Doctor's Little Helper

A Mobile Emergency Hand Surgery Assistant

Diploma Thesis at the
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I hereby declare that I have created this work completely on my own and used no other sources or tools than the ones listed, and that I have marked any citations accordingly.

Hiermit versichere ich, dass ich die vorliegende Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt sowie Zitate kenntlich gemacht habe.

Aachen, October 2012
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Abstract

A doctor working in the emergency department of a hospital (ED) is exposed to a variety of situations where her knowledge may be insufficient; she may not necessarily be specialized in a certain domain or simply not up to date with new standards, procedures, or other knowledge needed to make a correct diagnosis. The latter doesn't mean being a bad doctor. Since (human) medicine is an area under constant development, procedures and medications can become outdated within a short time span. Further reasons for incorrect diagnoses may probably be accounted to the complexity of a highly multitasking work. Additionally, this work is not supported enough by the used software.

This thesis presents the process of application conception, development, and evaluation. First, the literature research triangulated with qualitative and quantitative observation reveals the multitasking and constantly interrupted nature of ED doctor's work. This finding leads to iterations of design from which the rationale of design decisions are presented in this thesis. Finally, the evaluation of form factor's influence on patients' and doctors' perception as well as the evaluation of the final software prototype — Doctor's Little Helper — are presented.

This work also provides guidelines for diagnosis-assisting applications for use in the area of hand surgery decision-making. The focus is primarily set on visualization of cases and the patient's injuries. These guidelines have also been used in Doctor's Little Helper.

Überblick

Ein Arzt der in der Notaufnahme eines Krankenhauses arbeitet, ist einer Vielzahl an Situationen ausgeliefert, in denen sein Wissen unzureichend sein kann; er ist nicht notwendigerweise in einer Fachrichtung spezialisiert, oder nicht auf dem neuesten Stand mit Standards, Prozeduren, oder anderem Wissen, das notwendig ist, um eine korrekte Diagnose zu stellen. Letzteres bedeutet natürlich nicht, dass der Arzt ein Schlechter ist. (Human)medizin ist ein Gebiet des ständigen Wandels; Prozeduren und Medikationen können sich innerhalb kurzer Zeit ändern. Weitere Gründe für falsche Diagnosen können in der Komplexität der Arbeit liegen, die zusätzlich nicht genügend durch die eingesetzte Software unterstützt wird.

Diese Arbeit führt durch einen Prozess aus Anwendungskonzeption, -entwicklung und -evaluation. Zunächst liefert eine mit qualitativer und quantitativer Observierung triangulierte Literaturrecherche die komplexe Struktur der Arbeit eines Arztes in der Notaufnahme. Diese Arbeit ist durch eine hohe Parallelität ausgezeichnet und unterliegt häufigen Unterbrechungen. Diese Erkenntnis führte zu mehreren Entwurfsiterationen, deren Entscheidungen im Laufe dieser Arbeit herangeführt werden. Es folgt eine Untersuchung des Formfaktors und der damit einhergehenden Auswirkung auf die Arzt-Patient-Interaktion. Zum Schluss wird die Evaluation der erstellten Prototyp-Applikation — Doctor's Little Helper — beschrieben.

Diese Arbeit liefert Richtlinien für entscheidungsunterstützende Anwendungen für den Gebrauch in der Handchirurgie. Der Fokus liegt hauptsächlich auf Visualisierung von Akten und der Beschwerden von Patienten. Diese Richtlinien wurden ebenfalls in Doctor's Little Helper angewendet.

Acknowledgements

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Thank you mum, dad, and Johanna for supporting me throughout my college years and always believing in my goals.

Special thanks to Dr. Dunda for his medical supervision and Melanie Hilgers for her assistance. Special thanks also to Sandra Schulze for her help and starring in the experimental videos, Guy Van Der Walt from Plasticboy Pictures for providing the 3D model of the hand for free, and Sebastian Graefingholt for making the folders look nice.

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Thank you whoever participated in the survey and in the interviews for your time and valuable feedback.

Conventions

Throughout this thesis the following conventions are used:

Research questions, lists, and definitions of non-technical terms or short excursus are set off in colored boxes for better perception.

Question 1: Example

Research questions according to problems arising during the thesis.

List 1: Example

- Item 1
- ...

Excursus 1: Example

Excursus are detailed discussions of a particular point in a book, usually in an appendix, or digressions in a written text.

Goal 1: Example

Specific goals set at certain stages

The whole thesis is written in American English.

Chapter 1

Introduction

This chapter gives an introduction into the research topic of this thesis. First, the reasoning for the need of clinical decision support is given. Next, a scenario introduces the reader into one of the typical problems of non-specialized doctors at an emergency department. After giving a short description of the emergency department doctor's work, initial decisions along with the questions behind them are presented. Finally, an overview of the chapters and their short description is provided.

A great number of death causes is to be accounted to diagnostic errors

In 1999, the U.S. Institute Of Medicine issued a report called "To Err is Human: Building a Safer Health System" [Institute of Medicine, 1999]. The intention behind this report was to raise awareness for diagnostic/medical errors. Until then, a study from New York claims, in a given year more people died from medical errors than from motor vehicle accidents, breast cancer, or AIDS [Centers for Disease Control Prevention (National Center for Health Statistics), 1999] (see figure 1.1). Naturally, complexity can lead to work being error-prone if not supported enough/in the right way. As a result of their study, Chopra et al. [1992] attribute between 70% and 80% of the incidents observed to a component named "human error".

Present knowledge needs to be activated

Cook et al. [1994] present incidents showing that even though highly educated and experienced doctors are in charge, sometimes errors are made due to knowledge not

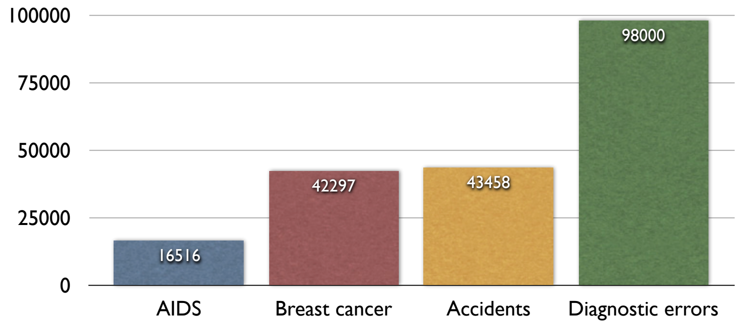


Figure 1.1: Death causes per year. Source: [Centers for Disease Control Prevention (National Center for Health Statistics), 1999]

being activated in a certain context. The activation of knowledge in such situations could possibly be accomplished with the support of mobile devices such as smart phones, tablet PCs, etc.

In the "Conference on diagnostic errors in medicine", held in Florida in 2009, two strategies were presented in order to reduce diagnostic errors [Berner, 2009]:

- educational interventions and
- clinical decision support

An application supporting the doctor's decision-making process as well as presenting recorded reference cases could serve both of the strategies proposed.

Doctor's Little Helper implements guidelines provided by this work

This thesis presents a case study in the hand surgery domain. It aims to provide rules for designing user experience for supporting a doctor's diagnosis decision in emergency departments. Based upon my research a software prototype will be presented. This application implements visualization techniques supporting doctors working in an emergency room during their decision-making process related to hand injuries.

1.1 An emergency department scenario

Peter, 45, falls on his hand late Saturday night. Living in a rural area, Peter and his wife Louis drive to the nearest hospital in the neighborhood. Arrived at the hospital, he is examined/treated by a doctor currently having his shift. This doctor, however, is an internist and is not specialized in the domain of hand injuries. The problem arising from this situation is the doctor potentially acting incorrectly due to not present or activated knowledge necessary for making the right decision. With specialized colleagues around serving as consultants this is not a problem; accessing specialized knowledge is a matter of minutes. But what if this scenario is happening at 2 a.m. and none of the specialized colleagues is around? The only way out would be calling up consultants and explaining the case over the phone (storyboard in figure 1.2). The story's ending with usage of assisting devices is shown in appendix E.

Existing medical software often does not integrate in doctor's work(flow)

The initial motivation behind this thesis was providing improvement to this kind of situations by creating a software application supporting this non-specialized doctor during his decision-making process. Research inspecting medical software utilized in hospitals revealed several flaws. Obviously, the software has not been designed to adapt a doctor's workflow leading to medical staff abandoning the installed software, introducing workarounds with traditional utilities such as pen and paper, and a general dissatisfaction with the systems in use [Chen, 2010]. Additional evidences are illustrated in chapter 2 and 3. With progressing research on the domain however, the focus has shifted onto visualization of patient-related data, rather than decision-making itself.

1.2 Understanding the characteristics of an emergency department doctor's work

In order to provide good support for the emergency department (ED) doctor's work, a good understanding of

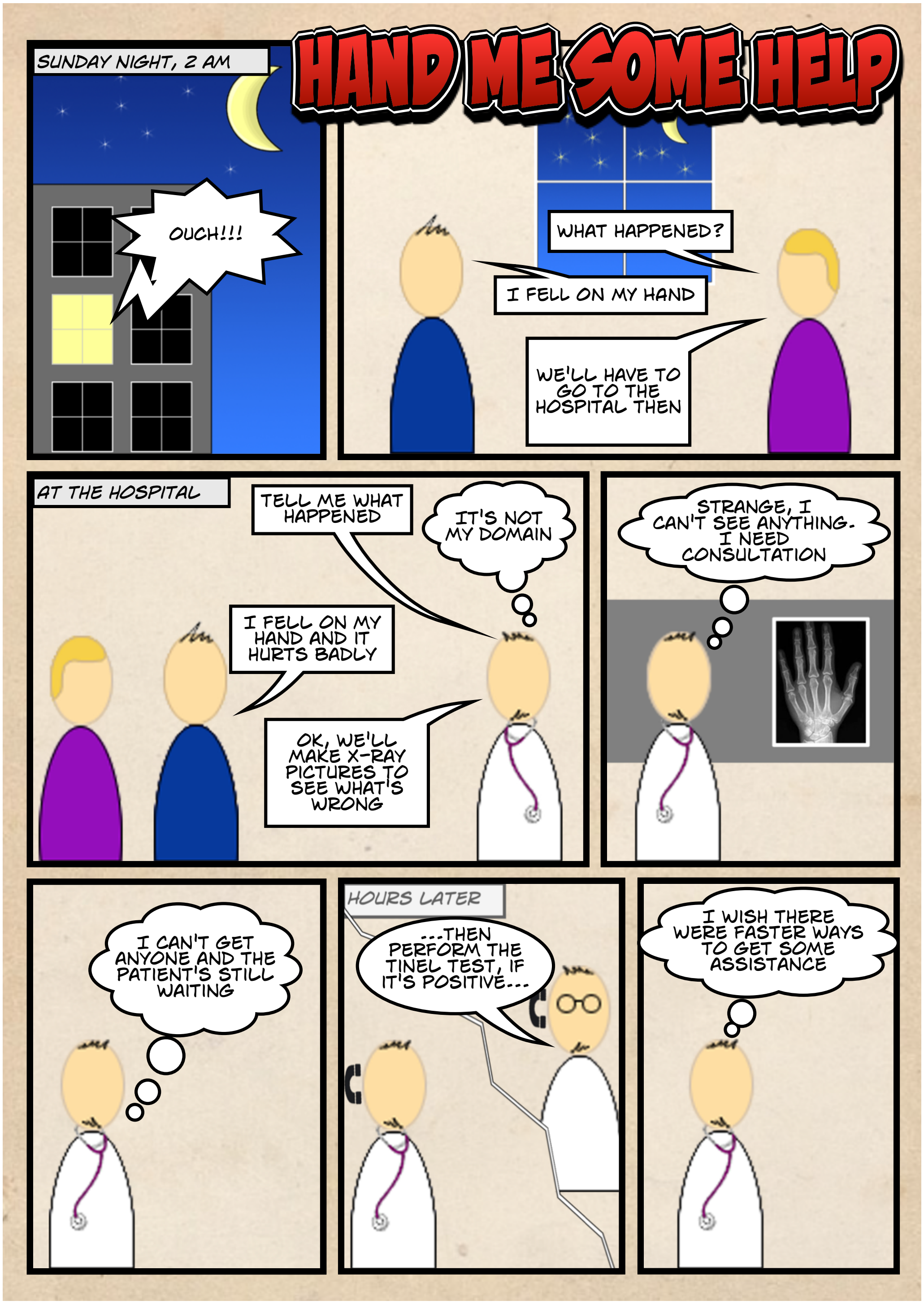


Figure 1.2: Storyboard: "Hand Me Some Help"

the problem domain is needed. Preliminary observations (chapter 2) conducted in the ED of Aachen Universitätsklinikum (UKA) revealed the work in an ED being characterized by high mobility. Usually physicians operate in several rooms in parallel constantly switching between patients. In addition to this, based on a case study, Yu et al. [2010] describe the work of an ED doctor as non-routine, context-driven, highly collaborative, multi-tasking, time-critical, and information-rich.

ED's physicians show highest acceptance of mobile devices at work

In conformity with this, an analysis by Bulletin Healthcare reports the ED's physician being the medical subdomain with the highest usage of mobile devices [Bulletin Healthcare, 2011]. The results reveal 40% of doctors working in emergency medicine use mobile devices with 90% of them using Apple's iPhone. These findings lead to the decisions of choosing a mobile phone as the target device and iOS as the target operating system for the resulting application.

Usage of everyday devices may negatively affect the doctor-patient interaction

The work of a doctor is characterized by an interaction with at least two other groups of people: other medical staff and most importantly: the patient himself. The efficiency of a doctor's work highly depends on the patient's collaboration. Research by Alsos et al. [2012] has shown that disturbances in the harmony of the doctor-patient interaction can have a strong effect on the quality of the doctor's work. The use of a mobile phone as used in everyday life has been suspected to possibly have a negative effect on the patient's perception of a doctor's professionalism. This could be resulting in subtle and constantly present stress. It has therefore been decided to investigate on this issue with the findings to be found in chapter 5.

1.3 Initial design decisions

This section presents several initial design decisions as well as questions that arose from making these decisions. These questions will be answered based on the findings in this thesis.

A software wizard could support doctors

The straightforward idea of supporting someone not famil-

Small-screened devices require splitting up content

iar with a certain procedure is to provide a wizard-like interface. Jennifer Tidwell provides a definition of a "wizard" in her book "Designing Interfaces" [Tidwell, 2007] describing its purpose as "leading the user through the interface step by step to do tasks in a prescribed order". Due to limited screen size on mobile devices, wizard implementations have to split up the contents into coherent groups (chunks) over a series of virtual screens with a wizard presenting one chunk per screen. A famous work by the cognitive psychologist George A. Miller sometimes referred to as *Miller's Law* (see excursus 1) describes the human working memory of being capable to hold 7±2 so called chunks of information. With each question (and the corresponding answer) being one chunk, long wizards could lead to the user forgetting his choices after a sequence of questions.

Excursus 1: "Miller's Law"

"The Magical Number Seven, Plus or Minus Two" is a paper published by George A. Miller in 1956 [Miller, 1956]. It states that the size of the human working memory is genetically determined and cannot be extended by training. According to Miller, our working memory is limited to holding up to 7 ± 2 chunks of information. A chunk is the largest meaningful unit of information recognized by the user (here: an issue/injury of the patient). This results in forgetting items, when being confronted in series of items exceeding that number.

Splitting up content could have a negative impact on usability

With the ED doctor's memory already being challenged, the following question arose:

Question 1: Q1

How to eliminate the need of scrolling across virtual screens in order to eliminate short term memory load

Another issue bound to wizards implemented in the described way is choosing arbitrary steps. Forcing the user to proceed in a predefined sequence may be a good idea if teaching the sequence is among the desired goals. More professional users on the other hand, need to be able to enter data in an arbitrary order. Research on desktop applications recommends the usage of secondary navigation clues [Burton et al., 1999] to provide such functionality. Due to the limited screen size, these clues ("Navigation Bars" in Apple's terminology) end up providing access to the previous and next screens/steps only. Ideally, however, the user should have a direct access to *any* step performed resulting in the freedom of choosing his own order of entering the required data.

Directly accessing arbitrary steps of the wizard one of the desired goals

When working shifts in the ED, doctors often have to work up to 24 hours in a row. By the end of such a long working period, the doctor's eyes end up being tired and cognitive abilities being slowed down. Forcing the user to read long lists of text on small-screened devices would lessen the usability and leads to:

Question 2: Q2

How to reduce the necessity of the doctor being forced to read on small screens

These two questions consequently lead to:

Question 3: Q3

How to visualize the data the doctor is entering

Reducing the need of reading trivially leads to the necessity of displaying as little text as possible. But if text and lists are going to be omitted, what other choices remain? The obvious solution is to use an interface based on graphical visualization rather than text-based designs. Research on currently available mobile health applications suggests the

Graphical visualization eliminates the necessity of reading

Utilization of graphical cues requires understanding of doctor's visual associations

usage of 3D visualization: according to Liu et al. [2011] 3D visualization is not widely spread yet, but highly liked by the users. Choosing a 3D model-based display technique also provides more flexibility in terms of displaying data than using 2D imagery. Utilizing graphical display however, introduces the necessity of understanding the doctor's work, the way she thinks, the work-based associations of colors and images, etc. These requirements imply the need for using the iterative user-centered design approach in order to meet the user's needs and provide a usable result. The following table provides an overview of the observations performed. In addition to these sessions, a biweekly meeting with Dr. Dunda, the consulting doctor of this thesis, has been arranged. These meetings served for checking up on the goals and discussion of steps to perform next.

Date	Type	Place	Understanding	Design	Evaluation
17.06.2011	orientation	ED	•		
21.06.2011	qualitative interview	ED	•		
24.06.2011	qualitative interview	ED	•		
12.08.2011	quantitative	ED	•		
15.08.2011	quantitative	ED	•		
19.08.2011	qualitative interview	PC	•		
26.08.2011	qualitative	PC	•		
23.12.2011	focus group	ED	•	•	
09.03.2012	survey	online	•	•	
09.03.2012	experiment	online	•	•	
14.03.2012	prototyping	UKA	•	•	•
29.03.2012	prototyping	UKA	•	•	•
30.05.2012	evaluation	UKA	•	•	•
28.06.2012	evaluation	UKA	•	•	•

Table 1.1: Overview of performed studies (ED = emergency department, PC = polyclinic, UKA = arbitrarily chosen free rooms inside the UKA

1.4 Chapter overview

Goals

The questions and goals driving the work on this thesis are divided into two areas concerning

- the doctor's workplace and his workflow and
- visualization of the patient's issues

Chapter 2 deals mainly with the former, asking what the structure of an ED doctor's looks like, the steps it is composed of, as well as their arrangement. The latter questions are the driving force throughout chapters 4 - 6. Starting out with general visualization ideas, more and more refined questions regarding visualization details such as useful color codings, shapes of colored overlays, or the type shape-distorting techniques evolve.

Chapter 2: The qualitative study performed in order to understand the problem domain of an emergency department will be presented in chapter two. Driven by the questions regarding the workflow of a doctor, Its results explain the structure of an emergency department doctor's work.

Chapter 3: Chapter three covers the related work available in the field of software development for the mobile health domain. Also, results of a market scan of existing mobile health applications are provided. Finally, a design space of mobile health applications is shown.

Chapter 4: Based on the results presented in chapter three, preliminary design decisions have been made. These decisions as well as a description of an early prototype serving as a proof of concept are described in this chapter.

Chapter 5: Questions targeting the device form factor arose during the first design phase. Answers to these as well as triangulation of initial design ideas by conducting an experiment on potential patients and a survey targeting doctors are presented in chapter five.

Chapter 6: Chapter six describes the phases of the iterative user-centered design process. The implementation process starting with simple clear foil prototypes, the thereof resulting UI structure, the interactive flash-prototype, and the final implementation is depicted in this chapter. In order to verify that the needs of the doctors have been met, qualitative evaluation of the application with doctors of the UKA has been performed. A detailed description can be found in chapter seven.

Chapter 7: The last chapter sums up the results of the thesis and its contribution. In this chapter I discuss the limitations of my findings and provide guidelines useful for developing medical/emergency department software. Finally, an outlook on potential future research is given.

Chapter 2

Understanding workflows inside the emergency department

In order to design software for use in the context of an emergency department (ED) one first has to understand the domain itself. With the goal of grasping the structure of an ED doctor's work several observational sessions have been conducted. The sessions were grouped into three phases. This chapter describes these phases, being the

Three phases of observation have been performed

- Phase 1: orientational,
- Phase 2: qualitative, and
- Phase 3: quantittive

sessions. An overview of the sessions can be found in chapter 1, figure 1.1.

2.1 Procedure

The sessions took place in the emergency department (ED) of Aachen's Universitätsklinikum (UKA). While the orientational and qualitative observation have been recorded us-

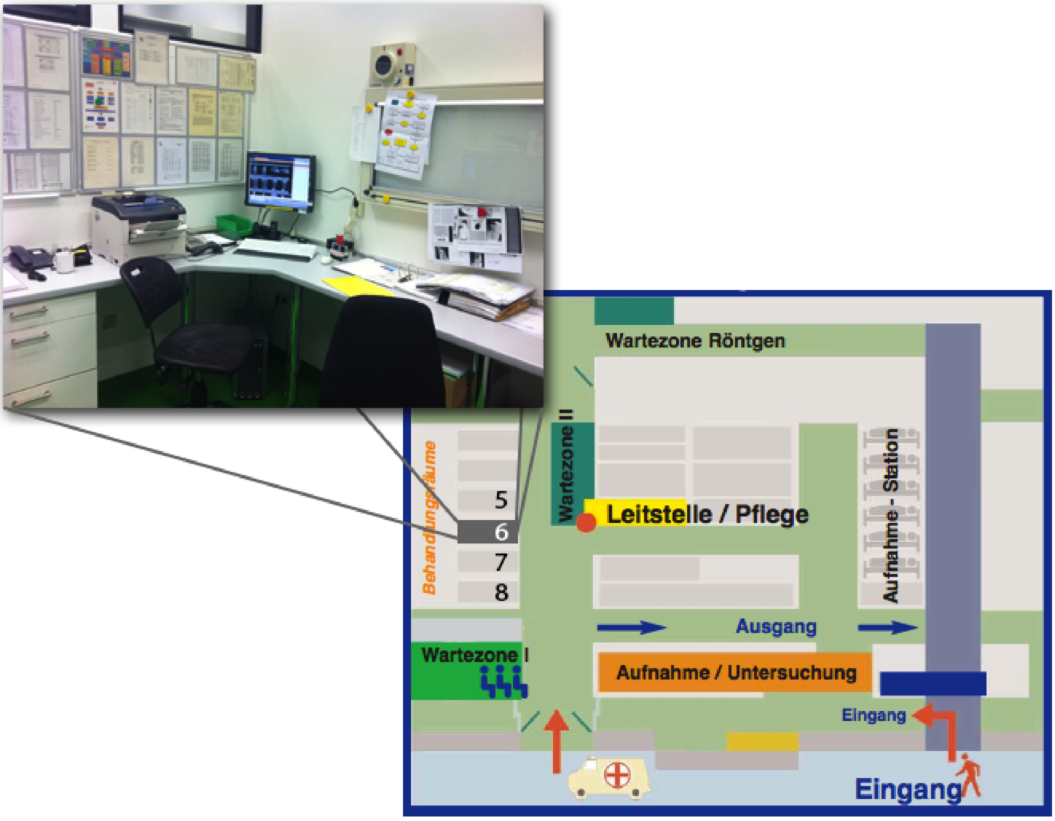


Figure 2.1: Overview of Aachen Universitätsklinikum's emergency department (right) and the surgical emergency doctor's room equipped with a workstation (top)

ing pen & paper, the quantitative session utilized a custom application written for that purpose (section 2.4).

Initial ortientational session revealed the overall structure of the UKA's ED

An initial visit served the purpose of learning about the UKA's ED itself. An overview of the ED can be found in figure 2.1. Over the period of 6 hours, I extracted structural information regarding the involved groups of people collaborating in the ED. The information has been gathered by walking around, observing, and writing down the observed information. Another focus was set on the interaction between these groups, as well as the activities performed.

