Master's Thesis

QIMQ
Design, Development and Evaluation of Quasi-Intelligent Medical Questionnaires for accident reporting

Bettina Sommerauer, BSc

Institute for Information Systems and Computer Media (IICM)
Graz University of Technology

Supervisor:
Assoc. Prof. Andreas Holzinger, PhD, MSc, MPh, BEng, CEng, DipEd, MBCS

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Masterarbeit

(Diese Arbeit ist in englischer Sprache verfasst)

Entwurf, Entwicklung und Evaluation von quasi-intelligenten medizinischen Fragebögen zur Unfalldokumentation

Bettina Sommerauer, BSc

Institut für Informationssysteme und Computer Medien (IICM)
Technische Universität Graz

Betreuer:
Univ.-Doz. Ing. Mag. Mag. Dr. Andreas Holzinger

Graz, September 2013

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Abstract

In this masters' thesis, a quasi-intelligent questionnaire was designed, developed and evaluated for touch screens. The currently small number of completed patient reports made it necessary to adapt a more user-friendly input system.

The focus of this work was on a user centered system enhanced using methods of usability engineering. In cooperation with the Bärenburg, the current system has been analyzed and as a result a user centered system was built. In addition, the categorization of accidents were reordered and restructured and a WHO-based questionnaire was developed. The new user centered system will guide the patients through a quasi-intelligent questionnaire for data acquisition, which is required for the patient report. By logically linked questions, the possibility of complex responses was handled.

Based on this, an intuitive usability system was designed, which can be filled out easily by the patients themselves to alleviate the work of medical doctors.

The evaluation in the Pediatric Surgery at Graz has shown that the system has proven itself; however, the environment was not optimal. Due to the condition of patients when they come to the emergency room, they are not able to work with an unfamiliar system.

Keywords

User Experience, Usability, Accessibility, Touch Screens, Councelling, Adaptation, Adaptivity, Weighting Algorithm

ÖSTAT-Topics (maximum 4)

1108	50 %	1138	20 %	1157	20 %	3927	10 %

ACM Classification

H.4, H.5, H.5.1., J.3

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Zusammenfassung

Im Zuge dieser Arbeit wurde ein quasi-intelligenter Fragebogen für Touchscreens entworfen und entwickelt. Als Vorlage dafür diente die bisher verwendete, aber nicht sehr benutzerfreundliche Eingabemaske, die aufgrund mangelnder Benutzerfreundlichkeit und des Mehraufwands meist unvollständig oder gar nicht ausgefüllt wird.

Bei der dafür neu entwickelten Anwendung wurde vor allem auf die Wichtigkeit des User-Centered Development Ansatzes insbesondere in der Medizin eingegangen und mit den Methoden aus dem Usablility Engineering ergänzt, da eine solche Anwendung gerade in einem Krankenhaussystem universell für unterschiedlichste End-BenutzerInnen abgestimmt werden muss. In Kooperation mit der Bärenburg wurde das gegenwärtige System analysiert und als Folge ein User-Centered-Design entwickelt. Außerdem wurde die Unfallkategorisierung komplett überarbeitet und ein WHO-konformer Patientenfragebogen entwickelt. Der neu entwickelte Fragebogen soll nun, statt wie bisher von den ÄrztInnen, von PatientInnen bzw. deren Begleitpersonen selbst ausgefüllt werden. Um die komplexe Möglichkeit der Antworten programmieren zu können, wurde eine logische und quasi-intelligente Verknüpfung der einzelnen Fragen entwickelt. Dieser Software-Prototyp soll durch eine einfache und intuitive Bedienbarkeit für die Patienten verständlich und leicht zu beantworten sein und somit auch die ÄrztInnen entlasten.

Schlüsselwörter

Benutzerfreundlichkeit, berührungsempfindlicher Bildschirm, Adaptivität, gewichteter Algorithmus

ÖSTAT-Fachgebiete (maximum 4)

1108	50 %	1138	20 %	1157	20 %	3927	10 %

ACM Klassifikation

H.4, H.5, H.5.1., J.3

STATUTORY DECLARATION

I declare that I have authored this thesis independently, that I have not used other than the declared sources / resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

Graz, 21th September 2013 ……………………………………………

First Name, Surname

EIDESSTATTLICHE ERKLÄRUNG

Ich erkläre an Eides statt, dass ich die vorliegende Arbeit selbstständig verfasst, andere als die angegebenen Quellen/Hilfsmittel nicht benutzt, und die den benutzten Quellen wörtlich und inhaltlich entnommenen Stellen als solche kenntlich gemacht habe.

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Vorname, Zuname

Danksagung / Acknowledgments

First of all, I would like to thank my boyfriend and my family, because they have supported me during my study period.

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I also thank Dr. Peter Spitzer, who has created not only the re-categorization of accident categories for the questionnaire, but also actively supported me in the evaluation, both the pilot test and the real-life test. I am also indebted to the employees of the “Bärenburg” for helping in the test phases.

Finally, I want to thank Dr. Johannes Schalamon who initially had the idea for this project.

Abbreviations

FDA	Food and Drug Administration (US)
HCI	Human–Computer Interaction
UCD	User Centred Development
UX	User Experience
UXR	User Experience Research
WHO	World Health Organization
KFV	Kuratorium für Verkehrssicherheit
ICECI	International Classification of External Causes of Injury
CI	Computational Intelligence
AI	Artificial Intelligence
ER	Emergency Room
EHR	Electronic Health Record
CDC	Center for Disease Control and Prevention
ICU	Intensive Care Unit
EPR	Electronic Patient Record

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1. Introduction and Motivation for Research

According to the KFV (the curatorship of transport safety in Austria), over 800,000 accidents occur annually, one-fifth concerning children under 14 years (KFV 2012). Worldwide around 950,000 children and adolescents under the age of 18 die each year of the consequences of accidents. In Europe alone the numbers are about 5,000 children per year (WHO, 2008). As you can see in Figure 1, almost three-fourths of accidents are attributed to home, leisure and sport activities.

