves*[18], which we enriched with data from the *Nominatim Reverse Geocoding API*[19]. For images we used *Dropbox*[20]. Dropbox is a cloud storage provider and offers automatically camera uploads to its cloud storage. For calendar events we used *Google Calendar*[21]. The user can conveniently authenticate all data sources with the authorization framework *OAuth 2.0*[22], without sharing his credentials. LISA periodically pulls data from these data sources and prepares advices or the speech.

[17]Bootstrap Website, `http://getbootstrap.com/`
[18]Moves App website, `http://www.moves-app.com/`
[19]Nominatim website, `http://open.mapquestapi.com/nominatim/`
[20]Dropbox website, `https://www.dropbox.com/`
[21]Google Calendar website, `http://calendar.google.com/`
[22]OAuth website, `http://oauth.net/`



(a) Homescreen: The user can create a bookmark with the app icon on the home screen and launch the app.

(b) Startscreen: The user can quickly navigate to the alarm clock or to the schedule from the start screen.

(c) Navigation Menu: The user can navigate with the unfolded navigation menu to other pages of the app.

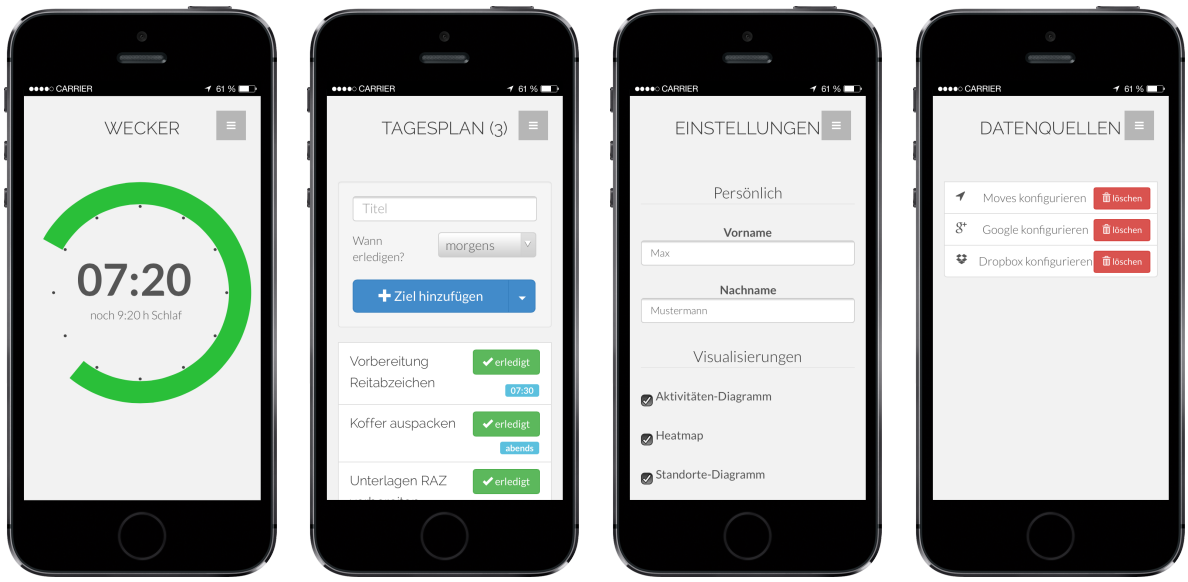
Figure 4.7: Navigation in the configuration web app.

4.5.4 Dashboard

The dashboard is a webpage (see figure 4.9), which is accessed with a browser. The dashboard refreshes itself every hour and is run in fullscreen. The content is divided into two columns.

The left column focuses on the past. The upper tile shows the last day in review. It presents a summary of the previous day. It shows the traveled distance of different movement activities, like walking, cycling, running and transport. Below, there are two advices, which are based on the past activities. Those should help the user to readjust its life and influence its behavior. The content of the next tile dynamically changes. It is a slideshow that slides through various visualizations (see figure 4.10), because there is not enough space to instantly show everything on the dashboard. The user can toggle the visualizations in the configuration app. Beside those visualizations, if available, past images of the last day are displayed. The visualizations helps to retrospectively look back and relive past memories. For instance, the location heatmap helps to mentally travel through places of the last day.

The right column (see figure 4.9) of the dashboard displays relevant data for today. For the upcoming day LISA displays the current date and time and weather. These were the top



(a) Alarm: The user can set up the alarm and get feedback how long it is until rise.

(b) Schedule: The user can import calendar events or manually add entries to the schedule.

(c) Settings: The user can configure general settings and adjust elements on the dashboard.

(d) Data Sources: The user can connect the system to different data sources.

Figure 4.8: Configuration with the web app.

information in our online survey the users want to consume directly after waking up. LISA uses the *Geo Location API* from *W3C* to determine the location and pass it to *Forecast.io*[23] to receive weather information. Below the first tile, LISA displays the schedule for the current day. It consists of calendar data from Google Calendar and previously manually set goals. In our initial mockup one schedule entry aggregated different data sources in a visually appealing way. LISA enriched every entry with different data, like related images, if possible. However, we had to remove this feature for the field evaluation. It was not applicable, because LISA did not get access to a large library of past images from the user.