The observation resulted in a list of actors, activities, utilities, and materials used. During analysis I have identified (professional) groups as well as their connections to each

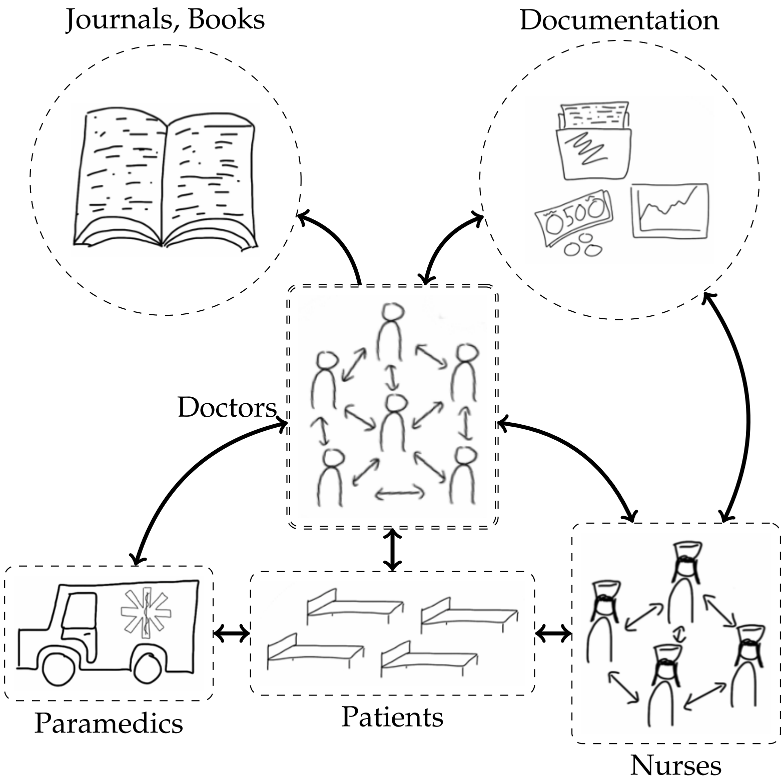


Figure 2.2: The ED doctors work domain

other. Once completed, the analysis revealed the structural and behavioral schema described in figure 2.2.

During all sessions, the focus was mainly set on the surgical emergency doctor's workplace. The observation revealed the doctor working in five rooms. Three of these (room five, seven, and eight in figure 2.1) are designated for examining and treating patients, one is used for patients staying overnight and being monitored. The remaining room six is the doctor's actual office where admissions take place. The doctor's office is the only room equipped with two computerized workstations used for tasks related to administration and documentation. These workstations are shared among all surgical doctors and other staff, such as nurses, currently having their shift. Next, the qualitative sessions have been conducted. The goal of the therein performed observations was to provide an overview of the doctor's work, resp. its structure. It was mainly driven by the question:

Observed subjects: surgical ED doctors

Qualitative session: what does the ED doctor's workflow look like?

Question 4: Q4

What does the structure of an ED doctor's look like? What are tasks/steps performed?

To answer this question I have shadowed (excursus 2) a doctor in the seconds phase of the observation for two days, four hours each.

Excursus 2: Shadowing

Shadowing is an observational technique [Czarniawska-Joerges, 2007] allowing to understand a certain profession. The observer follows the observed person step by step without interfering in his work in any way. This technique allows to experience the work situation of a shadowed person first hand, sometimes even resulting in seeing more than the observed person does.

The UKA ED doctor's workflow does not significantly differ from other hospitals

These sessions allowed me to classify the doctor's tasks, as well as the order in which they are performed. The list of the tasks can be found in figure 2.3. With the interest of this workflow being generalizable several interviews with doctors from other hospitals in Aachen have been performed. These interviews confirmed the workflow being valid for doctors working outside the UKA as well.

First result: (almost) sequential steps

The order of the tasks top to bottom means the order in which the tasks are usually performed. The arrows show that the sequence of actions is not predetermined and can differ depending on the patient's injuries. Multiple branches and loops in the sequence of actions are quite possible.

Once identified the tasks themselves as well as their order of execution, I wanted to know more about the structure, to find out in what way support could be provided:

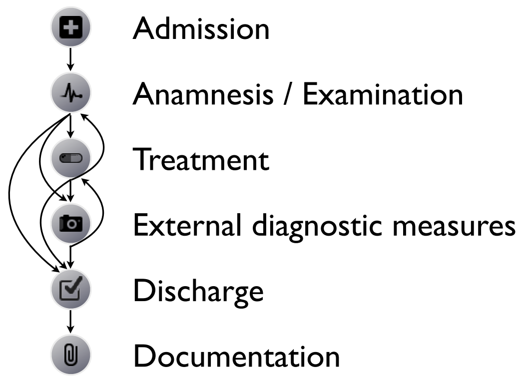


Figure 2.3: The ED doctor's typical workflow

> **Question 5: Q5**
>
> Are the steps sequential, interleaved, are there parallel activities?

2.2 The ED doctor's workflow

The observations have shown the workflow depicted above being idealized, i.e., one doctor is taking care of one patient at a time, without any further distractions. New patients arriving at unexpected times lead to an unpredictable time schedule which very often results in many patients being in a doctor's care in parallel. In addition, external examinations like X-ray, CATScan, or waiting for laboratory results of bodily fluids lead to interruptions of unknown length resulting in constant context switching between different tasks and/or patients.

An ED doctor has to handle multiple patients in parallel

Unfortunately, from what I have observed the existing software used in the ED does not support a doctor in handling these context switches sufficiently, if not at all. Because basic principles of usability [Shneiderman, 1986] such as "clear labelings/visibility", "speak the user's language" and most importantly "responsiveness" (in terms of adhering to the so-called "human deadlines" [Miller, 1968] and

The UKA's software suite badly supports the doctors

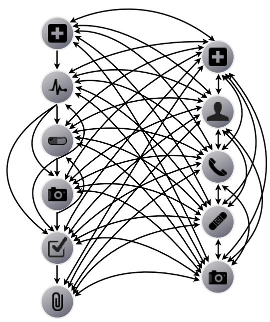


Figure 2.4: The complexity of the workflow including interruptions

[Card et al., 1991]) have not been followed, doctors at the UKA's ED have been asking colleagues for help with tasks like patient documentation. Doctors ending up in these types of situations exposed clear signs of anger and stress.

The ED's doctor is subject to a lot of distractions

The tasks as revealed by the observation mentioned above can be interrupted by any of the following at *any time*:

- new admission
- a colleague requesting help / consultation
- a phone call
- a waiting patient
- a patient returning from external diagnostic measures

This finding shows the complexity of an ED doctor's work. The resulting state machine is shown in figure 2.4.

2.3 Cognitive artifacts employed in a doctor's workflow

Often used tool: camera

While performing the observations, I have noticed every surgical consultant owning and using a digital camera. The consultants used the camera to take pictures of injuries and X-ray images. Asked about the frequency of using the camera in general, the hand surgeon's responses revealed it is a

Figure 2.5: Traffic light priorities given to patients, Source: UKA ED's wall and brochures

demanded feature of being able to make and share pictures of injuries they are asked to comment on.

Another fact worth being mentioned is the ED's priorization of cases according to their severity. The UKA's ED uses the traffic light colors for classifying injuries into low (=green), medium (=orange) and high (=red) prioritized cases. A picture of a sign explaining the priorities to the patients can be seen in figure 2.5. These traffic light levels have also been used for visualizing the severity of a case inside Doctor's Little Helper (see chapter 6 for details).

Traffic light prorization served as an idea for marking cases in Doctor's Little Helper

Shadowing the doctors has indicated a respectable amount of information needed to be present when being confronted with a huge variety of cases. This lead to:

Figure 2.6: Reference book used by surgeons

Question 6: Q6

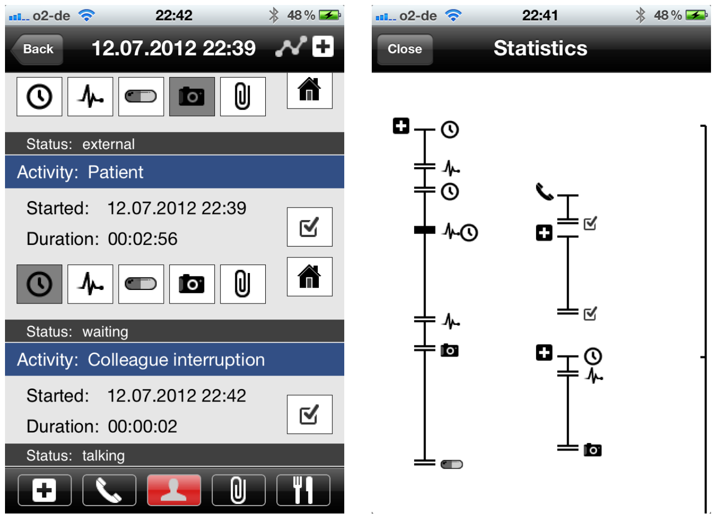
What are the doctor's sources of updated or forgotten information?

Interviews with doctors concerning this issue revealed several sources to be used:

- colleagues
- referential books
- the internet

Tools targeted for doctors should fit in their coat's pocket

During the observations, I noticed most doctors own pocket-sized referential books (figure 2.6). These can help when in need of forgotten information and their handiness makes them an appreciated tool. Doctors interviewed expressed their interest in replacing these with computerized



(a) Activity view (b) Generated statistics

Figure 2.7: DistractionMeter tool used for quantitative observation

versions. This fact explains the success of referential applications (UBurn, AOSurgery Reference, etc.) the market is currently offering.

The internet as a source for emergency department's physicians has already been dealt with. Tests performed by Abbas et al. [2010] for example, have shown poor performance regarding correct answers found using Google. Residents working in the ED turned out to use sub-optimal search techniques and extract their answers from web sites designed for laymen.

ED's physicians use Google as a source for information regarding diagnosis

Though this thesis does not cover the field of information delivery in general, a short discussion on this topic is included in chapter 7.

2.4 Quantitative observation

Once having identified the tasks and their interruptions, a quantitative observation session has been conducted. In order to simplify the data collection as well as its evalua-

UKA ED's doctors in charge of up to four patients in parallel tion, a data-collection tool called DistractionMeter (figure 2.7) has been implemented. Similarly to TaskObserver presented by Klug et al. [2007], this tool allowed me to follow fast paced situations without having to write which would be far more distracting. The observation was mainly driven by the question, how many parallel patients a doctor is in care of. It has been conducted on a Tuesday and a Friday between 4 p.m. and 8 p.m. since all emergencies in Aachen on Tuesdays and Fridays are delivered to the UKA. This allowed to see a realistic workload of the shadowed doctors on busy days. An excerpt of the results of this observation over the course of 30 minutes can be seen in figure 2.9. It turns out a doctor in the UKA's ED is in care of up to four cases in parallel. Asked about the workload, the doctors reported having seen even busier days.

2.5 Observations in the polyclinic

After having gotten some insights into the ED doctor's work and learning about his workflow, it has been decided to perform another observation in the UKA's polyclinic (excursus 3) for hand surgery.

Last session performed in the polyclinic with time-uncritical patients

Excursus 3: Polyclinic

A polyclinic is a place providing health care services (in this case) inside a hospital without the need for an overnight stay. Cases treated in the polyclinic most of the time are of non-critical nature.

Whereas the ED sessions served to learn about the potential target users, their work, and habits, the purpose of this observation was to learn more about the work of hand surgeons, the doctors of particular interest during this thesis. The observation consisted of two sessions, three hours each. I once again shadowed the doctor during his shift and observed his interaction with the patients, as well as the patients themselves.

Figure 2.8: An explanatory sketch drawn by a doctor for explaining an issue to a patient. The sketch shows a tendon rupture (top) and the possible treatment, the Lengemann suture (bottom).

Cases treated in the polyclinic are usually of non-critical severity. Therefore, the situations are more relaxed with the doctors having more time to explain the medical condition and possible treatments such as surgeries or non-invasive alternatives. The explanations were accompanied by the doctors drawing sketches on pieces of paper or tissues that were within reach (figure 2.8). I performed interviews with fellow doctors about their need of drawing sketches and it turns out the software enabling them to explain anatomy and/or pathology would be a feature most of the doctors would appreciate.

Doctors in the polyclinic use tissues/paper for explanatory drawings

2.6 Decision process of a doctor

Before making decisions about the visualization of the user's input one first has to define the set of data the application will require the user to enter. The performed observations, initial consultations by doctors, as well as example documents depicting the doctor's anamnesis process (fig-

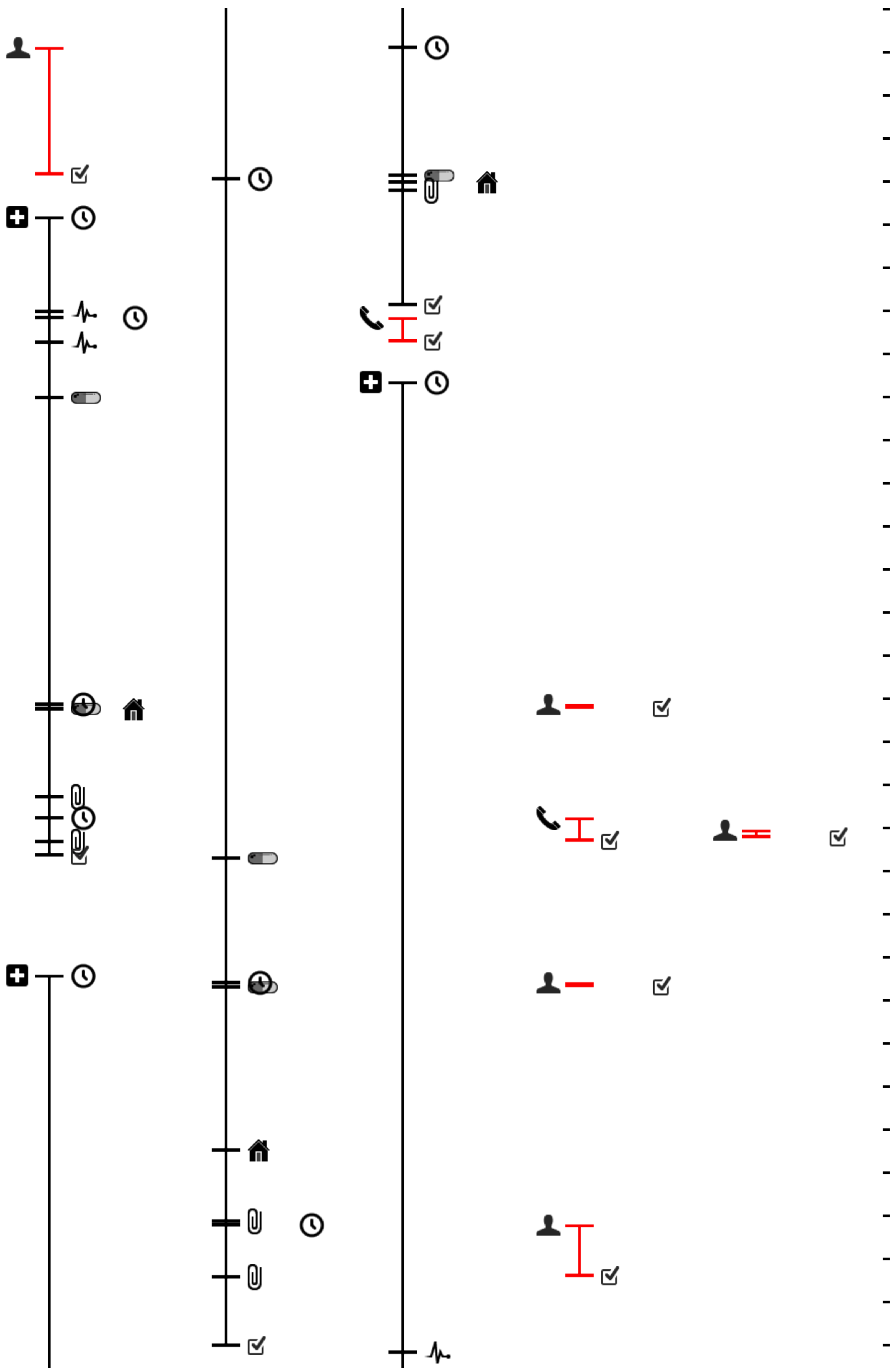


Figure 2.9: An excerpt of the doctor's occupation in 30 minutes. Black columns refer to patient activities, red are distractions

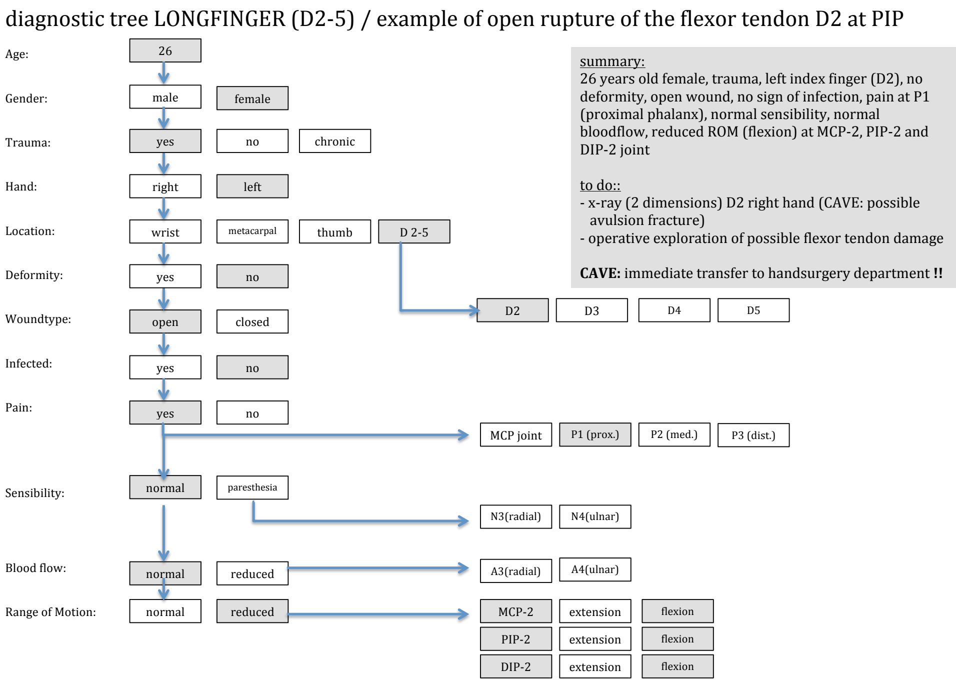


Figure 2.10: An exemplary examination and decision process as provided by hand surgeon Dr. Dunda, UKA Aachen.

ure 2.10) resulted in a initial set of items the user can assign to a case. This set, as well as the corresponding value ranges is shown in figure 2.11.

Decision process starts with anamnesis...

The decision process described in figure 2.10 starts off with anamnetic information being collected. The doctor asks the patient about general information such as age, the injury's type (traumatic or not), and the injury's or other ailment's location. The next steps consist of active examination by the doctor. These aim to find more detailed information about the problematic region such as "is there pain, if so where?", "are there any functional deficiencies?", etc. Based on the answers to these questions, further tests need to be performed, e.g., an X-ray image needs to be taken, if pain is reported, or deformities due to a traumatic injury are visible. In some occasions, however, X-ray pictures for example, are not expressive enough. There exist fractures for example, that cannot be seen by looking at the picture taken. In this case, consultation with colleagues becomes neces-

...and continues with examination

Pain tests reveal injuries not visible in X-ray pictures

sary. Also, special procedures like pain tests (chapter 4) are performed. These tests are statistically known to increase a likelihood of the presence of a certain injury. The implementation presented in chapter 6 provides a functionality for showing instructional videos that aim to educate non-specialized doctors on existing tests.

The observation process described in section 2.3 added one more item: **case severity** with the possible values normal, medium, and high. These values are used to classify waiting patients in UKA's ED (figure 2.5).

List 1: Basic diagnosis information

- **Age:** Number
- **Gender:** male/female
- **Traumatic injury:** yes/no
- **Hand location:** left/right
- **Location of injury:** wrist/metacarpal/finger 1-5
- **Deformity:** yes/no
- **Open wound:** yes/no
- **Infection:** yes/no
- **Location of pain:** any bone or joint of the hand
- **Reduced sensibility:** nerves N1-N10
- **Reduced blood flow:** arteries A1-A10
- **Reduced motion range:** any joint

Figure 2.11: Initial set of data for storing a diagnosis

An anatomic overview of the hand with the here needed parts highlighted can be seen in figure 2.12 . Note that this figure does not contain all parts a hand contains. Also, in order to avoid clutter in description of the bones, arteries, and nerves, names are provided in exemplary manner, but are easily derivable based upon the given information.

The hand as it is used in this thesis is divided into three

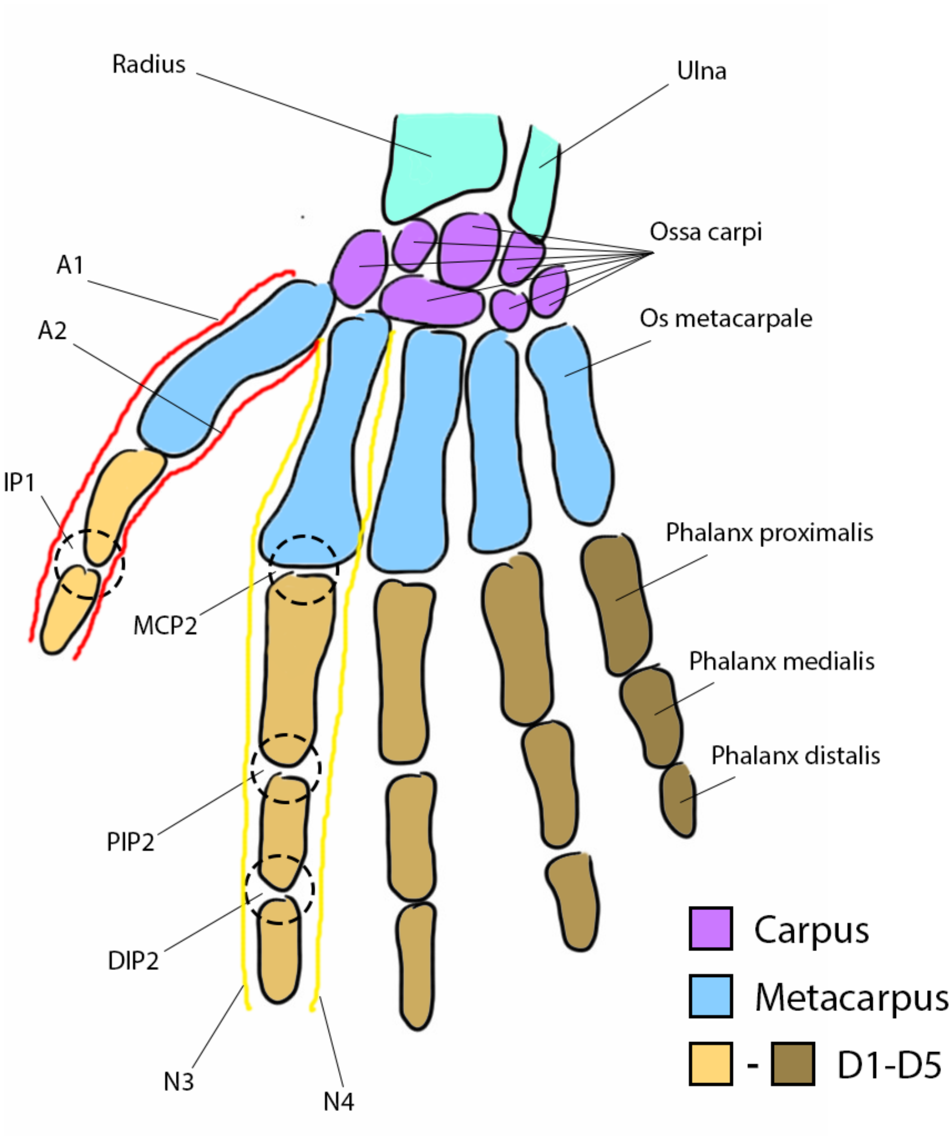


Figure 2.12: An anatomic overview of the hand

parts (figure 2.12):

- Carpus (Os carpi)
- Metacarpus (Os metacarpale)
- Fingers (Digitus manus 1-5)

Starting with the thumb, fingers are numbered D1 to D5. When referring to a joint or a bone located in that finger, the finger's number is appended to distinctly locate the body part (e.g. DIP2, phalanx distalis 5).

All of the fingers but the thumb consist of three bones: phalanx proximalis, phalanx media, and phalanx distalis. The thumb is missing the phalanx media.

Each finger has two joints: articulatio interphalangealis proximalis (PIP) and articulatio interphalangealis distalis (DIP) with the thumb missing the former. A finger is connected to the metacarpus via the articulatio metacarpophalangealis (MCP). The nerves traversing the finger are numbered from N1 (thumb) to N10 with each finger having two nerves, one on each side (ulnar and radial side of the finger). The blood supply is ensured via arteries also being numbered from A1-A10 in the same fashion.

2.7 Patient perspective

Patients are anxious. A doctor's success depends on his professional appearance.

Every patient being in treatment during my observations naturally showed signs of distress. Being unsure about their condition and not knowing what will happen next, patients are anxious and curious about the procedures they are about to undergo. Therefore, it is necessary for a doctor to appear as professional, reliable, and trustful as possible in order to calm down the patient. As I mentioned in chapter 1 the question arises:

Question 7: Q7

Does the usage of a mobile phone by a doctor in situations with patients around possibly have a negative effect on the doctor-patient interaction?

The online experiment performed in the scope of this thesis (chapter 5) targeted at answering this question.