	Anzahl			
	Verkehr	Arbeit, Schule	Heim, Freizeit, Sport	Gesamt
Getötete	552	186	1.776	2.514
Verletzte mit bleibender Behinderung	1.591	1.105	5.861	8.557
Verletzte mit stationärer Behandlung	11.951	13.751	137.272	162.974
Verunglückte insgesamt	46.410	171.556	606.300	824.000

Figure 1: Accidents and injuries split in injury indicators (KFV, 2012)

Consequently, leisure accidents are still the largest part of all injuries. Alarmingly, accidents during leisure time not only comprise the highest number of injured persons; these accidents also comprise the highest number of fatal accidents (Figure 2).

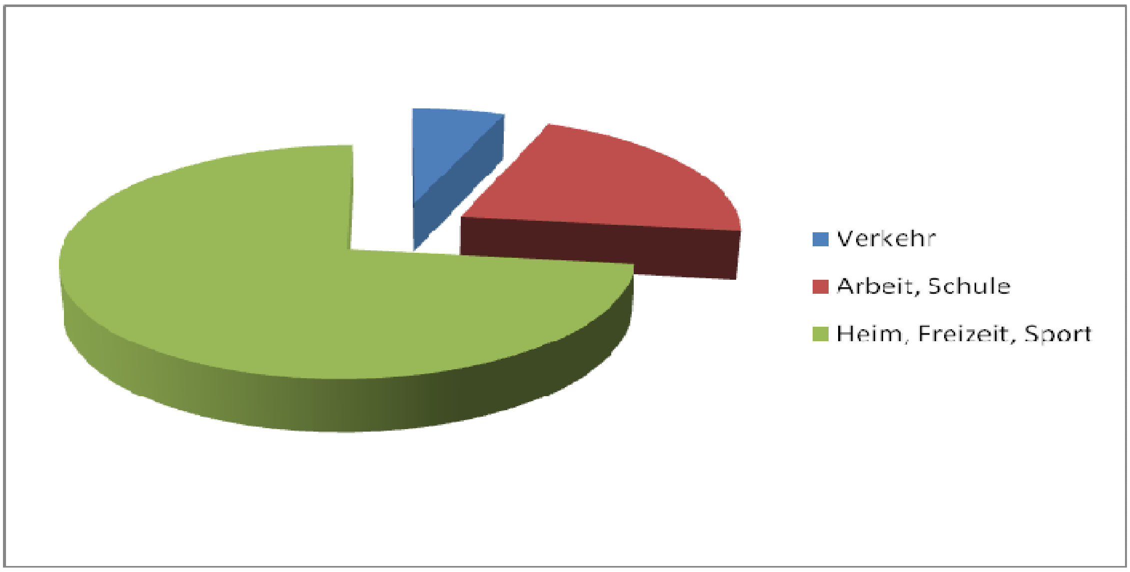


Figure 2: Deadly accidents in Austria (KFV, 2012)

If you reduce this to the number of accidents involving children aged from 0 to 14 years, you have an annual expectation of around 160.000 injuries with children, and 25 deaths. "Injury is a major problem for children and adolescents all over the world and the cause of significant morbidity and mortality" (Schalamon et al., 2011). In the age-group of children less than 14 years, approximately every second adolescent is injured at home or in their spare time and every fourth young patient has an accident during a sporting activity (Figure 3). 10%-25% of all injuries of children younger than 18 years will result in fractures (Schalamon et al., 2011). Statistically in Austria, a child dies as the consequence of an accident every week. Every single day, about 25 children under the age of 18 die needlessly in the EU as the result of an injury.

Altersgruppe	Anzahl				
	Verkehr	Arbeit, Schule	Sport	Heim, Freizeit	Gesamt
0-14	2.924	40.268	42.500	79.200	164.900
15-24	14.198	38.189	49.700	35.600	137.700
25-59	23.037	70.706	88.400	143.000	325.100
60+	6.182	1.784	18.300	149.700	176.000

Figure 3: Accidents and injuries split in age-groups (KFV, 2012)

As shown in Figure 4, the most common cause of death for children is still an accident.