4.5.5 Audio Stream

LISA needs the ability to speak. Therefore, we needed speech synthesis. There is a *Web Speech API Specification*[24] that adds voice recognition and speech synthesis to JavaScript. New browsers like Google Chrome integrated this api. Due to the hardware and software limitations of the Raspberry Pi the available browsers do not support speech synthesis yet or HTML5 audio

[23]Forecast.io website, `http://forecast.io`
[24]Web Speech API Specification, `https://dvcs.w3.org/hg/speech-api/raw-file/tip/speechapi.html`

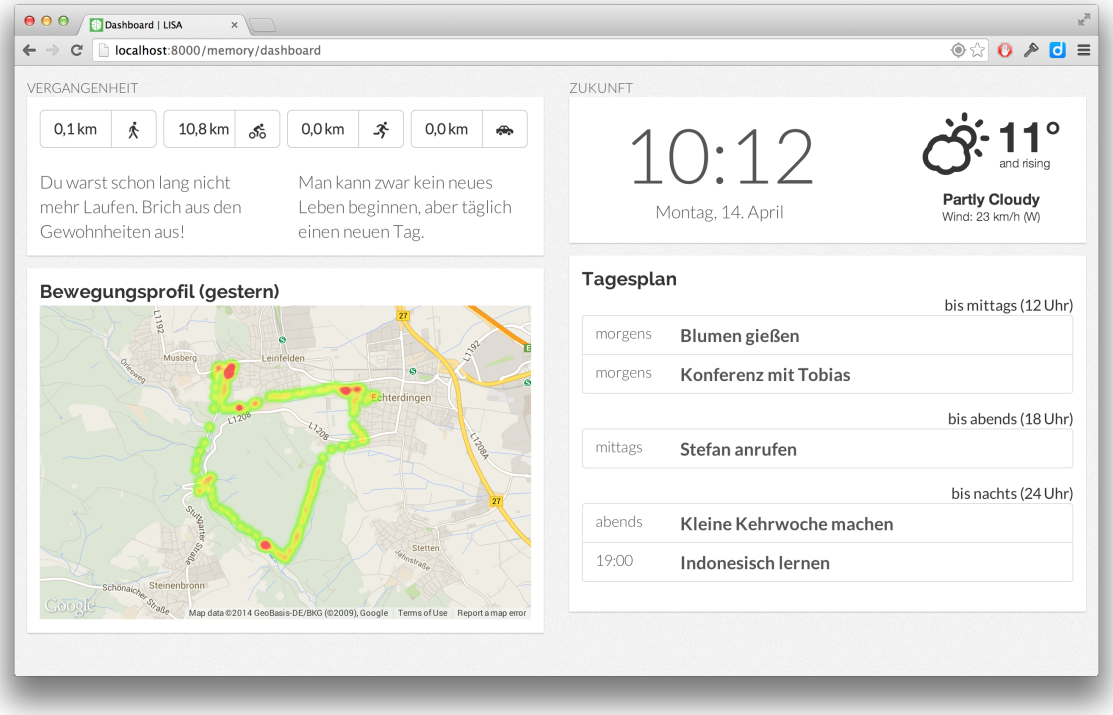
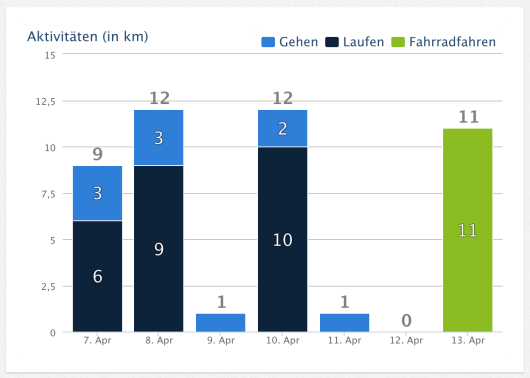


Figure 4.9: The projected dashboard.

tags. Thus, we had to find a workaround. Now, LISA uses Google Translate[25] to generate audio snippets. But the api is limited to 100 characters. For that reason LISA slices the text, requests the audio files, concatenates them and plays them with the command-line mp3 player *mpg321*[26]. The generated audio stream looks like this:

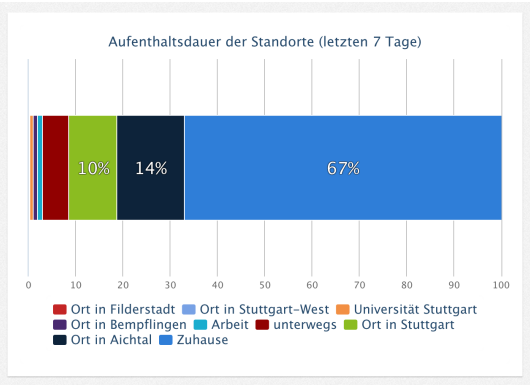
> Good morning, John. It's 7:05 a.m.
>
> Yesterday you walked 4 km and you were 57 km in transit.
>
> Your last run was one week ago. How about going for a run this evening?
>
> It seems like you are lately often at home or work. How about meeting some friends again or going to the cinema?
>
> For today, there are 4 events scheduled and the first starts at 8. Your entire schedule for today is as follows: *finalize paper*, *call Grandma*, *clean apartment* and *workout*.

[25] Google Translate, `http://translate.google.com/translate_tts?tl=en&q=helloworld`
[26] mpg321 website, `http://mpg321.sourceforge.net/`



(a) Activity Chart: The chart shows a summary of the activities from the last seven days.

(b) Location Heatmap: The heatmap shows the locations of the user from the last day.



(c) Location Chart: The Chart shows a summary of the places, where the user has been the last week.

(d) Image: The element displays images from the previous day.

Figure 4.10: The user can set up different visualizations, which are presented as a slideshow on the dashboard.

Now get up, grab an umbrella, because it will probably rain this morning and rock the day!

