Electronic Services to Support Diagnosis and Therapy of Migraine

Relationship between Smartphone Usage and Perceived Stress: A Cross-Sectional Study

Master Thesis

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Declaration

I declare that I have developed and written the enclosed Master Thesis completely by myself and have not used sources or means without declaration in the text. Any thoughts from others or literal quotations are clearly marked. This work was not used in the same or in a similar version to achieve an academic grading or is being published elsewhere.

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Place, Date Signature

Preface

Many people see migraine just as different kind of headache, probably self-caused due to insanitary lifestyle and easily treated by taking some painkiller. For patients it sometimes dramatically impacts their life, spending hours and days with painful attacks and after being over, waiting for the next to arise. Besides losing precious moments and facing social isolation, most patients complain about not taken seriously by their environment.

This thesis claims to raise awareness for migraine, obtain a better understanding of patient's needs and encourages to search for improvements in treatment.

I want to thank St. Pölten University of Applied Sciences for hosting Digital Healthcare and Jakob Doppler, being my first advisor, for inspiring discussions and guidance.

This thesis is dedicated to my wife Ingrid.

Abstract

In Austria 13% of population suffer from migraine, percentage of female patients even reaches 18%. Migraine attacks may last for several days and occur several times per month. Besides psychological strain for patients, inability to work causes damage to economy. An important aspect in diagnosis and therapy of migraine is identification of trigger factors, responsible for releasing headache attacks. Stress has been validated as one major trigger factor and several studies have demonstrated relation between smartphone usage parameters and perceived stress. After exploring potential of smartphones to sensor and document such parameters, an assessment of existing electronic services has illustrated limited use of new, digital techniques and in general, a focus on commercial interests of developers. Continuing related work, aim of this thesis was to research, if a simple parameter - usage time of a smartphone - relates to perceived stress. A survey, including 20 participants, was conducted over a period of four weeks. Participants daily had to report smartphone usage time and mark perceived stress level on a scale, included into questionnaire. A two-tailed Pearson correlation analysis was performed on received data, showing low correlation for individual and on total level ($\rho = 0.23$). Although a strong relation between smartphone usage time and perceived stress could not be verified, study proposes changes in design and selection of parameters, indicating future potential for stress prediction based on smartphone usage.

Kurzfassung

In Österreich leiden 13% der Bevölkerung an Migräne, der Anteil weiblicher PatientInnen erreicht sogar 18%. Migräne-Anfälle können mehrere Tage andauern und mehrmals im Monat auftreten. Neben der psychischen Belastung für die PatientInnen verursacht die damit verbundene Arbeitsunfähigkeit auch großen wirtschaftlichen Schaden. Ein wichtiger Aspekt bei Diagnose und Therapie von Migräne ist die Identifizierung von Faktoren, die für das Entstehen von Kopfschmerzattacken verantwortlich sind. Stress wurde als ein wichtiger Auslöser bestätigt und in mehreren Studien der Zusammenhang zwischen Smartphone-Nutzung und wahrgenommenem Stress gezeigt. Beginnend mit einer Analyse der im Smartphone vorhandenen und externer Sensoren zur Erfassung und Speicherung von Parametern, wird in der Folge der Einsatz solcher Techniken in elektronischen Services untersucht. Es zeigt sich, dass die verfügbaren 'Apps' wenig innovativ und vorwiegend von kommerziellen Interessen der Entwickler getrieben sind. Ziel dieser Arbeit war die Untersuchung, ob zwischen Smartphone-Nutzungsdauer und wahrgenommenen Stress ein Zusammenhang besteht. Über einen Zeitraum von 4 Wochen wurde eine Umfrage mit 20 Personen durchgeführt. Die TeilnehmerInnen mussten täglich die Nutzungsdauer ihres Smartphones angeben und das empfundene Stressniveau, auf einer im Fragebogen enthaltenen Skala, markieren. Es wurde danach eine zweiseitige Pearson-Korrelationsanalyse mit den gesammelten Daten durchgeführt, die sowohl auf Ebene der TeilnehmerInnen als auch insgesamt ($\rho = 0.23$), eine geringe Korrelation gezeigt hat. Obwohl die Alternativhypothese - Korrelation zwischen Nutzungsdauer und Stress - somit nicht bestätigt werden konnte, birgt der Ansatz unter der Voraussetzung eines geänderten Studiendesigns und zusätzlicher Differenzierung der Smartphone-Nutzungsdauer, Potenzial für eine Stressvorhersage.

Table of Content

1 Introduction – Migraine and Austrian Health Targets

Life expectancy in Austria ranks in the top of OECD countries due an efficient health care system. However, relating to share in healthy, symptom-free years of life, Austria drops to average. To go against this trend, 10 Austrian health targets were developed to prolong healthy life years of all people living in Austria and reduce cost of healthcare system [1]. Migraine concerns up to 13.7% of Austrian population, especially women, with a high number of people either not being diagnosed, or without adequate treatment. A high lack of work and limited work capability of affected persons result in aggregated economy losses. In addition, migraine often fosters social isolation and psychogenic diseases. With reference to Austrian health targets it is therefore remarkable, that no noteworthy migraine related initiative could be identified. Digital services supporting diagnosis and treatment of migraine as examined in this thesis, could become an important factor in the health target framework.

Chapter ‘2 Understanding Migraine’ gives a basic introduction into migraine, provides facts and figures and is followed by diagnosis- and therapy requirements, especially identification of trigger factors causing attacks. It closes with an overview on digital services and assessment of most downloaded migraine apps. With chapter ‘Detecting and Documenting Migraine related Parameters in Diagnosis and Therapy’, potential of digital technology is assessed. Options to automatically record (environmental) trigger factors, either by smartphone’s internal sensors, external devices or web services are evaluated. As stress has shown to be the most important trigger factor for migraine attacks, a cross-sectional study finally investigates, if smartphone usage relates to perceived stress, thus allowing attack predication based on automated recording of usage. A survey has been conducted, methodology, results and implications for electronic migraine services will be presented. Thesis concludes with summarizing insights and results from previous chapters, offering recommendations for future electronic services supporting migraine patients.

2 Understanding Migraine

Migraine is a chronical, neurological disease, in most cases characterized by painful headache attacks and attended by additional symptoms like nausea or sensitivity to noise or light [2]. In Austria, one-year prevalence of migraine is 10.2% (population above 15 years, migraine classification according to ICHD-1 definition). Prevalence reaches its peak of 13.7% between 30 – 49 years, is 11.1% for people between 20 – 29 years and falls to 6.3% after age of 50 years. In general, women suffer more than twice as often from migraine than men. About 22.4% of patients face attacks at least once per week [3, S. 281–283]. For Austria no incidence rate was published yet, however a study conducted in relation to prevalence of migraine showed, that half of patients are affected for the first time at age 15 – 19, a third of patients between 20 – 29 years. In a prospective study conducted in Germany with patients from 25 to 75 years, incidence rate for migraine (according to ICHD-2 classification) was 15.1 per 1000. Research did not differentiate between incidence and recurrence of migraine after a at least one year of absence of disease [4, S. 334–335]. Migraine patients do not only suffer from their disease, but also face massive constraints in their social- and working life [5]. Patients often have to short-term cancel appointments, are away from work sick, or show limited work performance due to headache. Planning becomes difficult as there are only few indicators allowing patient to recognize next attack.

Several European studies have demonstrated, that there is also a huge economic impact of headache and migraine, both for patients and society. Dependent on study setting and design, economic burden in EU is estimated between € 18 up to € 27 billion. Greatest share of migraine-related costs (77 – 93%) is related to work productivity losses [2, S. 321], either by absence or limited performance of employee. In many cases, there is also an impact on migraine patient's family or relatives and friends; during attack, children have to be looked after by somebody else, appointments need to get canceled and re-organized, dark- and silent rooms have to be shared and much more. In 2007 a project called 'Eurolight', supported by EC Public Health Executive Agency was initiated. Eurolight was the first at European Union level to assess the impact of headache disorders. This was done by bringing together professionals, lay organizations and individuals, thus collecting data from several European countries, including Austria. To enable consistent information and reporting, a couple of methods had to be developed first [6]. The study was based on structured questionnaires, including diagnostic questions and a variety of impact questions. In Austria, 400 General Practitioners

(GP) and 200 Neurologists participated. On a pre-specified day, they issued the questionnaire to 10 consecutive patients, asking them to fill and respond later. One month later, non-responders received a reminder. For all participating countries, 8.271 questionnaires were analyzed, female participation rate was 58%. Figure 1 presents an overview on countries involved, participation rates and average age of patients [6, S. 4].

Country	Participants (n)	Denominator (N)	Participation rate (n/N) (%)	Gender (% female)	Age (y) (mean [SD])	Employed or self-employed (%)	Married or living with partner (%)
Austria†	644	unknown, but not >6,000	not calculable	70	48.8 [16.0]	57	75
France†	876	2,400	36.5	68	50.2 [16.7]	52	80
Germany	318	3,000	10.6	57	44.6 [12.5]	70	65
Italy	487	3,500	13.9	58	43.4 [12.6]	68	92
Lithuania	573	1,137	50.4	59	40.9 [13.8]	65	67
Luxembourg	1,833	6,498	28.2	59	40.5 [12.7]	67	71
Netherlands	2,414	unknown	not calculable	50	42.6 [13.2]	69	69
Spain	999	1,700	58.8	59	42.7 [11.9]	83	69
UK†	127	720	17.6	65	48.0 [18.3]	54	67
Overall	8,271		27.5*	58	43.4	65	72

†Sample derived from health-care setting (see Table 1). *Excluding Austria and Netherlands.

Figure 1: Numbers of Participants, Participation Rates and demographic Characteristics of Samples per Country [6, S. 4]

A particular merit of the Eurolight project is that besides drafting a quantitative picture of European migraine 'landscape', it also evaluated the personal impact for patients. Figure 2 presents the assessment questions used, including response rate [6, S. 4].

Question	Proportion responding adversely* (%)		
	Overall	Male	Female
1. Have your headaches interfered with your education?	9.2	7.9	9.9
2. Do you believe your headaches have made you less successful in your career?	7.7	7.0	8.1
3. Have your headaches resulted in reduced earnings?	8.4	8.0	8.7
4. Do you avoid telling people that you have headaches?	31.4	30.1	32.1
5. Do you feel that your employer and work colleagues understand and accept your headaches?	36.3†	38.9†	34.9†
6. Do you feel that your family and friends understand and accept your headaches?	10.8	10.5	10.9
7. Taking into account everything you do to treat your headaches, do you feel you are in control of your headaches?	13.5	13.0	13.7

*"Yes" to questions 1–4; "no" to questions 5 and 6; "rarely" or "never" to question 7.
†Of those to whom the question was applicable (*ie*, having headache and being employed).

Figure 2: Personal Impact of Headache assessed by seven Questions [6, S. 4]

Response rates from Figure 2 show, that migraine patients not only suffer from pain, but disease is still not accepted by society as such and leads to social discrimination, even with family and friends. Figure 3 presents an overview on financial impact due to 'lost days' because of migraine. Values are clustered according to HALT index [7]. The 'Headache-Attributed Lost Time' index, is measuring days lost during three consecutive months because of headache. It

does not distinguish between lost workdays, lost housework days and lost social days. Although figures therefore cannot be translated into financial impact directly, it draws a realistic picture of time lost due to disease.

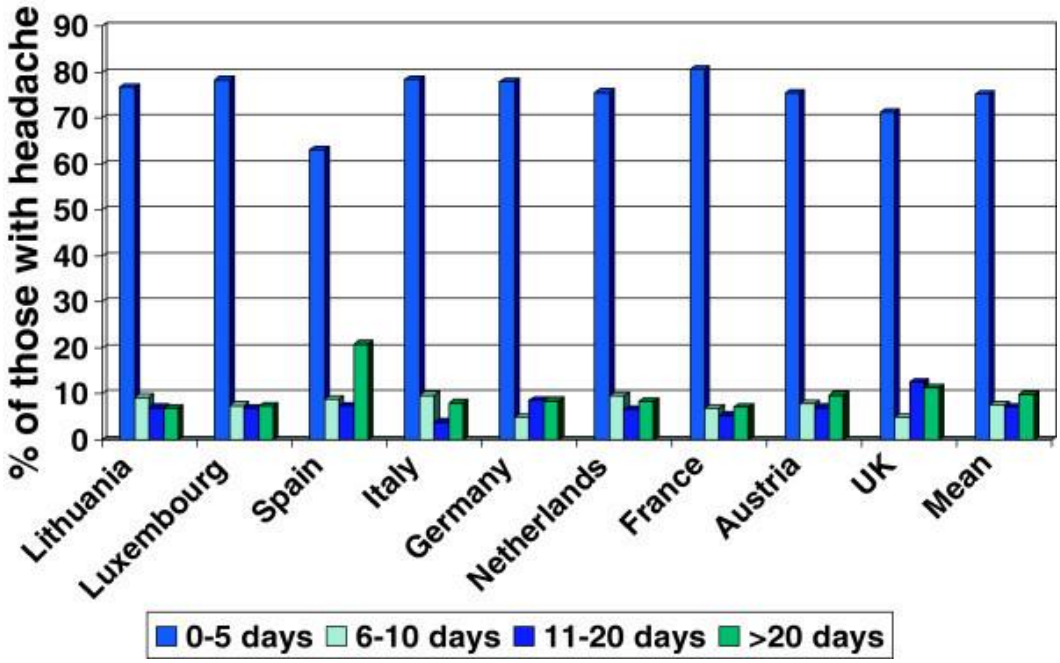


Figure 3: Personal Impact of Headache assessed by HALT Index (Days lost in preceding 3 Months), by Country [7]. No detailed data given in study.

Summarizing this chapter, migraine can be seen as a disease impacting 10 – 15% of population, causing not only pain, but implicating huge impact on patient's personal and social lives. Besides, disease also brings great financial impact on economy. It is therefore important, to diagnose migraine and find the right treatment or therapy as soon as possible. Lifting The Burden (LTB), a non-profit organization related to the World Health Organization (WHO), has initiated a global campaign with target on reduction of headache and migraine, especially in low-income countries [8]. Several studies also indicate a need for public awareness, however, this will not be covered in this thesis. This work focuses on diagnosis and therapy of migraine by use of electronic diary services and takes a closer look at sources for migraine, so called 'trigger-factors'. Prior to this, a better understanding of the disease is required. Next section therefore focuses on what is the difference between headache and migraine, what types of it can be distinguished and what is their typical progress.

2.1 Forms of Migraine, Difference to Headache

Many women and men are affected by headache at least a few times in their lifetime. International Headache Society has listed more than 240 types of headache [9]. Many people do not even know if source of pain is headache or migraine and therefore, disease sometimes does not get treated in the right way. According to World Health Organization (WHO), migraine counts among most frequent chronic diseases [10]. Primary headache – tension headache - usually comes with dull pain on both sides of the head. Attendant symptoms are uncommon and pain can be reduced by resting and fresh air. Patients with migraine suffer from headache in irregular intervals. Main difference to sole headache is, that additional symptoms like nausea, emesis or impaired visions can arise. In addition, people often are hypersensitive against noise, light and smell. Usually only one side of the head is affected and person concerned, senses it as pulsating and dragging pain, increasing with physical effort. Duration of a migraine attack can last between 4 to 72 hours and appear in different timely intervals [11]. Duration and level of pain vary from attack to attack. International Headache Society (IHS) speaks about chronic migraine (CM), if a patient faces more than 15 migraine days per month over a period of at least three months [12]. According to international classification schema, several types of migraine exist, however, most important differentiation is by ‘with’ or ‘without aura’. An aura arises shortly before headache attach starts. It is characterized by neurological disruptions like sight disorder, hemiplegia, sensory disorder at hands and arms, as well as disturbance of speech [13]. It is important to explain that migraine is not just another type of headache and that there is a variety of types, to understand complexity of diagnosis and therapy, described in next sections.

2.2 Diagnosis of Migraine

Basic cause for migraine is actually not fully understood, although several factors have been identified. Physicians assume a dysfunction of second messenger balance (central and peripheral serotonin level), thus resulting in disturbed blood flow in the brain. Indeed, imaging methods like magnetic resonance tomography (MRT), tomography (CT) or ultrasonic testing show abnormal brain structures during attack. Another theory is pointing to genetic defects being cause.

Besides research on possible root cause for disease, a number of so called ‘trigger factors’ has been identified, initiating migraine attacks. Amongst others, stress and

short of sleep are listed as most significant releasers [14]. Electronic migraine services should therefore allow to record trigger factors and best case, enable prediction on next attack. Most important for diagnosis of migraine is patient's awareness that regular headache requires a doctor's visit. On the other hand, general practitioners need to align with neurologist as disease is often accompanied by neurological diseases like depression. Any diagnosis starts with careful analysis of patient's medical history regarding type, duration and trigger of attack. Especially chronic migraine requires involvement of neurologist, to exclude any other cause than migraine. Based on anamneses, a classification of headache type according to IHS classification schema [15] is done (Figure 4).