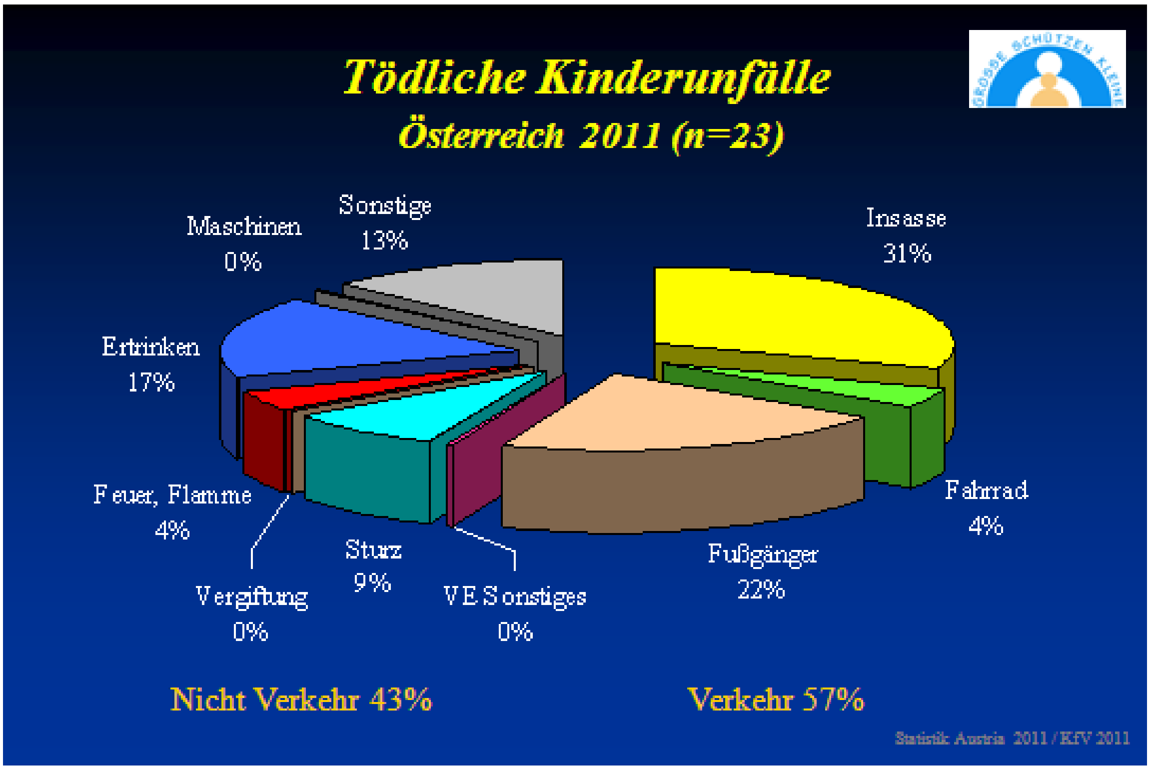


Figure 4: Fatal accidents with children split in cause of accident (GSK, 2013)

Although there has been a reduction in fatal accidents in the last 25 years, even more must be done in the future to reduce this accident rate. In contrast to the reductions in road accidents in recent years, the number of leisure accidents has increased slowly but continuously, respectively stagnated at a high level.

Accidents should not be accepted as fate or contingency, they have causal relationships, which can be analyzed by the accident research. Many accidents and their often long life consequences could have been prevented if correct information had been available.

In order to bring children more security in everyday life, it's important to have statistical information for analysis of the circumstances and the underlying causes.

1.1. The Current System

In order to obtain that information, every patient requiring medical care at the Department of Pediatric Surgery in Graz has to be recorded at the local medical information system. In this system, every patient has their own record with a patient report for each accident.

For the patient' administration, the Department of Paediatric Surgery in Graz currently uses a computerized documentation system, which is based on an SAP healthcare solution to store accident data. The system provides personal information about patients, their examination and the medical vita of the patient. The accident report, a paediatric injury data entry form, is part of the medical documentation system called openMedocs since 2004. In this system, there are accident reports for each patient (Figure 5), so that it's possible for every doctor to view the patient records at all time. The purpose of this patient reports are the collection of location, circumstances and diagnoses of accidents.

So, in a two year period, between December 2004 and October 2006, for example 21.582 cases were documented in the Medocs system (Schalamon et al., 2011).

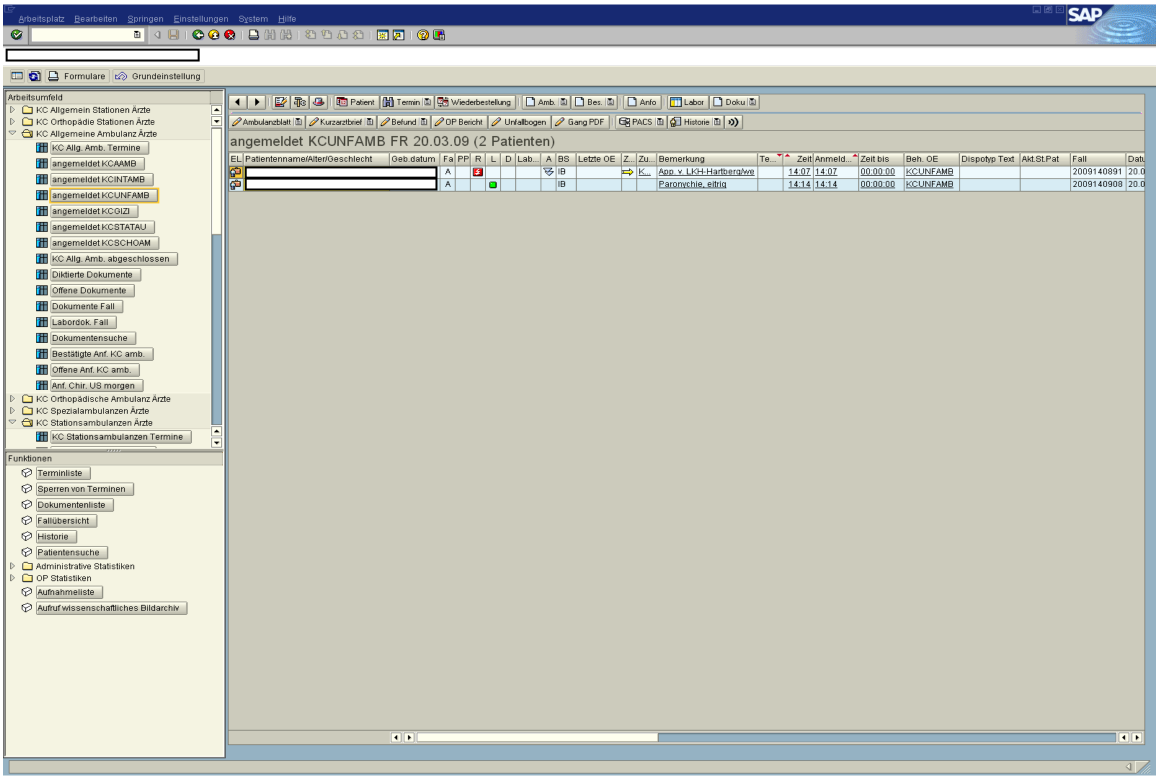


Figure 5: The layout of the medical scientists workplace: Work list Ambulance (Picture taken by Dr. Schalamon)

At the moment, physicians have to do many different types of work, which are not always directly related to medicine. One of these factors which cost a lot of time is the patient report.