4.6 Summary and Discussion

In this chapter we described our concept and implementation for a digital life assistant. We developed a holistic concept for a first prototype called LISA (lifetime intelligence software assistant) and defined initial requirements. For our first feedback cycle, we decided to cut down the requirements to a personal morning assistant that has different presentation modes (speech, dashboard and both). We assembled the hardware and disguised it in a wooden box,

which should function as a bedside device. We implemented a proof-of-concept software which uses the Python web framework Django and runs on a Raspberry Pi with two main purposes. Firstly, it provides a configuration app, which we realized as a web app and secondly, the software aggregates data sources (activities, images, calendar) into an e-memory. Furthermore the assistant delivers morning briefings in form of speech or a projected dashboard onto the wall/ceiling.

5 Evaluation

> It was astonishing how well LISA worked. I see a lot of potential in this prototype.
>
> *(Participant 4)*

This chapter describes the evaluation of the first version of our prototype. The goal of the study was to evaluate how and when to make use of the e-memory as memory prosthesis. The prototype should show the possibilities of future personal assistants that help people to learn from their pasts and optimize their lives.

5.1 Set-Up

In this field study we explored mainly the aspect how to present guiding information directly after waking up and how people want to consume such information. In addition we explored to which extent the e-memory influences the upcoming day giving feedback on past activities.

Each participant should have the same initial situation. Therefore, each participant had the same settings, used the same data sources and woke up with the same alarm sound in the morning. We used a repeated measures design [FH03]. We used the same participant in each condition. Each third day the presentation mode changed. In *dashboard mode* the projector displayed the information in form of a dashboard on the wall/ceiling. In *speech mode* LISA read the information out loud. In the last *speech and dashboard mode* the aforementioned modes were combined. We counterbalanced the order of the modes to prevent carry-over effects (see table 5.1).

We prepared two exact devices to speed up the study. Therefore, we cloned the SD card of the Raspberry Pi. Furthermore, we stuck a paper on the wooden box with important information. The emergency number was there if an unforeseeable event happens and the order of the different modes should helped the participants to always know what mode is going to wake them up. Furthermore, the participants completed after each condition (after two days) a survey, which consisted of 22 questions. To make it more convenient for the participants, we printed the surveys on paper and later digitized them (see appendix B).

Participant	1. Condition	2. Condition	3. Condition
#1	Speech	Speech and Dashboard	Dashboard
#2	Dashboard	Speech	Speech and Dashboard
#3	Speech and Dashboard	Dashboard	Speech
#4	Dashboard	Speech and Dashboard	Speech
#5	Speech	Dashboard	Speech and Dashboard
#6	Speech and Dashboard	Speech	Dashboard

Table 5.1: Order of conditions.

5.2 Procedure

The entire evaluation took place in the period of 20 days from 7th to 27th of April 2014.

We told the participants seven days before their turn to initiate the location tracking with the Moves app, in case they did not use it before. Thus, we had at least seven days of location information. Shortly after our evaluation Facebook acquired Moves.

The duration of one iteration lasted six/seven days. At the first day we visited the participants in the afternoon at home. Then we explained the purpose of the study and gave the participants a short introduction to the topic. Afterwards, we plugged in and set up LISA in their bedrooms. We connected LISA either with Ethernet or Wi-Fi to the local network. We put the projector into standby and checked if the configuration app was reachable in the local network. Next, we gave an introduction how LISA works and what information she displays. Together with the participant we configured the data sources. Finally, we checked the mode order according to our protocol and handed over the paper surveys.

The next six days the participants woke up with the specified modes — each mode lasting two days. After each condition the participants filled out their paper surveys.

To get the most information from the participants we organized a semi-structured interview on the last day. Finally, we saved the statistical data and reset LISA. Then we headed with the system to the next participant.

5.3 Participants

The study took place in small-scale, because of the limited time and the duration of one participant. Therefore, we wisely chose the participants in our circle of acquaintances, which satisfied our prerequisites. LISA for example needs at least a wireless Internet connection in the bedroom. Moreover the participants needed a smartphone, where the Moves and configuration