Summary

The research presented in this chapter has shown the structure and complexity of an ED doctor's work. These findings have been confirmed by other research presented in chapter 3. The complexity depicted in figure 2.4 leads to requirements when designing software targeted for doctors working in the domain of an emergency department:

- **Support for fast context switching:** doctors in the ED are forced to handle multiple cases simultaneously (section 2.4 for details). Software targeted towards these doctors should provide features allowing to quickly switch between cases. Therefore, to provide a quick overview of the doctor's cases, only a minimal set of information should be shown. The study described in chapter 5 aimed to find this set.
- **Support for fast retrieval of possibly already closed and partly forgotten cases:** doctors often have to find closed and therefore partially forgotten cases. In order to support the doctor at remembering and thus finding a case easily and fast, software should provide visual clues. Therefore, the implementation described in chapter 6 uses most important information for providing a good overview of stored cases.
- **Reduced distraction from other duties and interaction with patients:** doctors in the ED have to face a lot of new input constantly stressing the load of their working memory. Software designed for the ED doctor's use should keep the cognitive load at a minimum level. Furthermore, the software should assist and involve as little interaction as necessary. Therefore, preliminary design decisions made in chapter 4 include a fast and efficient technique for issue entry and avoid the input of text as much as possible.

Chapter 3

Related work

This chapter first provides the results of a triangulating literature review. Literature regarding research on an ED doctor's work confirms findings described in chapter 2 such as the high mobility and complexity observed. Literature on mHealth introduces into this topic, shows the benefits and flaws of mobile devices in medicine, and provides reasons for real-time 3D visualization as it is used in this thesis. Finally, research on visualization in medical applications is presented. However, unlike visualization used in chapters 4 et seq., the presented techniques use icons for visualization. Following the literature review, a short market scan of available mHealth applications is presented. Based on this market scan, a design space of medical applications has been created. The thereof resulting classification of applications can be found towards the end of this chapter.

Most applications and research use icons for visualization

3.1 Literature

The work of an emergency department's doctor has been subject to a lot of research. Yunan Chen [2010] for example, has investigated on EMR (electronic medical records) and reasons why clinical staff tends to not use them. Instead, physicians and nurses used "transitional artifacts" such as pen & paper to maintain their workflow. Another study by Yu et al. [2010] explores requirements for developing

Clinical staff often has to compensate flaws in EMR software healthcare applications and software systems. While each of the studies had a specific focus set, two characteristics of the ED doctor's work are highlighted by all of them: the complexity and mobility. The research reveals the work of an ED doctor as non-routine, context-driven, highly collaborative, multi-tasking, time-critical, and information-rich. For a detailed discussion of the ED doctor's workflow including a state machine depicting its complexity, see chapter 2.

3.1.1 The ED doctor's mobility / mHealth

As shown in chapter 2, the second main characteristic of an ED doctor's work is its mobility. ED doctors are in care of multiple patients in several rooms at the same time and thus move constantly. Therefore, their use of mobile devices is constantly growing. During the last couple of years, a new discipline has emerged: mHealth (excursus 4).

Excursus 4: mHealth

m(obile) Health expands on e(lectronic) health by using mobile devices such as mobile phones, PDAs, tablet PCs, and smart phones for health-related purposes. There are multiple definitions mostly differing in the target audience (doctor, patient, anybody) and field of use (dosage calculators, monitoring, decision support, reference, etc.). In general (and as it is used in this thesis), mHealth is defined similar to [Hadjileontiadis, 2006] by “mobile communications and network technologies for healthcare systems”.

Proven guidelines for mHealth are not established yet

With the field of mHealth applications for smart phones being a recent phenomenon, proven guidelines on well-working interfaces have not been established yet [Liu et al., 2011]. In their work, Liu et al. conducted a market research on currently available applications for the iOS platform. The top 100 applications according to their popularity were selected and examined from the view of a developer. Surprisingly, only three applications dealing with decision support were found and none of these had the highest (five star) rating by the App Store's customers. Based on the applications and their ratings, the authors suggest an increased incorporation of visualization using 2D graphics. Applications using these ways of visualization were highly liked by the users and were leading the rankings in the App Store. Matching the results of the market research performed for this thesis, no applications using real 3D imagery were found. Most of the applications using this way of display are either only atlases or using pre-rendered graphics. While the latter do enrich their visualization in some way, they do not offer a flexible way of showing the content from arbitrary angles. Additionally, zooming inside the content results in blurred and artifact-ridden images. Clearly — so the authors point out — mHealth apps still have great potential in improvement concerning 3D visualization. This reasoning, as well as existing ideas for visualizing a patient's injury have lead to the choice of using real time-rendered 3D models inside Doctor's Little Helper. See chapter 6 for details.

Utilizing 3D visualization is flexible and suggested by research

3.1.2 Benefits & problems of mHealth

Figure 3.1: MobileWARD by Kieldskov et al., 2007

mHealth applications provide benefits such as context-awareness and interactivity. Context-aware applications like MobileWARD [Kjeldskov and Skov, 2006] in figure 3.1, are able to present data based on the user's context (i.e. his location or him surrounding patients). Instead of being simply passive, on-demand content deliveries, mHealth applications and devices provide the possibility eliminating error-inducing situations in which problems such as mix-ups of patient medication can occur. The user is also able to explicitly query location-based data or let the device guide him to his next tasks. mHealth technology, however, also does introduce problems. There are two kinds of problems: technical and (induced by these): social. The problems are mostly related to the mobile device's form factor. Originating in the device's small displays, problems of visualization and navigation arise: how to display data efficiently without the device demanding too much of the doctor's attention? Doctor's Little Helper (chapters 4 and 6) addresses this issue by eliminating text input with the introduction of an easy-to-use touch-based issue acquisition.

mHealth applications must not demand too much doctor's attention

Eye contact with patients and nonverbal communication are important

Alsos et al. researched the device's form factor effect on doctor-patient interaction [2012]. They compare two form factors of computing devices — an electronic PDA and laptop on wheels — against the use of classic paper charts. It turns out, that it is crucial for a doctor to maintain eye contact with their patients. The authors report that doctors that were able to gaze more were more successful in detecting distress. In addition, classic paper charts offer good possibilities of non-verbal communication. Holding paper charts in different positions implies certain states in the interaction (i.e. holding it against the body indicates the doctor being done with examination). The most interesting result related to this research, however, was the physicians complaining about the PDA demanding too much attention. They felt the PDA became "some kind of a disturbing 3rd party". Finally, the participants found the user interfaces offering poor "information overview and awkward navigation". These findings find confirmation in [Svanæs et al., 2010]. Here, the authors state that in some situations, a shared view between several people (i.e. doctor and patient) is required. It once again shows an example of a social problem originating in technical issues.

Sometimes, a shared view with the patient is required

3.1.3 Visualization & Navigation

The human body provides implicit context and mostly eliminates the need for visual cues

Researchers have been trying to overcome the problems of data visualization on small-screened devices with various visual cues. In [Chittaro, 2006] for example, techniques such as "Focus + Context" and "Overview + Detail" are discussed. The human body as the area of navigation as it is utilized by Doctor's Little Helper eliminates the need for such additions. When zooming in on a model of the human body, the problem of context is alleviated. The location of interest provides an implicit context when zoomed upon. Only in some cases, an additional information of the body side would be required. The reason for this is anatomical information allowing doctors to identify the displayed body part related to the whole body. Reasons for this include that they are exposed to this all the time, e.g., when looking at X-ray pictures, CATScans, films, etc.

General guidelines do not target medical specifics

Holzinger & Errath [2007] investigated on the display of web sites on PDAs. Their research results in rules for web site display on small-screened devices. They suggest the replacement of text with faster-to-recognize visual elements such as colors and icons, and provide some rules on their usage. While these rules are applicable to native applications as well, they are somewhat general. They do not exploit domain knowledge in any way.

(a) Medical symbols (b) Diagnosis based on symbols in (a)

Figure 3.2: Medical symbols developed by Müller et al., 2010

Icon sets do not allow for being overlaid

The work by Mueller et al. (figure 3.2) provides an icon set for retrieval of patient-related data [Muller et al., 2010]. The authors simplified organs in order to provide simpler

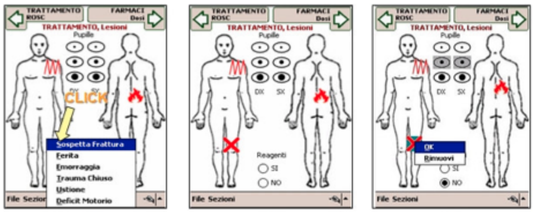


Figure 3.3: PDA-based ambulance run sheet by Chittaro et al., 2007

images and achieve success on retrieval of medical records. However, mixing these icons with a human body model in order to display the patient's issues in place would clutter the display, especially when multiple issues occur in one place. The approach presented in this work (chapter 4) does not incorporate icons for issue-displaying purposes. Instead, a novel input and visualization technique based on color-coded shapes and model distortion allows displaying multiple issues located at one place.

Some research simply transforms paper onto mobile devices instead of re-invention

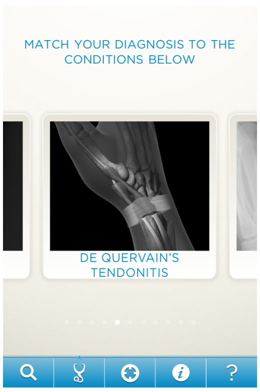
Chittaro et al. [2007] present a PDA application for ambulance run reporting. Example screenshots are shown in figure 3.3 Their prototype means to replace paper sheets previously utilized by firemen and paramedics on sites. The application presented in this work strictly adheres to the paper templates it means to mimic. The input of a patient issue if performed via tapping on the body part in of interest and selecting the issue from a drop-down menu. The selected injury is then displayed on the 2D model via an overlaid icon and/or textual information attachments. This technique, however, once again introduces the problem of displaying several issues in one place. While the research lacks a discussion of this problem, overlaying multiple icons in one place would result in unrecognizable symbols and is therefore not the optimal solution. Again, the solution presented in Doctor's Little Helper, particularly its utilization of direct manipulation of a 3D hand model and the visualization techniques presented in chapters 4 and 6, provides an overlap-free type of injury display.

3.2 Applications

A part of the preliminary work for this thesis included a market research. The research has been conducted in November of 2011 and was restricted to free or low-cost applications available in the iTunes App Store. Hints on existing applications originated from iMedicalApps.com as well as from interviews with fellow doctors. Unfortunately, there are not many decision-supporting applications in the App Store. Available applications are mostly targeted towards end users for self-diagnostic purposes. Six applications have been picked in order to depict the current standards for visualization and navigations.

3.2.1 Hand Decide MD

(a) Visualization of range functions



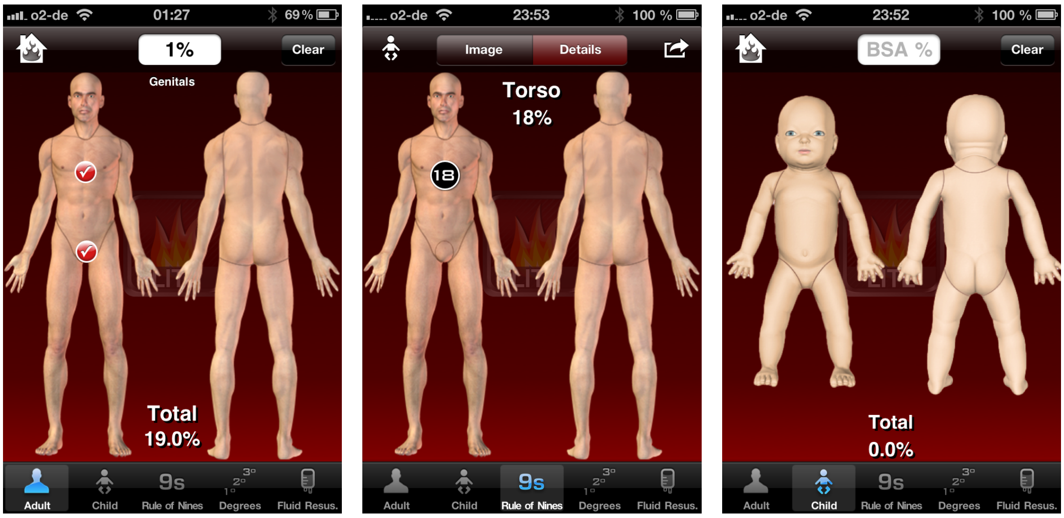
(b) Condition selection

Figure 3.4: HandDecide MD uses pre-rendered images. This results in reduced flexibility

HandDecide MD provides pre-rendered animations

HandDecide MD is meant to teach hand anatomy, conditions, and best practices. This application has been chosen as an example of applications using pre-rendered images. Here, static pre-rendered images are used for displaying the hand. It allows the user to animate basic features such as flexion of the fingers. However, this technique results in two major disadvantages: reduced flexibility and poor quality. Since the models of the hand are not rendered in real-time, viewing the hand from arbitrary angles is not possible. Also, when zooming closely into the images, compression-induced artifacts can bee seen. The application also provides multimedia content including videos explaining surgical techniques. The selection of these, however, has to be done manually and is not based on a patient's issues entered.

3.2.2 UBurn Lite

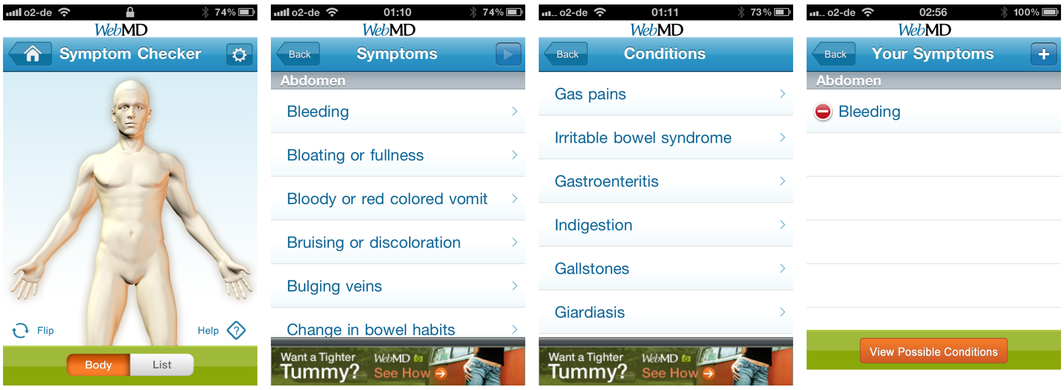


(a) Burn size (adult) (b) Rule of 9s (c) Burn size (infant)

Figure 3.5: UBurn Lite provides selection on pre-rendered images. Here too, the flexibility is reduced.

UBurn Lite (figure 3.5) is a diagnosis-supporting application supporting medical professionals in calculating the total body surface area (TBSA) of the burned patient.. The user taps on a pre-rendered model of the human body, which results in the application calculating the extent of the burns. Although the images are pre-rendered as well, they suffice in this use case. The application uses toggling check boxes for visualizing the user's selection. There is only one input required (the location of the patient's burn) and one output shown. Therefore, no wizard-like functions and no problems concerning navigation come up.

3.2.3 WebMD



(a) Location selection (b) Symptom selection (c) Conditions (d) Symptom management

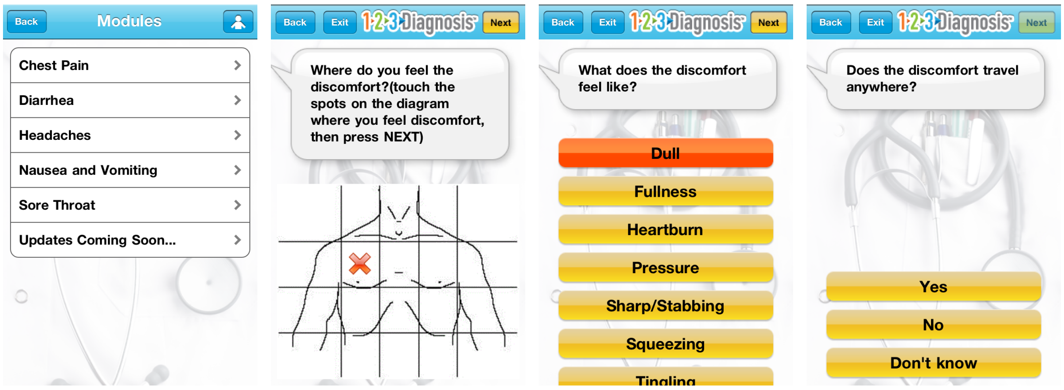
Figure 3.6: WebMD screenshots

WebMD is a shrunk down version of the public internet site, offering information regarding health and health care, including a symptom checklist, pharmacy information, and drug information. It is targeted towards laymen and provides a symptom checker, which is discussed here. The information is entered in one or several iterations, starting with a visual location selection. The selection happens on a static 2D image of the human body. Next, several steps displaying questions regarding pain and its context are shown. After each iteration the user is asked to change the list of symptoms, return to the first step, or proceed to a overview of possible conditions.

WebMD for iOS is a shrunk version of the existing web site

In my view, this application suffers a lot from the small format. Whereas the full-sized version of WebMD utilizes mouse hovering for showing the clickable (and distinguished) body regions, there is no way of knowing what selectable areas are provided. Furthermore, already selected regions are not marked as being so; the steps of the iterations are missing a visual connection in any way.

Missing features from desktop computers reduce usability



(a) Module selection (b) Location selection (c) Questions (d) More questions

Figure 3.7: 123 Diagnosis screenshots

3.2.4 123 Diagnosis

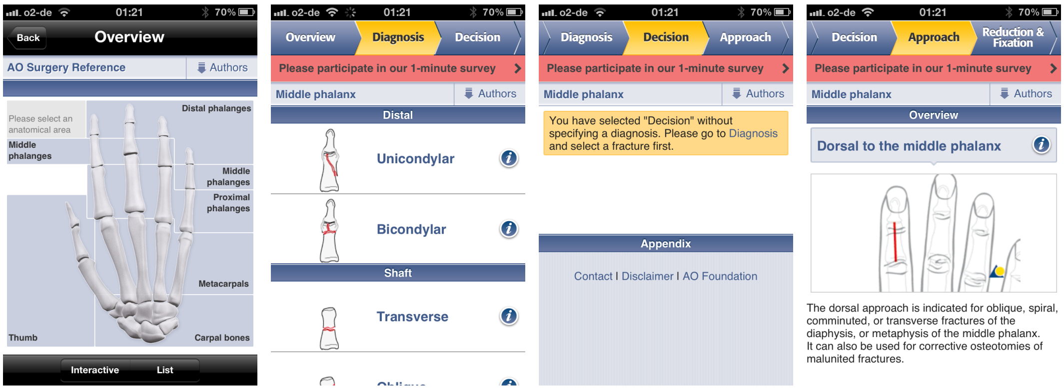
Long sequences of questions in 123 Diagnosis do not offer convenient access to previous questions

Similarly to WebMD, 123 Diagnosis is an application targeted towards users wanting to check upon their symptoms. It queries the user a very long sequence of questions regarding his issues. Unfortunately, the overview here is very bad. Users navigating through long sequences of (on average more than 20) questions have no chance in remembering their decision. Revising the choice requires navigating back through all steps performed, one by one. This kind of navigation is typical for iPhone applications and should be avoided when designing software for use in time-critical situations. Sample screenshots are shown in figure 3.7.

3.2.5 KittelCoach

Some applications are shrunk down books with no more than PDF functionalities

KittelCoach represents applications that are basically shrunk down books. There is almost no interactivity inside the program, solely book-like content enriched with hyperlinks is provided. This approach does not utilize any of the features modern smart phones offer for fast navigation, remembering the navigation path, etc.



(a) Step 1 (b) Step 2 (c) Step 3 (d) Step 4

Figure 3.8: AOSurgery Reference screenshots

3.2.6 AOSurgery Reference

AOSurgery Reference is another application porting a website to the iOS platform. It aims at doctors as its target group and provides diagnosis-supporting reference for procedures. The reason it is has been picked is its navigation cue display. The navigation bar used in this application has a width of approximately three times the screen's size. It is scrollable, but hides items being more than two steps away from the current. This problem arises from using text describing the steps. The necessity of scrolling could have been eliminated by using meaningful icons like Doctor's Little Helper does (chapter 6). This design choice would have resulted in a better information overview. Sample screenshots of are shown in figure 3.8.

Utilization of long navigation items devaluates the navigation bar

3.3 Design space of medical software

In order to get a better overview of medical software, a design space and the taxonomy is it based upon is presented.

The classification of the applications is performed according to four dimensions:

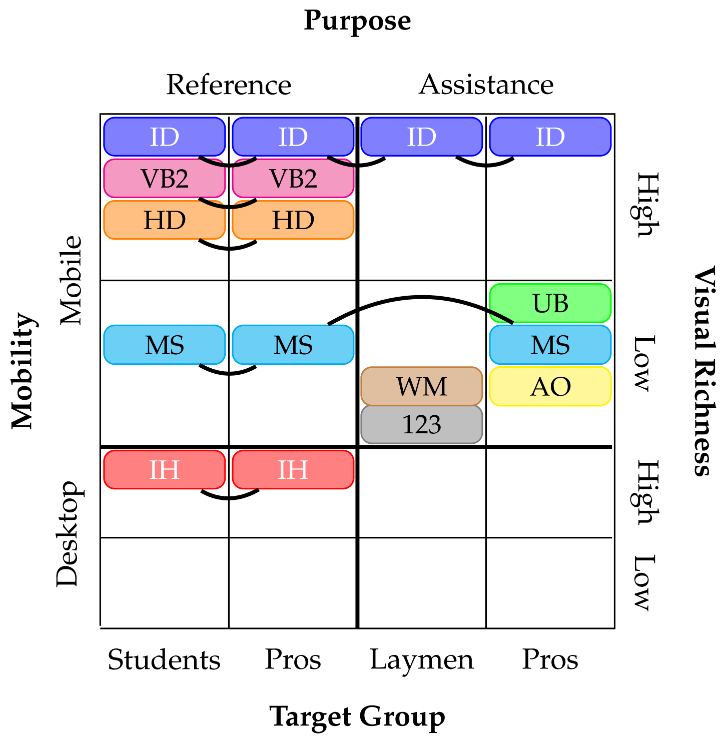


Figure 3.9: Taxonomy of medical software

- **purpose**: reference/teaching ⟷ emergency assistance
- **target group**: students (laymen) ⟷ professionals
- **display**: text/static images ⟷ directly manipulating multimedia content
- **mobility**: desktop ⟷ mobile devices

A set of representative applications for most categories has been selected and placed in the design space. These applications are:

- VB2 - Visual Body iPad2
- HD - HandDecide MD
- UB - UBurn
- MS - MedScape iPhone
- IH - Interactive Hand
- 123 - 123 Diagnosis

- KC - KittelCoach
- AO - AOSurgery Reference
- WM - WebMD

ID stands for an ideal mHealth application targeted at medical staff. This software would be optimized for mobile use, support assistance as well as reference, and provide high visual richness/flexibility. The latter would exploit the possibility of providing good mappings, and the human mind perceiving color/images faster than text. An alternative placement of this application would target students/beginners or professionals only and still providing good value.

3.4 Summary

While the research and applications presented in this chapter provide good value by providing an interface to huge databases of decision-related data, their interfaces as such are often sub-optimal and not suitable for a time-critical field of use. They either suffer providing dynamic visualizations, or expect the user to cope with a small virtual window of the whole picture being displayed. This thesis aims at providing visualization techniques improving on these issues. The presented techniques are introduced in chapters 4 and 6. They allow to implement less cluttered interfaces and therefore a higher ease-of-use.

Presented visualization techniques not suitable for time-critical usage

Chapter 4

Visualizing hand injuries for diagnosis and recall

This chapter describes the evolving design decisions. Starting off with basic ideas of displaying the diagnostic information using colored regions on the hand model, the visualization has been refined in several steps. Reasoning behind ideas regarding the regions' shape, determination of a proper color coding, as well as solutions to problems with multiple issues in one place are presented. Next, the focus group meeting and the therein received feedback is described. Finally, a short description of a prototype used for testing the targeted hardware's feasibility is given.

4.1 Preliminary design decisions

Naïve solution for abandoning scrolling: show everything in one screen

The obvious and naïve solution to question 1, namely reducing the need of scrolling through several screens, is to display all data at once/on one screen. The problem arising from this idea is the limited space on the iPhone's screen. Visualizing everything at once can quickly lead to a cluttered user interface with the displayed information being hard to extract by the user.

List 2: Basic diagnosis information required

- **Age:** Number
- **Gender:** male/female
- **Traumatic injury:** yes/no
- **Hand location:** left/right
- **Location of injury:** wrist/metacarpal/finger 1-5
- **Deformity:** yes/no
- **Open wound:** yes/no
- **Infection:** yes/no
- **Location of pain:** any bone or joint of the hand
- **Reduced sensibility:** nerves N1-N10
- **Reduced blood flow:** arteries A1-A10
- **Reduced range of motion (ROM):** any joint

Figure 4.1: Initial set of data for storing a diagnosis

Question 8: Q8

When showing all user input on one screen, how to display the data "efficiently", i.e., minimizing visual clutter and reducing the cognitive effort needed for information extraction.

The observations described in chapter 2 revealed a set of data to be entered into the application (figure 4.1).