When the patients arrive at the central administration desk of the outpatient clinic, a medical nurse gathers personal data and creates an empty patient report for each patient. These data are stored in the Medocs system, allowing the medics to read all the date on their computer in the doctor's office.

Theoretically, every doctor is required to fill out a patient report for every patient during the treatment. But their concentration is usually limited to the patient, so there is not time to type the accident cause, the accident mechanism, etc. into a prefabricated mask at the medics' workplace. Most often, the accident data is just collected and typed into the accident report after the treatment (see Figure 6). Consequently the patient reports are incomplete or sometimes even blank.

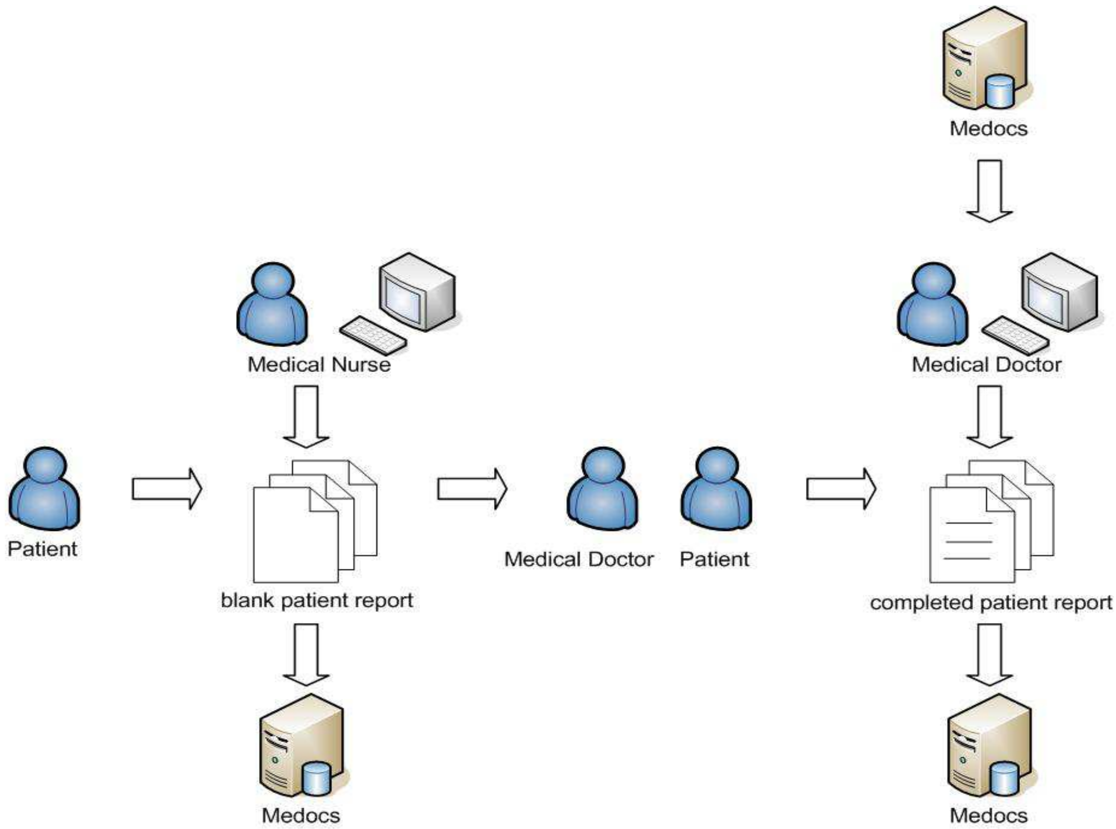


Figure 6: Current workflow of the patient report (Picture taken by me)

1.2. Problems

The currently used system has some severe disadvantages with regard to the user interface, categorization, standards and flexibility.

- **User Interface**

One obvious disadvantage is that the patient report is based on a text-based User Interface (see Figure 7) and as a result it is very user-unfriendly, which is also reflected in the number of completed patient reports.

At the moment it can be act on the assumption that only every second accident is detected with the current tool.

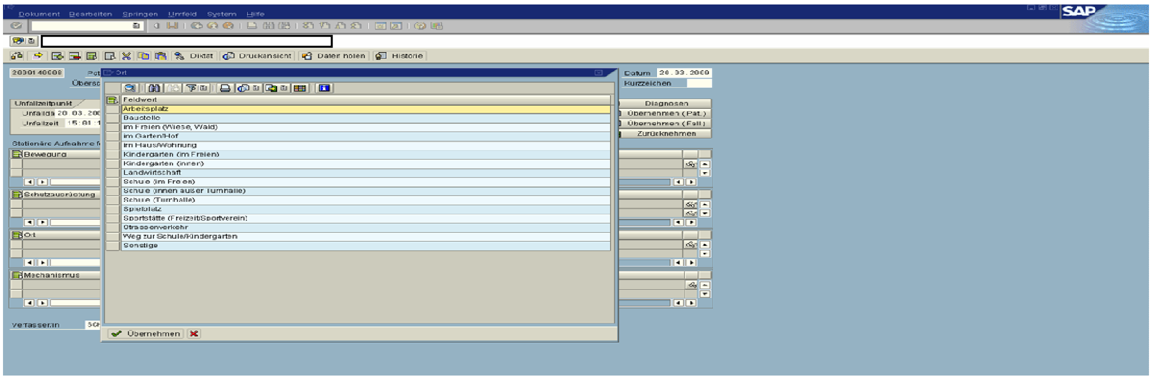


Figure 7: The layout of the current text-based user interface of a patient report (Picture taken by Dr. Schalamon)

Due to of this it is very difficult to find, for example, the required accident mechanism for the corresponding patient. As you also can see in Figure 7 there is only a list of accident mechanisms, which are completely unstructured and disorganized. Learning to understand how it works requires a lot of time. The data have to be typed in by the medics wasting valuable medical professional’s time, which would be better spent in different, more relevant medical core areas.