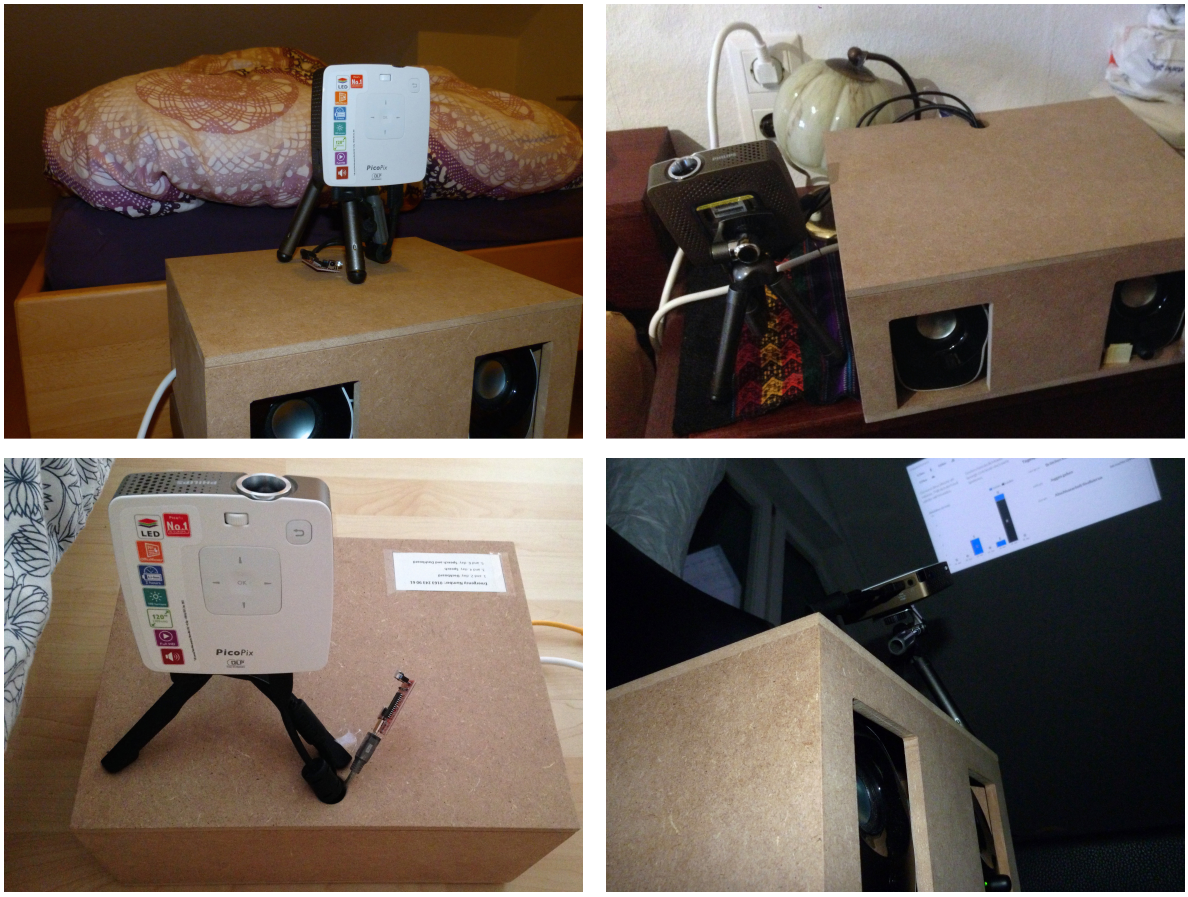


Figure 5.1: LISA in action.

app can run. Additionally, the participants needed a convenient surface (white and large enough) for the projection.

In total there were six participants, three male and three female. The average age was 30 ranging from 22 to 56 with a standard deviation of 12.88 and a median of 25. 83 % of the participants wore glasses and had a bed partner during the evaluation. 50 % were students and the other 50 % were employed. 67 % used an iPhone and 33 % an Android device. Just one person used a continuous location tracker before the study.

5.4 Results

In the following sections we describe the results of the surveys and the conducted interview. The participants understood, that LISA was a prototype and therefore the features were limited.

However, they instantly understood the vision and came up with various suggestions for improvements, which we also present in this section.

The participants liked the basic idea of a bedside device and were astonished how well it worked. Moreover, they liked to be woken up not just by a usual alarm clock. According to the interviews the combination of dashboard and speech was the most pleasant, then speech and then dashboard.

The sleeping duration ranged between 6 and 9 hours, which is usual for adults. Furthermore, we asked the participants about their wake up behavior. There were many different wake up styles. One participant instantly wakes up and idles for a couple of minutes in bed and reads news or similar things on his smartphone. Other participants snooze exactly one time up to undefined times until they get up. Yet another participant automatically wakes up 30 minutes prior to the alarm sound. For the future, LISA has to recognize and adapt to the individual wake up procedures, like we are going to discuss in the following NASA RTLX results.

The participants liked the idea of a personal cloud in their own territory. They did not have any privacy concerns and felt better, when the data is at home. Throughout the 13 days (7 days in advance and 6 days study) we gathered on average 178 coordinates (SD=58.52), 13 activities (SD=6.91), 5 location changes (SD=1.18) and 1.5 images (SD=1.07) per day. In the beginning of the study we assumed, that there would be two challenges that arise when there are two persons in bed: firstly, the other one can listen to personal information and violate the partner's privacy. And secondly, the audio output or the bright light of the projector can annoy and accidentally wake up the bed partner. The first issue did not bother the participants at all. The second issue was in our evaluation mainly no problem, because the bed partners got up around the same times. But it could be a problem, when the wake up times diverges.

We asked the participants some questions about the hardware. We assumed, that the size of the wooden box is too big, yet the participants just demanded a redesign of the look not the dimensions. Furthermore, we expected, that participants complain about the operation noise of the projector, but nobody did. Instead some participants complained about the brightness of the projector. Those participants had in common, that they slept in a completely dark room, where no sunlight comes through the roller shutter. Moreover, the projector has no keystone correction, which one participant criticized. In addition, the participants complained about the laggy performance of the configuration app and the dashboard. According to them it is sufficient for a prototype, but must be improved for a real product. This was a common problem and can be traced back to the performance of the Raspberry Pi. Other hardware has to be evaluated for future versions.

One participant for example said: "The prototype helped me to think about the next day and helped to structure it. Otherwise everything would be more spontaneous." (participant #3). Another said: "The advices were really nice." (participant #2). However, in our survey there was no significant change, that the participant better remembered their schedule or changed their habits because of the presented information. We argue, that it is a process in

the unconsciousness and it needs time and continuously nagging, like a mother does, to show effects. Furthermore, the mean of added goals per day was five with a standard deviation of 1.41. But the participants did not know, whether they would keep manually adding goals everyday. Therefore we have to further improve the automatic mechanisms to recognize and import tasks and calendar data.

The participants demanded more motivating images for the day according to the context of the schedule, like we previously defined in our drafts, but had to cut it out because of the limitations of the first evaluation. Moreover, the presented content has to be highly customizable. Some kind of *Plugin/Content Store* could be interesting for the future, where users can pick their favorite modules. One participant for example wants to study cue cards with the projector shortly before sleeping, because in the evening there is a more affective long-term recall. In the evening people are more aroused and have more points of relevance [GLB06].