ICHD-3 Code	Description
1	Migraine
1.1	**Migraine without aura**
1.2	**Migraine with aura**
1.2.1	Migraine with typical aura
1.2.1.1	Typical aura with headache
1.2.1.2	Typical aura without headache
1.2.2	Migraine with brainstem aura
1.2.3	Hemiplegic migraine
1.2.3.1	Familial hemiplegic migraine (FHM)
1.2.3.1.1	Familial hemiplegic migraine type 1 (FHM1)
1.2.3.1.2	Familial hemiplegic migraine type 2 (FHM2)
1.2.3.1.3	Familial hemiplegic migraine type 3 (FHM3)
1.2.3.1.4	Familial hemiplegic migraine, other loci
1.2.3.2	Sporadic hemiplegic migraine (SHM)
1.2.4	Retinal migraine
1.3	**Chronic migraine**

Figure 4: Migraine Classification Schema according to IHS (ICHD-3)

Based on classification, the right medical approach for treatment and therapy can be selected. An important support for diagnosis and therapy is the keeping of a headache diary, either on paper or by use of an electronic service. Diary allows to record on a regular (daily) base, when and where the pain occurred, how strong it was, duration and complaints that went along with it. Additional dependencies like menstruation, pain triggers like stress or food intake, as well as medications taken should be noted. The more detailed the documentation, the easier it is for the doctor to identify the triggers and determine the right therapy.

2.3 Therapy of Migraine

Migraine treatment is based on two main pillars:

- Prophylaxis - avoidance or reduction of future attacks
- Acute pain therapy during attack

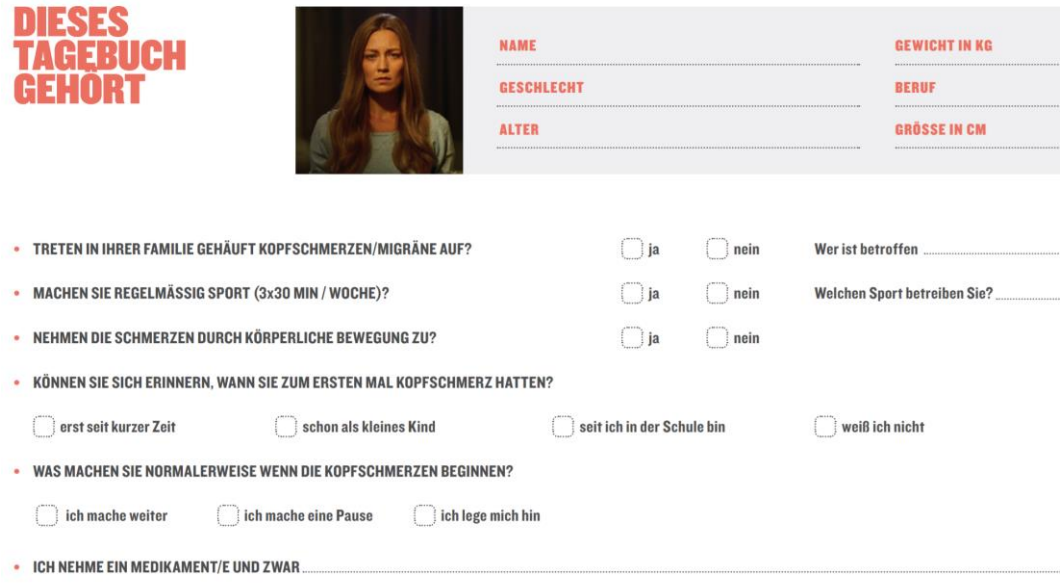
For acute therapy, currently there are mainly drugs available that mitigate the symptoms of an attack, but not always achieve the desired pain control. Depending on the severity of the migraine, various medication is available. Another option is relaxation exercises such as autogenic training and progressive muscle relaxation (PMR) according to Jacobson [16], which can help during attack. Since 2018 new medication has come to the market, promising reduction of attacks up to 50%. However, we will not focus on medical treatment in this work, but focus on what can be done to prevent from future attacks and which information is required, to find the right therapy. It should be mentioned that one side effect of medication could be medication over use (MOU) – pain medication taken too often can cause headache itself and in some cases, requires withdrawal in a hospital. Most important process supporting diagnosis and therapy is monitoring of patient's journey, during and between migraine attacks. A migraine calendar or diary allows recording of potential trigger factors, symptoms during attack and medication applied. In general, it can be said, that besides classification of migraine type and adjusting medication accordingly, diagnosis is focusing on identifying possible trigger factors, therapy tries to modify patient's risk factors.

Typical trigger factors are

- Stress
- Sleep-wake cycle shift
- Stimulus satiation
- Change in the weather
- Certain food / natural stimulant
- Hormone level changes

Which of listed factors triggers an attack is very individual and not all of them might apply, on the other hand there are many others and it is therefore important, to identify the most specific ones, that have an impact on patients migraine. A common migraine trigger is stress in the home or work environment. For example, changing job, conflicts with colleagues or in the family and high time pressure can trigger a migraine attack. For students, overworking at school and conflicts with other students are common migraine triggers [17]. Therefore we will have a closer look at 'stress' subsequently. For self-monitoring reasons, patients have to

maintain a migraine diary. Figure 5 and Figure 6 show an example, which can be downloaded and printed for further use [18]. Copyright notice can be found in Appendix A.



DIESES TAGEBUCH GEHÖRT

NAME ..... GEWICHT IN KG .....

GESCHLECHT ..... BERUF .....

ALTER ..... GRÖSSE IN CM .....

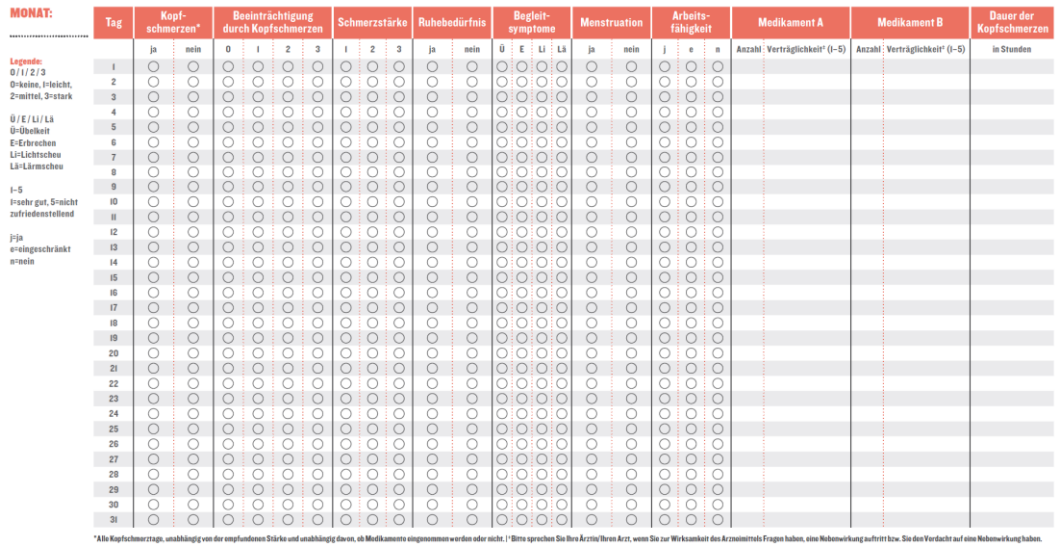
- TRETEN IN IHRER FAMILIE GEHÄUFT KOPFSCHMERZEN/MIGRÄNE AUF? ☐ ja ☐ nein Wer ist betroffen .....
- MACHEN SIE REGELMÄSSIG SPORT (3x30 MIN / WOCHE)? ☐ ja ☐ nein Welchen Sport betreiben Sie? .....
- NEHMEN DIE SCHMERZEN DURCH KÖRPERLICHE BEWEGUNG ZU? ☐ ja ☐ nein
- KÖNNEN SIE SICH ERINNERN, WANN SIE ZUM ERSTEN MAL KOPFSCHMERZ HATTEN?

  ☐ erst seit kurzer Zeit ☐ schon als kleines Kind ☐ seit ich in der Schule bin ☐ weiß ich nicht
- WAS MACHEN SIE NORMALERWEISE WENN DIE KOPFSCHMERZEN BEGINNEN?

  ☐ ich mache weiter ☐ ich mache eine Pause ☐ ich lege mich hin
- ICH NEHME EIN MEDIKAMENT/E UND ZWAR .....

Figure 5: Paper based Diary to track Migraine – General Section [18]

General section of diary is intended to support health care professional during anamnesis and used to record patient's status quo, background and development of disease. It also helps to get a first evidence for migraine instead of headache.



MONAT: .....

Legende:
0 / 1 / 2 / 3
0=keine, 1=leicht, 2=mittel, 3=stark

Ü / E / Li / Lä
Ü=Übelkeit
E=Erbrechen
Li=Lichtscheu
Lä=Lärmscheu

1–5
1=sehr gut, 5=nicht zufriedenstellend

j=ja
e=eingeschränkt
n=nein

Tag	Kopfschmerzen*		Beeinträchtigung durch Kopfschmerzen				Schmerzstärke			Ruhebedürfnis		Begleitsymptome			Menstruation		Arbeitsfähigkeit			Medikament A		Medikament B		Dauer der Kopfschmerzen
	ja	nein	0	1	2	3	1	2	3	ja	nein	Ü	E	Li	Lä	ja	nein	j	e	n	Anzahl	Verträglichkeit¹ (1–5)	Anzahl	Verträglichkeit¹ (1–5)	in Stunden
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31	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○					

*Alle Kopfschmerztage, unabhängig von der empfundenen Stärke und unabhängig davon, ob Medikamente eingenommen worden oder nicht. ¹*Bitte sprechen Sie Ihre Ärztin/Ihren Arzt, wenn Sie zur Wirksamkeit des Arzneimittels Fragen haben, eine Nebenwirkung auftritt bzw. Sie den Verdacht auf eine Nebenwirkung haben.

Figure 6: Paper based Diary to track Migraine and Symptoms [18]

Calendar view of diary allows to note following parameters

- Headache (yes/no)
- Disturbance due to headache (0 = none / 3 = strong)
- Pain level (1 = low / 3 = high)
- Need for rest (yes/no)
- Attendant symptoms (nausea, emesis, light sensitivity, sensitivity to noise)
- Menstruation
- Working capacity (yes / limited / no)
- Medication
- Duration of attack

There are hundreds of diaries available, however, many patients simply note what appears important to them on a sheet of paper or in an exercise book. Previous diary example does not allow to note trigger factors and also does not foresee more details on type of headache (one-, two-sided) or implications like an aura.

After a health care professional (HCP) has eliminated other (neurological) causes for headache, diagnosis process aims to distinguish frequent headache from migraine which can only be diagnosed definitely by MRT taken during attack, or most probably with preceding aura. In any case, identification of trigger factors will proceed and additional education on relaxation trained. Therapy is therefore dependent on symptoms recorded in the diary and usually it takes months to find the right approach. Often best achievable outcome of a therapy is reduction of migraine attacks. It is therefore obvious, that maintaining a diary is often very incriminating for patients, as before and during attack it is not possible due to pain perceived, after attack – which can take up to 72 hours – people do not remember all details or want to use time for things they could not do before. It has to be mentioned that after an attack, patients feel exhausted and when back to normal again, next attack might already start. This should be remembered when thinking about electronic services, which we will deal with in the next chapter.

2.4 Electronic Diary Services

The concept of service and service systems has changed over the years [19]. ‘Electronic Service’ is a very generic term for providing services over the internet. A more specific definition has been presented by Taherdoost et al. [20], reviewing existing services and technology concepts: e-services make use of information and communication technologies (ICTs) and consist of three main components:

- Service provider
- Service receiver
- Channels of service delivery (i.e., technology).

For example, as concerned to public e-service, public agencies are the service provider and citizens as well as businesses are the service receiver. Although Internet is the main channel of e-service delivery, other classic channels (e.g. telephone, call center, public kiosk, mobile phone, television) are also considered. In last years, technological performance of smartphones has made a big step ahead, offering processing and sensoring capabilities previously subject to workstations only. This evolution might have benefited a trend, to self-track activity- and health related parameters. Enabler for measuring and recording these data are electronic services, usually known as 'Apps'. Some of these services are designed to support diagnosis, or therapy of certain diseases. However, for most of them, no evidence is provided and their usage therefore questionable. Those included in final assessment later either make limited or no use of digital options and represent an electronic copy of paper-based diaries. Overview includes services allowing to at least maintain a migraine diary as presented in previous section and in best case, support patient journey during full lifecycle. We will limit such e-services to applications available for smartphones (Apple, Android).

2.4.1 Patients Journey and Requirements

To better understand requirements for a service we need to take a holistic view on patient's journey and decide, where support is needed. Typically, there are five phases a patient has to pass through:

- Awareness
- Pre-Diagnosis
- Diagnosis
- Therapy/Treatment
- Long-Term

In the awareness phase, patient is seeking for information about his disease. This can have been initiated by increase in frequency of headache, severity or appearance of an aura. A general practitioner might get consulted for the first time, a health campaign might have called patient's attraction or a relative is recommending to search for help. During pre-diagnosis, daily observation and occasional tracking of headache, symptoms, duration and other parameters is started. At this stage, a first intentional look at possible trigger factors is done. Main purpose is to create precedents for following examination. Diagnosis phase is

focusing on anamneses and medical history of patient, usually a neurologist will get consulted and if any other (neurological) disease can be excluded, migraine is diagnosed. Now, individual treatment path (therapy) can begin. Medication is selected to reduce occurrence of attacks and reduce pain, however, there is no standard schema that can be applied, as every migraine is unique. It is essential that person concerned tracks headache, attendant symptoms and medication on a daily base. This helps to adapt medication and ensure, that best possible therapy is applied. Second important element of therapy is to reduce triggers for migraine attacks by modification of lifestyle. Lifestyle has to be seen in a wider context, starting from nutrition habits, sports, working conditions up to personal attitude and stress balance. To complement therapy, relaxation trainings help patient to either avoid attack or result in a moderated progression. Jacobson relaxation is often referred to as an example [16]. Finally, as migraine is a chronic disease, there is also a long-term aspect. Migraine changes over time, especially for women due to alteration in hormonal balance. Lifestyle and work life in general change, leading to modification requirements in treatment or therapy. New medication is developed, long-term medication requires adaption, often psychological disorders like depression arise and many other factors make patients seeking for help and advice a lifetime.

2.4.2 Overview and Comparison

Healthcare applications (migraine diary apps) installed on a smartphone, regardless if downloaded from Apple's iTunes App Store or Google's Play Store, represent just software. However, it is not the app itself but the service the app enables, that (hopefully) creates value for the user. Looking at actual numbers of health-related apps, available in either iTunes App Store (Apple) or Google Play Store, it is obvious, that it is nearly impossible for patients and health care professional to choose the right one [21]. Total number of downloads and user ratings might be a first indication but do not necessarily ensure quality of service. Many apps have been developed by technicians without any involvement of patients or health care professionals, that way not allowing to record relevant data or causing improper usage. Although migraine apps are under most common health apps available, they belong to the least researched. In most cases, available services have just transformed diaries from paper- to electronic format. Only few apps have been developed together with patients or doctors, and even less are classified as medical device. Stubberud and Linde assume, that mHealth apps for migraine, therefore have a commercial and economic, rather than a scientific, incentive [22]. Besides the app itself, support is another important topic.

A search was performed on smartphones with Android and IOS (Apple) operating systems in February 2019, using below terms (English/German):

- Migraine / Migräne
- Headache / Kopfschmerz
- Migraine Diary / Migräne Tagebuch
- Headache Diary / Kopfschmerz Tagebuch
- Headache Migraine Diary / Migräne Kopfschmerz Tagebuch

Only apps free of charge have been selected, as seriously user should be able to test the app before deciding to pay for it. However, these could still offer ‚In-App-Sales'. Also search was terminated if app did not seem to support headache or migraine, for example was a ‚head training', game or somehow recognized to be an advertisement. Table 1 and Table 2 provide an overview on results for iPhone (Apple) and Android (Google). Some of the apps show public rating results. These were not used for further selection and in general, should be dealt with care; a review for some of the ratings showed, that feedback received was most frequently positive, dates of feedback were clustered around a short date range, which was release date of service, followed by ‚thanksgiving' of the author. It can be assumed that at least some of the ratings are outcome of marketing activities, rather than real user replies. Knowing that tracking of migraine and attacks requires time, it is obvious that immediate user feedback on apps recently released, in best case can assess ‚look and feel'.