- **Lack of Logic in the categorization**

A further disadvantage is the categorization of the accident causes and mechanisms. It is very difficult to understand the logic behind the categorization; as a result, some accident mechanisms are not shown in appropriate category. Medics often waste valuable time looking for an accident cause in the wrong category. Due to these facts, many medics do no detailed categorization and just use global categories. In addition, there is the problem that the given accident data set are not complete, because there is a lack of newer types of accidents; such as slack line or trampoline. For this reason, doctors never can be sure whether the accident is not found because they are looking in the wrong category or because the accident is not included in the database. Additionally these aspects lead to confusion and incomplete reports.

- **Lack of Standards**

Also, the accident mechanisms do not equate to the WHO standard, which is important so that the data can be used for international comparisons. The ICECI is a system of classifications in the WHO family and is useful for injury surveillance. It is especially important in the case of accidents as it enables a systematic description of occurred injuries, designed to assist injury prevention. When the accident information is in accordance with the WHO standard, it is easier to present Austria statistics worldwide.

1.3. Planned System

The aim of this diploma thesis is a completely redesign of the accident reports.

The idea is to relocate the data collection of how an accident occurs to archieve maximum benefits by making both useful and well usable applications, similar to the MOCOMED project (Holzinger et al., 2011), that allows the patient to complete the accident report independently. In addition, this questionnaire will be designed and developed in a new technology information retrieval system using a touch screen pc with a specially designed graphical user interface. It will implement a logical input mask and a new query management with only few sub levels and scrolling pages.

The new implemented tool will be a computer-assisted questionnaire, which is filled out in the waiting room in the outpatients, via touch screen technology.

The new system aims to ensure that, for every examined patient, an accident report will be added into the system. By outsourcing this process to the patients, they can be involved early in the treatment process and at the same time, the attending physicians can be freed to focus more on the treatments. Also the medic's contribution will be minimized as far as possible.

Figure 8: The Child Safety House in Graz (Picture taken by Dr. Peter Spitzer)

In Cooperation with the "Bärenburg" (Figure 8) a WHO-based patient questionnaire will be developed which provides information about location, mechanism, cause and other important facts about the accident.
The "Bärenburg" is a so called Austria Child Safety House, working for the European Child Safety Alliance. As shown in Figure 3 most accidents occur at home or during leisure time. Therefore the aim of the "Bärenburg" is to make the home and the leisure

activities more secure for children and adolescents. For this reason, statistical information about occurred accidents is very important.
Such accident reports, which are collected in the Medocs system, are documents which can used for a collection of accident data, in order to make a statistic evaluation possible. For example is it important to know how many bikers knocked down by cars in 2010. This accident report contains information about the accident itself, the accident mechanism, the protection mechanisms, etc. to obtain statistically useful data.

The first part of the master’s thesis, chapters 2 and 3, overviews the state of the art of EHR systems worldwide, describes the advantages of a complete collection of accident data. It describes active and passive strategies for the prevention of accidents and their “return of investment”. Also there are a few words about the first child safety house in Austria.
The second part, chapters 4, 5 and 6, describes the planned integration of the developed front-end interface in the current system and the implemented questionnaire and the following evaluation at the Department of Pediatric Surgery in Graz. Chapter 4 overviews the state of the art of mobility and touch based technology in the medical industry. Chapter 5 describes the redesign of the accident categories, the designed mock-ups, the implementation phase and the integration in the hospital information system Medocs. Chapter 6 presents the test phases and discusses the real life pilot scheme at the Department of Pediatric Surgery in Graz.
The third part, chapters 7 to 9, finally conclude this master’s thesis by discussing results, lessons learned and presenting an outlook in the future.

2. Theoretical Background and Related Work

Today the health care industry is booming, providing a large quantity of relevant data. The necessity of computerized systems in the medical sector is indisputable. However, the advantages of digitised data to support an easier handling with patient records also have a potential drawback; bad usability. In a paper by Nielsen (Nielsen, 2005) the author describes twenty-two ways that usability can often be a matter of life or death. In this example, Nielsen shows the possibility, whereby an automated hospital system could cause wrong medication to be dispensed to patients. Consequently, the statement reveals that good design can save lives.

2.1. EHR systems

The study by Holzmann (1999) is demonstrative in the context of emergency response documentation. In this paper he discusses the theoretical criteria a system supporting emergency response should fulfil. One of the most important passages in this paper in relation to my work is the fact, that a general problem in emergency response documentation is seen in the low quantity and quality of acquired data. Some studies cited by Holzmann show that 40% of the emergency sheets are typically either left blank or filled out erroneously. While it is not surprising that in ambulances the medics' "[…] eyes and hands must be on their patients rather than on the paper and pencil documentation traditionally used for recording findings and treatments" (Holzmann, 1999), we must still acknowledge that emergency medical information is often incompletely and inaccurately collected and delivered. Also the studies of Hammond et al. (1991) show that nurses documented events not when they occurred but instead noted a kind of summary at the end of their shift. The reason of this phenomenon is often the lack of time to deal with complicated patient reports in stressful situations. The main priorities of emergency medicine are to help patients, alleviate their pain and to do all this as quickly as possible. An interesting study was made by Grasser et al. (2011), where they evaluated 47 different report forms used for the documentation of medical

content. It was shown that there are large differences in their layouts and levels of detail of the information to be completed.
So we must not be surprised that the paper of Graham et al. (2004) cites a study illustrating that in medical devices many announced errors are not technical failures but rather user errors. The authors show that it is important and "[…] essential to systematically identify the existing usability problems so that the possible causes of errors can be better understood, passed on to the end-users (e.g., critical care nurses), and used to make policy recommendations" (Graham et al., 2004).