The participants criticized, that over the day they are disconnected with LISA. They want to always be connected to her, like our future work foresees. Other participants suggested multiple different digests per day, instead of continuous notifications over the day. LISA can for example send in the morning, noon and evening such digest per emails. It is better to learn little and often. This effect is called *distributed practice* [BEAA09, p. 71ff.]. In doing this, the briefing information should be distributed over the day, whenever the user needs it. Another interesting use case for notification is to connect to friends and make use of gamification mechanisms. Some participants wanted to get instant notifications, when close friends achieved something or walked more than the participant: "John walked already 5 km. Now it's your turn to beat this." We believe that gamification including social motivation can be a way to improve effectiveness for achieving goals. Similar results investigated Sahami Shirazi et al. [SCH+13]. Sharing information among friends impacts the awareness and connectedness, thus encouraging healthier behavior. Moreover, the participant envisioned also some community based *Rule Store*, that triggers actions or notifications according to information in the e-memory similar to the popular service *IFTT*[1].

The opinions of the alarm sound conflicted between participants. Some liked the alarm sound, but other disliked it. They demanded custom alarm sounds. One interesting idea came up during the conversations. They want to choose a theme or genre for their wake up, like heroic or jazz music. Fitting random music to the defined style should wake them up.

The participants envisioned a robust speech input to control LISA. Alternatively they could imagine controlling the projection with gestures for example with the *Leap Motion*[2]. Another interaction mechanism is to directly control the projection with the smartphone as some kind of augmented screen.

[1] IFTT website, https://ifttt.com/
[2] Leap Motion website, https://www.leapmotion.com/

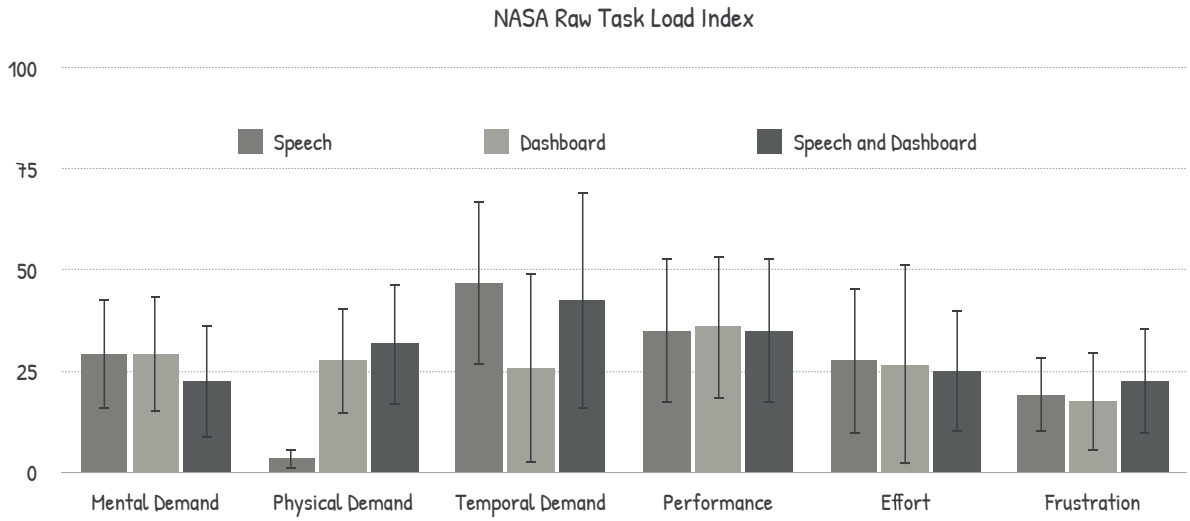


Figure 5.2: Results of the NASA RTLX survey.

Workload Parameter	**ANOVA result**	**Correction**
Mental Demand	$F_{MD}(1.08, 5.39) = 2.03, n.s.$	Greenhouse-Geisser
Physical Demand	$F_{PD}(1.07, 5.35) = 17.02, p < .01$	Greenhouse-Geisser
Temporal Demand	$F_{TD}(2.00, 10.00) = 1.65$, n.s.	Huynh-Feldt
Performance	$F_{PE}(1.00, 5.00) = 1.00, n.s.$	Greenhouse-Geisser
Effort	$F_{EF}(2.00, 10.00) = 0.06, n.s.$	Huynh-Feldt
Frustration	$F_{FR}(2.00, 10.00) = 0.58, n.s.$	Huynh-Feldt
Total	$F_{TL}(2.00, 10.00) = 0.59, n.s.$	Huynh-Feldt

Table 5.2: Results of the one-way ANOVA test on the NASA-TLX results.

5.4.1 NASA Task Load Index (NASA TLX)

The *Nasa Task Load Index* [HS88] estimates the subjective workload of tasks on six dimensions: mental demand, physical demand, temporal demand, performance, effort and frustration. We used the unweighted method, which is often referred to raw NASA TLX (NASA RTLX) [Har06].