Table 1: Search Results for Migraine/Headache in iTunes App Store (Apple)

Search Term	**Rank**	**App**
Migraine	#1	Migraine Buddy
Migraine	#2	HeadApp Kopfschmerztagebuch
Migraine	#3	Kopfschmerz-Tagebuch
Migraine	#4	Migraine Insight: Tracker
Migraine	#5	Ada
Migraine	#6	Migräne Schmerz sofort stoppen mit Selbst-Massage
Migraine	#7	doloTrack - Migräne App
Migraine + Diary	#1	HeadApp Kopfschmerztagebuch
Migraine + Diary	#2	Kopfschmerz-Tagebuch
Migraine + Diary	#3	Migraine Buddy
Migraine + Diary	#4	Migräne Schmerz sofort stoppen mit Selbst-Massage
Migraine + Diary	#5	Schmerztagebuch &Community CatchMyPain
Migraine + Diary	#6	Migraine Insight: Tracker
Migraine + Diary	#7	doloTrack - Migräne App

Headache	#1	iMigraine - migraine tracker
Headache	#2	KEIN Kopfschmerz - Soforthilfe Akupressur
Headache	#3	Headspace: Meditation und Ruhe
Headache + Diary	#1	HeadApp Kopfschmerztagebuch
Headache + Diary	#2	Kopfschmerz-Tagebuch
Headache + Diary	#3	Kopfschmerztagebuch - Lite
Headache + Migraine + Diary	#1	HeadApp Kopfschmerztagebuch
Headache + Migraine + Diary	#2	Kopfschmerz-Tagebuch
Headache + Migraine + Diary	#3	N1-Kopfschmerz
Headache + Migraine + Diary	#4	Migraine Buddy
Headache + Migraine + Diary	#5	Schmerztagebuch &Community CatchMyPain
Migräne	#1	Migräne App
Migräne	#2	M-sense: Migräne & Kopfschmerz
Migräne	#3	Migraine Buddy
Migräne	#4	doloTrack - Migräne App
Migräne	#5	Ada
Migräne	#6	Migräne Radar 2.0
Migräne + Tagebuch	#1	Migräne App
Migräne + Tagebuch	#2	M-sense: Migräne & Kopfschmerz
Migräne + Tagebuch	#3	Migräne Radar 2.0
Migräne + Tagebuch	#4	doloTrack - Migräne App
Kopfschmerz	#1	M-sense: Migräne & Kopfschmerz
Kopfschmerz	#2	Migräne App
Kopfschmerz	#3	Mein Kopfschmerz
Kopfschmerz	#4	Kopfschmerz-Tagebuch
Kopfschmerz	#5	N1-Kopfschmerz
Kopfschmerz + Tagebuch	#1	M-sense: Migräne & Kopfschmerz
Kopfschmerz + Tagebuch	#2	Migräne App
Kopfschmerz + Tagebuch	#3	Kopfschmerz-Tagebuch
Kopfschmerz + Tagebuch	#4	Mein Kopfschmerz
Kopfschmerz + Tagebuch	#5	N1-Kopfschmerz
Kopfschmerz + Tagebuch	#6	Migräne Radar 2.0
Kopfschmerz + Tagebuch	#7	HeadApp Kopfschmerztagebuch
Kopfschmerz + Migräne + Tagebuch	#1	M-sense: Migräne & Kopfschmerz
Kopfschmerz + Migräne + Tagebuch	#2	Migräne App
Kopfschmerz + Migräne + Tagebuch	#3	Mein Kopfschmerz
Kopfschmerz + Migräne + Tagebuch	#4	Kopfschmerz-Tagebuch
Kopfschmerz + Migräne + Tagebuch	#5	N1-Kopfschmerz
Kopfschmerz + Migräne + Tagebuch	#6	Migräne Radar 2.0

As there were much more search results returned from Google Play Store (Android), any search except for ‚migraine' was limited to five items.

Table 2: Search Results for Migraine/Headache in iTunes App Store (Apple)

Search Term	**Rank**	**App**
Migraine	#1	Migraine Buddy
Migraine	#2	Migraine Relief Hypnosis - Headache & Pain Help
Migraine	#3	Migraine Headache Diary HeadApp
Migraine	#4	Kopfschmerztagebuch
Migraine	#5	Kopfschmerzen zu lindern Musik
Migraine	#6	Migraine Insights
Migraine	#7	Curable: Back Pain, Migraine & Chronic Pain Relief
Migraine	#8	Migraine Monitor
Migraine	#9	Migräne App
Migraine + Diary	#1	Migräne Tagebuch
Migraine + Diary	#2	Migraine Buddy
Migraine + Diary	#3	Migraine Headache Diary HeadApp
Migraine + Diary	#4	Migraine Insights
Migraine + Diary	#5	Headary: headache diary
Headache	#1	Migraine Buddy
Headache	#2	Kopfschmerz-Tagebuch
Headache	#3	Migraine Headache Diary HeadApp
Headache	#4	Headache Diary
Headache + Diary	#1	Migraine Buddy
Headache + Diary	#2	Migraine Headache Diary HeadApp
Headache + Diary	#3	Headache Diary
Headache + Migraine + Diary	#1	Migraine Buddy
Headache + Migraine + Diary	#2	Migraine Headache Diary HeadApp
Headache + Migraine + Diary	#3	Headache Diary
Headache + Migraine + Diary	#4	Kopfschmerz-Tagebuch
Headache + Migraine + Diary	#5	Migraine Insights
Migräne	#1	Migraine Buddy - für Migräne und Kopfschmerzen
Migräne	#2	Migräne App
Migräne	#3	M-sense: Migräne & Kopfschmerz
Migräne	#4	Kopfschmerztagebuch
Migräne	#5	Migräne-Kalender einfach
Migräne + Tagebuch	#1	Migraine Buddy - für Migräne und Kopfschmerzen
Migräne + Tagebuch	#2	Migräne App
Migräne + Tagebuch	#3	Migräne-Kalender einfach
Migräne + Tagebuch	#4	Kopfschmerztagebuch
Migräne + Tagebuch	#5	M-sense: Migräne & Kopfschmerz
Kopfschmerz	#1	Migraine Buddy - für Migräne und Kopfschmerzen
Kopfschmerz	#2	M-sense: Migräne & Kopfschmerz
Kopfschmerz	#3	Migräne App
Kopfschmerz	#4	STOP Kopfschmerzen App
Kopfschmerz	#5	Kopfschmerztagebuch

Kopfschmerz + Tagebuch	#1	Kopfschmerz-Tagebuch
Kopfschmerz + Tagebuch	#2	Kopfschmerztagebuch
Kopfschmerz + Tagebuch	#3	Migraine Buddy - für Migräne und Kopfschmerzen
Kopfschmerz + Tagebuch	#4	M-sense: Migräne & Kopfschmerz
Kopfschmerz + Tagebuch	#5	Migräne App
Kopfschmerz + Migräne + Tagebuch	#1	Migräne App
Kopfschmerz + Migräne + Tagebuch	#2	M-sense: Migräne & Kopfschmerz
Kopfschmerz + Migräne + Tagebuch	#3	Migraine Buddy - für Migräne und Kopfschmerzen
Kopfschmerz + Migräne + Tagebuch	#4	Kopfschmerztagebuch
Kopfschmerz + Migräne + Tagebuch	#5	Kopfschmerz-Tagebuch

Although some Apps are named different, depending on store (Apple or Google), availability in both stores could be clearly identified. Selection of services for final comparison was based on availability in both stores and number of downloads. As Apple does not publish download statistics, figures from Google Play Store have been used.

Most downloaded Migraine Apps available in Apple and Google store were

- Migraine Buddy (1 Mio+ downloads)
- M-sense (100.000+ downloads)
- Migräne App (50.000+ downloads)

All applications included in search results were screened for functionality and features to create catalog of requirements, however, only selected services have been installed on Android smartphone for more detailed analysis. It can therefore not be ensured that, although application was classified to support a particular need, requirements of patients are fully met. Also, following overview does not say anything about quality of service. As already mentioned, there is only few evidence (if any) available for migraine services available.

As today only ‚star-ratings' or number of downloads is provided, an indicator for quality of apps is missing. For this reason, a mobile app rating scale was developed by Stoyanov et al. [23]. They developed a ‚reliable, multidimensional measure for trialing, classifying, and rating the quality of mobile health apps'. This scale was not applied here, however could be of help for future research on healthcare apps.

Minimum requirement for a migraine service would be ability to record date, time and duration of an attack, type of headache, side effects, treatment and impact. Table 3 shows additional features that could be of benefit for patients and were identified during apps screening before. Where available, URL of developer has been added. Those marked yellow will appear in later detailed comparison, all of

them are available from Apple and Google. For all other applications, source (store) has been added. It was not verified if available for both operating systems and if so, description for both matches. As said, it was also not verified, if description matched functionality and usability of service.

Table 3: Migraine/Headache Services and Special Functionality

Application	**Features**	**Store**	**URL**
Ada - persönliche Gesundheitshelferin	- AI supported symptom analysis and clinical decision support - Data sharing with doctor	iTunes	www.ada.com
Curable: Back Pain, Migraine & Chronic Pain Relief	- Evidence based exercises to control chronic pain	Google Play	
doloTrack - Migräne App	- AI powered migraine analytics with prediction - Every new data record trains algorithm - Trigger include weather (temperature, forecast, UV)	iTunes	www.dolotrack.com
Headache Diary	- Medication reminder	Google Play	
HeadApp Kopfschmerztagebuch	- Connected to Apple Health Kit - Sleep-Diary - Document archive	iTunes	www.myheadapp.com
Headary: headache diary	- Customizable screen modes (dark/light colors)	Google Play	
Headspace: Meditation und Ruhe	- Guided meditations to reframe stress	iTunes	www.headspace.com
iMigraine - migraine tracker	- Encrypted storage of user data for privacy protection	iTunes	www.imigraine.io
KEIN Kopfschmerz - Soforthilfe Akupressur	- Headache acupressure training supported by photos and videos (Chinese pressure points)	iTunes	www.drbargak.com
Kopfschmerzen zu lindern Musik	- Anti-stress-musik (Tension headache)	Google Play	www.rehegoo.com
Migraine Buddy 	-Trigger include environmental information (air pressure, weather) - User defined fields - HIPAA compliant cloud solution - Connected to Health Kit	iTunes	www.migrainebuddy.com

	for sleep analysis - Share migraine status with family and friends		
Migraine Insight: Tracker	- Nutrition analysis and food trigger identification - Nutrition-migraine-charts	iTunes	www.migraineinsight.com
Migraine Monitor	- Connect to and share data with doctor - Anonymous connection with patient community - Daily tips from neurologists for prevention - Mood and stress level tracking	Google Play	
Curable: Back Pain, Migraine & Chronic Pain Relief	- Hypnosis techniques (30 min audio sessions)	Google Play	www.surfcityapps.com
Migräne App 	- Quick test for headache or migraine identification - Muscle relaxation training - Medication overuse (MOH) warning - Connectivity to social media - Expert-/doctor finder with video-live-chat - Tutorial video	iTunes	www.schmerzklinik.de
Migräne Radar 2.0	- Public migraine research project, powered by anonymous patient data diaries	iTunes	www.migraene-radar.de
Migräne-Kalender einfach	- Diary with 2-click migraine recording	Google Play	
M-sense: Migräne & Kopfschmerz 	- Evidence based expert knowledge - Relaxation techniques - Medical device	iTunes	www.m-sense.de
N1-Kopfschmerz	- Data exchange with doctor - Data can be exported - Medication overuse warning - Individual customizing of tracking - Application support by developers	iTunes	www.n1-kopfschmerz.com

Schmerztagebuch &Community CatchMyPain	- Pain localization by means of zoom able graphics - Community to exchange with other patients - Satisfaction-, fatigue- and stress tracking - Email functionality to send diary - Offline- or cloud usage with data synchronization - Anonymous data sharing for research usage	iTunes	www.catchmypain.com
STOP Kopfschmerzen App	- Virtual doctor-patient anamnesis simulation - Individual questions and answers, based on AI powered matching with medical database, holding more than 1500 symptoms/combinations - Probable root cause diagnosis and individual information to support consultation with doctor	Google Play	

Advances in digital and mobile technology have increased the number of health apps in general and migraine related services in particular. Research done for m-Health or e-Health services shows that only few applications have been developed based on clinical evidence or have scientific validation. When searching global app stores for health apps, migraine apps are the third most common right after diabetes and depression, however, they appear under the least researched. A study of Stubberud & Linde [22] asked how new solutions should be developed and listed five domains to be considered:

- Proper usability and functionality designs with healthcare professionals and end user involvement
- Meet market and Society demand
- Adhere to guidelines, recommendations and regulations
- Ensure accountability and availability
- Consider including concepts from Big Data and Internet of Things.

Other research required to self-develop a headache diary for adolescents and young adults, as due to absence of quality standards with existing apps, use for research and clinical purposes was compromised [24]. Based on patients‘

feedback, an electronic headache diary called ‚my Wireless Headache Intervention diary (WHI) was developed. Although only basic functionality was implemented, service has undergone a formal usability, feasibility and psychometric testing. Authors acknowledge further room of improvement. To distinguish between patients with different types of migraine, machine learning techniques over imaging and questionnaire were researched. Applying automatic migraine classification allowed identification of patients with sporadic or chronic migraine and patients at risk of medication overuse with over 93% accuracy [25]. A recently published research paper exploring ‚Burden of Migraine in Europe' is based on diary data collected with Migraine Buddy application. A retrospective, cross-sectional analysis was done to demonstrate the high burden and impact of migraine on health-related quality of life and work productivity. The study was funded by Novartis Pharma AG, a Suisse pharmaceutical company, in the forefront of launching a new drug to reduce migraine attacks [26]. Besides initial question, study demonstrates that data collected with health apps may contribute to future research. To allow further use of data, standardization is required.

2.4.3 Assessment of most downloaded Diary Services

The following comparison finally assesses ‚Migraine Buddy', ‚Migräne App' and ‚M-Sense' services based on a criteria check list, which is the result from previous research. It has to be mentioned that the assessment does not provide a final rating or recommendation but should give an overview on functionality supported by the applications and allow developers to improve their service.

In a first step, basic and advanced features have been collected using software ‚MindManager' version 17.1. (Mindjet is a product of Corel GmbH) in brainstorming mode. After searching for suitable umbrella terms, all items have been assigned. Figure 7 shows MindManager chart for Migraine Diary Service.

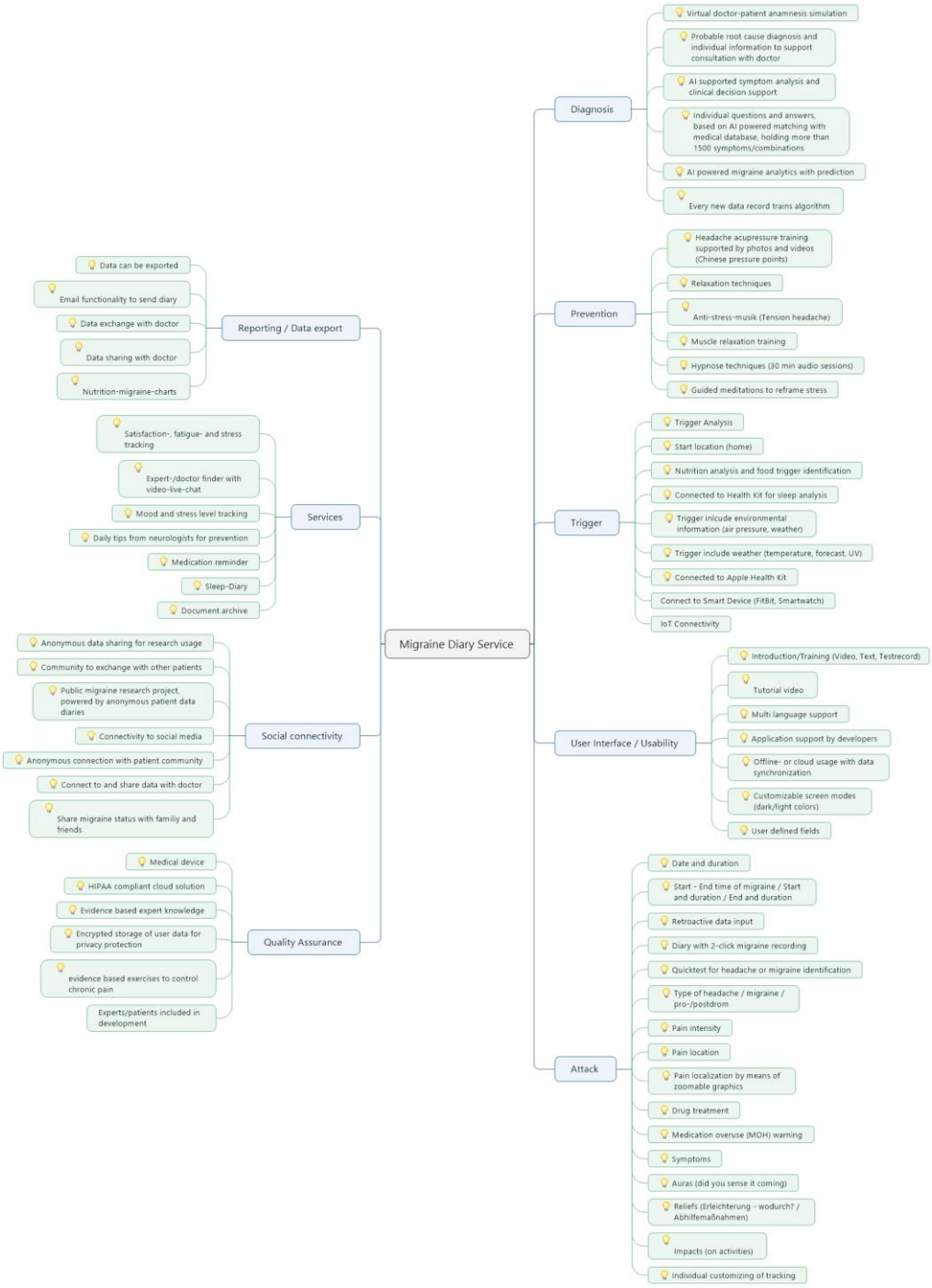

Figure 7: Clustering Migraine related Items in MindManager Chart

Following umbrella terms have been created:

- Diagnosis: Symptom analysis and decision support
- Attack: Parameters to record in diary

- Trigger: Analysis and recording of potential trigger factors
- Prevention: Techniques to prevent attack or reduce pain
- Reporting / Data export: Analyze records and share with doctor
- Services: Helpful additional functionality
- Social connectivity: share data, connect with others
- User interface / Usability: Easy start and usage for migraine patients
- Quality Assurance: Development, data privacy, evidence. HIPAA stands for ‚Health Insurance Portability and Accountability Act', a common US data protection standard for healthcare data. MIDAS, Migraine Disability Assessment Score, is a scale to rate level of impairment due to attack.

Final assessment and comparison of selected migraine diary services is presented in Table 4.