Having the small screen of the iPhone in mind, I kept looking for a possibility to further reduce the data displayed in the wizard view in order to rearrange the UI elements. The first five items of those listed in figure 4.1 are static in terms of the decision process; they do not affect the suggested diagnosis. Therefore, the decision has been made not to display any of them while querying the user input regarding the patient's issues. The freed up space was then used to

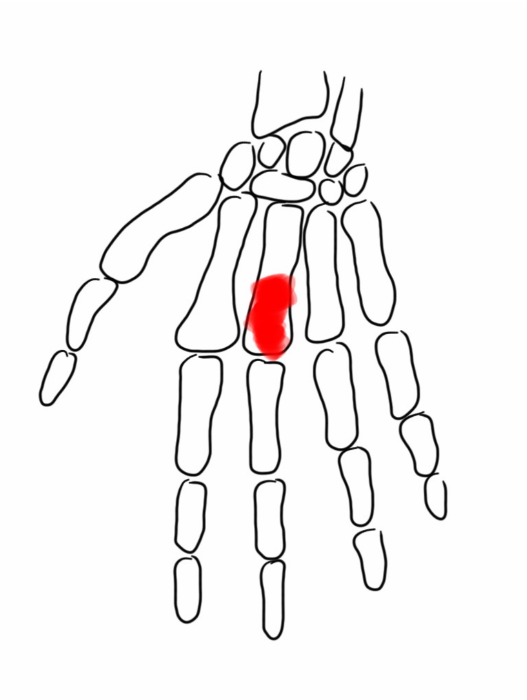


Figure 4.2: The early idea of showing a patient's issue. The red mark shows the location of an injury.

display the questions in the final prototype.

Looking at the different injuries/issues a patient can have, two main visual cues have been determined:

- **color overlay:** infection, open wound, etc.
- **shape distortion:** luxation, fracture, or swelling.

With the premise of extinguishing the user's need of reading large amounts of text, the choice fell on displaying a model of a human hand and using colors on one hand, and shape distortion on the other.

Two visual cues picked up for engineering

Using colors and shapes, one can exploit the human perception by putting emphasis on areas of interest with the help of coloring them and thus drawing the user's attention on the patient's issues very quickly. An example of an early sketch is shown in figure 4.2. The red mark is simply denoting the location of some injury the patient has.

Colored shapes allow providing location information quickly

Question 9: Q9

When using colors for displaying the patient's issues, what color coding is understandable for a doctor?

Red is associated with a lot of issues and therefore a problematic color

When looking at the patient's issues from the anatomic point of view, however, a problem arises from the fact that a lot of injuries are connected to blood. An open wound for example, is characterized by blood extravasating out of the wound. Also, arteries are always drawn in red. Therefore describing an arterial disfunction such as a reduced blood flow is again connected with blood. The problem here is having one color — red — being associated with multiple issues. After studying the book presented in figure 2.6 an initial color coding has been determined:

- **Open wound:** red. Reasoning behind assigning red to this issue included blood extravasating and being visible.
- **Reduced sensibility:** yellow. In most anatomic books and sketches, nerves are depicted in yellow. Therefore, it was a straightforward decision to choose this color.
- **Infection:** green. One of the human body's chemical reactions upon body tissues being invaded with disease-causing microorganisms is to produce and exudate called pus. The color of this fluid ranges from (brown-)yellow to green. Since yellow was already taken (see above), the decision fell on using green for this type of issue.
- **Reduced blood flow:** blue. Reduced blood flow initially leads to extremity/limbs turning blue (venous blood flow) or white (arterial blood flow). Despite the fact that the information gathered in the application concerns the arteries, blood flow reduction is the underlying issue in both cases and should provide a good mapping.
- **Pain:** red rings. Rings represent a target, red color used for pain. This visualization is often used in advertising when showing the location and/or presence of pain.

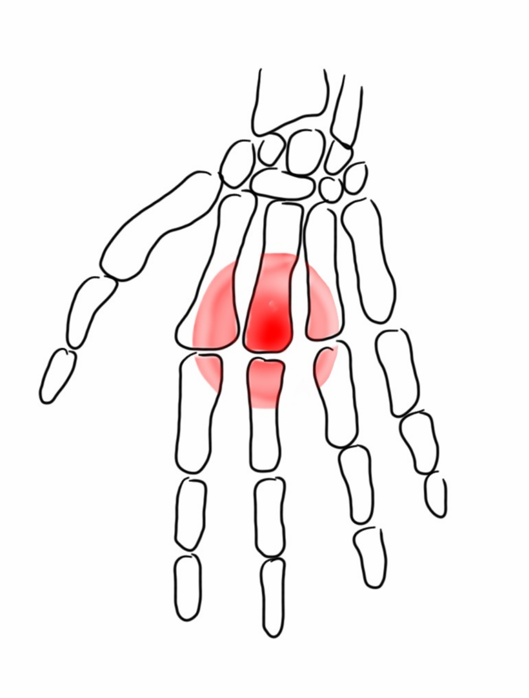


Figure 4.3: An issue shown using a circular shape

The understanding of these color codings was tested with users using the app. More on testing the color codings in chapter 6. Having answered the question of color coding the patient's issues, the question of how to display the colored area arose.

Question 10: Q10

How (in what shape) to display the color assigned to an injury?

According to Jürg Nänni, the author of "Visual Perception" [Nänni, 2008], there is more cognitive effort to perceiving rectangular shapes, than it is to perception of circles. Apparently, edges involve additional neuronal image tools and thus slow down the process of perception. Therefore, it has been decided on displaying the location in a colored circular/elliptic shape. To add additional location information, the intensity of the colored shape is not equally

The chosen elliptic shapes enhance the efficiency of perception

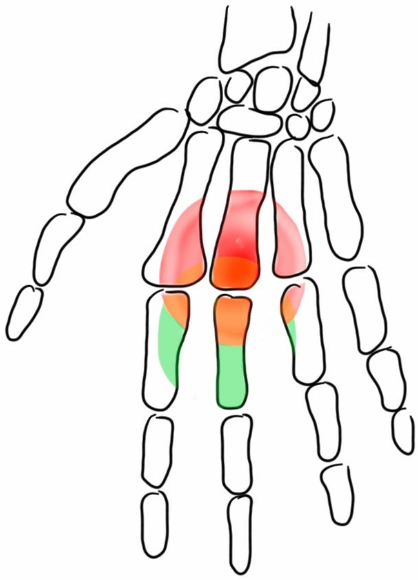


Figure 4.4: The problem of two issues overlapping. The red-colored shape overlaps with the green shape, resulting in a new color in the overlapping area.

Fading opacity emphasizes center of injury

Overlapping shapes result in new colors

spread. Starting with the opacity of 1.0 in the shape's (and injury's) centre, towards the border, the opacity is linearly faded out. This allows the user to (a) localize the location of interest by its displayed intensity, as well as (b) to partially overlap near-existing shapes. Now, a lot of times, there are multiple issues in one place, or at least very near to each other. With the described technique of opacity-blending, simply blending the colors one on top of the other would result in new colors. These colors may already have been assigned to a different issue and thus mislead the user. The problem is shown in figure 4.4 where the red and green circles overlap. This results in another orange/brown color in the overlapping area having the potential to reduce the efficiency of the user's perception.

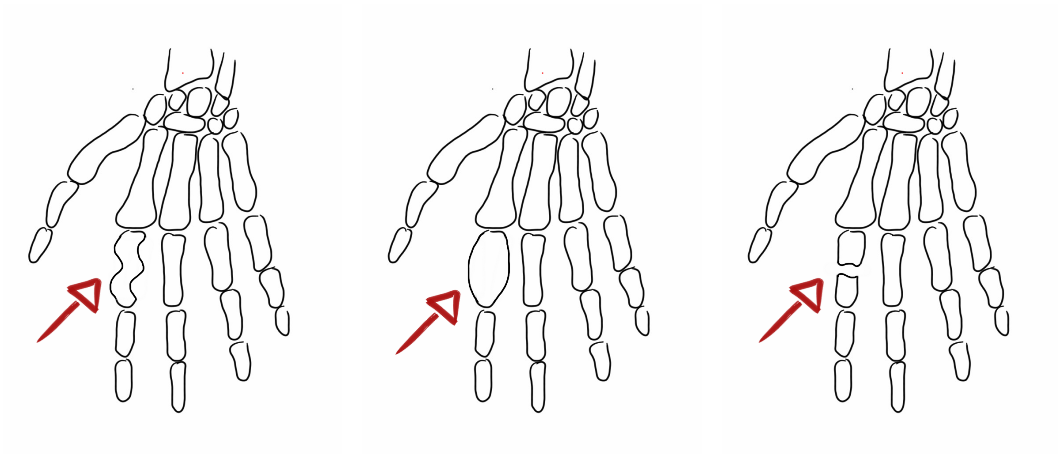
Question 11: Q11

How to display multiple issues located near to each other?

The idea resolving this issue was not present until the stage of early prototypes and is described in chapter 6.

Whereas using colors for issues listed above would probably work well, injuries being visible by a change of the body's shape should be also visualized the same way, in order to achieve a good mapping: by shape distortion of the displayed hand model. In addition, distortion of the model provides another dimension of visual cues which allows more issues to be displayed in once place. Therefore, initial ideas for displaying a fracture (distortion) or swelling included a sine distortion and "blowing" up the limb of interest in order to mark the location of interest. Sketches are shown in figure 4.5.

Adding shape distortion allows more issues to be shown in one place



(a) Sine deform (b) Blow-up of bone for swelling (c) Bone fracture

Figure 4.5: Ideas for distorting the bones for visualization of deformities

With almost all of the injuries of interest being covered, one last group of body parts remained undealt with: joints. Looking back at the decision tree in figure 2.10, there are questions concerning a reduced range of motion, as well

Reduction in joint functionality is shown using text

as positive results on certain pain tests. Both these data are connected to joints and should therefore be displayed at these body parts. Unfortunately, having already used up most distinguishable colors as well as reasonable shape deformations, there was no other choice left than using text for displaying joint-related information. The possible values of range functions that can be reduced, as well as the list of pain tests the user can perform are shown in figure 4.6 resp. 4.8. As the number of the simultaneously possible values maxes at four, the initial decision was to use the initial letters (e.g., E for Extension) to be used and shown inside the joint in question. Since the names for the pain tests are not distinct with Tabatiére and Tinel starting with the same letter, adding "i" for Tinel (which takes up less space than the "a" in Tabatiére) was necessary.

List 3: Range functions

- **E**xtension
- **F**lexion
- **O**pposition

Figure 4.6: Range functions of finger joints

4.2 Evaluating the visualization: paper prototype & focus group

The observations conducted in the UKA's ED as well as inquiries in form of interviews with fellow doctors have lead to more detailed design ideas. Based on the features suggested by the interviewees as well as observed facts, an initial UI structure has been developed. It consisted of four main views:

- Case view (list): provides an overview of all cases. The cases are depicted as folders as used in real world to provide a good mapping

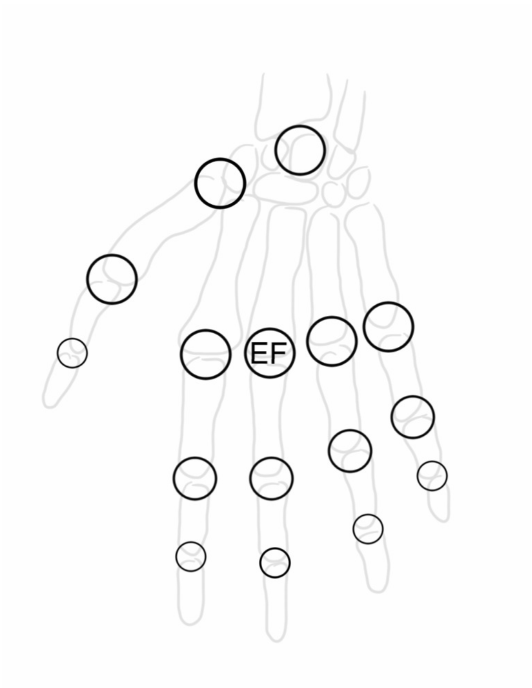


Figure 4.7: Idea for visualizing reduced range of motion. Here a simultaneous reduction of extension (E) and flexion (F) is shown.

- Case view (detail): a zoomed in folder for emphasis on a selected case. When opened, additional information such as taken photos is shown.
- Wizard view: provides the functionality of accessing a patient's injuries as well as their visualization. Additional links to instructional videos are provided
- Search view: searching for stored cases

with the case view being divided into a list and a detail view. Sketches of these ideas are shown in figure 4.9. These sketches served as the basis for paper prototypes. These prototypes were meant for presenting the ideas elaborated so far to another group of doctors in order to get feedback and see if the ideas corresponded to their needs.

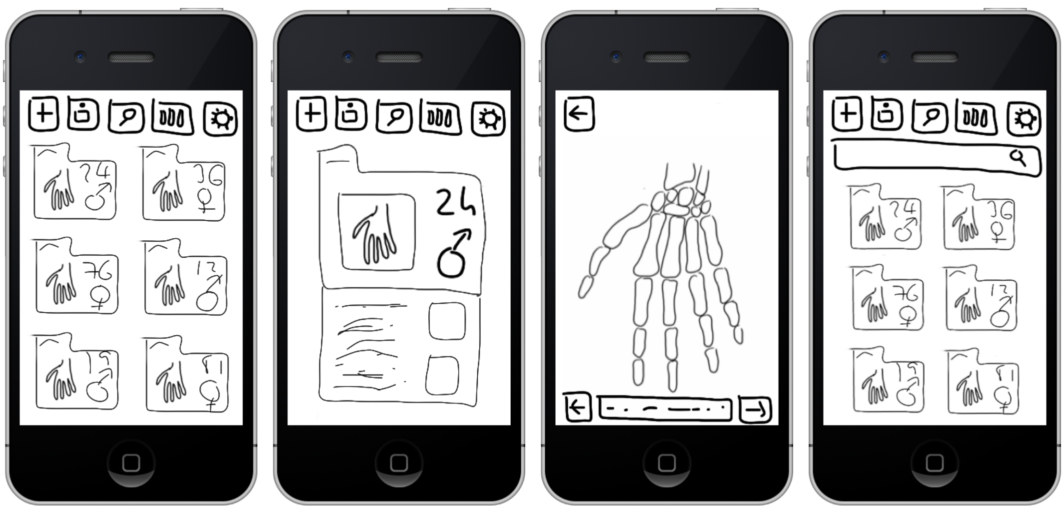
Simple sketches served as basis for paper prototypes

To get more detailed feedback on the developed paper prototypes a meeting with four doctors of the UKA has been

List 4: Pain tests

- **F**inkelstein
- **T**abatiére
- **Ti**nel
- **W**atson

Figure 4.8: Pain tests named after their inventors



(a) List view (b) Detail view (c) Wizard view (d) Search view

Figure 4.9: Initial sketches

A focus group meeting with four doctors served early feedback

set up. These doctors served as a focus group of potential future users of the application being developed. The doctors were all specialized in the domain of hand surgery, male, and between 29 and 35 years old (*M*=32.5, *SD*=3). The agenda set up ahead of the meeting and serving as a guide for the discussion is shown in appendix A.

Excursus 5: Focus group

A focus group is a moderated discussion group that is usually used in market research to get qualitative feedback. Most of the time, focus groups are composed of people belonging to the potential target audience of a product in development. Focus group meetings allow to get early feedback on initial ideas. Key elements of focus groups are:

- the topic is set by the moderator/researcher
- the topic is introduced by a short presentation
- the end result is created throughout a constructive discussion among the participants

Another goal was to talk to the doctors in a more relaxed atmosphere, giving them more time to think about the ideas they are confronted with. The doctors have been shown the drafts and took part in a discussion, as well as presenting other ideas and thoughts on decision-supporting software. The prototypes shown to the doctors are presented in figures 4.10-4.12. Since the doctors did not agree on the meeting being recorded in any way, the meeting has been recorded using pen & paper. The mostly structured nature of the meeting that has followed the prepared agenda helped when evaluating the results.

Focus group members mainly dissatisfied with existing applications

The meeting resulted in valuable information being fed back. The doctors once again have confirmed the general findings of the observation sessions (chapter 2) such as the high parallelism and workload of the doctors. Reasons that primarily accounted for being unsatisfied with the current software were:

- incoherent user interface
- slow and limited feedback
- not fitting in the doctor's workflow

These reasons, however, are not of generalizable nature. They are strongly related to the software that is used at the UKA. The software suite combines several distinct programs into one package and makes no effort in doing so in an integrative way. This results in using several programs requiring different approaches to be remembered.

The goal, that has really been appreciated was the reduction of (text-based) input to a lowest possible level. Incorporating touch-based interaction with hand model and not having to type texts would provide a more intuitive way of interaction and speed up the work, so the doctors suggested.

Doctors demanded a textual transform of the touch-based input

Another demanded feature that stood out was the ability of generating a report based on the (3D) model-driven input. A further leading idea regarding this transcription was generating a documentation on what has been done in terms of the patient's treatment. Until now, each of the doctors is to document every billable activity that has been performed. Doing so results in looking up the procedure's code in a database and crossing it off the printed document that represents the "invoice" for a patient. Integrating this tedious and repetitive (as perceived by the participants) activity into the touch-based solution would save time and make the additional context switch performed during this activity obsolete.

The participants repeatedly expressed their need of being supported in their memory. Two ways of doing so have been discussed:

- making scribbles
- taking pictures
- recording audio

Only one of the doctors had experience in mHealth applications. The software he used was AOSurgery Reference and was satisfied in general. A discussion of this application can be found in chapter 3.

The initial fears of the iPhone leading to stress in doctor-patient interaction have unfortunately been confirmed. The participants were of the same opinion that the device being associated with private use such as texting messages or surfing the web could have a negative affect on patient or their relatives. People observing a doctor using his smart phone (either while interacting with a patient or simply when walking by) could tend to mistake the doctor for being constantly not focused on his duties. This would result in negative perception and maybe mistrust against the doctor. This problem, however, would be easy to solve simply by putting a case around the phone disguising it as a work-related device. Furthermore, a doubt in the device's size in general was expressed. The doctors said, a bigger device would be preferred. The iPad as a solution was discarded very quickly with its size being seen as too big and not fitting into a doctors pocket. This concern has also been investigated in the survey described in chapter 5.

Focus group meeting confirmed fears concerning the smart phone's form factor

Finally, the doctors got to see the paper prototypes created for this session. The general reaction was quite positive with two important items of constructive criticism as feedback:

- though the idea of identifying a patient by a picture was seen as being good, 2 doctors said they sometimes remember the patient as "being a smelly obese bald man". This information, however, cannot be graphically visualized. They agreed on freely assignable visuals (picture taken, rendered image, etc.) being a good idea and supportive.

Remembering a patient sometimes based on not visualizable associations

- the overall response was to make the arrangement of visualized data being freely customizable. It seems even with four people of the same profession and education, there is no consistent mental model for presenting the data and the individual preference varies greatly.

Applications expected be freely customizable

Towards the end of the session, three last ideas have been discussed:

1. speech input for controlling the device
2. context awareness

(a) Paper prototype: list view (b) Paper prototype: detail view

Figure 4.10: Paper prototypes for the list and detail view

3. visualization of procedures

Speech input

Speech input may be problematic in noisy and stressing surroundings and discloses information

Despite demanding speech input regarding the data channel, there was no doubt left that controlling the device via speech is not suitable to the context of an ED. The doctors expressed their concerns over issues like privacy (data cannot be restricted to the user interacting with the device), distraction (being preoccupied with work and using speech

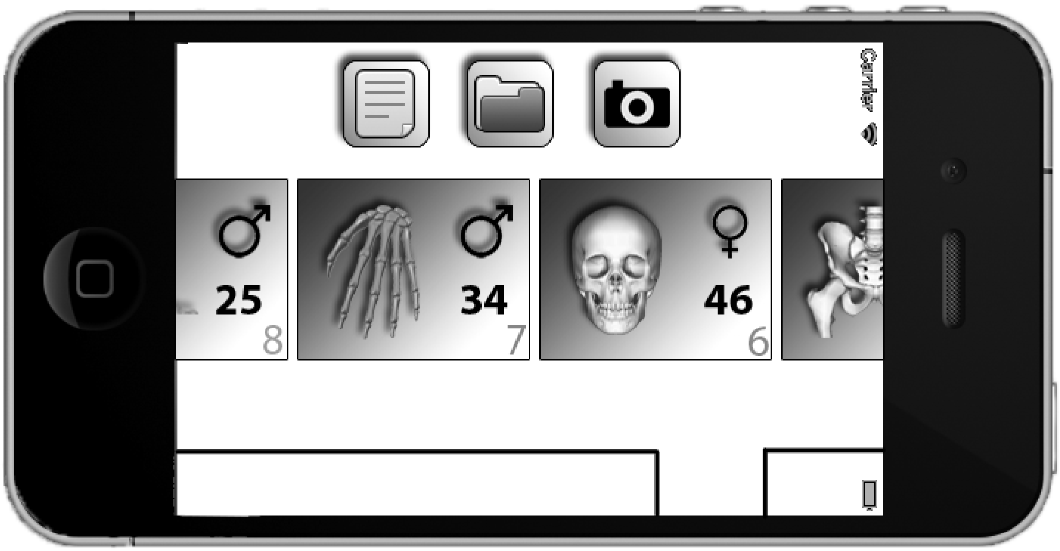


Figure 4.11: Prototype of the idea of context awareness

in order to perform tasks not connected with the thoughts), unintentional activation, and problems concerning noisy surroundings making the speech input badly functioning. Whereas the last concern could be alleviated by advances in speech recognition, the former are of general nature and cannot be avoided.

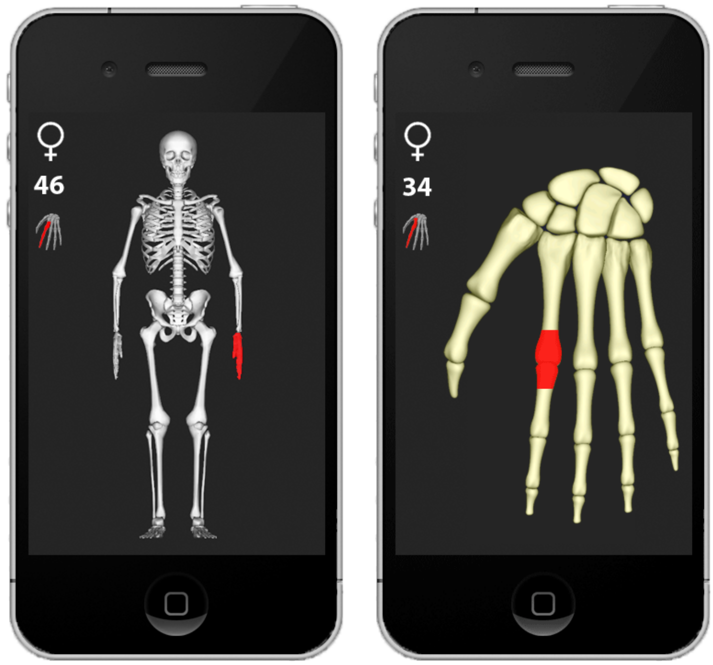
Context awareness

Context awareness considered a huge help when used in big hospitals

The doctors generally agreed on context awareness being very supportive feature. Being a consultant for example, doctors need to manage their list of tasks manually. Being told when and *where* a patient awaits their presence, managing their cases would become easier with the doctor being able to concentrate on the patient's issues instead of finding them. The feature would be especially handy for doctors being new to the hospital. With the UKA having almost 1300 beds it is definitely a place to become familiar with.

Visualization of procedures

The last topic discussed, was the support in explaining procedures a patient is about to undergo. The participants stated, that this kind of explanation has to be done very often. Unfortunately, once again with the doctor's schedule being packed, there often is not enough time for doing this thoroughly. Visualizing anatomy on a hand set and being able to show it to a patient, would be a feature — the doctors said — very welcome and timesaving.



(a) Paper prototype: model/wizard view

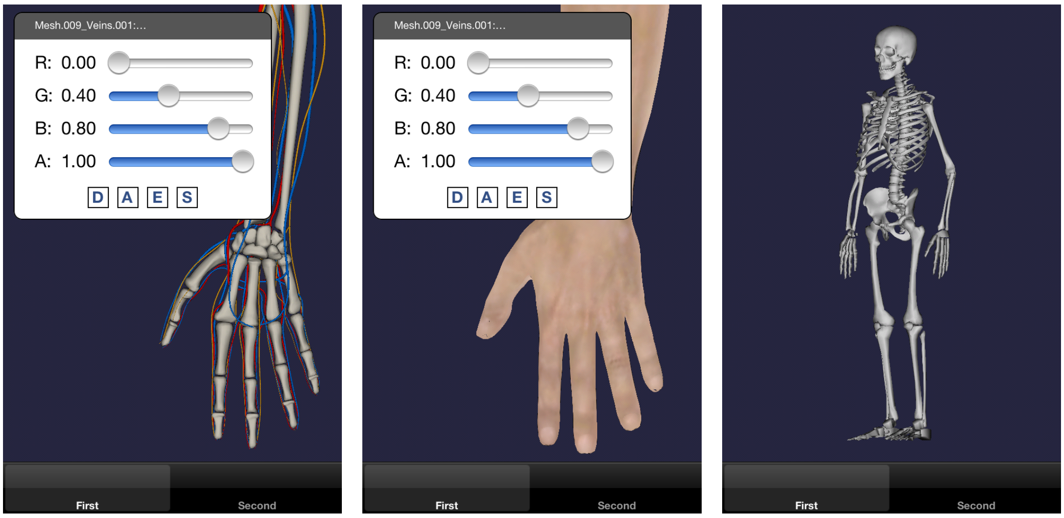
(b) Paper prototype: model/wizard view zoomed in

Figure 4.12: Paper prototypes. Red markers highlight the regions of interest.