Figure 5.2 visualizes the results of the raw NASA TLX survey. Furthermore, we run on each parameter of the NASA TLX results a one-way repeated-measures ANOVA, which is shown in table 5.2. The *mental demand* in the combination mode was slightly better, because the participants had multiple stimuli (audio and visual) to process the information. According to the interviews, the visualizations were interesting, but for some participants on the dashboard

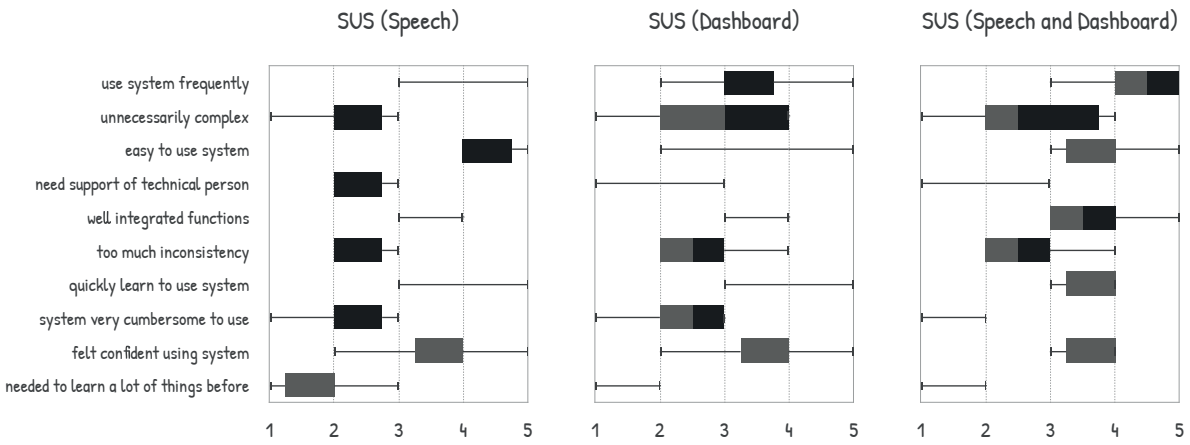


Figure 5.3: Results of the System Usability Scale survey.

were too many information at once. Nevertheless, they wished even more pretty pictures, traffic prognosis, incoming personal messages, news and more detailed weather information, like sunrise and sunset data. This matched our results from our online survey (see chapter 3). Like we assumed in the beginning, the wearer of glasses had difficulties with the dashboard. Some could not read anything without their glasses that is why they found the speech mode most enjoyable. So they first had do find and grab their glasses to actual see the dashboard. For this reason in the dimension *physical demand* the speech mode was best. Bonferroni post hoc tests revealed a significant difference in physical demand between speech and dashboard, CI_{95} = -45.28 (lower) -3.05 (upper), $p < .05$, and between speech and the combination (speech and dashboard), CI_{95} = 51.89 (lower) -4.77 (upper), $p < .05$. No other comparisons were significant. In the dimension *temporal demand* the dashboard mode was best. After 5 minutes the dashboard automatically turned off. This time was sufficient for the participants to consume the information. For some participants the speed of the speech was too fast and they demanded longer breaks between different sections, because the mind slowly wakes up. Furthermore, some participants did not like the voice of the woman and some pronunciations were not right and confused them. Therefore the temporal demand was worse whenever speech was involved. Some participants demanded some optional repetition mechanism, if they are not fully awake in the beginning of the speech. LISA should understand when the user is awake and can follow her voice. The other dimensions *performance*, *effort*, and *frustration* had no significant differences between the modes.

5.4.2 System Usability Scale (SUS)

To get feedback on the usability, we used the *System Usability Scale* (SUS) [Bro96]. SUS is a quick and reliable assessment tool to measure usability. The test consists of ten statements,

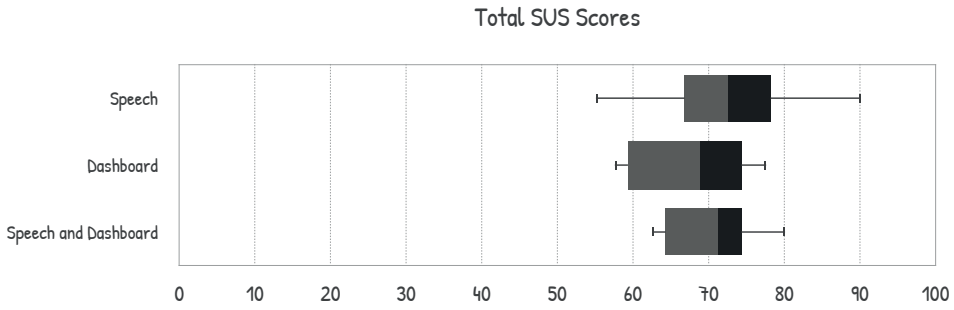


Figure 5.4: Total SUS Scores of System Usability Scale survey.

that are valued on a five point Likert scale. The survey has alternating items to avoid response biases.

Figure 5.3 shows the detailed results of each SUS question as box plots for the three different presentation modes. Figure 5.4 shows the overall SUS scores as box plots. Dashboard has a median score of 68.75, Speech has the score 72.50 and the combination has the score 71.25. We expected such close results, because the different modes used the same configuration app. The difference was just the non-interactive presentation in the morning. The speech mode had some outlier as figure 5.4 visualizes, although the median scores are close to each other. We can narrow down this outcome to the aforementioned problem of glasses. Because of blurred visions wearers of glasses preferred the speech mode. Our results are slightly better than the average SUS score of 68 [Fro13]. This score is pleasant for the first prototype, yet it gives us room for improvements.

5.5 Summary and Discussion

In this chapter we described the evaluation of our first version of our prototype with six participants at their homes in a small-scale pilot study. The focus of the evaluation was to find a convenient presentation assembly. Therefore, we mainly evaluated three presentation modes (speech, dashboard and the combination of speech and dashboard).

We used two standard surveys, the System Usability Scale and the NASA Task Load Index, to allow a better comparison for future works.