A study of Wu et al. (2006) demonstrates the integration of patients in the composition of emergency response documentation. It shows that mobile devices enhanced quality of care by reducing medics' time in the accessing, retrieving and recording of data, allowing them to concentrate more on patient care. The result of this study is clear. Of two randomized trials in which two different handheld mobile electronic medical records were used, both found that the use of handheld computers improved documentation.
Due to interface design problems, human errors in medical device use are large. But these problems can be potentially addressed through UCD.

2.2. Mobility and Touch Screen

Nowadays mobile devices play an increasingly important role. The usefulness of handheld computers in medicine is accepted, even among patients. Thus it is not astonishing that mobile devices are also used in medical care. According to various studies, mobile computing applications are commonly accepted in the area of Medicine and Health (Chen et al., 2009 and Chittaro et al., 2007). The studies show that users who are completely unfamiliar with mobile devices, such as a tablet pc, can quickly learn how to use it. The goal of the paper by Chittaro et al. (2007) was to design an easy-to-use system for collecting and handling emergency medical care data. In this study, the author is interested in the reactions of users who are not familiar with the employed technology. The result shows that the evaluation was much more positive than they expected. Although all participants had never used a PDA before, all participants quickly learned how to effectively operate the system and “[…] expressed willingness to employ such technology in their daily practice” (Chittaro et al., 2007).

Mobile devices, e.g. mobile phones with advanced performance and especially tablet computers, use a touch screen as the main interaction method. For this reason, the design of applications running on such devices is crucial for the success of the application and the device. Above all on mobile devices, usability plays a big role in its acceptance. When using such devices it must be clear that the limited space on the screen brings significant usability challenges (Oehl et al. 2007). The study by Sax et al. (2009) shows, that a touch-based mobile device can be used successfully with appropriate design. For this reason, the necessity of usability is presently acknowledged for the development of medical mobile devices, as the study of Graham et al. (2004) and the study of Hoelcher et al. (2011) shows.
The specifics of mobile devices pose special challenges in design and usage of mobile questionnaires, especially when multiple questions are included. Therefore, while several studies are accomplished (Richter et al., 2006; Brewster et al., 2003; Lam et al., 2006; Kanstrup et al., 2009) and some solutions have been developed, there are not known tutorials on developing mobile questionnaires. The user experience evaluation by Vaeaetaejae et al. (2010) defined the four most important things to keep in mind in the development of questionnaires for mobile devices: the small screen size, the data entry method and interaction style, the mobile context and the chosen implementation for the questionnaire.

There are several previous reviews on mobile computing in hospitals including reviews by Lu et al. (2005). The study gives a comprehensive picture of handheld implementation in healthcare and the possible roles of PDAs. It can be clearly stated (Sung-Huai et al., 2010) that the user information satisfaction resulting from the use of a mobile electronic medication administration record is significantly higher than that observed with the benchmark paper-based workflow, as also proven by the study proves by Geiger et al. (2003).

In recent years, the gestural interface technology has been increasing in mass consumer products, especially products such as the Apple iPhone or the Nintendo Wii videogame console; pioneers in this technology. More and more, consumer electronics manufactures have developed gesture control elements and included this technology in a whole range of mobile electronic devices, such as laptops, cell phones, PDAs, remote controls, navigation systems and digital cameras. Therefore, it is not surprising that there are also studies about the use of Nintendo Wii Remote Controller for the topic e-Teaching. For example, the study from Holzinger et al. (2010) shows the design and development of a low-cost demonstrator kit for the Wiimote. Results show that gestures can enhance the quality of learning processes of children. We communicate through speech and gestures; consequently they are an important part of non-verbal communication. "Studies demonstrated that gestures influence the students' comprehension of instructional discourse, thereby influencing students' learning" (Holzinger et al., 2010).

Generally all devices with touch screens are easy to handle. Regardless of the size of the touch screen device, the handling is always simple. The intuitiveness of the touch screen has led to its widespread distribution, from public kiosks to mobile phones.
Touch screens are currently gaining popularity in the information technology industry. But touch screen-based devices also present a challenging trade-off between visual expressivity and ease of interaction. The paper from Donker et al. (2007) shows that a mouse or keyboard is an unfriendly, indirect operation form and hard for children to use. However because fingers are the most natural of all input devices, even children can easily learn the handling of touch technology.
There have been a number of user evaluation studies of touch screen interfaces. For example the study by Kölsch et al. (2002) shows a general survey about text input with touch screen computers. This paper presents a closer look at touch-typing as an input method and highlights its benefits.

Particularly the study by Holzinger (2003) points out that all patients found the use of touch interfaces very simple. The simple finger-touch interaction is also suitable for novice computer users. This paper shows that any person can easily handle a simple application without prior experience or instructions.

Also a paper by Yu et al. (2010) focuses on touch technology for children. Figure 9: Children play with touch screen technology demonstrates the simplicity for young children to interact with touch screens.

A nice side effect of using a touch screen pc is that the users don’t need any added accessories such as keyboard and mouse, which saves working space.