4.3 Hardware feasibility

Research-based ideas for 3D visualization needed to be proven being feasible

Initial ideas for visualization of the hand inside the application included using real time-rendered 3D models. These ideas have been strongly backed up by market research for iOS-driven devices presented in [Liu et al., 2011]. In order to check upon the iPhone's GPU being powerful enough to display the hand model, a sample application has been developed.



(a) Hand model (b) Texture capabilities (c) Benchmark

Figure 4.13: Screenshots of the OpenGL|ES 1.1 test application

This test application used OpenGL|ES 1.1 with its fixed function pipeline for displaying the hand model. A sample screenshot of the application is shown in figure 4.13. The app has been used to perform basic benchmarking tests. The application displayed a real-time rendered 3D model and allowed the user to perform basic actions such as zoom and rotation. Animations were triggered via a double tap and automatically zoomed in on the selected body part. The results have proven the iPhone 4S and newer to be powerful enough for displaying 3D models consisting of about 120,000 vertices at sufficing frame rates of 40-60 frames per second.

iPhone 4S is powerful enough to display real time renderings of hand model

Chapter 5

Quantitative study: implications of the device form factor

The initial literature review, the observations at the UKA's emergency department, as well as talks with the focus group have lead to unanswered questions. There was also need for quantitative feedback by potential patients, as well as doctors. Therefore, two surveys — each of them containing an online experiment — have been designed. Both surveys had the goal of a better understanding of the target group and the subjects they encounter in their every day (work) life. The first survey was targeted towards the potential patients, the second towards the doctors.

Two online surveys, one for patients and one for doctors aimed at answering questions

5.1 Patient's attitude towards the form factor

5.1.1 Background

The smart phone is a device used in our everyday life for mostly private purposes such as surfing the web, gaming, texting messages, and other social interaction such as Facebook or Twitter. Therefore, it is likely that the mobile phone is perceived by people around the user as being used for private rather than professional activities.

Whereas studies such as [Houston et al., [2003]] aimed at finding the patient's acceptance of mobile devices used by doctors in general, the more specific goal here was to find out, whether the of the form factor has an influence on the patient's perception of the doctor's professionalism.

The smart phone's recent change in capabilities may have affected its perception

Nowadays, the smart phone is probably primarily being associated with private activities mentioned above. Recent changes in the smart phone's capabilities however, lead to the devices being used for professional purposes as well. Unfortunately, at the time of the interaction one cannot see, and therefore, judge, the purpose it is used for. The communication channel between the user utilizing the smart phone and the device itself is closed for people watching the interaction and does not allow any insight into the ongoing communication. I therefore conducted an online experiment with the goal G1 to investigate this issue.

Tablet PCs were expected to have a small impact on the patient's perception

Mobile computers are not entirely new to the medical field. Tablet and mobile computers (i.e., laptops on wheels) are being used by medical staff for quite some time now. Therefore, the tablet PC's form factor has been included in the conducted survey. The question here was, whether there is a difference in the perception/acceptance of these devices when compared with mobile phones. The device was expected having a small, however not significant, impact on the patient's perception.

Goal 1: G1

Find out, whether the utilization of a smart phone, when compared to a tablet PC and paper chart, has a negative effect on the impression the doctor leaves on the patient and/or him/her accompanying people.

5.2 Task

The participants were divided into three groups, each of them first seeing a video of the same one minute long anamnesis/examination procedure starring a doctor and a patient. Each version of the video contained a different device used by the doctor during the interaction. The audio track has been removed from the video in order to eliminate any distractions and confounding variables during the experiment. The video has also been edited to be as short as possible on one hand, expressive enough on the other, not exceeding the participants attention span for too long.

Three groups, each saw a different tool used by the doctor

Next, each participant was asked to answer several questions concerning their perception of the doctor's professionalism, friendliness, interest in the patient, and the harmony of the situation in its whole. The answers were collected using Likert scales with possible values ranging from one (i.e., very unprofessional) to five (i.e., very professional). The participants were also given the chance of giving a reason behind their choice in form of free text.

Participants estimated the doctor's professionalism

Finally, the following set of everyday devices was presented:

List 5: Everyday devices

- smart phones
- tablet PCs
- computers in general
- TV sets/media centers

Figure 5.1: Everyday devices presented in the survey

The participants were asked to pick activities which they associate with each of these devices. The possible choices are listed in figure 5.2. Here, multiple selections per device were allowed. These associations were collected to provide a more detailed explanation behind the participant's answers. A member of the smart phone group stating his

Associations of everyday devices served to put the participant's choice into perspective perception of the doctor was professional, friendly, and interested, would probably not think that a smart phone's primary purpose is limited to private use.

List 6: Assignable activities

- media consumption
- maintaining social contact (Facebook, Twitter, SMS)
- work organization
- creativity
- gaming

Figure 5.2: Activities to be associated with everyday devices

An additional an optional page collected demographic data such as age, gender, work experience in the medical field, and the amount of hospitalizations within the last ten years. Reasons for the last two questions included assumptions that participants being used to doctors operating with a smart phone could be simply used to it because of working in a hospital or having been there several times in most recent time. In case of the participant's positive perception, their background could qualify their choice.

5.3 Experimental design

(a) Control group: paper chart (b) Treatment 1: tablet PC (c) Treatment 2: smart phone

Figure 5.3: Screenshots from the videos on device factor perception

The experiment's design has been set to between groups, so each of the participants would see only one variation of the independent variable (i.e., one version of the video). The independent variable was the device's form factor, with overall two variations and one control group setting. The devices used were a smart phone (a Samsung Galaxy S3) and a tablet PC (Apple iPad). The control group saw the doctor using a classic paper chart as it is known to be used in hospitals.

Between group design hid the purpose of the experiment

Since there was no existing survey software available allowing to present one random video per visitor but registering which he has been shown and repeatedly showing it to him every time he comes back, a custom software had to be implemented. This was necessary to ensure every member of a certain treatment group sees only one variation of the independent variable and is not able to make guesses on the background of the experiment.

Custom survey software ensured the experiment's internal validity

In addition, all questions concerning the video have been presented in a shuffled order per participant. This measurement meant to eliminate potential leading of the participants by putting emphasis on the first question following the video, and therefore eliminating suspicion the first question would be the most important.

Randomized questions avoided emphasis on questions

Sample screenshots of the videos are shown in figure 5.3, the full survey can be found in appendix B.

Based on the assumptions made, the following null-hypothesis has been formulated:

> **Hypothesis 1: $H1_0$**
>
> The device has no (significant) impact on the user's perception of the doctor's professionalism.

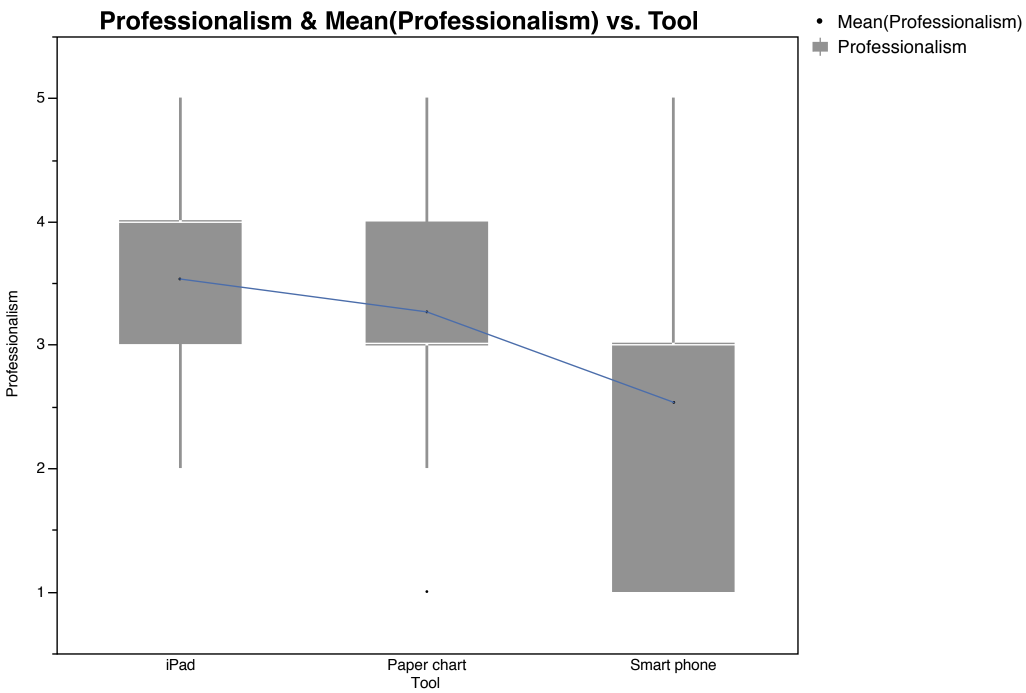


Figure 5.4: Box plot of the perceived professionalism

5.3.1 Results

A total of N=45 people participated in the experiment, with 15 participants per condition. 19 participants were female (42.22%), 24 male (53.33%), and 2 of unspecified gender (4.44%). The participants' age ranged between 11 and 62 years, with a mean of 30.95 (SD = 6.18).

Doctor using the smart phone received an overall lower score

The box plot of the answers regarding the perception of the doctor's professionalism is shown in figure 5.4. The doctor using the smart phone during the examination received an overall lower score (M=2.53, SD=1.25) when compared to using a tablet PC (M=3.53, SD=0.74) or a classic paper chart (M=3.27, SD=1.1). A Kruskal-Wallis test with α set to 0.05 revealed a significant effect of the form factor on the perceived professionalism ($\chi^2(2)$=6.1062, p=0.0472). Therefore, the null hypothesis has been rejected.

A posthoc pairwise comparison using the Wilcoxon rank-sum test showed a significant difference betwen the smart

Level	-Level	p-Value
Paper chart	smart phone	0.1028
Paper chart	iPad	0.4807
smart phone	iPad	**0.0174**

Table 5.1: Nonparametric pairwise Wilcoxon comparison results

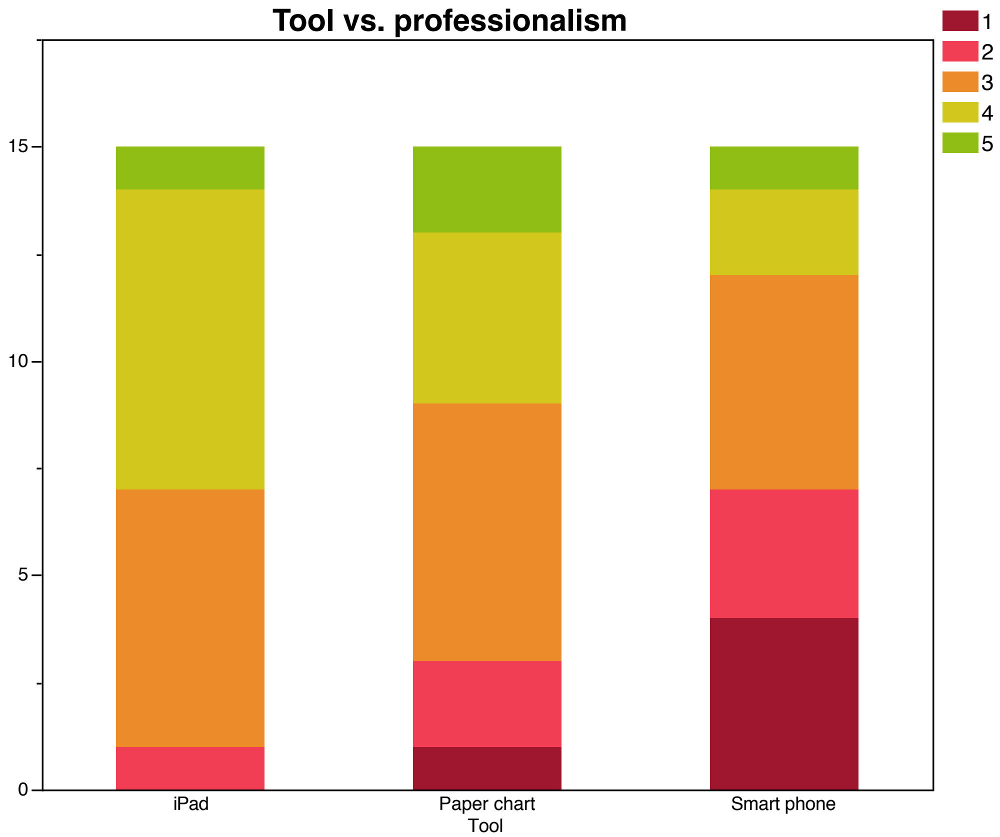


Figure 5.5: Distribution of the perceived professionalism from 1 ≙ very unprofessional to 5≙ very professional

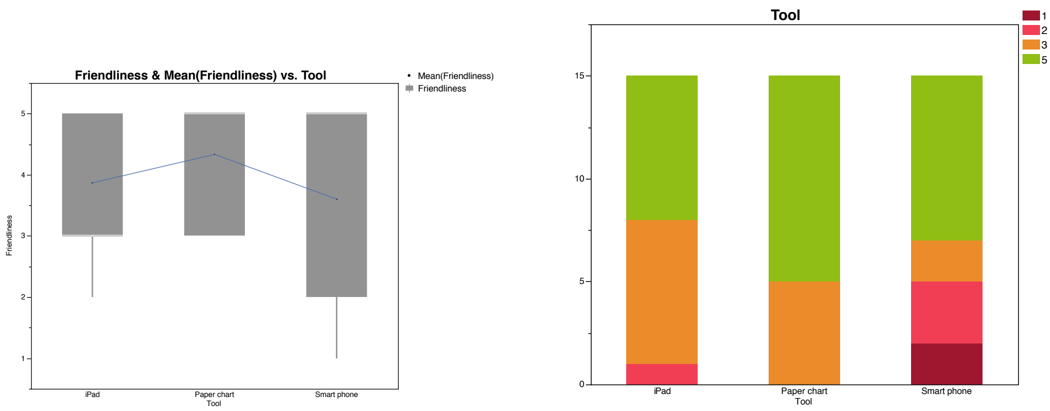
phone and the tablet PC (Z=-2.38, *p*=0.02) but not between the paper chart and the smart phone (Z=-1.63, *p*=0.10) and between the paper chart and the tablet PC (Z=-0.71, *p*=0.48) (figure 5.1).

Only a significant difference between the smart phone and the tablet PC was found

Figure 5.5 shows a detailed distribution of the scores. Clearly, the doctor using using the smart phone lead to more participants perceiving the doctor's professionalism

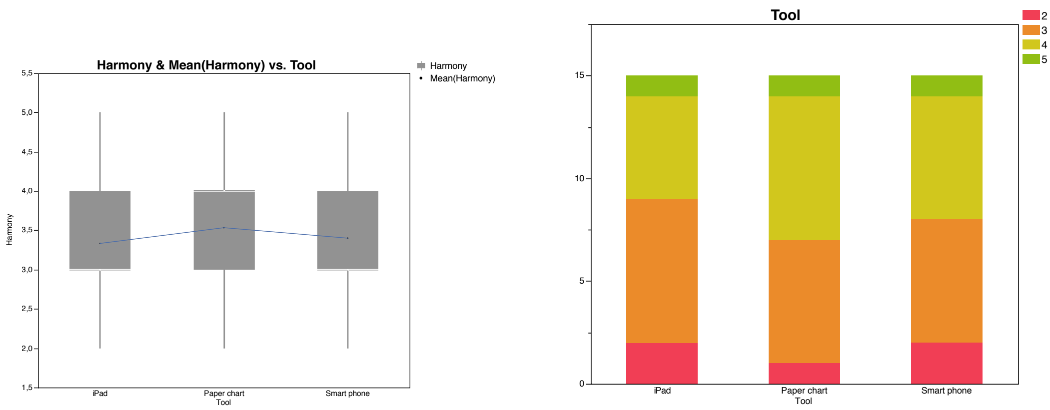
The smart phone may have negative impact on the doctor's professionalism

to be bad, or very bad (46.67%) than using the tablet PC (6.67%) or the paper chart (20%). These results indicate a tendency of a smart phone as a working device having the potential of causing distress in the doctor-patient interaction. I therefore suggest to disguise smart phones in order to guarantee a stress-free situation. This, for example, can easily be accomplished by enclosing the device within a case (see section 7.1 for the hereof resulting guideline).



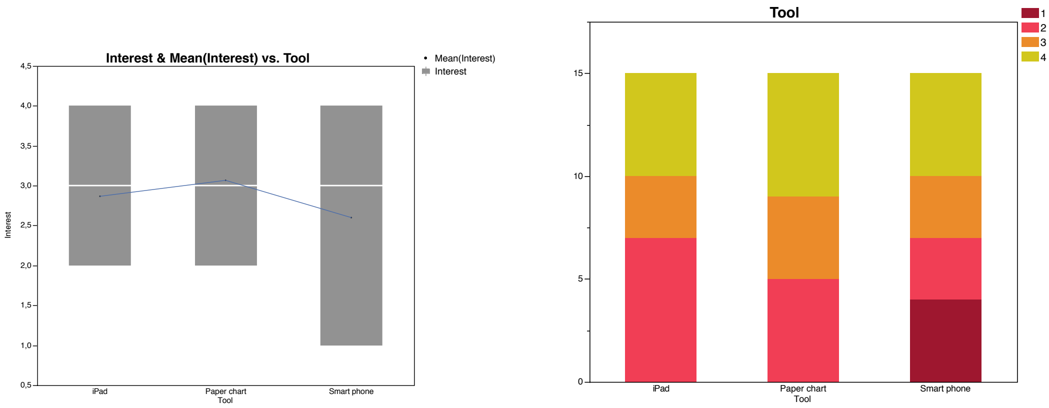
(a) Box plot: friendliness (b) Distribution: friendliness

Figure 5.6: The box plot and score distribution of perceived friendliness of the doctor



(a) Box plot: harmony (b) Distribution: harmony

Figure 5.7: The box plot and score distribution of perceived harmony of the situation



(a) Box plot: interest (b) Distribution: interest

Figure 5.8: The box plot and score distribution of perceived interest in the patient

Answer	$\chi^2(2)$	p-Value
Professionalism	6.1062	0.0472
Friendliness	2.1248	0.3456
Harmony	0.5506	0.7593
Interest	1.2309	0.5404

Table 5.2: Overview of Kruskal-Wallis test results

5.3.2 Qualitative evaluation

Participant's expressed clear disapproval of the doctor's interaction with a smart phone

In order to understand the reasoning behind the choices when judging the doctor's behavior as unprofessional or very unprofessional, a qualitative analysis of the optional free text input has been performed. Only two of the participants (50%) who judged the doctor as very unprofessional used the opportunity of explaining their choices. These participants however, very clearly expressed their dissatisfaction with the doctor's "playing with his smart phone" in front of the patient. They said the doctor "does not show interest in the patient" and "is constantly typing on his smart phone" when justifying their choices regarding the doctor's friendliness and interest in the patient. Despite the amount of explanations staying low, they show that there are people feeling treated in an unprofessional way because of the doctor's interaction with a smart phone.

The questions concerning perceived friendliness, the harmony of the situation shown, and the interest of the doctor did not show any significant impact of the device's form factor. The resulting box plots are shown in figures 5.6-5.8. The overview of the results of the Kruskal-Wallis tests for all answers regarding the video is shown in table 5.2.

5.3.3 Association of activities with everyday devices

Device	media	social	work	creativity	gaming
smart phone	65.12%	90.7%	83.72%	39.53%	55.81%
tablet PC	84.62%	79.49%	56.41%	51.28%	74.36%
computers	90.7%	95.35%	88.37%	93.02%	62.79%
TV sets/media centers	97.67%	0%	0%	0%	20.93%

Table 5.3: The participants' association of devices and their purposes

The last step of the analysis consisted of the evaluation of the purposes which the participants associated with the presented device classes. The results are presented in table 5.3. Computers and TVs are omitted from the following discussion, since their inclusion in the possible answers solely served to hide smart phones and tablet PCs among further electronic everyday devices with potentially overlapping associated purposes.

Discussion

Most participants associated the smart phone with social interaction

As expected, most of the participants (90.7%) associate the smart phone with social interaction. On the other hand, many participants (83.72%) associate working with smart phones, too. This shows the participants accepting the smart phone as being part of *their* working life. It seems, however, they do not expect this device to be used by a doctor. Even with the tablet PC being less associated with work-related purposes, the smart phone seems to represent a distracting device not entirely accepted during an examination. Another surprising result is the overall high association of a tablet PC with not work-related activities such as gaming or media consumption and still the tablet PC not having negative impact on the doctor-patient interaction. Here, the lower association of the tablet PC with social interaction may be the main reason accounting to the reported perception.

These results present possible reasons for the smart phone being a device with potential to negatively affect a doctor's work. With the smart phones becoming more and more omnipresent, this could change in the near future. Until then, a simple case hiding the device from the patient should forestall any problems.

The perception may change in the future with the smart phone becoming accepted

5.4 Doctor survey

5.4.1 Background & design

The findings from observation sessions as well as triangulation with the focus group have shown that there certainly seems to be room for improvement in the field of medical software. The first goal of this survey was to confirm this finding. The survey aimed at finding out what current flaws there are in terms of visualization, navigation, and workflow integration.

Findings regarding dissatisfaction with medical hard-/software had to be confirmed

Goal 2: G2

Learn more about hard- and software used by the participants and their satisfaction with it. Set focus on:

- visualization
- navigation
- workflow integration

The survey first gathered experience-related data with medical software in the field of mHealth. Participants have

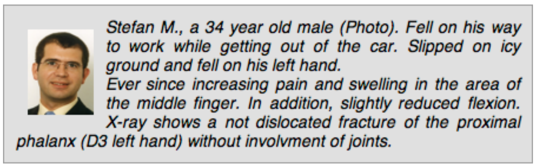


Figure 5.9: The sample case presented to doctors in the survey

been asked about their satisfaction and got room for qualitative feedback. During the focus group interview the mobile device's size has been complained about a lot. The survey did also aim at finding out the optimal size of a mHealth device and by this backing up or discarding the interviewed doctor's view.

> **Goal 3: G3**
>
> Find out what is the optimal mHealth device size is, as perceived subjectively by a doctor.

Survey aimed to generalize previous findings

The second part of the survey dealt with a central design goal of Doctor's Little Helper: supporting the doctor in remembering and finding cases quickly. The idea was to provide sufficiently visually stimulating information on a patient so doctor's are supported in their context-switching activities. The members of the focus group already have named their preferred data they would consider important. But is this data generalizable?

> **Goal 4: G4**
>
> Find out what the smallest subset of patient related data is needed, in order to support a doctor on finding a case quickly.

Sample fictional case was presented

Participants have been presented a sample fictional case (figure 5.9). They were asked to read the description, and proceed to the next step and not to go back and review the case. Here they have been presented a folder, and several pieces of information describing the patient, his injury, as well information describing the circumstances of the incident (see list 5.10).

List 7: Patient related data

- photo of the patient's face
- age
- gender
- severity
- X-ray image of the finger
- X-ray image of the hand
- photo of the finger
- photo of the hand
- a field for free text input

Figure 5.10: Patient data assignable to a case

Drag & drop assigning of items allowed prioritization of visual cues

They were asked to assign the data represented by images to the case by using drag & drop and by this showing what is important to them. By allowing the doctors to change the selected images in their size, they have been enabled to prioritize the selected data simply by making it bigger. Once again, the survey software had to be adapted to support this kind of data entry. A sample screenshot is shown in figure 5.11.

Finally, demographic data has been collected. For the full survey see appendix C.