Table 4: Final Assessment and Comparison of selected Migraine Diary Services

	Migraine Buddy	Migräne App	M-sense
			
Developer	Healint Singapore	Schmerzklinik Kiel, Germany	Newsenselab Germany
Version	26.1.6 (2616)	1.6 (30)	1.4.3 (9785)
Diagnosis			
Doctor-patient anamnesis simulation (VR)			
Individual diagnosis/information based on medical database match			
AI supported symptom analysis			
AI powered migraine analytics/prediction			
Applied machine learning algorithms			
Quick test headache or migraine identification		x	
Attack			
Attack recording (start/end, duration)	x	x	x
Retroactive data recording	x	x	x

Omit parameters during attack recording	x		x
Type of headache/migraine	x	x	x
Pain intensity	x	x	x
Pain location	x		
Pain localization by means of zoom able graphics	x		
Drug treatment during attack	x	x	x
Medication overuse warning (MOH)		x	
Aura	x	x	x
Symptoms	x	x	x
Reliefs - how to improve attack	x		
Impact on activities (home, work, school)	x	x	
Individual customizing of tracking parameters	x		x

Trigger

Individual setup of triggers for tracking	x		
Analysis of trigger factors	x		x
Nutrition analysis and food trigger identification			
Weather information, based on location (temperature, humidity, air pressure)	x	x	x
Environmental information, based on location (UV, phase of the moon, air pollution)			
Sleep analysis	x		x
Combinable with HealthKit (i.e. Apple)	x		
Combinable with Fitness Tracker (FitBit)			
Combinable with Smartwatch (i.e. Apple)		x	

Prevention

Guidance for Progressive Muscle Relaxation (PMR) training according to Jacobson.		x	x
Headache acupressure training based on Chinese pressure points.			
Guided meditations to reframe stress		x	x
Guided hypnosis techniques			

Anti-stress-music (tension headache)		x	

Reporting

Individual report creation	x		
Various individual reports can be stored	x		
Diary data can be exported	x	x	x
Various export formats available (csv, xlm)		x	
Diary data can be sent by email	x	x	
Diary data can be shared with health care professional over portal/cloud			
Pre-built reports for dedicated analysis (migraine-nutrition-chart)			x

Services

Satisfaction tracking (days without migraine)	x		
Fatigue tracking			
Stress tracking			x
Sleep diary			
Regular migraine tips/information		x	
Doctor/expert finder with video-live-chat		x	
Medication recording (therapy)		x	x
Medication reminder	x		
Archive to store documents (diagnostic findings, laboratory values)			
Managing doctor appointments	x		
IoT connectivity			
Alexa / Echo interface (speech control)			

Social Connectivity

Share status with family and friends	x		
Anonymous data sharing with and connection to migraine patients community	x		
Connectivity to social media		x	
Anonymous data sharing with migraine research projects/institutions	x		

User Interface / Usability

Tutorial (video, photos)	x	x	x
Manual available			
Testrecord can be created/deleted	x		x
Multilanguage supported	x		
Application support by developers	x	x	x
Offline-/cloud usage with data synchronization	x		x
Customizable screen modes (dark/light colors)			
2-click' migraine recording		x	

Quality Assurance

Medical device		x	x
HIPAA compliant cloud solution	x		
Encrypted storage of user data			
Application compliant to GDPR		x	x
Evidence based expert knowledge		x	x
Evidence based scales (i.e. MIDAS)	x	x	
Evidence based exercises		x	
Specialists and patients involved in development	x	x	X

Migraine Buddy of course offers the most complex diary functionality, any data related to headache/migraine can be recorded. Recording of trigger factors is focusing on a set of existing items, although any other can be added manually. Analysis of migraine and reporting, as well as interface for automatic data recording is very limited. Initial approach of Migraine Buddy might have been a questionnaire for collecting headache/migraine related data. This impression is strengthened by multilanguage support, training material, application support and option, to anonymously participate in research programs and additional questionnaires. Indeed, Migraine Buddy is the worldwide most used migraine service and owns the largest patient data pool. For patients starting an electronic migraine diary, the service offers detailed recording facilities, on the other hand, data entry during attack will be limited and it is questionable, if in retrospect all details will be remembered and entered.

Migräne App is a class 1 medical device and represents a cooperation between ‚Schmerzklinik Kiel' (a hospital focused on headache) and ‚Techniker Krankenkasse', a German health insurance company. Although a wide range of information about headache and migraine is offered, user should already have

visited a doctor, being diagnosed with migraine and have a basic understanding of her or his disease. Diary functionality is restricted to recording of only essential migraine related data, no recording of trigger factors is included. Diary data can be viewed in a single report sheet, data export options are great. Relaxation training videos are included, however, like many other functions, are linked to content in the Internet. As external content is not embedded in the application, it is sometimes difficult to get back to the main menu. Focus of ‚Migräne App' is clearly on supporting doctor-patient relationship of (German) migraine patients. As no analysis, especially on potential triggers is included, doctors might recommend it to support diagnosis and therapy. For patients that want to keep control over their disease and are searching for a less tight relationship to specialists, App cannot be recommended. It has to be noticed that European Data Privacy Regulations are fully met, service does not require any registration and all data is stored on local smartphone only.

M-sense of course offers the most appealing user interface, is classified as a class 1 medical device and has a clear commercial focus. The company is looking for cooperation with employers for funding of additional services, mainly in the area of migraine prevention by relaxation trainings and trigger analysis. Anonymized data is also used for research purposes and app can be used as front end for headache related clinical trials. Base module offers a very good introduction in handling of diary and basic understanding of migraine. Diary itself is perfectly designed, however parameters, symptoms and trigger factors are limited to the absolutely essential. Reports are predefined, analysis of trigger factors is limited as no individual entry is possible (besides taking notes). As ‚Pro' version is liable to pay, additional functionality was not assessed. During testing, several smaller bugs were found, also export of data could not be verified. In summary, M-sense offers a beautiful and easy to use diary which in collaboration with migraine specialists perfectly supports therapy. Offered relaxation services (each module starting at EUR 7.99 per month) could help to prevent future attacks by up to 40%. Due to weak reporting and export options, service cannot be recommended unrestricted.

3 Detecting and Documenting Migraine related Parameters for Diagnosis and Therapy

To identify personal trigger factors, a migraine diary has to be maintained. Sometimes a pattern can be found in these entries, for example, that migraine prefers to appear after a long day at work or after eating certain foods. If such patterns are identified, it can be evaluated, if trigger avoidance results in reduction of attacks. Information typically recorded in a paper-based migraine diary is:

- Time of day, duration and strength of headache
- Headache with aura or any other symptom ahead
- Nausea, intolerance to light, sound or noise, sight disorder
- Food intake before attack
- Physical overstrain, stress
- Menstruation, hormone taking
- Medication taking, dose, effectiveness
- Events preceding attack

Although patient might already know some triggers, advanced identification of those, having an impact on personal wellbeing, requires a systematic approach. It is self-evident to look at nutritional habits first and for a long time, some food, especially chocolate, red wine, cheese and citrus fruits, were suspected to cause migraine [27]. Red wine, chocolate and also bananas contain Tyramine, a metabolite of amino acids. Tyramine regulates noradrenaline, a second messenger responsible for vasoconstriction, also in the brain, thus resulting in a migraine attack. On the other hand, insufficient food intake very often causes attack too. There is no real evidence for food being trigger factor and newly, this approach is questioned.

Common for trigger factors is, that patient usually has to manually record them in the diary. Due to multitude of factors, especially environmental parameters like weather, temperature or air humidity, manual recording seems unfeasible. Digital world not only opens a wide range of new opportunities to automatically measure and record environment but also for identification of symptoms; for example, stress might be identified by measuring number of received business mails per day or interpreting pupils' reaction when interacting with the smartphone. Continuous

recording allows identification of potential triggers, either by direct logging like air humidity and surrounding noise or indirect, by deviating stress from smartphone usage time. While existing electronic services have more or less replaced paper-based approach, limited use of digital options is made. All together - automatic measuring, recording and tracking of environmental parameters - might result in detection of trigger factors, thus allowing prediction of attacks. Parameters could be obtained by sensors built in a smartphone or by connecting with external sources and will be described in following sections.

3.1 Smartphone internal Sensors

Nowadays, smartphones have available a multitude of inbuilt sensor. Besides video and audio (camera, microphone), actual Apple smartphone XS for example includes:

- GPS
- Digital compass (magnetic sensor)
- Face ID
- Barometer
- Three-axis gyroscope
- Accelerometer
- Proximity sensor
- Ambient light sensor

Samsung's top model 2018, Galaxy Note 9, operating on Android, additionally includes a fingerprint- and a pulse sensor.

It might be beneficial to include data generated by (some of) these sensors into daily records of migraine diary, to detect potential triggers for attack, or recognize related patterns. By applying algorithms used for (unsupervised) machine learning like K-means Clustering, structures in data could be detected. K-means clustering is used to group (cluster) data with similar characteristics [28]. For sensors like inbuilt barometer to measure air pressure, or an ambient light sensor to indicate level of sunlight patient is exposed to, it seems to be more obvious, that these data can serve for analysis as a potential trigger. Other inbuilt sensors might not show benefit at first glance; accelerometer for example, measuring speed increase however might indicate, that patient is performing sporty activities or trying to catch the bus. As already explained, excessive sport could initiate a migraine attack, running after public transportation could cause stress, resulting in headache. Another source of information is the smartphone itself. Duration of daily usage,

type of app opened, or even handling of applications and services by swiping over the screen can be used as source for analysis of trigger factors. An analysis of human smartphone interaction and stress, focusing on gestures, has been performed by Ciman and Wac [29].

An overview on available sensors for each smartphone operating system (Android, IOS) can be obtained from the internet, however, although a couple of sensors has been included, not all of them might be built-in in available hardware. When developing services and apps, it is therefore important, to check availability before pulling data. Sensors available for Android are listed in developers documentation [30], an example for motion sensors is described in Figure 8 [31], for environmental sensors in Figure 9 [32].

Sensor	Sensor event data	Description	Units of measure
TYPE_ACCELEROMETER	SensorEvent.values[0]	Acceleration force along the x axis (including gravity).	m/s^2
	SensorEvent.values[1]	Acceleration force along the y axis (including gravity).	
	SensorEvent.values[2]	Acceleration force along the z axis (including gravity).	
TYPE_GRAVITY	SensorEvent.values[0]	Force of gravity along the x axis.	m/s^2
	SensorEvent.values[1]	Force of gravity along the y axis.	
	SensorEvent.values[2]	Force of gravity along the z axis.	
TYPE_GYROSCOPE	SensorEvent.values[0]	Rate of rotation around the x axis.	rad/s
	SensorEvent.values[1]	Rate of rotation around the y axis.	
	SensorEvent.values[2]	Rate of rotation around the z axis.	

TYPE_LINEAR_ACCELERATION	SensorEvent.values[0]	Acceleration force along the x axis (excluding gravity).	m/s^2
	SensorEvent.values[1]	Acceleration force along the y axis (excluding gravity).	
	SensorEvent.values[2]	Acceleration force along the z axis (excluding gravity).	
TYPE_ROTATION_VECTOR	SensorEvent.values[0]	Rotation vector component along the x axis (x * sin(θ/2)).	Unitless
	SensorEvent.values[1]	Rotation vector component along the y axis (y * sin(θ/2)).	
	SensorEvent.values[2]	Rotation vector component along the z axis (z * sin(θ/2)).	
	SensorEvent.values[3]	Scalar component of the rotation vector ((cos(θ/2)).[1]	
TYPE_SIGNIFICANT_MOTION	N/A	N/A	N/A
TYPE_STEP_COUNTER	SensorEvent.values[0]	Number of steps taken by the user since the last reboot while the sensor was activated.	Steps
TYPE_STEP_DETECTOR	N/A	N/A	N/A

Figure 8: Motion Sensors that are supported by the Android Platform [31]

Sensor	Sensor event data	Units of measure	Data description
TYPE_AMBIENT_TEMPERATURE	event.values[0]	°C	Ambient air temperature.
TYPE_LIGHT	event.values[0]	lx	Illuminance.
TYPE_PRESSURE	event.values[0]	hPa or mbar	Ambient air pressure.
TYPE_RELATIVE_HUMIDITY	event.values[0]	%	Ambient relative humidity.
TYPE_TEMPERATURE	event.values[0]	°C	Device temperature.[1]

★ [1] Implementations vary from device to device. This sensor was deprecated in Android 4.0 (API Level 14).

Figure 9: Environment Sensors that are supported by the Android Platform [32]

Besides coding examples and background information on usage of sensor values, formulas for conversion are described. Not all available sensor data is directly measured by sensor hardware, some values are calculated based on data from various sensors. Some data will also require calibration, filtering or modification, which presumes some theoretical background in physics. A similar framework and operating system knowledge from Apple can be found in 'Apple Developer Documentation' [33].

3.2 External Devices

While automatic recording of sensor values is limited to those available in patient's particular smartphone, there are several other options to collect either patients- or environmental data and have them included automatically into diary service. In this section, self tracking devices – fitness tracker and smart watches - are under investigation.

A search was performed on the internet, looking for ‚most popular fitness tracker 2019' and first result taken for reference [34].

Top ten devices listed there are

1. Moov Now
2. Fitbit Charge 3
3. Garmin Vivosmart 4
4. Huawei Band 2 Pro
5. Withings Pulse HR
6. Samsung Gear Fit 2 Pro
7. Honor Band 4
8. Garmin Vivosport
9. Amazfit Bip
10. Garmin Vivofit 4

Depending on model, devices offer different functionality. Most interesting for being integrated into a migraine diary service are devices that offer heart rate tracking, as there is limited options to get this value from smartphone's inbuilt sensors. Another benefit of these devices is, that they can be used for tracking without smartphone as they offer internal data storage and access to memory at a later stage. All of them are waterproof, allowing to measure parameters while for example taking a swim. Finally, battery life is from at minimum one week (Samsung Gear Fit: 3 days) up to one year.

Fitness trackers are a simple and cheap way to monitor activity and health with little to no effort, nevertheless they can provide a wide range of health related information, from heart rate and other vital parameters to quality of sleep, step count and even stress.

Second group of devices to collect vital parameters are smart watches. They usually offer more functionality and when linked to a smartphone, enable internet based services like message or call information, speech controlled internet search and much more. Top 3 devices returned on previous search were

1. Samsung Galaxy Watch
2. Apple Watch 4
3. TicWatch E2

In short – all of them offer a wide range of health related data that might be useful to collect. It is notably, that Apple watch 4 offers an ECG feature within the heart rate tracker, allowing to test atrial fibrillation risk. Although medical device certification has been received for US only, it is actually the only device that would integrate with certified migraine services. As any smartwatch can be linked to either Android or IOS operated smartphones, accessing data is done via SDK from Google or Apple as described in previous section (internal sensor access). Reading data from a fitness tracker is enabled via vendor provided API, for example FitBit's developers web API [35] or Garmin's health API for developers [36]. Data access is usually obtained via vendor's portal. In a first step some registration is required, second, parameter has to be requested resulting in value to be returned. An example of parameters that can be requested from Fitbit's portal is shown in Figure 10.

Scope	Description
`activity`	The activity scope includes activity data and exercise log related features, such as steps, distance, calories burned, and active minutes
`heartrate`	The heartrate scope includes the continuous heart rate data and related analysis
`location`	The location scope includes the GPS and other location data
`nutrition`	The nutrition scope includes calorie consumption and nutrition related features, such as food/water logging, goals, and plans
`profile`	The profile scope is the basic user information
`settings`	The settings scope includes user account and device settings, such as alarms
`sleep`	The sleep scope includes sleep logs and related sleep analysis
`social`	The social scope includes friend-related features, such as friend list, invitations, and leaderboard
`weight`	The weight scope includes weight and related information, such as body mass index, body fat percentage, and goals

Figure 10: FitBit Scopes [35]

Unfortunately no common standard for life tracker devices has been established, which means, that for every device a routine has to be created to enter portal and access data. As devices are replaced frequently by new models, resulting in modification of APIs and SDKs, keeping migraine diary service up-to-date might pose a big challenge. It could make sense to consider only one fitness tracker model and focus on smartwatches, as development kits usually remain downwards compatible. However, integration of tracking devices into migraine services could provide extremely helpful insights for diagnosis and therapy. Keeping in mind that changes in sleep-wake cycle and stress are seen as most impactful trigger factors, automatic recording by just wearing a wristband would allow a much better assessment of migraine.

3.3 External Sensors Connected via IoT

A very common trigger for attack is the weather and several radio- and television stations already offer related services for migraine patients. In most cases, these services just confirm that attack already happening, probably was caused by the

weather. Migraine prediction is based on observing weather parameters (temperature, air humidity and pressure) over time. It would therefore be meaningful if weather trend information is available for patients and included in diary data recorded. Some people operate small meteorological stations at home, either with analog display or newly digital versions, allowing to transmit data to a display mounted inside home. Although some of these digital stations allow even wireless transmission of weather data, none of them follows a common standard that would allow to connect it to a smartphone. On the other hand it would not be reasonable for patients to manually enter weather data into a diary.