Figure 9: Children play with touch screen technology (Yu et al., 2010)

2.3. HCI and Usability

To deal with such an enormous amount of data, improvements in usability are increasingly necessary (Mchome et al., 2010). Because the end-users in this domain are

patients, clinicians or nurses, adaptive user interfaces should be designed for these users. So the study by Mchome et al. (2010) shows that health care quality and performance can be enhanced by implementing adaptive user interfaces. Some further studies have concluded that usability is one of the most critical factors in the acceptance of a new computerised system, especially in relation to negative examples (Levenson et al., 1993), where bad usability led to the mistreatment of cancer patients.
In addition there are several field evaluations (Schaechinger et al., 1999, Schumacher et al., 2009 and Zhang et al., 2003) that show the importance and necessity of usability. The paper from Schumacher et al. (2009) shows a five-step process for specifying the usability of EHR systems. These steps help in the selection of an EHR. The authors of this paper believe that EHR systems corresponding to these facts are more likely to be adopted, meet the needs of their users, and reduce the chance of usability-related abandonment. Therefore it is not surprising that usability issues are factors in why EHR implementations can fail. In times of reduced funds for health care expenditures, it is important not to stress medics with complex data entry. In many cases, user interfaces of medical devices are so badly designed and difficult to use that they facilitate a range of human mistakes. “The layout and the design […] greatly affect the user’s ability to successfully perform functions and extract information during operation of a device, especially during critical events” (Sawyer et al., 1996). The FDA’s report describes a variety of errors produced by medical device interface design. In addition, the FDA detected that a badly designed user interface can cause errors and operating inefficiencies even when operated by a well-trained, competent user. “Good user interface design is critical to safe and effective equipment operation, installation, and maintenance” (Sawyer et al., 1996).

In this context, another paper (Leitner et al., 2007) assumes one of the reasons is bad documentation in the design of the paper sheet. The protocols they used for their evaluations seemed not to be designed on the basis of task orientation and logical workflow. “Thus, the lessons learnt emphasize that usability plays an important role in reducing medical costs, saving patient’s life and saving time” (Mchome et al., 2010).
For this reason it’s important to integrate the user. To get the maximum benefit of an application, especially with new devices such as touch screen computers, the application

of a UCD approach is strongly recommended (Hartson et al., 1989; Karat, 1996). But Karat (1996) poses the question, wheter the methods of good design for a follow-on release of a word-processor, for example, are the same as those for an EHR system. Thus one can say that a good design isn't always a good design. Each implemented application and their designs must be matched with the end-users.

2.4. UCD

Bad usability prevents the user from using devices. However, this should be prevented. Despite recommendations that the users, in this case patients, should be involved in the design phases of health technology, there are only few papers about this topic. The paper of Read et al. (2008) shows, that the topic of Child Computer Interaction is a growing subfield of HCI. It has emerged as an important research discipline within HCI. Children now grow up immersed in technology, so in recent years, "there has been an increasing trend for children to use information and communication technology in its various forms" (Markopoulos et al., 2008). A search of the literature on interaction design and children shows a variety of research approaches in this domain. Mainly, this thematic reaches out into areas of child psychology, learning and play. Child Computer Interaction differs from HCI fundamentally in priorities and different methods (Read et al., 2008).

That children are an increasing part in usage of interactive technology isn't surprising. Today's generation is growing up with "new" technologies. Children's culture has changed in recent years and this is often attributed to the influence of electronic and digital media. Devices, such as mobile phones or computers, are new technologies for most people; but for children and adolescents these devices are everyday objects. The paper (Lego, 2003) presents exactly this topic. The author says that the way in which children and young people today use different media has been changed enormously. With the development of new interactive products and interactive media an integral part of children's everyday lives in the industrialized world has been changed step for step in recent years. "This development has occurred quickly, and we know relatively little about its importance to children's play, culture and learning (Lego, 2003)." Computers and video games are a normal part of life for millions of children.

This fact brings up the question of why one should not link this with health care and so with emergency response documentation.
In contrast to adults, developing a computer-based patient report for children does not mean that the adolescents are motivated to fill out the questionnaire. In order to motivate children for fill out the questionnaire the challenge lies in designing serious games that integrate benefit and fun.
A study from Lampert et al. (2009) demonstrates that serious games have great potentials in health care. Also another study (Suhonen et al., 2008) demonstrates that it’s important that a system, such as a mobile device, for children and adolescents has to be useful and fun. Thereby the result shows that with the integration of gaming elements the intrinsic motivation remains high.
Primary serious Games operate in the field of health promotion and prevention as a medium for information campaigns. The use of serious games in the domain of prevention and health promotion is primarily based on the Entertainment-Education approach, the Game-Based Learning Theory and depends on the Bandura's social cognitive learning theory (Bandura, 1977).
The HIV / AIDS prevention theme is currently a large part of serious games, e.g. “Catch the Sperm“. Also the study from Coyle et al. (2011) is a positive example of game based learning. It shows that adolescents are sold on gaming. The young people were especially impressed that this behavioral therapy did not use paper but the computer. The feedback from the adolescents: It was a game and so it was more fun than just talking.

Several studies (Susi et al., 2007; Eck, 2006) show that experts do not doubt the advancement in the field of serious games in continuous further development of patient care.
To develop a system, which has a user-friendly interface, it is important that the handling is easy and the way to solve a particular problem is simple. In software engineering, developing intelligent adaptive systems creates new challenges, particularly in relation to correctness and reliability. The paper from Juan et al. (2003) describes a meta-model for intelligent adaptive systems to handle these challenges. In

another paper (Sterling et al., 2005), it is shown that future systems will be intelligent and adaptive, but there are still enough hurdles to overcome.

Especially in UCD, the interaction between the user and the system is important. However, this interaction cannot be static, the system must react with the users input, in other words, the application must be adaptive. Software still requires many advances to be acceptable for cognitive and intelligent systems. How far we are away from this level of sophistication is shown, for example, in the low usability of help files in most applications. The paper from Kinsner (2007) describes some of the challenges of developing adaptive, intelligent and cognitive systems. That the medical domain has already given some thought to this thematic is demonstrated by the papers from Sutherland et al. (2008) and Rouse (2007).

3. Prevention of accidents

Accidents cannot be accepted as destiny. Events, such as accidents, have causal relationships and can be analyzed by accident research. Based on research results, it is possible to select the most efficient and effective prevention measure. Technical measures and improvements in product safety are key factors in protection, but changes of behavior and the development of separate risk awareness must not be ignored.