5.4.2 Results

Most participants were surgeons

A total of *N*=15 doctors has participated in the survey. The participants' age ranged 27 to 41 (*M*=33.13, *SD*=4.12). They had at most 13 years work experience (*M*=5.5, *SD*=3.74) and

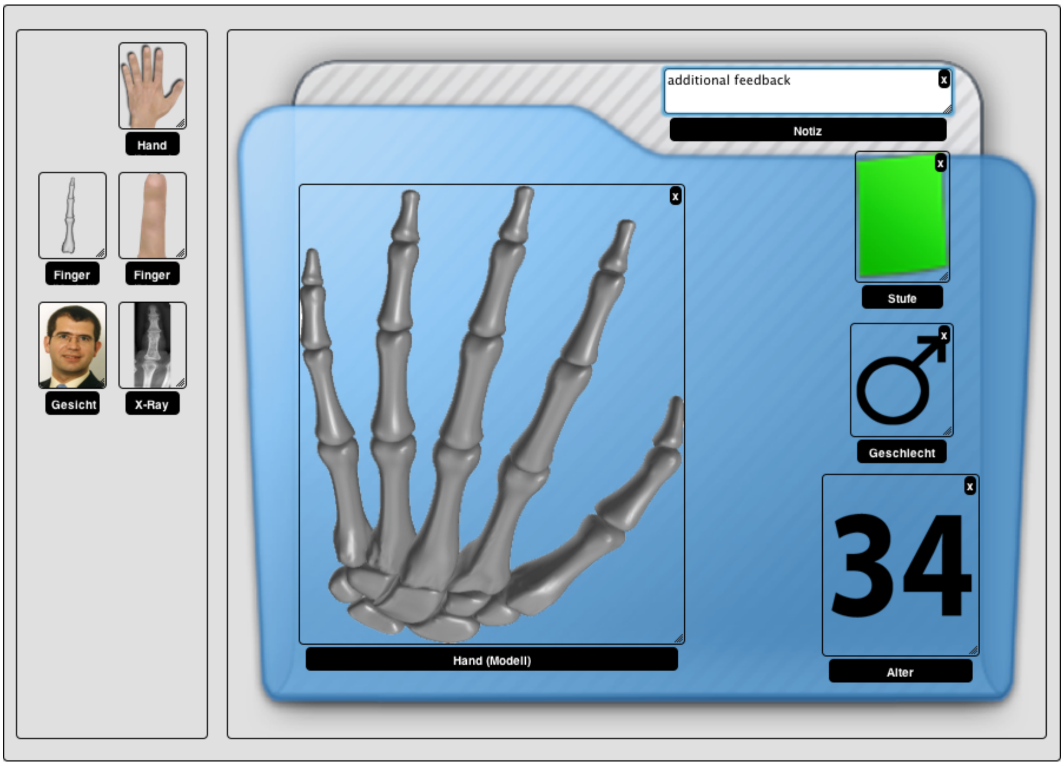


Figure 5.11: An example of the doctor's data-assignment

were primarily surgeons (80%). Since the number of participants is small enough, a subset of the raw data is presented in figure 5.4. The results have been divided into groups for easier summary:

Experience and general satisfaction with mHealth solutions

Only few participants had tablet PC experience at work

Doctors were satisfied with their devices

All of the participants stated having experience with smart phones. Only 40% already have worked with tablet PCs before. The purpose all of the doctors used the devices for was reference. 53% additionally had experiences with decision-supporting software. Satisfaction with the used devices was measured on a Likert scale from one to five (very satisfied to very unsatisfied). The overall mean satisfaction with the used smart phones and tablet PCs was 4.21 resp. 4.25 (≙ "satisfied").

					Experience		Satisfaction		Purpose	
Gender	Age	Domain	Work in ED	Practice (yrs)	SP	TPCs	SP	TPCs	Ref.	DS
female	39	Plastic surgery	•	10	•		4	-	•	
male	29	Surgery		0	•		3	-	•	
male	27	Trauma surgery	•	1	•		4	-	•	
male	35	Surgery	-	6	•		5	-	•	
male	31	Plastic surgery		3	•	•	5	5	•	
male	35	Plastic surgery		9	•	•	5	-	•	•
male	33	Orthopedics/trauma surgery		6	•	•	-	-	•	•
male	34	Plastic surgery		7	•	•	5	5	•	•
male	36	Plastic surgery		9	•		4	-	•	•
female	27	Plastic surgery	•	1	•		4	-	•	•
female	31	ENT	•	3	•		4	-	•	
male	35	Anaesthesia	•	7	•	•	4	4	•	•
male	35	Surgery	•	4	•	•	4	3	•	•
male	41	Plastic surgery	•	13	•		4	-	•	•
female	29	Pediatrics	•	3,5	•		4	-	•	
M	33.13			5.5			4.21	4.25		
SD	4.12			3.74			0.58	0.96		

Table 5.4: Raw result data from doctor survey. Satisfaction scores from one = (very unsatisfied) to five (very satisfied). - = no answer, • = yes/present. SP = smart phone, TPCs = tablet PCs, DS = decision support

Visualization and navigation

Mostly text visualization was reported. Satisfaction was only neutral

All but one participant described the used applications' visualization as "mostly text", with 60% enhanced by 2D images. This result once again proves not many applications utilizing 3D visualization techniques and confirmed me in the decision to pursue the goal of usable 3D display. The overall satisfaction concerning the visualization turned out to be just sufficient, getting a mean score of 3.54 ($\triangleq$ "neutral"-"satisfied").

Form factor

Doctors suggested devices five to nine inches tall

Being asked whether small screens are considered problematic, 80% answered with "yes". Two third of these named "readability", the remaining 33% "split content" their main concern. Concerning the optimal size of a mobile device, 86% of the users suggested a maximum size of nine inches, with 40% expressing the preference of even smaller devices down to five inches.

Workflow support

The workflow support by the existing applications has been considered almost satisfying with a mean score of 3.6. Most of the applications used did not force the user to enter values before continuing, and allowed an arbitrary order of data input.

Patient information

Most participants draw sketches for patients

80% of the participants stated that they would explain anatomy and/or procedures to patients on daily basis. 73% of the doctors draw sketches. This finding supports the idea of software being able to support the doctor in this activity. While a freely manipulative 3D model as partially implemented in Doctor's Little Helper would eliminate the doctors need of drawing, specialized animations would be a feature supporting doctors in this activity.

Case visualization

X-ray cue prioritized the highest

Almost all of the offered assignable items have been used. The top four images were: X-ray picture (46%), photo of

Nr	Face	Hand(P)	Hand(M)	Finger(P)	Finger(M)	Age	Prio.	Gender	X-Ray
1		●				•		•	●
2	●		●			•			⬤
3									
4		●	●						●
5									
6	●								●
7			●	●	●				
8					●				
9		•	●	●					
10									
11									
12	●	●				●	●		
13		●				●		•	⬤
14				●	●				●
15		●	●			●		●	⬤

Table 5.5: Priorities assigned to suggested visualizations by participating doctors. Size of the bullet corresponds to the priority given. (M) = Model, (P) = Photo

Results did not reveal a clearly determined set of data

the hand (40%), image of the hand model (33%), and age (33%). The X-ray picture however, was the one prioritized the highest. Apparently, every doctor has his own preferences when it comes to remembering cases. Therefore, applications aiming for best support should empower the user with assigning their own combinations of images displayed. Initially, however, no pictures exist in a newly created virtual case. To cope with this and due to time constraints on this thesis not allowing to explore this feature in detail, Doctor's Little Helper always presents the rendering of the hand model on the cases' front view. An overview of the assignments as performed by the participants is shown in figure 5.5.

Results not generalizable due to small sample size

Unfortunately, the number of participants stayed very low, leaving generalizations not possible. Three aspects however, were answered uniformly by most participants and have been therefore picked out for discussion:

- **device size**
- **concerns regarding small screens**
- **visualization techniques used so far**

Smart phone's size considered too small

Device should fit in the doctor's coat's pocket

Apparently, the smart phone with an average of four inches diagonal display size is being considered too small. Having interviewed several doctors, most of them state they love "going mobile", as long as the device is not too small. Ideally, the device would have the size of a doctor's white coat's pocket. This explains 40% of the participants voting for a device between five and nine inches. A device that size would also solve the unpopular necessity to read on small screens, but remaining a handy tool at the same time. Luckily, the iOS platform allows to develop universal applications for a smart phone and a tablet PC without huge amounts of extra work required. The application developed in the scope of this thesis can therefore easily be converted to the iPad and so satisfy a wider range of potential users.

Mostly text-based interfaces encourage research on visualization

Summing up, the survey once again shows the main visualization technique for mHealth applications so far being text-based. In my opinion it results from the widely used approach of simply scaling down existing eHealth applications and/or keeping the development costs at a minimum. It once again confirmed the need for research of new visualization techniques as presented in chapters 4 and 6 being necessary.

Chapter 6

Implementation & Evaluation

The implementation process was performed in several iterations of user-centered iterative design. This chapter describes the steps performed, the problems arising, as well as their solutions.

6.1 Low fidelity prototype & general UI structure

After already having run through the process of early prototyping with storyboards, initial sketches, and paper-mockups (see chapter 4), paper prototyping was the next step. This session has been conducted with the help of a fellow doctor (female, 34, five years work practice). To prototype closer to the targeted device (and its limiting size), it has been decided to use a technique incorporating clear foil instead of paper (figure 6.1). The cut out foil was placed on the phone running an application constantly displaying a white screen. This way, a change of UI elements was a matter of seconds. The foils have been prepared according to the prototypes in figure 4.9 and the participating doctor has been asked to perform a predefined series of steps and comment on each step he was about to perform. The steps

Clear foil prototyping allowed fast UI changes

Figure 6.1: Clear foil prototypes

targeted the three tasks:

- browse existing cases (open, close)
- create a new case
- search for a case

With the mapping being very clear and thought of as "promising", the session primarily resulted in abandoning the idea of the hand overview when querying the user for details, as it has been considered unnecessary.

Next, a general UI structure has been defined. The structure as well as the connections between the views is shown in figure 6.2. The main view starts off in list mode and allows the user to browse through the cases. By performing a pinch gesture, the displayed cases are stacked and the

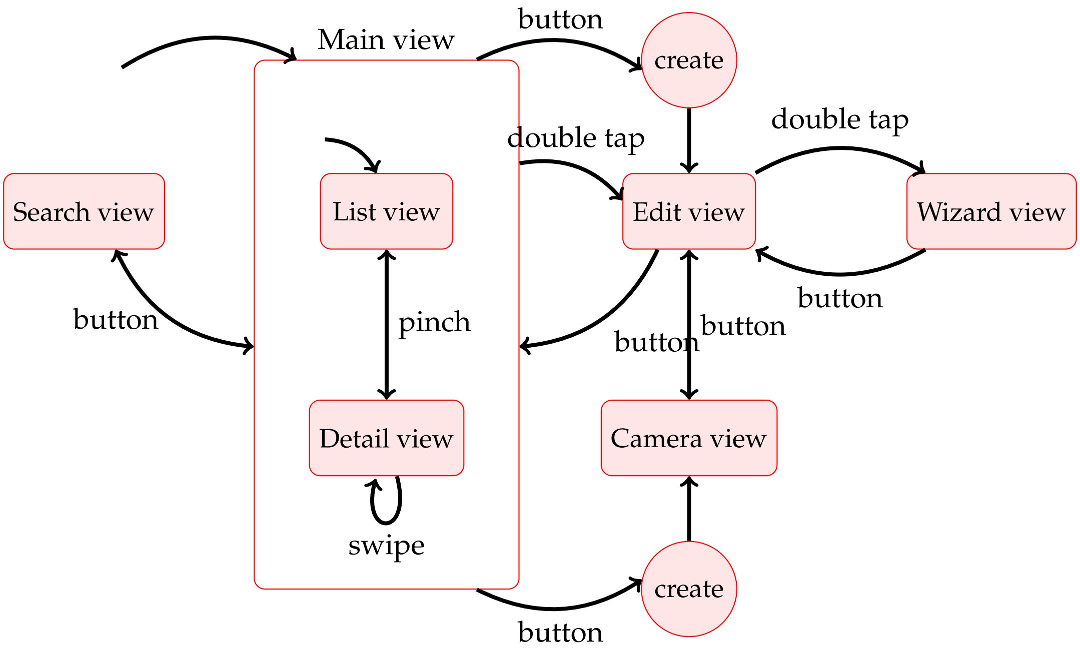


Figure 6.2: Overview of the general UI structure

main view switches to the detail mode increasing the size of the case and displaying one case at a time. The user now can browse the stack by performing a swipe gesture. These gestures have been chosen since they map to a real setting, where cases are lying on a desk and could be treated the same way. Switching to different views is done by tapping on buttons in the navigation area displayed on top of the screen. This way the user can switch to the search view for finding cases, the edit view for changing the case's contents, or the camera view for taking pictures and attaching them to a case. When creating new cases, the application automatically changes to the edit view or (serving as a shortcut) to the camera view allowing to take pictures and attaching these to the newly created case. When editing a case, the user can perform a double tap on the displayed rendering of the hand, switching to the wizard view which is used for entering the patient's injuries.

6.2 Flash prototype

First interaction-based flash prototype evaluated with the think-aloud protocol

The first software prototype was implemented using Adobe Flash . The goal of this prototype was to see a more concrete UI and its elements. It also offered the possibility to include basic interaction and add animation. Screenshots of this prototype are shown in figure 6.3. For the purpose of evaluation, another meeting with Dr. Dunda has been set up. The evaluation has been performed using the think-aloud protocol, with the doctor being asked to follow the same procedure used with the clear foil prototype. Finally, he was asked to give feedback on the UI.

(a) List view (b) Detail view (c) Edit view (d) Wizard view

Figure 6.3: Flash prototype screenshots

The session revealed the question section of the wizard view (see figure 6.3 (b) bottom) being too big and it overlaying the model was reported as being not optimal.

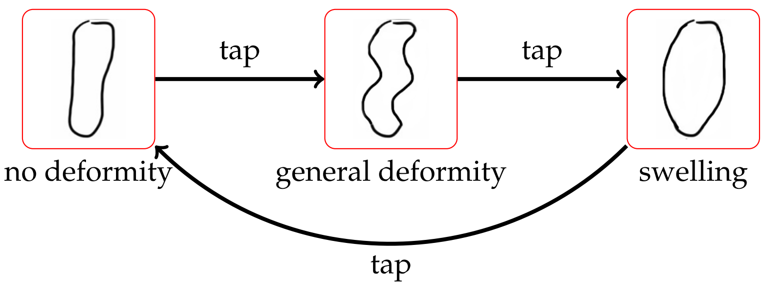


Figure 6.4: The three-way-switch behavior regarding a deformity

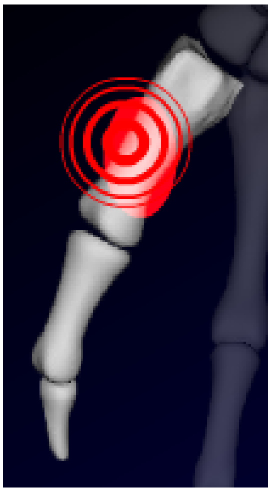


Figure 6.5: Pain visualization overlapping with its background

Deformities have been combined into a three-way-switch

Initially, the wizard's steps concerning deformity and swelling of a limb, have been shown as separate steps. Unfortunately, the resulting buttons turned out to be too small for easy selection by touch. Apple's guidelines suggest a minimum size of 44 points [Apple Inc., 2012]. Therefore, and because of the fact that a swelling is a special form of a "deformity", the two steps have been combined into one. The final prototype's behavior when tapping on a bone is described in figure 6.4.

Pulsing pain circle was too distracting

The doctor performing the evaluation has also suggested finding another solution for the pulsing circle displaying a patient's pain (see figure 6.3 (d)). The idea in general was thought of as being very good. Unfortunately, the circles turned out to be too distracting when being displayed at the same place as other issues like open wound or a wound's infection (figure 6.5). After discussing all possible solutions including the display of a static symbol, the decision fell on using another color - orange - for the next prototype.

Though the navigation bar allowing arbitrary step-selection has been thought of at an early stage, the icons representing the steps were still not fully developed. During a meeting with Dr. Dunda, the images have been discussed and determined. An evaluation of these icons has been performed with the the help of the final prototype and

(a) Target (b) Deformity (c) Open wound (d) Infection (e) Pain (f) Bloodflow (g) Sensibility (h) Motion range

Figure 6.6: Navigation icons

is described in the next section.

6.3 Final prototype

6.3.1 Visualizing multiple types of symptoms in one location

Ring-composed shapes served as a solution for overlapping issues

Switching to OpenGL|ES 2.0 allowed greater rendering possibilities

Parallel to evaluating the prototypes, the solution for displaying of multiple issues in one place slowly emerged. Instead of blending the colors one on top of the other, the issues are combined into one circle with several rings, each one representing one issue around that area. Scribbles turned out to look very promising. As a side effect, the rings indicated the problem centre, even though some parts of the rings were not visible. Unfortunately, this kind of display is not doable with the technique used for the prototype in chapter 4. OpenGL|ES 1.1 does not allow this kind of manipulation on 3D objects to be performed easily. Also, the sine deformation of the model intended for displaying deformities of swellings cannot be done efficiently. Therefore, a transition to Open GL|ES 2.0 with custom GLSL (OpenGL Shading Language) shaders rendering the hand model had to be performed.

6.3.2 Constrained rotation

Unconstrained rotation provided too much freedom

Initially, rotation of the model was possible in all axes. Test users, however, complained about having too much freedom leading to abandoning this feature, leading to the

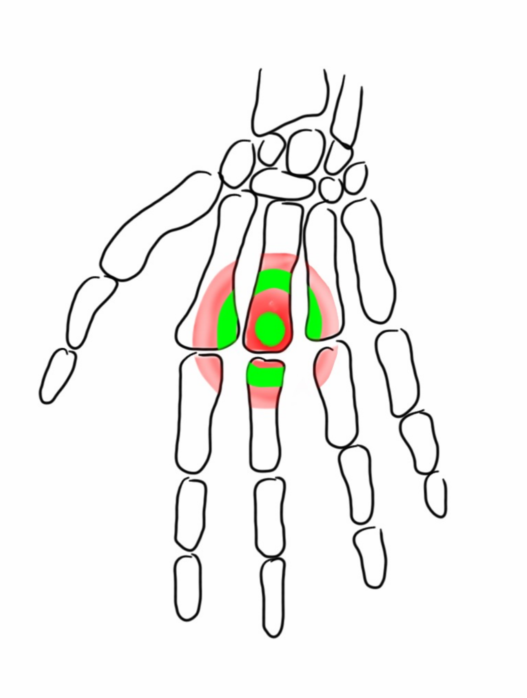


Figure 6.7: Visualization of multiple issues in one place

model rotating in the Y axis only. Ideally, the user should not have to rotate the model at any axis when entering the patient's issues. Unfortunately, rotation was not avoidable at the steps querying information on the patient's reduced blood flow or reduced sensibility.

With the arteries and nerves being much smaller compared to the bones and additionally being partially occluded by the bones (figure 6.8), rotating the model became necessary. Two measures against this flaw have been taken:

- zooming into the region of interest
- fading other body parts out and making them untouchable

Partially fading away body parts resulted in a more usable interface

At the first step inside the wizard, the user is asked to double tap on a region which the application then zooms upon. Other bones, arteries, and nerves of the hand additionally become semi-transparent (figure 6.9). This way, tapping on

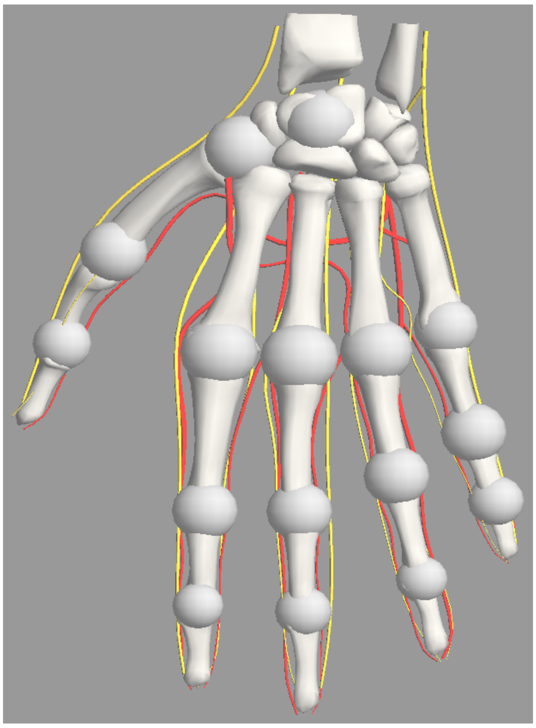


Figure 6.8: Overlapping of body parts inducing the necessity of rotation and context sensitive fade-out

(a) Arteries (b) Nerves (c) Joints (d) Bones zoomed in

Figure 6.9: Zoom of regions of interest and fade-out of unimportant body parts

a nerve or artery became much easier to the user and resulted in positive feedback. The same technique has been chosen for selecting joints. The general rule was: fade out unnecessary and therefore misleading visual information. This has the benefit of advising the user which body parts

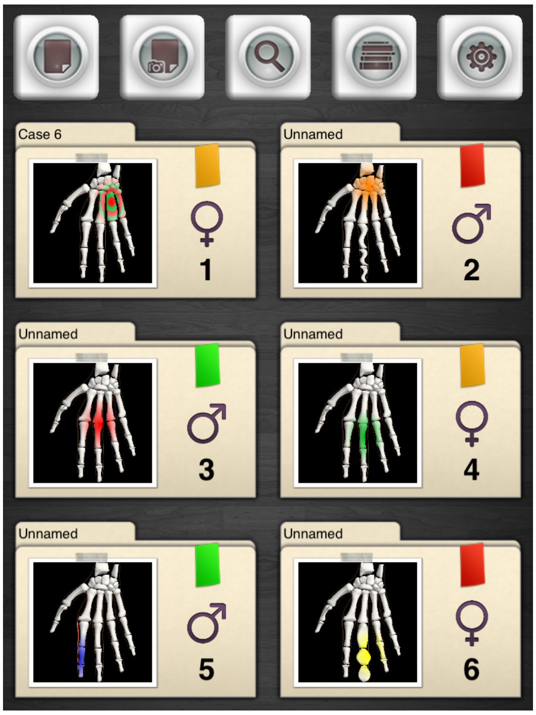


Figure 6.10: Cases used for evaluation

can be selected and becoming a visual cue, without adding instructional messages, or image-based cues.

6.3.3 Test session with medical students

Once a testable version has been finished, a meeting with three medical students (specializing in hand surgery, aged 23-25, being in their 6th-8th semester of studies) was set up. The students have first been interviewed according to a prepared questionnaire (appendix D). All participants had a normal color vision and were not "color blind" in any sense. All but one used a smart phone in their private life. The goal of this meeting was to get early feedback on the final prototype. Each of the students was interviewed separately and has been performed a series of tests with.

Symptom visualization

During the first test, the students have been presented al-

Students had to recognize visual cues

List 8: Expected test session answers

1. open wound, infection, and swelling at os metacarpale 4
2. deformity at D3, pain located at wrist
3. open wound at os metacarpale 3
4. infection at phalanx proximalis 3
5. reduced blood flow at A3 D2
6. swelling at D3, reduced sensibility at N6 D3

Figure 6.11: Expected test session answers for test cases shown in figure 6.10

ready stored cases shown in figure 6.10. The expected answers numbered by the patient's age display on the case are listed in figure 6.11. Starting with one injury per case the number of injuries has increased with progress. The goal here was:

Goal 5: G5

Find out whether the test person can name the issue presented in a stored case. By doing so, confirm that the

- color coding
- shape distortion

are being recognized correctly.

Red, yellow, and orange were most problematic colors

The tests have shown color coding being subject to personal associations. Even though the participants had the same state of education in the same discipline, they differed in the recognition of the color meaning. Orange, being the backup color chosen for pain, was initially not recognized by anyone of the students. One person did not choose green

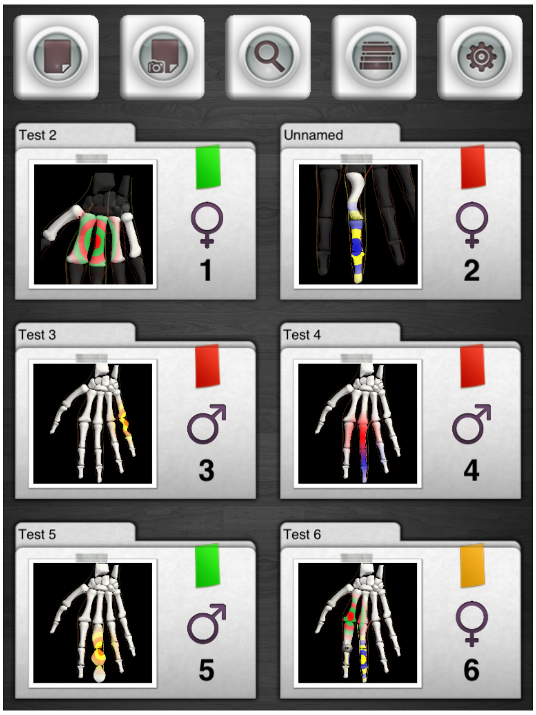


Figure 6.12: Retention test assignment sent to participants

standing for an infection as her first choice, and all three students thought yellow would stand for some kind of infection as well. It seems that even sticking to color coding used by schematic drawings in medical books is not a guarantee for colors being recognized instantly. Though the initial recognition failed in some cases, after giving hints and explaining the ideas behind the colors however, the meanings have been named correctly and even considered being a good choice after all.

As expected, the most problematic color was red. Answers concerning this color included: open wound, rash, arterial problem, and infection. Once again, after explaining the choice with an open wound expelling blood and therefore being shown in red, everybody agreed on the design choice.