Searching for solutions to easily transmit any sensor data to a common space allowing to access it from smartphone or over the internet guided me to the ‚Internet of Things' (IoT). The idea of IoT is to create a platform where any device can connect to any other device, usually based on internet technology. As most sensors cannot be cabled to the internet directly, wireless transmission could take place either via WLAN connection or by use of GSM modules. Although these technologies are not always 100% reliable, they will fit for the purpose to make available and record various sensor data in an electronic migraine diary. Looking for application areas with similar requirements, I became aware of the fast growing field of smart home solutions. Smart home solutions usually offer a backbone to connect electric- or electronic devices to allow home operations from any place of the world. Either you can switch off the light or turn on heating from your smartphone while you are stuck in traffic, more futuristic prototypes enable the refrigerator to ask for your permission to put milk on the shopping list as your daughter took the last bottle out for breakfast. Many IoT solutions offered can only be used with devices from a dedicated manufacturer or require to fulfill a certain specification and even have to undergo a registration process with the vendor. More open networks like ‚Conrad Connect' [37] either limit the number of smart devices and data volume per user or do not offer a programming interface (API), thus preventing integration into own software. Developing a prototype to connect a sensor with the smartphone using IoT technology, microcontroller environments like Arduino or Rasperry were rejected, as they require electronic circuits to connect the sensor and additional programming, commercial smart home kits have not been shown flexible enough for prototyping. Finally ‚Smart Home Kit' from vendor ‚littleBits' [38] was selected to develop a prototype. LittleBits is a system of electronic building blocks that snap together to quickly create working solutions. No electronic knowledge is required and the modules hold together just by magnetic power. Besides power supply and an internet connection kit, other blocks either can input-, output- or control data.

Figure 11 shows internet connection module (over WLAN) and a variety of sensors (temperature, sound, light).

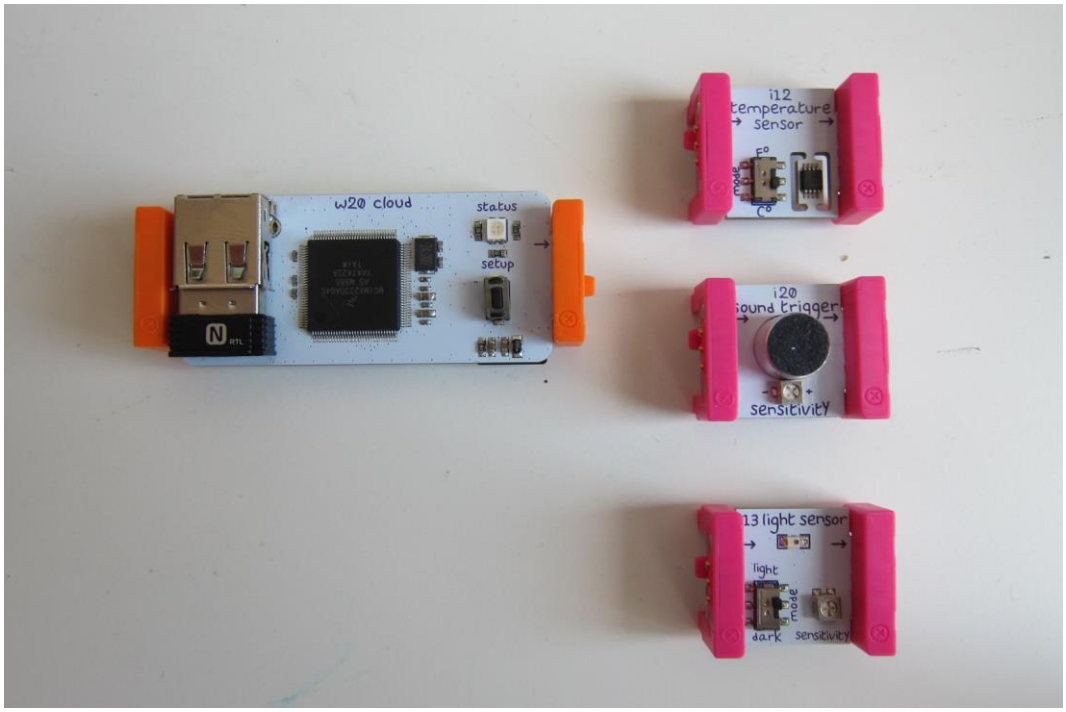

Figure 11: littleBit Cloud Module and Sensors

Prototyping a solution transmitting sensor data over the internet to a smartphone, starts with setup of internet connection module ‚w20 cloud'. All steps are described at the vendor's homepage. First a test circuit with power supply, push button, lamp and finally the internet module is switched together. The cloud module hosts a webserver to setup connection to WLAN access point, thus connecting to littleBit cloud environment over the internet. Next, registration for littleBit's IoT cloud is done and first device - called CloudBit – enabled in control center user interface. Circuit previously built and connected to the internet is detected and communication directions can be tested. Pushing the button on the littleBit module will result in a screen button appearing switched or released, clicking on the screen button the lamp of the littleBit module will light. With this, setup was completed and own circuit could be created. A temperature sensor was followed by a display module and data sent to cloud. This would allow to measure outside temperature and send to smartphone. The final setup of this prototype is shown in Figure 12.

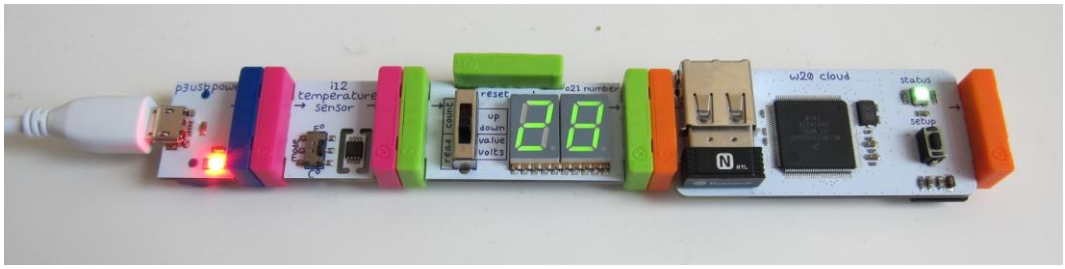

Figure 12: Prototype to measure Temperature

In the Cloud Control Center, CloudBit (MigraineControl) was configured to receive data from prototype, also display of value was changed to digital. After some seconds, data sent from module was displayed on screen (see Figure 13).

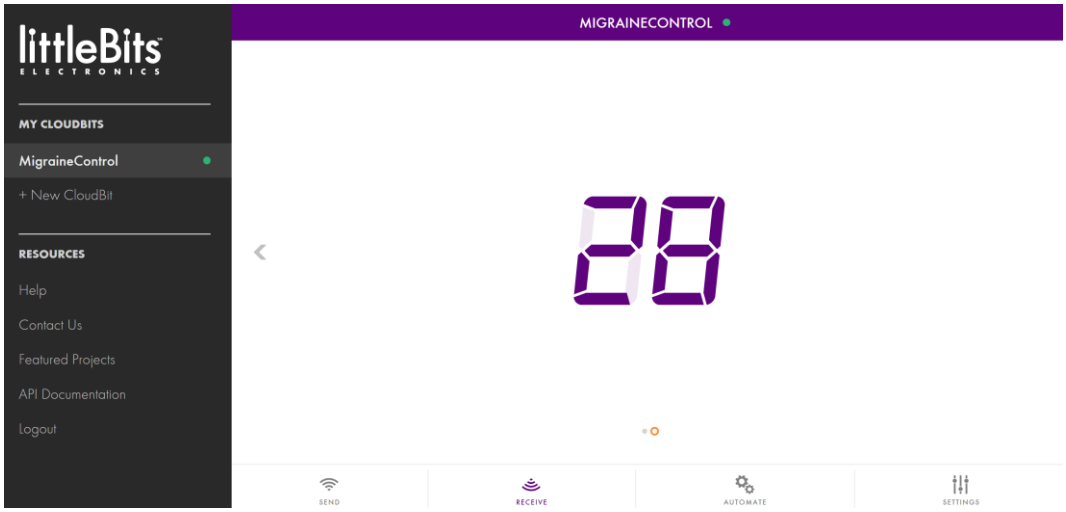

Figure 13: Temperature Data received from Sensor

Next, littleBit cloud was accessed from Android Smartphone, showing same results. It has to be mentioned that there is no dedicated Android or Apple software available for download, control center is based on HTML with responsive design. Figure 14 shows data transmission from sensor prototype to smartphone.

Figure 14: Android Smartphone connected to Sensor Prototype

Difference between temperature displayed on module and smartphone is due to delay in data transmission. Whilst value increase was immediately visible on module, it took some seconds to get updated on smartphone display. This demonstrates, that the setup cannot be used for time critical applications. For direct CloudBit- and sensor data access an API supporting JavaScript is available, values can be transferred in JSON format. It has to be mentioned again, that littleBit kit allows data transfer in both directions and the platform also supports IFTTT framework, to connect with other devices over internet. Several sensors could be linked together and if a specific weather situation occurs, a warning could be sent to patient. Sensor data can also be shared with other users, thus allowing a broader patient community to benefit from available sensor values.

3.4 Connecting to External Services

Many environmental data is available in the internet. This could be values like particulate pollution, ozone levels or weather related data. In this section I take a closer look at available data and services that might fit for a migraine diary service and how to access. Although there is a couple of professional services available on the market, for example ‚Zentralanstalt für Meteorologie und Geodynamik' (ZAMG), a research center assigned to the public health department in Austria,

data access is not public and different subscription models are available. I will therefore focus on services offering (limited) access for free and sources of open data. Two examples – ‚Open Weather Map' and ‚data.gv.at', a portal offering all types of data collected in Austria for free – will be described. Open Weather Map [39] is a platform providing current- and forecast weather for a selected location. A wide range of information is available, amongst others, wind, cloudiness, pressure, humidity and of course temperature. Figure 15 shows portal information related to a particular part of Vienna/Austria.

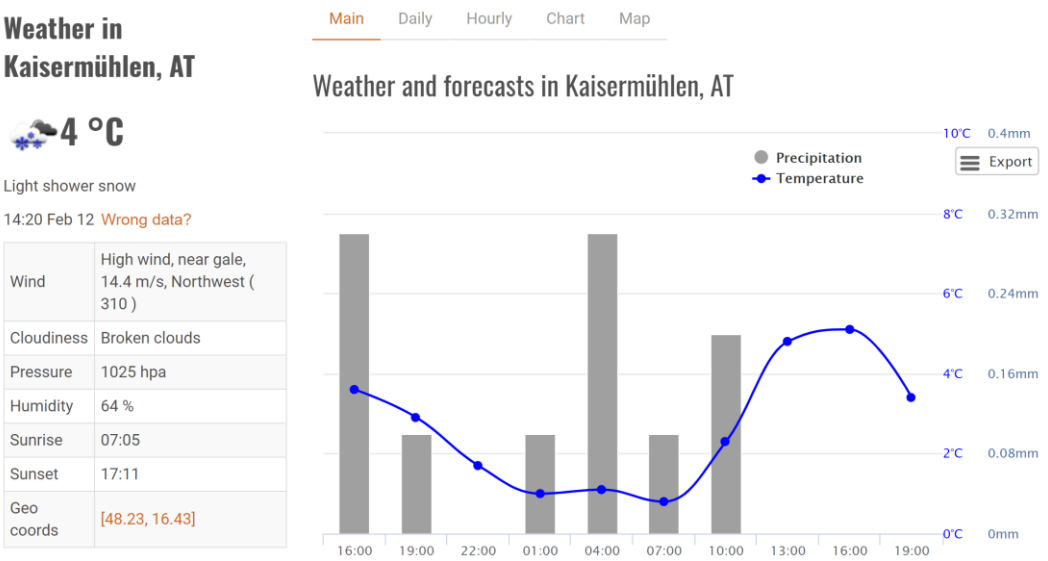

Figure 15: Open Weather Map Data for Vienna (Kaisermühlen) [39]

For accessing weather, a basic data API is offered for free, for more options several monthly subscription models are available, all of them documented well. In addition, satellite images and pollution data (still in beta state) can be used. Current weather data for any location, including 200.000 cities worldwide, is provided by over 40.000 weather stations and can be received in JSON, XML and even HTML format. Starting with an API call for a certain location, data is sent back for further processing. Figure 16 and Figure 17 show examples of API response received in JSON and XML format.

JSON

Example of API response:


```
{"coord":
{"lon":145.77,"lat":-16.92},
"weather":[{"id":803,"main":"Clouds","description":"broken clouds","icon":"04n"}],
"base":"cmc stations",
"main":{"temp":293.25,"pressure":1019,"humidity":83,"temp_min":289.82,"temp_max":295.37
"wind":{"speed":5.1,"deg":150},
"clouds":{"all":75},
"rain":{"3h":3},
"dt":1435658272,
"sys":{"type":1,"id":8166,"message":0.0166,"country":"AU","sunrise":1435610796,"sunset"
"id":2172797,
"name":"Cairns",
"cod":200}
```


Figure 16: JSON Example of API Response (OpenWeatherMap) [39]

XML

Example of API response:


```
<current>
    <city id="2643741" name="City of London">
     <coord lon="-0.09" lat="51.51">
     <country>GB</country>
     <sun rise="2015-06-30T03:46:57" set="2015-06-30T20:21:12">
    </city>
    <temperature value="72.34" min="66.2" max="79.88" unit="fahrenheit"/>
    <humidity value="43" unit="%">
    <pressure value="1020" unit="hPa">
    <wind>
     <speed value="7.78" name="Moderate breeze">
     <direction value="140" code="SE" name="SouthEast">
    </wind>
    <clouds value="0" name="clear sky">
    <visibility value="10000">
    <precipitation mode="no">
    <weather number="800" value="Sky is Clear" icon="01d">
    <lastupdate value="2015-06-30T08:36:14">
</current>
```


Figure 17: XML Example of API Response (OpenWeatherMap) [39]

Both formats allow easy usage in almost any programming language, as also data structure is provided. Other options described in API offer selection of unit format (standard, metric, imperial) and multi language support. This could be helpful for

migraine services running in different countries. Another open data portal, operated by Austrian government, can be found at data.gv.at [40]. The portal also acts as a single point of contact to the European portal (www.europeandataportal.at). Open Government as well as Public Sector information is clustered in so called data catalogues, ‚Health' and ‚Environment' data could be useful for migraine services. As most of these data records were collected for specific purposes by federal state, communes or villages and have been fed into open data portal for free, information sometimes is of limited use and no unique format (like JSON) can be expected. Before used in any application, data records have to be validated if up-to-date and really fit the purpose. Historic data is not always available so when calling API (link provided with each dataset), most recent record available is returned. Figure 18 shows an example of meteorological data valid for city of Salzburg (Austria), returned on API call provided.

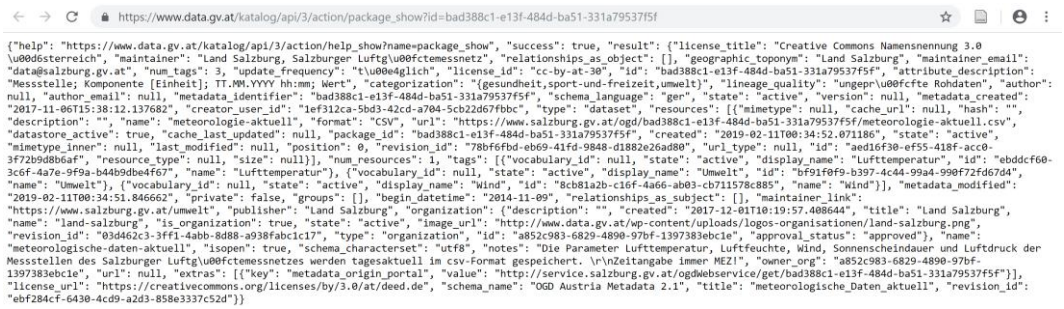

Figure 18: Meteorological Data returned on API Call to Open Data Portal [39]

Although data is for free, limited geographical coverage and variable refresh dates require validation algorithms before usage, which on the one hand might make services with cost more interesting but then again could be the only option to obtain certain specific data. As trigger factors could be nearly everything, recording ‚unsusual' data might long-term turn out as potential marker for migraine – who knows.

3.5 Excurse: Future Migraine Services

A step towards usage of digital options and connected environment was done in December 2018, where the first Migraine Innovation Challenge and Hack ('Migraine Hackathon') was held in Tallinn, capital of Estonia, Europe [41]. Becoming an independent state in Europe 1991, limited resources forced Estonian Government to early digitize public services including health, education, legal and other governmental services, thus transforming the country into the ‚European

Silicon Valley‘. In e-Estonia [42] nowadays every citizen has its own digital ID allowing access to public services. An important part of Estonia’s digital Society is eHealth. The system was introduced in 2008, integrating data from different health care providers - who might work on different systems – into standardized electronic health records. Built on this are several digital health services, accessible by patients and healthcare professionals in real time. Data can also be used by Government for national statistics, allowing to early recognize health trends and track epidemics. Migraine Hackathon was performed on a weekend, between 30. November and 2. December 2018 under the patronage of Riina Sikkut, Estonian minister of Health and Labour, initiated by the Estonian Headache Society, organized by Kitty Kubo, innovation lead of the ‚Connected Health Cluster‘ and supported by Novartis, a pharmaceutical company. The main idea was to bring together all kind of ‚migraine owners‘ like patients, their close ones, health care provider and representatives of patient organizations together with startups, designers and IT developers, interested in developing patient-centered, easy-to-use solutions that could be deployed in the Estonian healthcare system. 43 participants from China, Latvia, Lithuana, Mexico, Germany, Egypt, Spain, Finland, Ukraine and Columbia (via virtual session) formed teams, working on solutions to improve life of migraine patients. For reward, development grants, startup incubator support, membership accounts to Connected Health Cluster and tickets for ‚Latitude59‘, Estonia‘s flagship startup & tech conference were offered.

All teams were presented following challenges at start:

- Challenge 1: How can we make migraines easier to recognize and more efficient to diagnose?
- Challenge 2: How can we help migraine patient to understand and self-manage their condition better?
- Challenge 3: How can we make tracking migraines easier for both the patient and doctor?