The combination of speech and dashboard was the overall winner of the study, yet plain speech won in usability, because wearers of glasses have difficulties with the projection. Speech is suitable for the first wake up phase to facilitate information. Later a projector gives more opportunities to work with more stimuli, but is in general not mandatory.

The participants did not instantly change their behaviors, because of the presented information. But it helped to raise awareness. A more continuous nagging for example with notifications or digests could be a solution and has to be further investigated.

Two interesting ideas came up in the final interviews. The participants wished some kind of plugin/content store and a community based rule store. With the plugin/content store the participants want to compose individual features to create a custom version of LISA. The community based rule store should help how LISA makes decisions and informs the user.

6 Conclusion

> The more you tell the world about yourself, the more the world can give you what you want.
>
> *(Sam Lessin, Facebook)*

This chapter outlines the entire work and discusses future work. We sum up our conducted requirement studies, our prototype and our final evaluation. Finally, we discuss possible directions for future work and show a broader vision for this topic.

6.1 Summary

Machines disappear more and more and blend into life, so that humans can live their mundane lives without starting apps, plugging in devices or making unnatural gestures. Devices learn to live with humans instead of humans learning to live with them. Experiences make people what they are. Those omnipresent tracking devices and their sensors experience the same things as their owners, thus creating e-memories and surrogate brains.

In western society time and attention are the new currency. Instead of storing everything in the brain people outsource information to personal assistants, thus saving time. This can be smartphones as well as simple notes on paper. The goal is to save time having all information at one's fingertips instead of trying to remember and possibly failing in doing so. Context-aware assistants can free the mind and improve mental health. Life-logging technologies enhance cognitive abilities. The Google Search for example became an indispensable service for problem solving, thinking and acquiring knowledge. People are just a few clicks away from a massive amount of human knowledge. The personal e-memory adds a new source to this search, which can be used to improve life.

E-memory is a cross-cutting issue. The topic around e-memory is interdisciplinary and involves various domains in psychology and computer science. In the beginning we identified seven emerging main challenges of life-logging technologies — data fragmentation, utilization, reliability, data protection, privacy and human acceptance.

Since the Recall project is currently in an early stage and exploration phase, this thesis gives a broad overview about requirements. We spend a lot of effort to understand how people envision life-logging technology to be able to help them throughout their daily lives. Therefore,

we conducted a series of focus groups with 19 participants and an online survey with 125 participants. Our results were manifold and helped us to develop a concept for a prototype. However, the human factor plays an important role. People have a lot of concerns about e-memory and its technologies. However, we think there is still a lot of uncovered potential. Give a man a calculator and he can do advanced math. Give a man an e-memory and he can do advanced thinking.

According to our gained insights from the requirement studies we developed a vision and a concept for a tool that leverages the e-memory. The broadly defined goal is to develop an early warning system. As a result we developed a first prototype in form of a smart alarm clock that laid the foundations for this vision. The system uses recorded personal data to wake users up and provides the participants with useful information tailored to the imminent day via audio and a visual dashboard using a projector. We build a wooden box with the necessary hardware and called the system LISA. She was installed in the users' bedrooms.

Summed up, the prototype laid the foundation for a context-sensitive assistant that addresses several issues. LISA (1) overcomes data fragmentation and aggregates various data sources, thus converting big data to smart data, (2) helps organizing and remembering daily routine, (3) increases awareness, thus she guides and motivates to change bad habits and (4) respects data protection and privacy and locally stores all information in one personal cloud device.

In a first evaluation in the field, we explored preferred types of media, content and features to augment memories and help users to an informed morning start. In total six participants participated in the evaluation. In the first phase of wake up speech is most important to facilitate information. Later a projector gives more opportunities to work with more stimuli, but is in general not mandatory. Further results of our evaluation are part of our future work.

6.2 Future Work

There are various directions to improve LISA. Since LISA is a prototype, we had to make some limitations for our first evaluation cycle. Further improvements have to add more value to LISA. To think outside the box, the following topics outlines the most important directions:

data aggregation More data sources and tracking devices have to be integrated — especially data sources, which we identified in our requirement studies. The difficulty is to not simply add data sources, instead those sources have to be brought into context to, for example, build bridges to the past. For example current messages or news should be enriched with related experiences from the past e-memory.

omnipresence LISA can currently just communicate with the users at their homes. This should be further improved to allow remote access or proactive notifications/digests on smartphones. Other continuous connections to LISA, like a portable audio assistant with

a wireless headset or simulated phone calls should be explored. The prompter should give compact information about the current and future situation and help navigating through daily life.

data utilization During the evaluation of the first version the participants came up with the idea of a community based rule store. The community defines general rules, which trigger certain actions, if a condition in the e-memory is satisfied. Users can then choose and activate sets of rules, like transit recognition or burnout protection. The rules of such a store can increase the perceived intelligence of LISA.

content extension Right know the box of LISA just communicates with the user in the morning disguised as an alarm clock. Further use cases of the box itself should be explored. It is hard to know what is interesting to the user. Therefore a plugin/content store could be one solution to tailor the content to the user.

hardware improvement The first contact with LISA is the installation of the box itself. The installation process should be simple, because this is the first impression of the system. The hardware with its overall performance should be further improved. Especially alternatives, mainly for the Raspberry Pi, should be found to speedup the system. Backup and update mechanisms should also be considered.

further studies We evaluated the first version with a small group of participants. This user-centered process should be continued. But to get generally valid results and to get further feedback new studies with larger groups of participants should be conducted.