Retention of color coding

Retention test was completed without any errors

Although the tests have shown the color codings to be understandable when explained, it had to be ensured, the

List 9: Expected retention test answers

1. infection and open wound at os metacarpale 3
2. deformity at phalanx proximalis 3, reduced blood flow at A5 D3, reduced sensibility at N6 D3
3. deformity and pain at phalanx proximalis 5, reduced sensibility and pain N10 D5
4. reduced blood flow at A6 D3, open wound at phalanx proximalis 3
5. swelling at D3, pain at phalanx media 3, reduced sensibility at N6 D3
6. open wound and infection at os metacarpale 2, swelling at phalanx proximalis 2, reduced blood flow at A5 D3 and reduced sensibility at N6 D3

Figure 6.13: Expected retention test answers

meanings could be retrieved after not being seen and/or worked with for a while. It has been decided to perform another test with the users. Two weeks after the tests, the students that have participated, have been sent an e-mail. This e-mail contained another screenshot of the application showing six new cases. The students have been asked to describe the cases they see in the picture. The responses have all correctly identified the patient's issues and proved the color codings to work even though the students have not been confronted with them for a longer period of time. The image is shown in figure 6.12. The expected answers are shown in figure 6.13 and are again numbered regarding the patient's age as shown in figure 6.12. Note that the cases not necessarily made sense. It was simply a test for the color coding and shape distortion being rememberable.

In addition to naming the issue associated with the presented color, students were asked to name the detailed location of the injury in the case they see. This task was accomplished by all students without any problems, showing the elliptic color-coded display of the issue being a good design choice.

The test has shown the need for users being able to choose a color coding of their choice. Another argument supporting this is approximately five percent of males having difficulties in color recognition [Blake and Sekuler, 2006]. They either suffer from total color blindness (daltonism), or are unable to distinguish certain color combinations. Even if users have the same association of colors to issues, them being (partially) color blind could result in unusable software.

Five percent of males are color blind

Whereas the color coding test contained negative results, the recognition of the shape distortion was concluded without any problems. Each of the students recognized the deformity and the swelling at their first guess.

Co-located color visualization

The second test aimed at the recognition of multiple issues as presented in figure 6.7. The goal was:

Goal 6: G6

Find out whether the idea of multiple rings showing a patient's collocated issues works well with new users.

The users have been shown cases with two or three issues in one place and once again were asked to name the issues as well as their location. All three testers were able to fulfill the task without any problems. This time even, they have been able to name the issues correctly, even if their initial guesses in the previous test were wrong. This has also proven the logical explanation behind the color coding leading to the students adapting to the color meanings very quickly.

Ring-based display was immediately understood

Entering data

The last test required the students to enter a new case when using the software. Two fictional cases have been compiled (see appendix D), and the tester asked to enter the data into the application. The issues have been named in a random order, leading to the user having to recognize the navigation bar's icon for the issue and not simply stepping one step forward at a time. Next to the application's general usability, the main goal was:

Goal 7: G7

Find out, if the icons depicting the patient's issue and serving for navigational purposes work as expected.

Navigational icons were recognized correctly

The students' performance in the last test is considered as good, and so was the students' feedback. No mistakes were made in recognizing the icons and entering cases. Both, entering the patient's issues, as well as entering the static data concerning the case (age, name, etc.), have been performed without any problems.

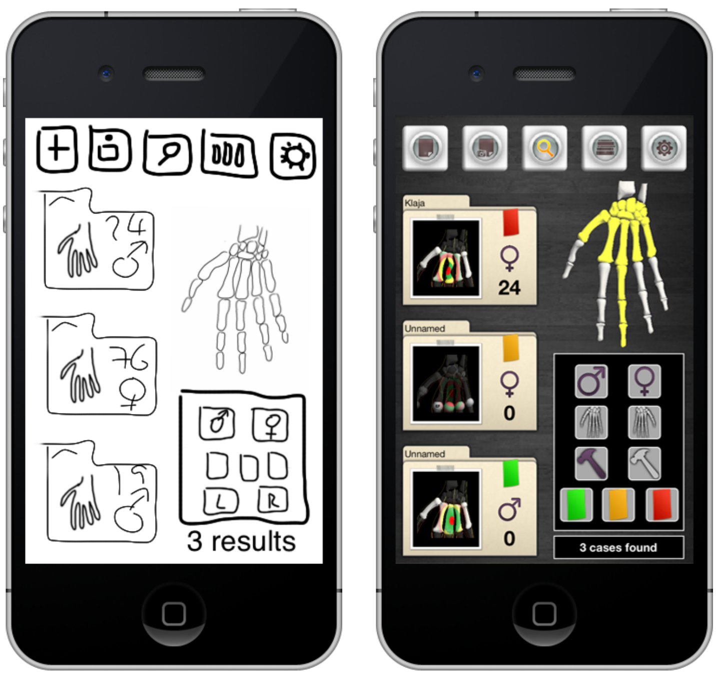
Minor problems originated from the students expecting a double tap instead of a single tap and vice versa. Opening a case for example, was tried to be achieved via a single tap on the folder. This problem, however, is not limited to this application. I have observed users initially using a single tap where double tapping was expected in many applications on the iPhone. Changing this behavior would adjust to the user's initial guess, but also result in random unintended taps initiating unintended actions. Further minor issues were identified concerning the "target", "pain" and "clear" icon. The target icon (figure 6.6 (a)) is meant to serve as "go to a safe place" as described in Jennifer Tidwell's patterns [2007].

Selecting this button leads to the application resetting all display changes such as zoom level, rotation, or body part selected. The intention behind this button was not immediately understood. Later on, however, it has been used frequently to zoom out of the selected bones.

The button leading the application into entering the patient's pain initially showed red rings as introduced in the flash prototype. The rings have lead to it being initially confused with the "target" icon. This issue has been resolved by simply agreeing on the "thunderbolt" as serving as a replacement.

Finally, the "clear" icon had to be redesigned as well, with its first version not obviously giving the affordance of resetting the current issue when tapped.

6.3.4 Eliminating text input in search



(a) Sketch (b) Final implementation

Figure 6.14: Final idea & implementation of the search view

The search function was implemented as a visual filter with toggleable body parts

One of the most important features of an application is fast retrieval of stored data. The search view for retrieving cases has been planned from the early stages on. However, it has not been implemented until late in the development process. Reasons for this accounted to missing ideas on query input. Though the screenshot in figure 4.9 (d) shows a text field intended for search term input, the final idea has not emerged yet. Text input on the iPhone can be a tedious task to undertake. Therefore, a simpler idea has been developed: symbolic filtering of the cases. Instead of typing in information as text, the filter was set on toggleable body parts as well as other icons representing the case's information. The search view constantly displayed a list of cases fitting the current combination of involved body parts selected. Though not being able to search for a patient's name, narrowing down the search results via selecting the region of interest could be performed via a single tap and without typing (and correcting) text. An example sketch of this search view as well as the screenshot of a final implementation of this feature is shown in figure 6.14. A meeting with a medical student, as well as tests performed on three non-medical students have gotten very positive feedback. The meetings have shown the users understanding the feature instantly and being able to search on cases without any introduction.

6.3.5 Test session with doctors

Two doctors performed the same tasks as the students

With the software being feature-complete, another qualitative evaluation with two doctors working at the UKA's hand surgery department has been performed. Both doctors were 29, male, and had an experience of 2-3 years of working as plastic surgeons. They both owned an iPhone and used it for personal purposes only. The procedure in this session was the same as with the students using the same fictional cases (section 6.3.3). I first gave a short introduction into the topic and explained the purpose of the test. Then, the doctors have been shown the application and given a short explanation of the interface. They have been asked to identify the pre-set cases (figure 6.10) by looking at the renderings. Once again, the color coding issue revealed individual associations to be present. The doctors initially did not always agree with the coding chosen. However, once explained, they agreed on the coding being a good visualization technique, but suggested the user should be able to change the coding according to their needs. Finally, the doctors were asked to perform entering of two sample cases into the application's database. They were told to think loud while performing the actions. The doctors' overall performance was satisfying and showed the interface being understood quickly.

Test session with doctors was satisfying

The general response on the program's UI has been positive. The doctors appreciated the features offered by the program and suggested additional features. A feature requested that has been standing out was a template system. Doctors often treat patients that can be grouped into classes. One doctor suggested storing templates for faster creation of new cases and so saving time upon creation.

Template system was suggested

The doctors also suggested alternative visualizations of the patient's issues. One of the doctors suggested using overlaid symbols resembling drawings they use on paper (i.e. "#" for a fracture, or separation of displayed 3D objects). Since the idea of using icons would complicate the recognition when viewed from a longer distance, it was agreed on not being suitable to be shown on a small-screened device. Another ideas included displacement and rotation of the 3D objects for displaying of luxations or fractures. These however, would require manipulating the model with complex algorithms not doable in the scope of this thesis.

Alternative visualization was suggested by the participants

Finally, taking scribbles, notes, and dictation support have been features repeatedly coming up among the requests and should be taken into consideration in any future work.

Summary

When designing software one has to be careful of becoming jack of all trades (and master of none). Though there are a lot of features that were suggested, the application created in the process of this thesis concentrates on the most important and therein researched properties:

- **Fast data acquisition** is possible through simply touching the 3D model at the appropriate position. Concerning the issues that are supported by this application, no complicated textual information is necessary.

- **Multi tasking support** is provided by showing only most important on the folders' front. This information means to support the doctor in fast context switching by showing him the most important information concerning a patient's record. Furthermore, the rendering of the 3D model used when entering the patient's issues allows the doctor to quickly get an overview of the case, e.g. the location of the issues and their types.

- **Intuitive navigation** is achieved by displaying the cases in real-looking folders with a minimal set of information on their front.

- **Teaching capabilities** are included in the form of the ability of displaying videos explaining procedures. In addition, the order in which doctors are expected to enter the patient's issues, implicitly teaches him in what order the procedures are performed best.

Chapter 7

Summary and future work

This work contributes to research on visualization of patient records in mHealth applications. This last chapter sums up the work performed, its contributions, and limitations. Finally, a discussion of improvements and follow-up research ideas are presented.

7.1 Guidelines

The following informal and more or less general guidelines should reflect the findings of this thesis as well as lessons learned.

Support for fast context switching

Doctors in the ED are forced to handle multiple cases simultaneously. Software targeted towards these doctors should provide features allowing to switch between cases in a fast way. Doctor's Little Helper for example, only shows a minimal set of important information when displaying an overview of the cases.

Show minimal set of data in overview views

Support for fast retrieval of possibly already closed and partly forgotten cases

Figure 7.1: A folder as displayed in Doctor's Little Helper depicting implementation of several proposed guidelines.

Determine what information is most important

Doctors often have to find closed and therefore partially forgotten cases. Sometimes patients already have been treated for the same or another issue at the same hospital. In order to support the doctor at remembering and thus finding a case easily and fast, software should provide important information only. With this set of information being minimal (see next guideline), the doctor is able to quickly remember the case (figure 7.1).

Reduce cognitive load

Exploit combinable dimensions of visualization such as colored shapes and shape distortion

Doctors in the ED have to face a lot of new input constantly stressing the load of their working memory. Software designed for the ED doctor's use should keep the cognitive load at a minimum level. This can be achieved by replacing text with meaningful icons (figure 6.6). Another way to accomplish this goal is using advanced visualization techniques such as presented in chapters 4 and 6. Exploiting color-based, and shape-distorting techniques helps to process information. Also, fading out unimportant information based on current context helps to reduce the amount of information that needs to be processed (figures 6.9 and 7.1).

Determine and include all involved parties

The doctors work takes place in a complex eco system of its own. It is mandatory to grasp the overview of the system as well as determining the interactions between the parties involved. In this example, interviewing the nurses gave hints at reasons for being dissatisfied with used software and using traditional tools like paper as workarounds. Interviewing patients revealed their perception of mobile devices used by doctors, etc.

Ethnographic research necessary for software targeted for hospital use

A doctor's free time is very limited and very valuable

Due to the complexity described in chapter 2, collaborating with doctors requires a lot of patience. Therefore: prepare everything in advance, prepare as many alternatives as possible, and — by doing so — reduce the number of iterations needed. Especially when interviewing a doctor during his working hours, emergencies are likely to come up and so delay gathering of results needed.

Beware when using colors

Using colors can enhance visualization in many ways. Unfortunately, five percent of males suffer from disabilities concerning proper color recognition. While this is recognized really quickly when performing experiments with test people visiting, remotely conducted tests may fail because of this issue. When planning online experiments, make sure to include questions concerning any kind of these problems in order to maintain the experiment's validity.

Always think of imperfections of the human body

Make as little assumptions as possible

When working inside a domain other than the one one is an expert in, making assumptions is the last thing to do. Even though being very familiar with emergency departments in general (I have worked as a paramedic for a period of 14 months), people working in an ED naturally think in their own way. Making too many assumptions before checking up on them with *several* people working in the field (the more the better) raises the possibility of wasting valuable time.

People with the same background are individuals after all

Provide research-based defaults, but let the user decide

As stated above, people in the ED have their own routines and think in their own way. This applies to all disciplines. In the case of the ED, we have the inclusion:

Doctor in the ED $\subset$ doctor $\subset$ individual

with the groups from the left to the right having less and less in common. Even though doctors may have had the same education, share the same workplace, and partially overlap in their habits, they are still individual and may have different associations based on their personal history, origin, social surrounding, etc. Ethnographic research may help finding a common ground, but individual differences can break down any rule previously set up. It is therefore necessary to provide mechanisms for changing the defaults, enabling the user to adjust the software to his needs. In the case of Doctor's Little Helper, freely assignable color-coding and user-definable composition of information presented on the folders would implement this guideline. These features, however, haven't been implemented with time-constraints not allowing to perform enough evaluation.

Watch out for device use implications

Form factor's association can have a negative impact

As shown in chapter 5, the device resp. its form factor can have an impact on the device's use perception. With devices primarily used in different contexts, they might cause mistrust, anxiety, and discomfort for people involved. It is therefore necessary to inspect the device's perception and disguise the device when necessary. This could be accomplished by using a casing that hides the device itself by notably changing the device's form and/or size.

7.2 Summary and contributions

Preliminary research revealed an ED doctor's work(flow) description

I have first presented an overview of the emergency department as a problem domain. Based on observation, contextual inquiries, and triangulation with other research, a description of the domain in general, as well as detailed information describing the emergency department doctor's workflow has been given. The results revealed the mobility and complexity of a ED doctor's work (chapter 2).

With the patient playing an important role in a doctor's work, an online experiment has been designed to learn about a potential patient's perception of doctors working with mobile devices such as smart phones (chapter 5). The experiment proved doctors using the smart phone being subject to biased perception. It lead to the conclusion that everyday devices may have a negative impact on the doctor-patient interaction.

There is potential bias caused by the smart phone's form factor

Collaboration with doctors allowed to get early feedback on initial ideas. A survey has been conducted to answer questions regarding visualization of patient data. The survey also targeted possible experience-based improvement suggestions from the doctors (chapter 5). It revealed the doctors being overall satisfied with the mHealth devices they use. It has also shown existing applications not utilizing advanced visualization techniques, the doctors' need for support with patient education, and the preferred device size being about five to nine inches. Another finding was the need for software being adaptable by the doctors in order to provide visual information fitting their individual preferences.

The participating doctor's preferred device size is five to nine inches

Based upon the findings from my research and with the hereof resulting knowledge about the complexity of the ED doctor's work, design goals regarding mHealth software have been set. These goals were leading the work on Doctor's Little Helper, an application being one of the contributions of this thesis. The application provides a wizard-like interface for entering injury-related data. It utilizes real-time rendered 3D models of a human hand allowing the doctor to input patient's data via direct manipulation. The application also focuses on displaying an overview of the stored cases, as well as an easy-to-use search interface for fast retrieval of data (chapter 6).

Doctor's Little Helper utilizes 3D rendered models and provides a wizard-like interface

The central techniques of the visualization of the patient's issues are blended color-coded shapes and shape distortion of the 3D model. Unlike other software, Doctor's Little

New visualization techniques based on colored shapes and shape distortion have been presented

Helper refrains from using icon-based visualization and so allows to visualize several issues at one location without suffering from a loss of clarity. The elliptic shape used in Doctor's Little Helper allows a fast-to-grasp overview with the user immediately locating the region of interest (chapters 4 and 6).

The application has been implemented using an iterative user-centered design technique. Four cycles have been performed, each one consisting of a design, implementation, and evaluation/analysis phase:

- focus group meeting with paper mockups
- clear foil prototyping
- a flash software prototype
- final implementation

The overall response I have gotten from potential users during the qualitative evaluation was positive with constructive criticism being fed back to me. The results contributed to basic guidelines presented in section 7.1.

The application provided, is to be seen as a proof of concept. Due to time limits, not all ideas have been included. A short discussion of these ideas is presented in section 7.4.

7.3 Limitations

Work presented is limited to hand surgery

This work has been concentrating on the hand surgery as a sub-domain of medicine. Although the general overview of an emergency department, as well as the ED doctor's workflow are generalizable and confirmed by research in this field, the software itself and the techniques used for visualization are not. The injuries have been selected according to typical and most common injuries occurring in this sub-domain. Therefore, these issues are a small subset of all possible issues to be visualized. The thesis omits a number of issues and thus simplifies the general problem of visualization. However, I believe that applying this color-based visualization to more sub-domains and more organs would be possible. This requires further research and collaboration with domain-experts in order to understand the domain-related modifications needed.

7.4 Future work

Due to time constraints and insufficient resources not all of the initial ideas have been followed and mostly abandoned despite of being issues worth being researched. This chapter provides a discussion of these ideas for future research.

7.4.1 Reliable source of up-to-date information

Reliable up-to-date content should be provided

As reported in chapter 2, doctors are in need of updated information. While search engines such as Google provide a great degree of freedom, they sometimes report information sources targeted for laymen. In general, the ability of ED residents' ability to identify correct answers to clinical questions seems to be rather poor [Abbas et al., 2010]. Books on the other hand provide well-established facts and procedures. However, because of the longer issuing cycles printed media is most likely to contain older or even outdated information. Decision-supporting software should take advantage of knowledge-/evidence-databases in order to provide accurate and up-to-date medical information.

7.4.2 Context awareness

Context awareness would help in large hospitals and high workload

Initial mockups presented to the doctors participating in the focus group revealed the doctors' interest in context aware applications. Research on context-aware applications has been done by Kjeldskov et al. [2006]. This research discusses the benefits and problems of context-awareness. They present a prototype application called MobileWARD designed to support nurses their mobile work. The results presented included problems concerning the user interface.

I think incorporating the visually simple and easy-to-use style of interface presented in this thesis could very well address these issues. Research of this type however, cannot be performed with time-critical patients.

7.4.3 EMR integration & Collaboration

EMR integration could provide alternative collaboration workflows

Doctors in the emergency department are known to use consulting colleagues when unsure of making diagnoses. The process of consultation is initiated by phone calls, followed by explanations over the phone, and ends in consulting doctors visiting the emergency department. I have observed this process to be wasting valuable time. Doctors are not always reachable via phone, do not have time to make an instant visit, etc. With collaboration-supporting features included, online consultation could be enabled. Sending a case via an intranet connection would eliminate the need of personal presence. An extension of this feature could include colleagues from distant hospitals being available for consultation.

7.4.4 Alternative visualizations

Patterns would widen possible visualizations

So far, the visualization performed is mainly done in two dimensions: color and shape distortion. With more injuries/issues to be displayed, the practicable amount of colors would be quickly used up. An expansion of the available visualization space could be performed by adding another dimension: patterns. As an example: in our case, pain is shown using orange. An alternative representation could incorporate stripes instead of a solid color. In order to find out what works and what does not an extensive user test would have to be performed to ensure the user's eye is not being overstrained.

7.4.5 Finer interaction techniques

As for now, the user simply taps on the location of interest. The application uses a fixed-radius shape to render the corresponding issue. Further ideas include gesture-based interaction with the application. An example would be determining the size with two fingers, or proportional to the duration of the touch performed. Whereas the former technique would leave the user in charge, the latter however, could introduce problems in stressful and time-critical situations.

Fixed radius display could be eliminated by time-dependent interaction

7.4.6 Animated visualization

As observed in the polyclinic, doctors often find themselves in the situation of explaining anatomic facts and procedures to the patients. Doctors observed used pieces of paper, tissues, and similar aids for doing so. Having a flexible 3D engine around, the visualization could be extended for (better) explanatory purposes. Doctors interviewed about the frequency of the explanations performed stated they are not as often performed as it is necessary, simply because of time constraints not allowing them to. Advanced visualization would empower doctors to perform these explanations at ease and so reduce the patient's fear of upcoming procedures.

Animations could serve doctors explaining procedures, teaching, etc.

Appendix A

Focus group agenda

Focus group meeting 23.12.2011

(1) Introduction:
- Who am I, what am I doing:
  - Diploma thesis with the goal of design guidelines for mHealth/medical software + iPhone app
- What this meeting is for:
  - Triangulation: check on ideas and findings, get feedback

(2) General findings:
- Parallelism
- High workload
- Software not always fitting into doctor's workflow
- Up-to-date reference needed
- Central sources available?

(3) Discussion:
- Software for doctors in general:
  → Satisfying? If not, why?
  → Bad user interfaces?
  → Bad workflow integration?
  → Does it provide support for parallelism/workload-reduction?
  → Missing functionality? If so, which?
- Impact of badly designed systems on doctor-patient interaction?

(4) Experience with mHealth:
- If so, in which domain?
- How much?
- Satisfactionary? Helping? Useless? → Why?
- How is the screen size problem coped with in existing applications?

→ Is it a good solution?

(5) Discuss the "smart phone problem"
- perception by patients may lead to stressed patients being distrustful?
- would this make an impact on interaction?

(6) My main goals (basically derived from the findings mentioned):
- Support parallel work
- Improve efficiency by improving
  - Visualization
  - Navigation
  - Adapting into doctor's workflow
- If participants do not get why I focus on the visualization: after 12 hours of work, it would be far easier to have to look at one screen with the human body and being able to visually grab the context without having to search through several screens.

(7) Parallelism:
- How do doctors memorize their current workload (also not closed cases from days before)?
  - → Which data is memorized? (name, body part, injury, gender, age)
  - → Which would be the smallest subset for optimal use (explain: needs to be visualized on a small screen)
- PROBLEM: what if the doctor memorizes the body part that is responsible for an injury (nerves in the back for example) instead of the location where the patient feels the pain?
- ! Show prototypes of visualization/navigation
- ! Prototype ON PAPER, so doctors may draw around, make notes.

(8) Navigation:
- 3D model suggested by research and highly demanded (most downloads on the app store)
- Verify this is the way to go
  - → Easier to perceive? Easier to navigate?
- Explain the idea of having ONE screen of content and no navigation stack switching back and forth
- Show prototypes

(9) Speech based control/input:
- Could it help?
  - → If so where? (Problem: speech cannot be "hidden"
  - → communication is open
  - → everybody around the doctor can listen what he is doing)

Questionnaire for the focus group

Age: __ years old

Gender: ☐ female / ☐ male

Education: ____________________________

Specialization: ____________________________

Work experience: __ years

Satisfaction with used software:

☐ very satisfied
☐ satisfied
☐ neutral
☐ unsatisfied
☐ very unsatisfied

Experience with smart phones in private use: ☐ yes / ☐ no

Experience with smart phones at work: ☐ yes / ☐ no

Sources used for staying up-to-date:

☐ subscriptions to periodicals
☐ active (re)search
☐ attending conferences
☐ other: ____________________________
☐ very unsatisfied

Frequency of actively refreshing knowledge:

☐ less than monthly
☐ monthly
☐ quarterly
☐ biannual
☐ annual
☐ less often

Appendix B

Appendix B: Online survey (patient)

Umfrage: Einführung

Einführung und Übersicht über die Umfrage

Seite 1/5. Fortschritt: 20%

Weiter

Allgemeines zur Umfrage

Herzlich willkommen und vielen Dank im Voraus für die Teilnahme bei dieser Umfrage. Die Teilnahme kostet Sie nur wenige Minuten ihrer Zeit. Die Teilnahme ist anonym. Es werden keinerlei persönliche Daten gesammelt und gespeichert. Einzig eine demographische Datenerhebung (Alter, Geschlecht, etc.) findet statt. Die Eingabe dieser Daten ist optional und dient rein statistischen Zwecken.

Die Umfrage ist wie folgt gegliedert:

1. *Kurzes Video zur Doktor-Patient-Interaktion*
2. *Fragen bezüglich des Videos*
3. *Zusätzliche Fragen*
4. *Demographische Datenerhebung*

Sie haben anschliessend an die Umfrage die Möglichkeit, Ihre E-Mail-Adresse anzugeben, um nach Auswertung der Umfrage über den Sinn und das Ergebnis informiert zu werden.

Weiter

Umfrage: Video zur Doktor-Patient-Interaktion

Beispielvideo

Zurück | Seite 2/5. Fortschritt: 40% | Weiter

Video

*Bitte schauen Sie den folgenden Film, und beantworten anschliessend die Fragen darunter. Bitte beachten Sie: das Video enthält absichtlich **keinen Ton**.*

Wie empfanden Sie das Interesse des Arztes am Patienten?