Over the whole weekend, all teams had access to migraine patients, patient organization representatives, health care professionals including neurologists, health care experts and pharmaceutical companies, allowing great insights in migraine patients lives and understanding the difficulties, to recognize, diagnose and therapy the disease. In the evening of the third day, ten teams presented their ideas for solutions developed during the event. Pitches, each taking three minutes were followed by another round to answer the questions of the international jury. Participants addressed a wide range of problem areas, showing that although there is hundreds of migraine apps available, any of them just covers a small part of patients‘ requirements. Quite the contrary, it seems that many of them focus on

just diary functionality or support patient-doctor relationship, but never dealt with patients daily life. As all solutions presented offered some innovation, a quick overview will be given below. However, at the end of the day, Estonian startup ‚hINF' and ‚Elephant Diary', an international team formed during the contest, shared the first price, a development grant endowed with EUR 5000, followed by ‚MedAid', receiving the third price, six months of startup incubation to build their own business.

Consecutively ideas and key features are described in alphabetical order:

Brain Candy

Treatment plan that can be shared with doctor, allowing access to real-time patient status, based on Google Healthcare API and cloud services, no app required.

BrainVoice

Smart home solution to adapt living environment for migraine patients according to pain level (light, radio, doorbell, temperature), controlled by smartphone.

Chameleon

Migraine diagnostic tool by use of infrared data glasses. Vision test, pupil diameter test and questionnaire (British medical research questionnaire), allow to distinguish between headache and migraine. Research is done if a smartphone could replace glasses.

Decdoc

Decision support system for general practitioners to better recognize and diagnose migraine patients. Doctor is guided through a decision tree and questions to patient are proposed which ensures reasonable referral to neurologist.

Elephant

Migraine mode for smartphone (like flight mode). During attack, patient activates migraine mode by pressing one button. Migraine start/end will be recorded into diary automatically, other symptoms can be recorded later by swiping through screens. In migraine mode, display will reduce to dark, ring tone level reduced, automatic messages are sent to family members, appointments can get cancelled automatically. It is also planned to connect with AAL houses, so that if in migraine mode, for example curtains are closed and light is dimmed. Data from diary is sent to doctor before an appointment takes place.

hINF

Medical tele-treatment platform for patients and their clinics. AI powered chatbot (‚virtual nurse') supports treatment, based on symptoms entered by patients. All information gets stored in structured record for doctor's access. If virtual digital visit requires support from medical care team, appointments are automatically created.

Medaid

Medical record, including reports extended by migraine diary. Data can be shared with doctors participating in the platform, appointments can be managed directly from the App. Doctor can monitor treatment status and recommend OTC medication.

MigrainED

Evidence based migraine education to patients, using entertaining visual content. Search engines like Google do no offer filters for evidence based information. Platform includes videos, infographics and scientific papers.

Migic

AI based voice recognition solution to communicate with migraine diary without writing. API is planned to connect the solution with any eHealth system.

Minudoc

Marketplace and video consultation platform to doctors and other healthcare professionals, allowing patient access to medical help within 4 hours timeframe. Appointment scheduling and payment solution, with strong focus on data privacy. It is planned to allow connecting with other eHealth solutions, for example a migraine diary that could then be shared during video consultation.

In previous sections an overview on existing diary services has been given, showing a wide range of functionality ending up with a comparison of most downloaded migraine apps. The importance of trigger factors has been introduced and an outlook of future services and applications has been presented. By closing this chapter we will now take a different, non-technical, view at trigger factor ‚stress', being main trigger for migraine.

4 Study on Relationship between Smartphone Usage and Perceived Stress

In chapter '2 Understanding Migraine' it was described that several studies have identified stress being a major trigger for migraine. What if digital opportunities would allow to identify a parameter indicating stress, thus facilitating prediction or at least probability for a migraine attack? Being aware of a multitude of options, from smart-devices to wearables, this work continues the Headache Prediction Study (HAPRED), aiming to forecast individual headache attacks using perceived stress, published in July 2017 [43] and a review, titled 'Forecasting Migraine Attacks and the Utility of Identifying Triggers' performed in July 2018 [14]. A study was performed to answer the question, if smartphone usage is related to perceived stress and could allow electronic services to indicate stress level of user. Before study design and results can be presented, it is required to take a quick dive into 'stress' itself.

4.1 Stress and Perceived Stress

This section is intended to prepare for a common understanding of the term 'stress', which is widely used to describe challenging tasks in work environment, emotions before a big exam or caring for children, it may have positive or negative connotation and can be root cause or impact. There is no common accepted scale to measure stress, therefore difficult to compare and dependent on individual's perception – what might be 'normal' for one could already harm wellbeing of others. Stress can be translated as (physical) pressure, or power encountering resistance. First scientific publication on 'general adaption syndrome' in Nature 1936 has been published by Hans Selye, a physician born in Vienna [44, S. 2]. Selye defined stress as "total number of human's reactions on internal- or external demands". Any reaction, regardless if physical or psychological can be classified and assigned to either a:

- Physical layer (i.e. headache, sleep disorder)
- Emotional layer (i.e. nervousness, pessimism)
- Mental layer (i.e. thinking, cognition)
- Behavioral layer (how we act)

- Vegetative layer (autonomic nervous system)

Selye differentiates in positive and negative stress, being activated by stressors and that they should be balanced over time to prevent individuals from disease. This approach assesses stress based on life events, occurring within a temporal framework and characterized by person's inability to adjust to these events (for example unemployment or intense levels of noise). Research focused on psychosocial and environmental stressors and their risk for physical and psychological illness, thus developing stress measures based on objective criteria [45, S. 386]. The Standard Stress Scale (SSS) measuring stress in the life course, as described by Gross and Seebass [46, S. 6] is based on a questionnaire, asking for stressful life events, including anxieties about the future. Overall stress index is determined by number of dimensions (stressful events) applying and rating given by person. Stress index as delivered by SSS showed high significance in explaining health.

Lazarus later defined stress as "A relationship between the person and the environment that is appraised by the person as relevant to his or her well-being and in which the person's resources are taxed or exceeded" [47, S. 19]. From Lazarus' perspective stressor effects occur if a situation is appraised as demanding and insufficient resources are available to scope with it. His model is including the cognitive appraisal process individuals engage in, when they encounter stressful stimulations [48, S. 90]. Lazarus' model describes stress as the interchange between the appraisal of the stressor and person's perceived ability to cope. This approach led to the development of the Perceived Stress Scale (PSS), one of the most used scales to measure perceived stress. The PSS measures the degree to which life events are appraised as stressful [45, S. 385] and has been adapted to several languages. The German version of the PSS has been validated by Klein et al. [49]. Initial number of 14 items (PSS-14) has been varied to adapt for target group or serve a specific use case. A four-item scale (PSS-4) has been developed to be used for taking measurements quickly (for example at telephone surveys), however it showed relatively low reliability. Today, a ten-items scale (PSS-10), is commonly used [48, S. 90]. When using the term 'perceived stress' in following research on smartphone usage, it describes a numeric value between 0 to 10, reflecting the subjective rated ability of a person to cope with minor life events, occurring within last 48 hours.

4.2 Perceived Stress - from Validation to Prediction

Origin for subsequent research was an article in The Journal of Headache and Pain [17], presenting a case-control study on perceived stress in patients with migraine. Authors' objective was to examine the clinical significance of perceived stress, being the most common trigger for migraine. If predictors for perceived stress could be identified, this would allow for better stress management, thus preventing or reducing migraine attacks. Perceived Stress Scale (PSS), measuring stress appraisal during the preceding month [45], was used to determine relationship between various independent variables, showing, that perceived stress correlates well with migraine-specific quality of life questionnaire (MSQ). Repeated stress therefore should be avoided to prevent repeated attacks, causing transformation or chronification of the disease. Clinical should early identify patients to modify perceived stress through pharmacological or non-pharmacological interventions such as cognitive behavioral therapy and biofeedback. Authors conclude that study has some limitations, for example measuring stress for the preceding month keeps stress state over a month still unknown and suggest a long-term observational study to evaluate the impact of chronic migraine on perceived stress. Houle et al. concluded, that stress has received considerable attention for being a trigger, however, no evidence was available to support forecasting headache attacks [43, S. 1]. As perceived stress scale (PSS) can only be applied for preceding month, stress was assessed using the Daily Stress Inventory (DSI). Headache intensity ratings were assessed using a 0 – 10 Numerical Rating Scale (NRS). DSI is a well validated 58-item scale, developed to provide a self-report instrument for daily assessment of sources (relatively minor stressful events) and their impact [50]. These minor stressors differ from major life events by their higher potential for occurring on a daily base and their less severe impact upon the individual. It has to be mentioned, that DSI was designed for use with adult population and items had to be aligned with target group. In addition, a daily rating of stress was collected, using a Likert-type scale from 0 to 10. Results showed, that female participants on average reported higher stress scores for same frequency of events, which is not an atypical finding, but should be considered. Authors finally noted, that although DSI is a valid measure of daily levels of minor stress, a larger number of individual's score, over a longer period of time, would provide more reliable data and therefore improve diagnostic accuracy.

Headache Prediction Study (HAPRED) developed a prediction model for persons with episodic migraine, using perceived stress as trigger factor. As headaches are

currently unpredictable, patients are often unprepared to take medication in a timely manner, thus requiring acute attacks treatment. Participants had to manage an electronic diary, recording headache, symptoms, intensity and DSI on a daily base. It was assumed, that a high level of current stress would increase probability of an attack after stress has subsided. For evaluation purposes, three models including various aspects of daily stress were developed. Interestingly, each model showed similar predictive performance and adding predictors to the same model did not improve it. Although evidence was given for validity of prediction model, authors state that it should be treated as a first step and has certain limitations; it is not clear if model can be generalized for other population than that included in the study, furthermore length of questionnaire could lead to fatigue within a person, resulting in inaccurate responses. It is also recommended for future studies to evaluate the use of abbreviated assessment tools to reduce participant's burden and apply stress-migraine association across different groups of patients. This suggestion was taken up by Turner et al, publishing an article about 'Forecasting Migraine Attacks and the Utility of Identifying Triggers' in July 2018 [14]. The review underlined the importance of measuring stress being a migraine attack trigger and necessity to develop valid forecasting models to allow treatment of headchache before the actual experience of pain. Such models should require one trigger only for prediction, however authors concede that such models would not be applicable for all patients. With reference to HAPRED study authors complain about "fuzzy" forecast ability; for patients it would be more helpful if model predicts either 0% or 100% probability of an attack, than for example 75%. Summing up, stress-based forecasting models can be seen as an important step towards preemptive headache therapies. Future research should improve models in precision, utility and validity to allow clear treatment decisions. On the contrary, Marmura observes focus on trigger factors being overrated [51]. Although he confirms that analyzing combinations of various predicting factors show private- or work stress to be most common, very often they cannot be avoided or easily modified. As migraine attacks often arise after stress subsides, premonitory symptoms may be confused for triggers. Recommendation therefore is to better focus on healthy lifestyle choices and use prevention.

4.3 Related Work

Measuring stress is difficult due to the fact that people have different perceptions and because of subjectivity of self reporting. It is therefore important to find ways of objectively measuring parameters and smartphones seem to become a valid

instrument to do so. Smartphones have become an everyday item in people's life and as presented in several articles are, nearly anytime in reach. It therefore is not surprising, that a number of papers is evaluating relationship between parameters provided from smartphone's built-in sensors and psychological or physiological human parameters. Research has been done to either validate or predict stress, based on data, gathered by daily use of people's smartphone.

Mobile communication technologies have impacted our professional life, anytime-anywhere-availability has moved the border between work and life, in some cases completely removed it. Aggregation and concentration of work has led to new diseases, starting with increased stress levels and in worst case scenario, ending up with burnout and unemployability. To go against this trends and find the right work-life balance, focus of research was people's workplace and finding models to recognize or predict increased stress levels, allowing to prevent from endangering health. In their paper Garcia-Ceja et al. describe different approaches to use smartphone's sensor technologies like sound analysis, image processing from in-built camera or by use of physiological sensors, to detect stress [52]. They finally present how accelerometer data can be used for automatic stress detection, by identifying significant sensor parameters and applying them to user clusters, obtained by developing a similar-users model. Smartphone app usage in work environments for stress predication has been presented by Ferdous et al. [53], resulting in evidence that usage patterns show high correlation with self-reported stress levels. Another article, investigating in relationship between smartphone usage and mental health, aiming to identify reliable features for prediction, reason that incoming and outgoing call duration, as well as network statistics were often suitable [54]. Using 'interaction with smartphone' instead of in-built sensors for assessing stress was researched by Ciman and Wac [55]. As people use smartphone applications through a set of gestures like 'tap', 'scroll', 'swipe' and others, these can be used to record related parameters, for example start- / end position of gesture, speed of execution, or duration of screen is touched. For study execution a laboratory approach was chosen, allowing to acquire data under no-stress and stress conditions. Good results in recognizing correlation between gesture and stress group was achieved, however, could not be transferred to real-life conditions. Although another benefit of this method is, that no personal- or privacy-sensitive information has to be collected, authors see a possible limitation in the fact that analysis is focused on data correlation and it is therefore "not possible to understand the causality of stress and behavior of users" [55, S. 63]. A differentiation between personal and work life was done by Makinson et al. [56], when exploring impact of smartphone usage on work-life balance and stress. Authors conclude, that although smartphones have potential to increase stress and

might impact work-life balance negatively, no clear evidence could be provided. Percentage of participants reporting increased stress due to increased smartphone usage was similar to those, perceiving it has reduced.

4.4 Study Design and Setup

As described in chapter '2 Understanding Migraine', efforts in improving migraine patient's life are targeted on attack prevention, thus using trigger factors for prediction. Stress, in particular perceived stress, has turned out to be a strong predictor. This work intends to find out, if 'daily smartphone usage time' is (positively) related to perceived stress. Previous studies, described in section '4.3 Related Work', already proved evidence, however, authors recommend a further reduction of measured sensor data, ideally find the 'one and only' trigger allowing to measure stress. It was therefore decided, to relate total time of per day smartphone usage with perceived stress level, collected once a day. Although digital opportunities offer a wide range of sensor data to collect, aim was to verify if a simple value (usage time), ensuring a high level of data privacy for participants, could be used for stress prediction.

A cross-sectional study was performed to answer the hypothesis:

- H0: No relation between smartphone usage and perceived stress exists
- H1: Relation between smartphone usage and perceived stress exists

Sample size of participants n=19 was calculated using G*Power, a statistical software developed by University Kiel in Germany (www.gpower.hhu.de), based on below parameters (see Figure 19).

- Correlation: Bivariate normal model
- Type of power analysis: A priori
- Tails: Two
- Correlation ρ H0: 0
- Correlation ρ H1: 0.6
- α error probability: 0.05
- Power: 0.8

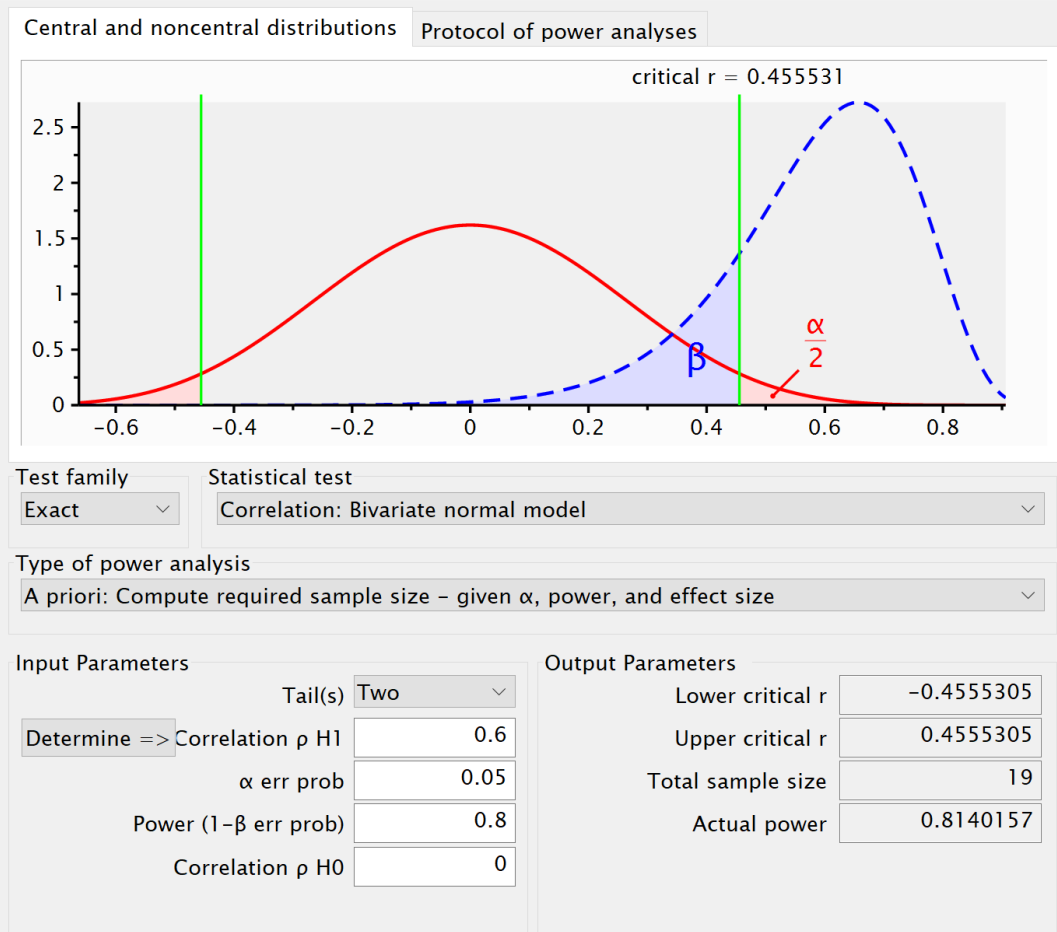

Figure 19: G*Power Sample Size Calculation

In total 20 Austrian participants were recruited and as communication and questionnaires were conducted in German language, original terms are given in brackets for reference. Study approach was sent to ethics committee of lower Austria (Ethikkommission Niederösterreich) for review and was classified ‘uncritical’, as no intervention takes place and no patients are involved.