If we take a look into the future, the ultimate aim is to understand how our brain works by developing step-by-step intelligent systems. Science fiction is a good source for such visions. In *Iron Man* there is an artificial intelligent super computer called J.A.R.V.I.S. (Just A Rather Very Intelligent System). Tony Stark, the main character, interacts with the computer like a real person. J.A.R.V.I.S. responds like a real person but has immense computing power and access to giant data sources. Another movie from 2013 is called *Her*. Theodore purchases an artificial intelligent operating system and builds a relationship with "her". Those two movie examples have in common that the systems communicate and behave like a human. In the movie *The Final Cut* from 2004 people can pay to have their babies implanted with memory chips. The chip records every moment of life so that after death people can relive some moments from the decedent. In *Superman* Clark Kent communicates with the preserved consciousness of his real father Jor-El in the form of a hologram. And in the recent movie *Transcendence* the consciousness of Will Caster is transferred to an intelligent system and his likeness survives his body's death. The last three examples show the vision of afterlife, self-preservation and digital immortality. Current progress paves the way to allow us to capture and fossilize a complete life. This development creates unimagined possibilities for example to talk to or discuss with dead people. Those ghosts or avatars open a door to new knowledge acquisition and transfer, because the inevitability of death and the evanescence is bypassed to a certain

degree. However, the superior maxim should be always to use e-memories for the improvement of wealth in society.

A Online Survey

Tools augmenting memory:

With this study I want to verify a previous study, improve my prototype and lay the foundations for another field study. This study is part of my diploma thesis at the University of Stuttgart. The aim of my work is to develop a tool that supports the user in daily life using life logging technologies.

The collected data will be kept anonymous and used only for the purpose of this research study.

--
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Self-Reflection (past)

Imagine a tool that analyzes your past and presents the information in a visually appealing way. (sleeping time, walking time, distance,...)

* = Required Question

When would you prefer to look at a summary of your past day? *

(Check ANY that apply)

- ☐ in the morning
- ☐ before noon
- ☐ at noon
- ☐ in the afternoon
- ☐ in the evening
- ☐ at night
- ☐ never

How many minutes would you spend to look at such processed summaries? *

Do you have any other comments?

Planning (future)

* = Required Question

Do you have a random or regulated daily routine? *

1 2 3 4 5

very random ○ ○ ○ ○ ○ very regulated

Do you plan your day in advance? *

1 2 3 4 5

never ○ ○ ○ ○ ○ always

When do you plan your next day?
(Check ANY that apply)

☐ a few days before ☐ during the entire previous day ☐ in the evening of the previous day

☐ in the morning of the current day ☐ never

☐ Other: _____

Which tools do you use to organize your daily routine (tasks and events)? *
(Check ANY that apply)

☐ pocket calendar (paper) ☐ wall calendar (paper) ☐ digital calendar ☐ notepad (paper)

☐ digital notepad ☐ Other: _____

How many minutes do you spend planning your next day? *

_____

Do you have any other comments?

_____

_____

_____

_____

_____

_____

_____

_____

Prototype

* = Required Question

How do you wake up in the morning? *
(Check ANY that apply)

☐ alarm ☐ radio ☐ music ☐ person
☐ light ☐ I wake up on my own ☐ Other: _____

What information do you want to know directly after waking up in the morning? *
(Check ANY that apply)

☐ date and time ☐ weather ☐ summary of the last day ☐ schedule/events of the current day
☐ news ☐ messages ☐ social media ☐ traffic ☐ public transit ☐ horoscope
☐ nothing
☐ Other: _____

How should information be presented in the morning in your bed? *
(Check ANY that apply)

☐ projection ☐ monitor ☐ speech ☐ smartphone/tablet
☐ not at all ☐ Other: _____

Do you want to receive location- and time-based guidance during the day? *
e.g. "Use the stairway to reach your walking goal." or "Go to bed now, so that you are well rested tomorrow."
(Circle ONE choice)

yes no no opinion

How many notifications per day about guidance are acceptable?

_____

Do you have any other comments?

_____
_____
_____
_____
_____
_____
_____
_____

Person

* = Required Question

What is your gender? *
(Circle ONE choice)

male female not specified

How old are you? *

What is your employment? *
(Circle ONE choice)

working student self-employed / freelancer unemployed

Do you have any other comments?

B Evaluation Survey

Mode: _____ Participant: _____

General Survey

	Strongly disagree				Strongly agree
It was pleasant being woken up.	○	○	○	○	○
I changed my habits because of the presented information.	○	○	○	○	○
I better remembered my schedule.	○	○	○	○	○
If applicable: L.I.S.A. disturbed my bed partner.	○	○	○	○	○

How many hours did you sleep?

Day 1	Day 2

Do you have any other comments?

Mode: _____ Participant: _____

NASA Task Load Index (TLX)

MENTAL DEMAND
How mentally demanding was the task?

Very Low Very High

PHYSICAL DEMAND
How physically demanding was the task?

Very Low Very High

TEMPORAL DEMAND
How hurried or rushed was the pace of the task?

Very Low Very High

PERFORMANCE
How successful were you in accomplishing what you were asked to do?

Perfect Failure

EFFORT
How hard did you have to work to accomplish your level of performance?

Very Low Very High

FRUSTRATION
How insecure, discouraged, irritated, stressed, and annoyed were you?

Very Low Very High

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All links were last followed on May 12, 2014.

Declaration

I hereby declare that the work presented in this thesis is entirely my own and that I did not use any other sources and references than the listed ones. I have marked all direct or indirect statements from other sources contained therein as quotations. Neither this work nor significant parts of it were part of another examination procedure. I have not published this work in whole or in part before. The electronic copy is consistent with all submitted copies.

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