Bitte geben Sie an, wie fokussiert der Arzt Ihrer Meinung nach war. Bitte kreuzen Sie eine der folgenden Möglichkeiten an.

○ sehr interessiert ○ interessiert ○ neutral ○ weniger interessiert ○ uninteressiert ◉ keine Angabe

Warum?

Geben Sie ggf. eine Begründung an.

Wie empfanden Sie die Freundlichkeit des Arztes?

Bitte geben Sie an, wie freundlich der Arzt in Ihren Augen erschien. Bitte kreuzen Sie eine der folgenden Möglichkeiten an.

○ sehr freundlich ○ freundlich ○ neutral ○ unfreundlich ○ sehr unfreundlich ◉ keine Angabe

Warum?

Geben Sie ggf. eine Begründung an.

Wie empfanden Sie die Professionalität des Arztes?

Auf eine genaue Definition von 'Professionalität' möchten wir an dieser Stelle verzichten. Dieses ist auch nicht wichtig. Bitte kreuzen Sie eine der folgenden Möglichkeiten an.

- ○ sehr professionell
- ○ weniger professionell
- ○ neutral
- ○ unprofessionell
- ○ sehr unprofessionell
- ◉ keine Angabe

Warum?

Geben Sie ggf. eine Begründung an.

Wie empfanden Sie die Interaktion zwischen dem Patient und dem Arzt?

Bitte geben Sie an, wie gespannt <-> harmonisch Sie die Interaktion wahrgenommen haben. Bitte kreuzen Sie eine der folgenden Möglichkeiten an.

- ○ sehr harmonisch
- ○ harmonisch
- ○ neutral
- ○ gespannt
- ○ sehr gespannt
- ◉ keine Angabe

Warum?

Geben Sie ggf. eine Begründung an.

Zurück Weiter

Umfrage: Weitere Fragen

Bitte beantworten Sie die folgenden Fragen.

Zurück | Seite 3/5. Fortschritt: 60% | Weiter

Assoziationen zu Geräten

Im folgenden möchten wir wissen, welche Einsatzzwecke Sie mit den präsentierten Geräteklassen assoziieren. Es ist jeweils ***mehrere Antwortmöglichkeiten*** *erlaubt. Sollten Sie die Frage nicht beantworten wollen/können, klicken Sie keine Antwort an.*

	Medienkonsum *Videos schauen, Musik hören*	**Sozialer Kontakt** *SMS, E-Mails, Twitter, Facebook*	**Arbeitsorganisation** *Termine, Erinnerungen, Kontakte*	**Kreative Arbeit** *Aufnahmen (Photo/Video), Texte schreiben, etc.*	**Spielen**
Smartphone *z.B. iPhone, Android-Phones, Windows Phone 7.*	☐	☐	☐	☐	☐
Tablet-PC *z.B. iPad, Samsung Galaxy Tab, etc.*	☐	☐	☐	☐	☐
Computer *z.B. Notebooks, Desktop-PC, etc.*	☐	☐	☐	☐	☐
Fernseher / Mediencenter	☐	☐	☐	☐	☐

Zurück | Weiter

Umfrage: Demographische Datenerhebung

Hier bitten wir Sie, uns statistische Daten zur Verfügung zu stellen. Diese Daten sind anonym und werden nur zu statistischen Zwecken gebraucht. Sollten Sie einzelne Angaben nicht machen wollen, so lassen Sie das Feld bitte leer.

Zurück | Seite 4/5. Fortschritt: 80% | Fertig

Alter

Ich bin ____ Jahre alt

Geschlecht

○ männlich ○ weiblich ◉ keine Angabe

Arbeit im medizinischen Umfeld

Arbeiten Sie, oder haben Sie jemals im medizinischen Umfeld (Krankenhaus, Arztpraxis, etc.) gearbeitet?

○ ja ○ nein ◉ keine Angabe

Krankenhausaufenthalte

Wie oft waren Sie in den letzten 10 Jahren zwecks Behandlung in einem Krankenhaus?

○ weniger als 5 mal ○ 5 - 10 mal ○ mehr als 10 mal ◉ keine Angabe

Zurück | Fertig

Umfrage: Vielen Dank!

Möchten Sie im Anschluss der Auswertung Informationen über den Hintergrund sowie den Ausgang dieser Befragung informiert zu werden, so haben Sie hier optional die Möglichkeit, ihre E-Mail-Adresse anzugeben. Sobald die Befragung abgeschlossen und ausgewertet ist, schicken wir Ihnen an die von Ihnen angegebene Adresse eine E-Mail die die Hintergründe erklärt.

Seite 5/5. Fortschritt: 100%

Weiter

Kontaktmöglichkeit

Bitte geben Sie - falls gewünscht - Ihre E-Mail-Adresse an. ***Diese Angabe ist optional und wird nicht mit den Umfrageergebnissen verknüpft gespeichert***

Meine E-Mail-Adresse lautet:

und ich möchte über die Hintergründe und den Ausgang der Befragung informiert werden.

Weiter

Appendix C

Appendix C: Online survey (doctor)

Umfrage mHealth: Einführung

Einführung und Übersicht über die Umfrage

Seite 1/7. Fortschritt: 14%

Weiter

Allgemeines zur Umfrage

Herzlich willkommen und vielen Dank im Voraus für die Teilnahme bei dieser Umfrage. Die Teilnahme kostet nur wenige Minuten ihrer Zeit. Die Teilnahme ist anonym; es werden keinerlei persönliche Daten gesammelt und gespeichert. Einzig eine demographische Datenerhebung (Alter, Geschlecht) findet statt. Die Eingabe dieser Daten ist optional und dient rein statistischen Zwecken.

Die Umfrage ist wie folgt gegliedert:

1. *Seiten 2 und 3: Fragen bezüglich Erfahrung mit mHealth-Software*
2. *Seite 4: Beispielfall*
3. *Seite 5: Wiederfinden von Fällen*
4. *Seite 6: Demographische Datenerhebung*

Sie haben im Anschluss an die Umfrage die Möglichkeit Ihre E-Mail-Adresse anzugeben, um nach Auswertung der Umfrage über die Hintergründe und das Ergebnis informiert zu werden.

Weiter

Umfrage mHealth: Erfahrung mit mHealth (1)

Angaben zu Ihren persönlichen Erfahrungen mit mHealth-Anwendungen und dazugehöriger Hardware.

Zurück | Seite 2/7. Fortschritt: 28% | Weiter

Mit welchen Geräten haben Sie Erfahrungen gesammelt?

Smartphones, Tablet-Computer, etc.

- ☐ Smartphones
  iPhone, Samsung Galaxy, etc.
- ☐ Tablet-PCs
  iPad, Samsung Galaxy Tab, etc.

Sonstiges ____________

Verwendungszweck

Zu welchen Zwecken haben Sie die Geräte hauptsächlich benutzt?

- ☐ Referenz
  Nachschlagewerk
- ☐ Decision support
  Expertensystem, Dosierungsrechner, etc.
- ☐ Worfkflow management
  z.B. Verwaltung von Patientendaten

Sonstiges ____________

Zufriedenheit mit den eingesetzten Smartphones?

Bitte geben Sie an, wie sehr Sie mit der Benutzerfreundlichkeit zufrieden waren. Sie haben zusätzlich die Möglichkeit anzugeben was gut/schlecht war und was Ihrer Meinung nach verbessert werden könnte.

	sehr zufrieden	zufrieden	neutral	unzufrieden	sehr unzufrieden	keine Angabe
Smartphones *iPhone, Samsung Galaxy, etc.*	○	○	○	○	○	◉

Warum?

Geben Sie ggf. eine Begründung an.

Umfrage mHealth: Erfahrung mit mHealth (2)

Visualisierung und Navigation

Zurück | Seite 3/7. Fortschritt: 42% | Weiter

Visualisierung

Welche Art von Informationsdarstellung wurde hauptsächlich benutzt?

- ☐ überwiegend Text
  Es wurde überwiegend Text benutzt
- ☐ Bilder (2D)
  Inhalte wurden mit Bildern in 2D untermalt
- ☐ Bilder (3D)
  Inhalte wurden mit Bildern in 3D untermalt
- ☐ Animationen
  Inhalte wurden mit Animationen versetzt. Hierbei geht es nicht um Animationen wie das Scrollen von Bildschirminhalten wie z.B. in bei Smartphones, sondern um z.B. Animationen zur Darstellung des menschlichen Körpers, etc. die aktiv gesteuert werden können.

Wie zufrieden waren/sind Sie mit dieser Visualisierung?

○ sehr zufrieden ○ zufrieden ○ neutral ○ unzufrieden ○ sehr unzufrieden ◉ keine Angabe

War der Bildschirminhalt auf mehrere virtuelle Bildschirme aufgeteilt?

Bei Geräten mit kleinem physikalischem Bildschirm werden die Inhalte häufig auf mehrere Bildschirme verteilt, um den Bildschirm nicht mit zuviel Information auf einmal zu "überfluten".

○ ja ○ nein ◉ keine Angabe

Wenn ja, waren sie mit der Aufteilung zufrieden?

Hatten sie zuweil das Gefühl sich zuviel Informationen merken zu müssen, weil Sie über mehrere Bildschirme verteilt war? Kreuzen Sie dann bitte "nein" an.

○ ja ○ nein ◉ keine Angabe

Ist eine beschränkte Bildschirmgrösse

☐ ja, wegen der Lesbarkeit ☐ ja, wegen der aufgeteilten Inhalte

problematisch?

Welche Bildschirmgrösse würden Sie für Ideal halten?

Angegeben sind die Bildschirmdiagonalen mit Beispielen

- ( ) < 5" *Smartphone*
- ( ) 5" - 9" *Smartphone - Tablet-PC*
- ( ) 9" *Tablet-PC wie iPad*
- ( ) 9" - 11" *Tablet-PC - kleines Notebook*
- ( ) > 11" *mehr als ein Notebook*
- (•) keine Angabe

Die Navigation erfolgte hauptsächlich durch?

Bitte geben Sie an, welche Technik man benutzt, um innerhalb der Funktionen der Software zu navigieren

- [ ] Animierter Wechsel
  Durch Klicken auf Bildschirmelemente wurde der Bildschirm durch eine Animation rein- oder rausgeschoben.
- [ ] Nicht animierter Wechsel
  Bildschirminhalte wurden "plötzlich" ausgetauscht, ohne dass eine Animation erfolgt ist.
- [ ] Zoom-Techniken
  Der Kontext wurde verändert, indem in die Oberfläche hinein- oder aus ihr herausgezoomt wurde.

Sonstiges:

Wie zufrieden waren Sie mit der Navigation?

( ) sehr zufrieden ( ) zufrieden ( ) neutral ( ) unzufrieden ( ) sehr unzufrieden (•) keine Angabe

Warum?

Geben Sie ggf. eine Begründung an.

Was hätte verbessert werden können?

Können Sie sich vorstellen, Software während Ihrer Arbeit mit Sprache zu steuern?

( ) ja ( ) nein (•) keine Angabe

Falls Nein, warum?

Geben Sie ggf. eine Begründung an.

Workflow-Unterstützung

Wie gut hat Sie die Software in Ihrer Arbeitsweise unterstützt?

Zufriedenheit mit der Workflow-Unterstützung:

○ sehr zufrieden ○ zufrieden ○ neutral ○ unzufrieden ○ sehr unzufrieden ◉ keine Angabe

Die Reihenfolge der Eingaben entsprach meiner Arbeitsweise

Die einzutragenen Daten waren an die Reihenfolge angepasst, in der ich normalerweise die Werte erfasse/aufschreibe

○ ja ○ nein ◉ keine Angabe

Die Applikation hat mich gezwungen Werte einzutragen

*Bestimmte Aktionen liessen sich nicht durchführen, wenn ich Eingaben (**obwohl nicht vorhanden**) leer lassen wollte.*

○ ja ○ nein ◉ keine Angabe

Die Applikation hat mir schnellen und wahlfreien Zugriff gegeben.

Ich war stets frei in der Auswahl der einzutragenen Daten und in der Reihenfolge der Eingaben.

○ ja ○ nein ◉ keine Angabe

Die Unterstützung wäre besser gewesen, wenn

Patienteninformation

Wie oft erklären Sie den Patienten die Anatomie bzw. bevorstehende Eingriffe?

○ täglich ○ ca. 1x / Woche ○ ca. 1x / Monat ○ ca. 1x / im Jahr ○ nie ◉ keine Angabe

Zeichnen Sie dabei Zeichnungen?

○ ja ○ nein ◉ keine Angabe

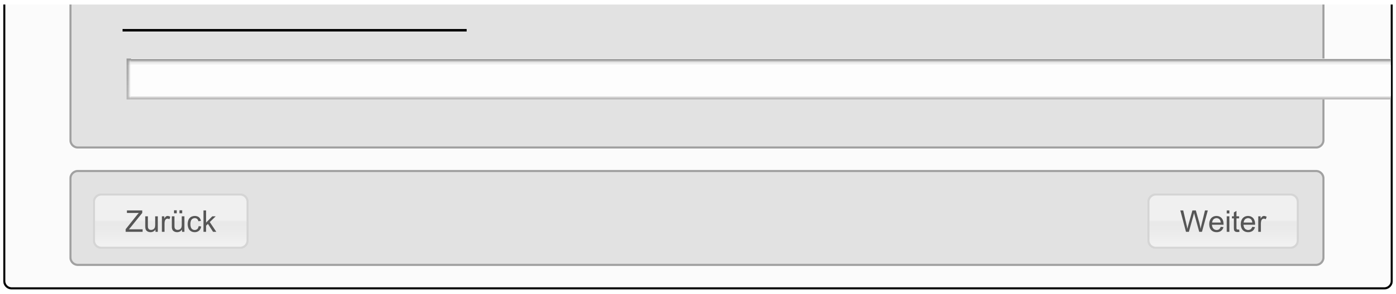
Zeigen Sie vorgefertigte Bilder/Videos?

○ ja ○ nein ◉ keine Angabe

Benutzen Sie dafür Software?

○ ja ○ nein ◉ keine Angabe

Wenn ja, welche?


Zurück
Weiter

Umfrage mHealth: Beispielfall

Wir präsentieren Ihnen hier einen Beispielfall. Bitte merken Sie sich den Fall und klicken dann auf "weiter". Sie werden auf der nächsten Seite gebeten, die Daten anzugeben die Ihnen helfen, sich an diesen Fall zu erinnern.

Zurück | Seite 4/7. Fortschritt: 57% | Weiter

Der Fall

Stefan M., ein 34 jähriger Mann (Foto links). Am Vortag auf dem Weg zur Arbeit beim Aussteigen aus dem Auto auf Glatteis ausgerutscht und auf die linke Hand gefallen.
Seitdem zunehmende Schmerzen und Schwellung im Bereich des Mittelfingers mit leicht eingeschränkter Beugefähigkeit. Radiologisch zeigt sich eine nicht-dislozierte Grundgliedfraktur D3 linke Hand ohne Gelenkbeteiligung.

Zurück | Weiter

Umfrage mHealth: Wiederfinden von Fällen

Zurück | Seite 5/7. Fortschritt: 71% | Weiter

Zuweisung der Wichtigkeit

Welche Informationen sind für Sie von Bedeutung, wenn Sie an einen Fall erinnert werden sollen? Erinnern Sie sich an den Fall, den wir Ihnen vorhin präsentiert haben. Stellen Sie sich vor, der abgebildete Ordner ist eine Patientenakte. Welche Informationen würden Ihnen behilflich sein, sich so schnell wie möglich an den Fall zu erinnern? Bitte ordnen Sie mit Hilfe von ***Drag & Drop*** *die links stehenden Bilder auf dem Ordner rechts an. Sie können die Bilder zusätzlich* ***skalieren****, um den Bildern eine grössere Bedeutung zuzuweisen. Klicken sie hierzu rechts unten in das Bild und ziehen es dann mit der Maus gross. Sie müssen nicht alle Bilder verwenden. Mit Hilfe der Textbox "Notiz" können Sie uns zusätzliches Feedback geben.* ***Stufe*** *bedeutet hierbei, dass der Fall unkritisch ist.*

Zurück | Weiter

Umfrage mHealth: Demographische Daten

Bitte füllen Sie die folgenden Fragen aus. Die Fragen dienen lediglich statistischen Zwecken.

Zurück | Seite 6/7. Fortschritt: 85% | Fertig

Alter, Geschlecht, etc.

Alle Angaben sind optional.

Alter — [ ] Jahre

Bitte geben Sie Ihr Alter in Jahren an.

Geschlecht — ○ männlich ○ weiblich ● keine Angabe

Herkunft — -- keine Angabe --

Bitte wählen Sie das Land an, in dem Sie geboren wurden

Fachrichtung — [ ]

Chirurgie, Interne medizin, etc.

Berufserfahrung — [ ] Jahre

Wie lange arbeiten Sie bereits als Arzt?

Arbeiten Sie in der Notfallmedizin? — ○ ja ○ nein ● keine Angabe

Notarzt, Regelmäßiger Dienst in der Notfallambulanz, etc.

Zurück | Fertig

Umfrage mHealth: Vielen Dank!

Vielen Dank für Ihre Teilnahme. Möchten Sie im Anschluss der Auswertung Informationen über den Hintergrund sowie den Ausgang dieser Befragung informiert zu werden, so haben Sie hier optional die Möglichkeit, ihre E-Mail-Adresse anzugeben. Sobald die Befragung abgeschlossen und ausgewertet ist, schicken wir Ihnen an die von Ihnen angegebene Adresse eine E-Mail, die die Hintergründe erklärt.

Seite 7/7. Fortschritt: 100%

Weiter

Kontaktmöglichkeit

Bitte geben Sie - falls gewünscht - Ihre E-Mail-Adresse an. ***Diese Angabe ist optional und wird nicht mit den Umfrageergebnissen verknüpft gespeichert***

Meine E-Mail-Adresse lautet:

____

und ich möchte über die Hintergründe und den Ausgang der Befragung informiert werden.

Weiter

Appendix D

Appendix D: Evaluation document

Evaluation session

Color coding

- ☐ Deformity
- ☐ Swelling
- ☐ Open wound
- ☐ Infection
- ☐ Pain
- ☐ Reduced sensibility
- ☐ Reduced motion range
- ☐ Reduced blood flow

Order of performed checks

- __ Deformity/Swelling:
- __ Open wound:
- __ Infection:
- __ Pain/Pain test:
- __ Reduced sensibility:
- __ Reduced blood flow:
- __ Reduced motion range:

Case 1

Miller, male, 45 years old, left hand, not traumatic, reduced blood flow at A5, reduced sensibility at N5, pain at phalanx distalis D3.

Expected actions

- ☐ tap button "new case"
- ☐ tap on age and change it
- ☐ double tap image
- ☐ change function to "reduced blood flow"
- ☐ tap on location
- ☐ change function to "reduced sensibility"
- ☐ tap on location
- ☐ change function to "pain"
- ☐ tap on location
- ☐ tap on button "save"
- ☐ tap on button "save"

Case 2

White, female, 23 years old, right hand, traumatic injury, high severity, reduced motion range at DIP4 (flexion and extension), pain at DIP4, open wound at DIP1, deformity at OS MC 4, swelling at phalanx proximalis 4.

Expected actions

- ☐ tap button “new case”
- ☐ tap on age and change it
- ☐ tap on hand symbol and change hand
- ☐ double tap image
- ☐ change function to “reduced motion range”
- ☐ tap on joint
- ☐ select flexion and extension from menu
- ☐ dismiss dialog
- ☐ change function to “pain”
- ☐ tap on location
- ☐ change function to “open wound”
- ☐ tap on location
- ☐ change function to “deformity”
- ☐ tap on location of deformity
- ☐ tap twice on location of swelling
- ☐ tap on button “save”
- ☐ tap on button “save”

Questionnaire evaluation

Age: __ years old

Gender: ☐ female / ☐ male

Color deficiency:

- ☐ no / not known
- ☐ ____________________________

Work experience (doctor): __ years

Semester (student): __

Specialized subdomain: ____________________________

Works in the ED : ☐ yes / ☐ no

Experience with touch-based smart phones in private use:

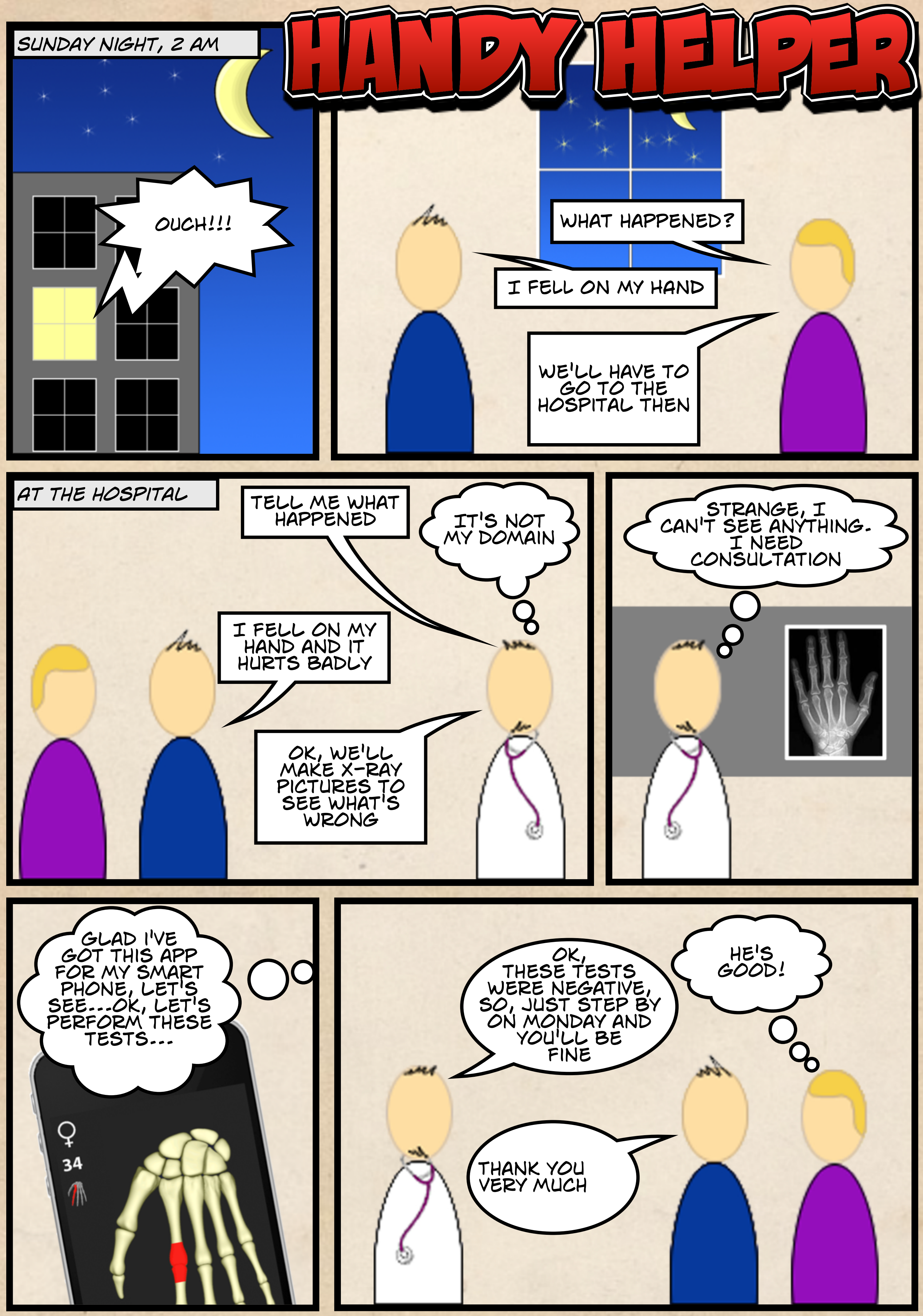
- ☐ iPhone
- ☐ Android
- ☐ Windows Phone
- ☐ other

Experience with touch-based smart phones at work:

- ☐ iPhone
- ☐ Android
- ☐ Windows Phone
- ☐ other

Appendix E

Appendix E: Storyboard "Handy Helper"


HANDY HELPER
SUNDAY NIGHT, 2 AM
OUCH!!!
WHAT HAPPENED?
I FELL ON MY HAND
WE'LL HAVE TO GO TO THE HOSPITAL THEN
AT THE HOSPITAL
TELL ME WHAT HAPPENED
IT'S NOT MY DOMAIN
I FELL ON MY HAND AND IT HURTS BADLY
OK, WE'LL MAKE X-RAY PICTURES TO SEE WHAT'S WRONG
STRANGE, I CAN'T SEE ANYTHING. I NEED CONSULTATION
GLAD I'VE GOT THIS APP FOR MY SMART PHONE, LET'S SEE...OK, LET'S PERFORM THESE TESTS...
♀
34
OK, THESE TESTS WERE NEGATIVE, SO, JUST STEP BY ON MONDAY AND YOU'LL BE FINE
HE'S GOOD!
THANK YOU VERY MUCH

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