Services measuring usage time were initially developed to enable better self-control over time spent with the smartphone. Besides giving an overview on total- and single time per app, user can set limits to identify ‘time-sinks’. Apple has included such functionality into operating system iOS 12. At the time this thesis was written, Apple removed several applications using screentime from iTunes App-Store or forced developers to limit application’s functionality [57]. European competition authority will have to decide if Apple is protecting enduser’s privacy or preventing them from too detailed insights in their (sometimes extensive) smartphone usage. Therefore, when developing migraine services based on iOS12 screentime, it should be considered that Apple might allow only limited

access. Measuring screentime on Android smartphones requires downloading of software. Because of most downloads and good user ratings, QualityTime by NComputing Global Inc. (www.qualitytimeapp.com) was selected.

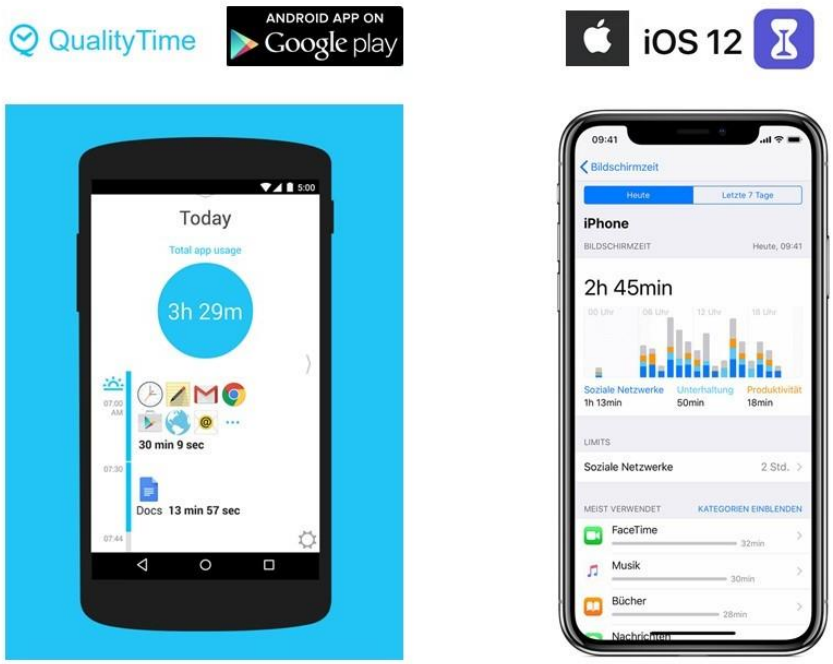

Figure 20: Android Quality Time and Apple iOS 12 for measuring Screen Time

During installation, QualityTime offers a cloud service to store captured data. Although this would have made participant's data collection easier, it was omitted due to data privacy concerns. Study participants were informed, that they could skip this option ensuring that usage data gets stored on smartphone only. Perceived stress was measured by a single question: "How stressful did you perceive the overall day?" ("Wie 'stressig' war der Tag insgesamt?"), using a ratio scale with "stress-free" ("stressfrei") representing "zero" and "extreme stressful" ("extrem stressig") as maximum value. Appropriate value was entered by moving a slider to the corresponding position on scale. Although scale did not show labels, slider position was assigned to a whole-number between "0" at the left, to "10" at the right position. This scale was selected as it has already proven of value in previous studies. For data collection "Survey Monkey" (www.surveymonkey.de), an online tool to create and manage surveys, was used. In the period February 2nd to March 1st, 2019 participants received a daily questionnaire on their smartphone, asking for number of hours and minutes, as displayed in either QualityTime (Android) or Screentime (Apple) for day in scope. Second question was about

perceived stress, which had to be marked with a slider on a scale, directly on the screen. When ready, questionnaire was submitted. Questionnaire did not allow to update or correct values, once submitted. In case of wrong values submitted, participants had to send correct values to a given contact email address for manual correction. This did never happen. In addition, all questionnaires were checked twice a day for plausibility of data received. In two cases, participants were contacted to confirm on values submitted. Once a value greater “24” was submitted for field “hours” which was a typo and got corrected, another case showed unusual high smartphone usage time, which finally got confirmed and explained by participant. Besides this, no values had to be questioned or corrected. An example of daily questionnaire received by participants can be seen in Figure 21 below.

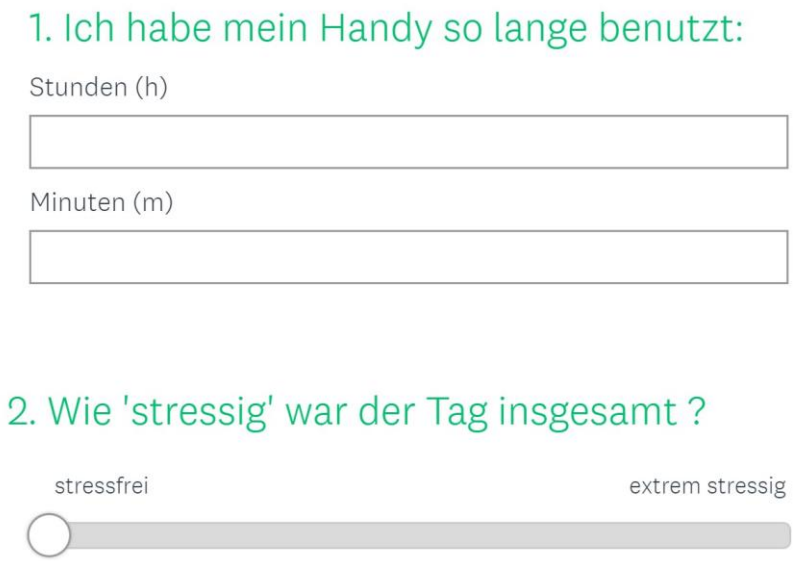

Figure 21: Study on Smartphone Usage and Perceived Stress. Daily Questionnaire sent to Participants, asking for 1. Usage Time (Hours/Minutes) and 2. Perceived Level of Stress (stress-free to extreme stressful)

Question 1, “I used my smartphone for:”, was asking for smartphone usage time in hours and minutes (“Ich habe mein Handy so lange benutzt”), question 2, “How stressful was your overall day?” (“Wie ‘stressig’ war der Tag insgesamt?”) invited users to rate level of perceived stress between “no stress” (“stressfrei”) and “extreme stressful” (“extrem stressig”).

Emails were scheduled to be sent daily at 2 a.m., to allow participants to rate each previous day. As participants were given 48 hours for reply, all questionnaires indicated day and date to avoid any mix-up. Sustained response time was selected

to ensure rating is well-balanced, even after a day full of stressful events. Second, to allow flexibility especially at weekends and avoid questionnaire itself becoming a source of stress and finally, to prevent from non-responding in time due to technical issues. Most frequent root cause for emails not being received was classification as 'spam', especially Gmail (Google) was very strict and in one case, moved questionnaire into category 'advertisements', sometimes unpredictable, differing day by day. As many smartphones are setup to just allow to check inbox, participants had to wait until there was access to a workstation, allowing to release email to inbox and set 'no spam' classification. Another issue was caused by Survey Monkey's scheduler – it was not recognized, that surveys created at 'early morning', are not allowed to be scheduled for same day, resulting in being planned for the next but one day. As some participants complained about pending email, a manual release was performed for that day. After 48 hours, surveys were locked for further submission from participants. As free version of Survey Monkey did not offer to keep more than ten surveys in parallel, data had to be exported to an Excel file and stored there. Old questionnaires were deleted to allow creation of new ones. Creation of new survey was done by copying previous day and changing weekday and date. On March 5th, all remaining, locked surveys finally got deleted from Survey Monkey. Data exported to Excel has been made anonymous by replacing email address through combination of attribute 'gender' (F, M) and consecutive number. Any assignment table was deleted, further processing and analysis therefore is based on anonymous data sets. Participants received a weekly summary on some survey results, for example highest and lowest smartphone usage or most stressful days during previous week, to keep them motivated.

4.5 Study Execution - Participants and Recruiting

It was assumed that there is no difference in stress perception between migraine and non-migraine patients, therefore data were collected from 20 healthy subjects. Knowing that statistically more than 10% of people suffer from migraine and even more from regular headache it is most probably, that a few participants were with migraine. Nevertheless, this was never asked for, neither in recruiting phase nor later and should not have any impact on study and results. Emphasis was also put on data privacy in design and execution of study, as well as during analysis of participant's data. Data collection was limited to a minimum and all data, especially questionnaires, got deleted at earliest. As it was difficult to motivate participants,

especially younger ones, to daily submit questionnaire over a full month (28 days), data privacy and easy data input should ensure high response rates over time.

In total 20 participants were recruited. A link to a welcome website (see Appendix B) informing about the project was sent to candidates:

- Project description and procedures
- Terms and conditions (candidates were offered a EUR 20 voucher)
- Registration and confirmation
- Data privacy policies and data processing information
- Imprint

According to terms and conditions, applicants had to confirm to be over 14 years old and provide age and gender. By applying, candidates gave their consent for data processing, agreed to terms and conditions and confirmed to dispose over own smartphone with either QualityTime or Screentime (Apple) installed and working.

Smartphone usage data and self reported perceived stress values were collected from 7 female (35%) and 13 male (65%) healthy subjects, aged between 22 and 57 years (see Figure 22).

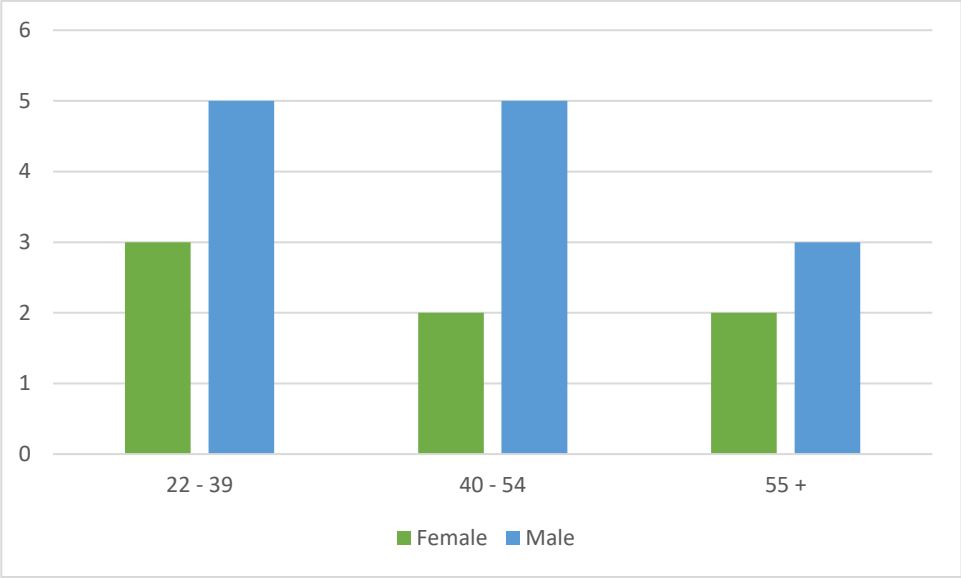

Figure 22: Study on Smartphone Usage and Perceived Stress. Total Number of Participants (n = 20) grouped per Age and Gender.

Data was collected over a period of four weeks, weekends included (28 days). Due to user compliance issues, the average number of user data received was 25.9

days. Users justified missing data with either weekend, vacation or travel. While response rates for female participants slightly, but continuously decreased from even 100% in week 1 to 79.6% in week 4, men's submission rate remained stable and above 93% over time (see Figure 23). Only 8 users fully delivered for all 28 days of survey, in one case submission was terminated after 12 days.

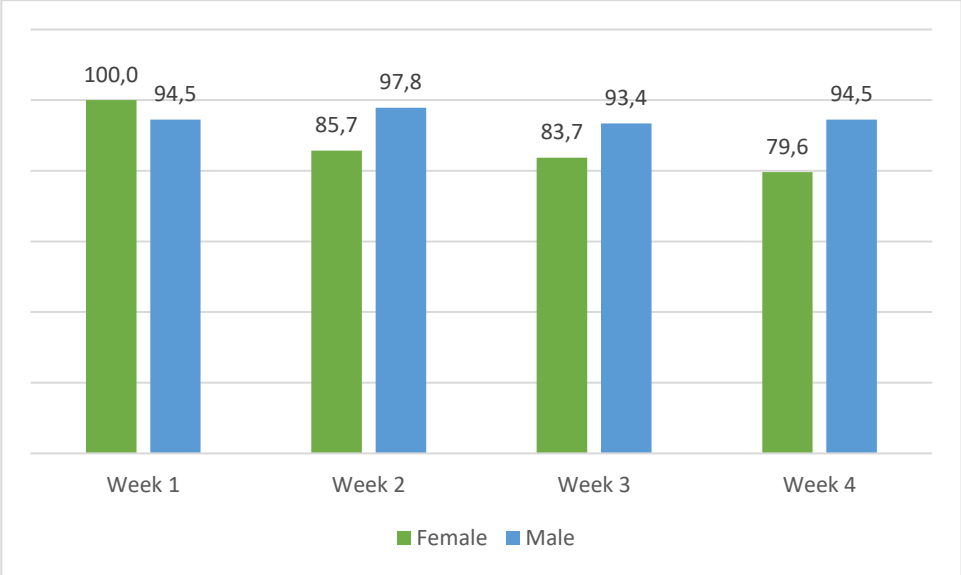

Figure 23: Study on Smartphone Usage and Perceived Stress. Participants Response Rates in %, grouped by Gender and Week.

4.6 Study Results

To obtain a general overview of the data collected, an exploratory data analysis was performed, using MATLAB (version R2018b) for visualization. In a first step an array was created, containing values for screen time and stress level and loaded to MATLAB. One data pair containing an extreme value for screen time was removed to allow a balanced presentation of all values in a scatter-plot. Although plot did not reveal any correlation between data, a statistical check on linearity was done and linear fit added to chart for reference (see Figure 24). Mean value for smartphone usage time was 128,7 minutes and for perceived stress was 2.994. At first glance no (linear) relation between x- and y-values could be identified.

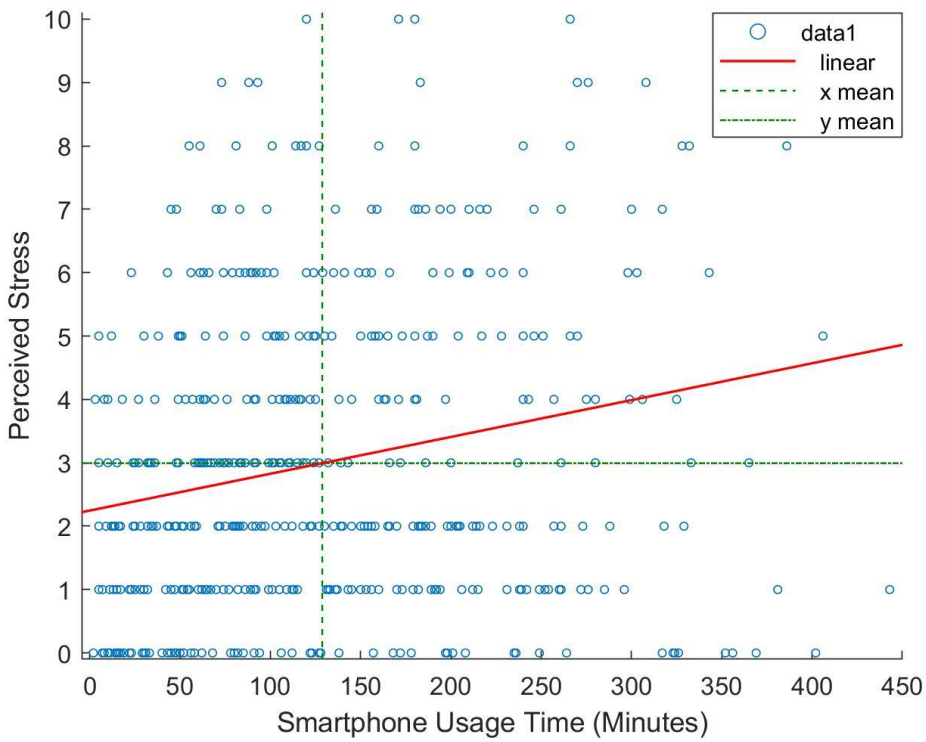

Figure 24: Study on Smartphone Usage and Perceived Stress. In total 517 Data Points were collected over a Period of four Weeks, each representing Users‘ daily Smartphone Usage Time in Minutes on X-axis and corresponding Perceived Level of Stress (Value Range 0 to 10) on Y-axis.

Visual inspection of data could not convey utility of usage time for stress prediction. In a next step correlation for each single participant was analyzed to check for significant relation. Two-tailed Pearson correlation was calculated using G*Power, for single participant and grouped by gender (see Table 5).

Table 5: Correlation between Smartphone Usage Time and Perceived Stress

WORKING DAY + WEEKEND												
				Smartphone Usage Time				Perceived Stress				
Participant	Gender	Age	N	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	Correlation
F01	f	55	28	240,3	86,0	74	402	2,2	2,7	0	9	-0,74
F02	f	40	24	223,1	61,4	156	356	4,4	3,0	0	8	-0,37
F03	f	35	24	202,8	52,6	120	300	6,5	2,0	4	10	-0,13
F04	f	37	27	84,1	74,4	7	325	2,7	1,6	0	5	0,8
F05	f	29	12	137,5	65,8	60	240	3,9	2,3	1	8	0,33
F06	f	49	28	112,0	83,2	8	318	3,5	2,0	0	8	-0,26
F07	f	55	28	14,8	11,0	2	45	1,1	1,5	0	5	-0,17
FEMALE			**171**									**0,11**
M01	m	52	27	73,2	23,4	32	127	2,5	1,4	0	6	-0,14
M02	m	57	27	75,4	45,2	7	189	3,4	2,5	0	9	0,58
M03	m	55	28	87,2	45,8	23	235	1,8	1,5	0	6	-0,9
M04	m	53	28	140,0	84,4	23	365	2,3	1,7	0	7	0,15
M05	m	24	27	129,1	46,8	52	275	3,4	2,1	0	8	0,15
M06	m	44	26	118,3	56,0	24	246	3,1	2,2	1	8	0,01
M07	m	38	28	147,0	67,1	32	261	1,6	1,6	0	7	0,29
M08	m	22	25	187,6	72,8	83	328	4,5	2,9	0	10	0,01
M09	m	33	28	97,9	68,0	14	264	0,0	0,0	0	0	0
M10	m	53	22	300,3	149,3	70	819	5,3	3,2	1	10	0,15
M11	m	54	27	145,8	65,2	63	303	4,2	2,0	1	7	-0,05
M12	m	29	28	110,1	53,1	32	299	3,8	1,6	1	7	-0,09
M13	m	55	25	28,6	16,7	5	56	2,0	1,0	1	5	0,16
MALE			**346**									**0,29**
TOTAL			**517**									**0,23**

As total correlation ρ = 0.23 is far below ρ = 0.6, hypothesis H1, relation between smartphone usage and perceived stress exists, had to be rejected. Quite the contrary, results strengthen the proposition, that smartphone usage time as a whole does not allow to predict stress.

Results also indicate, that there is no significant difference in correlation between female and male participants. A final analysis was done to figure out, if correlation differs for working days. As participants were not surveyed about their profession or even worktimes, an assumption was made; Monday to Friday was defined a working day (n = 20), data filtered and loaded to G*Power. Again, a two-tailed Pearson correlation was calculated for female, male and total number of participants (see Figure 25). It was resigned to calculate the same for weekends, as number of weekend-days (n = 8) was too low for practical results.

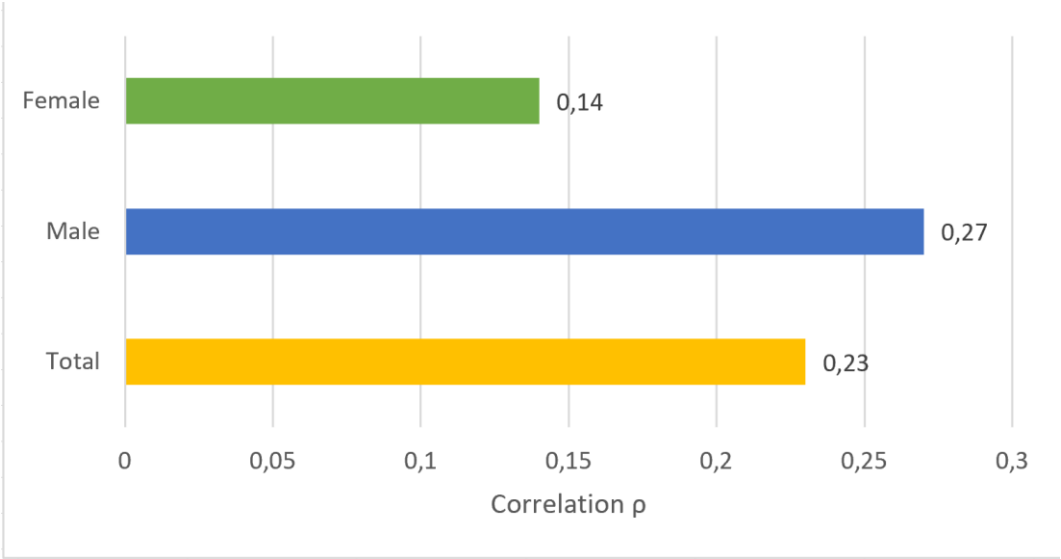

Figure 25: Overall Correlation (ρ) between Smartphone Usage Time and Perceived Stress Level. Overall Correlation on Workdays (Monday to Friday), grouped by Gender and in Total.

Resulting correlation for total number of participants on working days remained unchanged with ρ = 0.23, although values slightly changed for female from ρ = 0.11 to ρ = 0.14 and male, from ρ = 0.29 to ρ = 0.27. However, as these values cannot confirm on relationship between smartphone usage times and perceived stress neither, it can be assumed, that this will apply for weekend usage in the same way.

4.7 Discussion

Former studies demonstrated, that different ways of smartphone usage might be appropriate indicators to predict stress. However, most of these investigations required either collection of participants' personal (sensible) data, were performed under escapist 'general' conditions, valid only under very specific circumstances or for limited user base. Aim of this study therefore was to research, if under precondition of anonymous participation and simplicity of using one single parameter for stress prediction, relationship between smartphone usage and stress could be verified. Benefit of such an 'easy indicator' would be the advantage of using it in services and apps for migraine patients to predict attacks without considering possible user specifities. During initial discussion of study and design with colleagues and migraine patients most were convinced, that extended use of smartphone would result in higher levels of perceived stress. This might have been influenced by perceptions from work environment, presenting managers as being

always ‘on phone’ and finally ending up in burn-out. After study was completed, some participants provided feedback that first, study made them aware of their smartphone usage habits and they were sometimes astonished about time spent and second, that activities on smartphone were not always work related, but in some cases, even more time was spent on watching videos, listen to music or reading of news and books.

Study results could not confirm on relationship between smartphone usage time and perceived stress, on the contrary due to low correlation for most participants and in total, the opposite seems to be true. This might be owed to study design which was focused on collecting a single parameter and anonymous participation. As mentioned before, participants were made aware of their habits and this could also have influenced results. In the future it might be beneficial to redo the study and create an app for automatic collection of usage time and stress. Stress values could be received by external devices like Apple’s or Garmin’s smart watch, measuring stress based on heart rate variation. As most studies are based on evaluation by standard scales or perceived stress, this would create valuable evidence for values based on vital parameters. On the other hand, other than mobile phones in the past, smartphones nowadays have become daily companions and thousands of services and apps are supporting daily life, starting with wake up in the morning and measuring quality of sleep at night. It might therefore be necessary when collecting smartphone usage, to classify time by work- and leisure time. Given the fact that in today’s work environment border between work and life has become floating, classification could be supported by artificial intelligence (AI) procedures.

5 Conclusio

Although percentage of migraine patients in Austria on average is 15%, public awareness of this disease is low, resulting in those concerned feeling misunderstood by society and huge economic impact for organizations due to lack of work on the other side. It therefore seems embarrassing that migraine does not receive similar attention and support as other widespread diseases like cardiovascular or diabetes. Neither Austrian health targets nor public health system seem to include initiatives to raise awareness or enable fast and better treatment options, in contrary, campaigns are mostly driven by pharmaceutical companies, to enable access to markets for their products. Figures and data for migraine disease is difficult to obtain, as data is not shared between headache centers in Austria and other health care experts, publishing is limited to organizations like World Health Organization (WHO). Impression arises that public interest in this information does not exist which is astonishing, as any efficient utilization of public resources and budget should be based on clear and transparent operating figures.

Potential migraine patients on their long and painful journey towards (hopefully) right treatment are confronted with insufficient electronic support services. Although hundreds of migraine related apps are available for download to smartphone, most of them are useless for self-tracking or without clinical evidence. Many services have been developed by technicians without understanding migraine, or just rebuilt paper-based diaries. Even most downloaded and used services rather serve commercial interests of developers than patients. It is difficult to understand, that in a modern world of ‘big data’, ‘blockchain’ and ‘artificial intelligence’, available services do not make use of any digital opportunity available. Smartphones offer a wide range of in-built sensors and there is a multitude of sensors, easy to connect with, available on the market. However, none of the services assessed offers sufficient support for detection and automated documentation of so-called trigger factors, important parameters that might cause or promote migraine attacks.

Stress has been identified a major trigger factor for migraine and several studies have demonstrated that smartphone parameters can be used for prediction. Thereupon this study was focusing on smartphone parameters that can be easily obtained from smartphone and are uncritical in regards of data privacy, resulting in research on relationship between smartphone usage and stress. A survey was

conducted to answer the question, if smartphone usage time (screen time) relates to perceived stress. Total results as presented in section ‘4.6 Study Results’ and ‘4.7 Discussion’ did not show significant correlation and breaking down values for gender- and workday related analysis of correlation, did not confirm alternative hypothesis (H1) neither. This study could demonstrate too, that a widely held belief on extended phone usage causing stress, in general cannot be attested. However, participants’ individual responses over time confirmed, that relation between ‘usage’ and ‘perceived stress’ exists, although not linear. Study results raise several new questions:

- Is there any other, non-linear relation between smartphone usage and perceived stress?
- Does perceived stress relate to any single application or combination of applications?
- Are there other factors or circumstances that (together with screen time) allow stress prediction?

It has been discussed that automatic long-term logging of parameters could reduce, or even avoid possible bias of participants. If recording of application usage time could be done over several months in the background, without requiring manual user input and stress level could be automatically obtained from a smart-watch instead, would this result in higher correlation? The number of alternative trigger factors and digital opportunities to detect them is high; air-humidity measured by an external sensor, or electric skin conductivity recorded by wearables, might look more promising for prediction at first glance. However, there is a significant benefit on having a closer look on ‘usage time per application’ and try to identify services causing stress: whereas electric skin conductivity cannot be changed, usage time might be controllable by user. If for example, phone calls are identified as trigger for stress, they could be reduced and communication (at least partially) shifted to e-mail. Source for stress might not always be unambiguous, therefore use of AI learning algorithms is proposed to consider individual end user requirements. Trigger factor ‘smartphone usage’ might not only offer stress prediction, but avoidance or reduction too, thus can be another important step towards improving therapy and life of migraine patients.

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Appendix

A. Migraine Diary Copyright Notice

Kopfschmerz- und Migräne Tagebuch: Ein Service von Novartis Pharma GmbH und PatientPartner in Kooperation mit der Selbsthilfegruppe Kopfweh, Erstellt in Zusammenarbeit mit dem Spezialbereich Kopfschmerz, Univ.-Klinik für Neurologie Wien und dem Spezialbereich Kopfschmerz, Univ.-Klinik für Neurologie Innsbruck; Datum der Erstellung: Oktober 2018.

B. Subject Information and Welcome Page

A welcome page was created informing subject about study and survey, terms and conditions, data privacy and registration for participation.

Umfrage - Smartphonenutzung und Stress

- Projektbeschreibung
- Teilnahmebedingungen
- Anmeldung
- Datenschutz
- Impressum

Projektbeschreibung und Ablauf

Stress ist oftmals Auslöser für Erkrankungen. Kontinuierlicher Stress und belastende Lebensumstände können die Gesundheit beeinträchtigen und letztlich auch zu Burn-out führen.

Mein Name ist Christian Waldschütz und **ich untersuche** im Rahmen meiner Masterthesis, **ob zwischen täglicher Nutzungsdauer eines Smartphones und subjektiv erlebtem Stress** („wie gestresst fühle ich mich") **ein Zusammenhang besteht**.

Über einen Zeitraum von 4 Wochen werden von den TeilnehmerInnen die tägliche Nutzungsdauer des Smartphones und subjektiv erlebter Stress erhoben.

Die Erhebung findet im Februar 2019 (Umfrage: 2.2. – 1.3.2019) statt, die Teilnahme ist anonym möglich (siehe auch Datenschutz).

Die TeilnehmerInnen erhalten täglich ab 2.2.2018 ein Mail mit einem Link zu einem Onlinefragebogen (SurveyMonkey), der innerhalb von 48 Stunden zu beantworten ist:

Frage 1 – Nutzungsdauer des Smartphones (Stunden/Minuten),
Frage 2 – Wie stressig wurde der Tag erlebt (Markierung auf einer Skala zwischen 0 – 10).

Am Ende der Erhebung erhalten alle TeilnehmerInnen die **Auswertung der Umfrage, sowie einen Unkostenbeitrag** (siehe Teilnahmebedingungen).

Weiter zu den Teilnahmebedingungen

Teilnahmebedingungen

Für die Teilnahme ist ein Smartphone erforderlich, das die tägliche Gesamtbenutzungsdauer anzeigen kann.

Für Android Smartphones ist dazu die Installation einer App wie ‚QualityTime' erforderlich, beim Apple iPhone ist die Funktion ab IOS 12 bereits im Betriebssystem enthalten.
Die TeilnehmerInnen sind dafür verantwortlich, dass die Messung und Anzeige der Benutzungsdauer funktioniert.
Sind mehrerer Smartphones vorhanden, ist die Zeit jenes Gerätes das am meisten verwendet wird, anzugeben.
Wegen der vielen unterschiedlichen Smartphones, kann ich bei der Installation keine Unterstützung anbieten.

Als **Unkostenbeitrag** erhalten die TeilnehmerInnen **am Ende der Umfrage** einen **Amazon Gutschein in der Höhe von 20 EUR.**

Voraussetzung dafür ist, dass der Fragebogen an zumindest 25 Tagen beantwortet wurde, werden zumindest 21 Tage beantwortet, beträgt der Unkostenbeitrag 10 EUR, darunter erfolgt keine Erstattung.
Die täglichen Onlinefragen müssen innerhalb von 48 Stunden beantwortet und abgeschickt werden. Spätere Antworten sind ungültig und können nicht berücksichtigt werden.

Auf den Unkostenbeitrag kann wahlweise verzichtet werden, er wird dann zu Gunsten der St. Anna Kinderkrebshilfe gespendet.

Die **Zusendung des Amazon Gutscheines** bzw die Spende erfolgt innerhalb von 2 Wochen nach Beendigung der Umfrage, somit bis spätestens **15. März 2019.**

Die Umfrageergebnisse werden statistisch ausgewertet und dabei auch auf Plausibilität überprüft. Sollte erkennbar werden, dass Eingabewerte gefälscht wurden, erfolgt eine sofortige Sperre des Teilnehmers/der Teilnehmerin. Jede/r TeilnehmerIn darf sich nur einmal registrieren, beim Abschicken der Online-Fragebögen wird von SurveyMonkey daher auch die IP-Adresse aufgezeichnet.

An der Umfrage können **maximal 30 Personen** teilnehmen, diese werden binnen 48 Stunden verständigt.
Darüber hinaus ist eine Teilnahme nur mehr möglich, wenn jemand wieder absagt.

Weiter zur Registrierung und Anmeldung

Registrierung und Anmeldung

Mit der Registrierung für die Umfrage erklären sich die TeilnehmerInnen mit den Teilnahmebedingungen einverstanden und bestätigen, dass sie zumindest 14 Jahre alt sind und ihr Smartphone die tägliche Benutzungsdauer messen und anzeigen kann.

Für die **Registrierung bitte ein Mail mit folgenden Angaben an dh171811@fhstp.ac.at schicken:**

- Alter
- Geschlecht (m/w/inter)

Die Mailadresse kann jede beliebige sein, die Teilnahme ist daher anonym möglich.
Bitte beachten Sie, dass an diese Mailadresse auch die Umfrage geschickt wird.

Sie erhalten **innerhalb von 48 Stunden eine Rückmeldung, ob Sie für die Umfrage angemeldet sind**.

Hier geht's zu den Datenschutzbestimmungen

Datenschutz

Die Umfrage wurde der Ethikkommission Niederösterreich zur Prüfung vorgelegt.

In der Umfrage wird nur nach der täglichen Gesamtbenutzungsdauer gefragt. Welche Apps im Detail und wie lange verwendet wurden, ist nicht Gegenstand der Erhebung und wird auch nicht abgefragt. **Es wird zu keiner Zeit auf das Smartphone oder Daten der TeilnehmerInnen** zugegriffen.

Im Rahmen der Umfrage **werden folgende Daten verarbeitet**:

- Mailadresse
- Alter
- Geschlecht
- Smartphone Benutzungsdauer (Stunden/Minuten), täglich
- Subjektives Stresserleben (Wert zwischen 0 und 10), täglich

Die TeilnehmerInnen haben das Recht, die Teilnahme jederzeit und ohne Angabe von Gründen zu beenden.
Bitte ein Mail an dh171811@fhstp.ac.at schicken, es werden dann alle Daten innerhalb von 48 Stunden gelöscht.

Falsche Eingaben bei der Umfrage werden richtiggestellt, soferne innerhalb von 24h nach der erfolgten Eingabe eine Benachrichtigung an o.g. Mailadresse erfolgt.

Die Daten werden nicht an Dritte weitergegeben. Alle Daten der Umfrage werden 1 Monat nach Vorliegen der Gesamtergebnisse gelöscht.

Für die **Onlineumfrage wird „SurveyMonkey“** verwendet.
Die darin eingeblendeten Werbeanzeigen stehen in keinem Zusammenhang mit dieser Umfrage.
Es gelten diesbezüglich die Datenschutzbestimmungen von SurveyMonkey.

Weiter zum Impressum

Impressum

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Zurück zur Startseite - Stressumfrage