A risk cannot always be eliminated, but it can be reduced or even abrogated with support tools, be they technical, physical or mental.
To avert an accident means that the knowledge of hazards is available. Or you need to know about a possible backlash decision that cannot be effectively an accident. Thus, a detailed analysis of the circumstances of the accident is an essential prerequisite to identify existing factors and recommending effective accident prevention. Only thus can meaningful and purposeful implications for the prevention of accidents (Jordan et al., 1991) be derived.

3.1. Active and passive prevention

There are two strategies for accident prevention. The first is an active strategy which aims to prevent the event itself, like scalding at the stove or falling from a window. The second strategy is a passive strategy, which tries to prevent or to minimize the injury, such as protective equipment such as helmets or airbags in the car.

In Figure 14, you can see an active strategy: lockable window handle prevents the fall from the window.

Figure 10: active strategy for accident prevention (GSK, 2013)

A passive strategy for accident prevention can be seen in Figure 15. In this example the helmet does not prevent the fall but reduces or prevents a serious head or brain injury.

Figure 11: passive strategy for accident prevention (GSK, 2013)

With regard to the levels of intervention the technical level of intervention is a very effective, but also the most expensive way to prevent an accident. Especially in safety technologies in the automotive industry, the latest developments are directed not only at the injury but also on reduction and prevention of accidents.

But these possibilities are limited to the areas of home, leisure accidents and sports. The accident research supplies a great input to make objects and items of everyday life safer (Manciaux, 1985).

A high quality accident database is the basis for the analysis of accidents and the creation of regionally effective and efficient prevention measures, which lead to a reduction of suffering and treatment costs.

According to calculations by the CDC (CDC, 2000) the following "return on investment" can be expected through accident prevention measures:

- Each euro invested for a smoke detector saves € 69 to total economic accident costs;
- every euro spent on a child safety seat saves € 32 or
- every euro invested for the operation of a poison center saves € 7.
- Also, a special consultation of a medical practitioner in accident prevention saves ten times the invested costs.

While the calculation of costs for a child which has had an accident cannot express the anxiety of parents and the suffering of the little patient, it can clarify health budget issues for tertiary prevention (accidents and accident treatment) and where they could be used much more effectively for efficient accident prevention.

Accident prevention is part of prophylactic medicine, as is inoculation, and it is not only important for the individuals themselves and their families but also of overriding public health interest. Accident prevention wins a priority public health importance both by the growing size of the accident costs as well as by the possibilities of successful work, because accidents in industrialized countries

- until the age of 45 over 50% are the most frequent cause of death,
- according to the infectious diseases are the second leading cause of inpatient or outpatient treatment,
- take a significant role in economy (total costs) and national health (for example years of life due to premature death) in the health system.

Even if the "Vision Zero" has to be a vision in accident occurrences, the Styrian as well as the international experience, e.g. from Sweden, shows us, depending on the accident area, that a further reduction of accidents and injuries by 35% - 50% is a realistic medium-term objective.

The acquisition of absolute numbers of accident events in Austria are based on projections that form the basis of Austria's target group interviews in a few hospitals. This earlier system EHLASS was replaced by IDB (Injury Data Base EU-funded project).

Due to the collection of data across multiple steps (paper, interview, anonymization) there are data with low depth of information. Thus, these data are considered to be very "soft" data. In addition, special children's wards, especially pediatric surgeries, are not included in the detection process. By the way, it should also be noted that the amount of base data per year at the Pediatric Surgery in Graz is greater than the annual data base that underlies the IDB projection for Austria.

3.2. The "Bärenburg"

Because of these problems, the Univ. Department of Child and Adolescent Surgery Graz decided to expand their own medical "home data" to the accident data in 2005. In the newly created Centre for Accident Research, the Scientific Department of accident research and prevention of Univ. Department of Child and Adolescent Surgery Graz and the club "Große Schützen Kleine" now closely work together. The reason for this is, on one hand, to publish results of scientific research of accidents and, on the other hand to effectively lead to changes in behavior and conditions of the population. With the

“Bärenburg”, the child safety house in Graz, a central teaching and learning place has been created to make accident prevention available and especially understandable.

The Bärenburg, which can be seen in Figure 16, is an Austrian institution localized in the area of the LKH Graz. Their common interest and goal is to prevent children from beeing harmed in a normal household. It's the first building of its kind in Austria. In cooperation with KAGes and the association “Große Schützen Kleine” the idea of a child safety house in Austria was born.

Figure 12: The "Bärenburg" (GSK, 2013)

As I mentioned before, annually 164,900 children are involved in accidents in Austria, of these 25,000 are in Styria alone. Throughout Austria a child dies as a result of an accident every week. Three-fourths of all accidents involving children occur at home, in the house or garden. However, very often, parents do not realize how easily many of these accidents involving children in living quarters could be prevented (GSK, 2013).

So the “Bärenburg” demonstrates how accidents with children can be avoided and makes it possible to visit different rooms (such as the kitchen, bath-room) to satisfy oneself how these ideas are being realized (Figure 13).

The idea originally came from Australia, where Child Safe Houses are well established. Here in Austria the project began in 1998; it took about 10 years until 2008 until the Bärenbug was completed.

Figure 13: Example for more safety at home (GSK, 2013)

The slogan “Sharing knowledge, helps reduce accidents and save children's lives!” from “Große Schützen Kleine” is to be communicated to everyone.

At the department of Pediatric Surgery, 14.000 children and adolescents are treated after an accident annually. This means that on average, every day almost 40 children visit the emergency department of this hospital (GSK, 2013).

An analysis of accident severity (Figure 18) leads to a differentiated approach of this large set of numbers. Around two-thirds of the children are only present once, 27% of injuries are considered as medically severe (brain injuries, surgical care, fracture, multiple trauma). 9% of all trauma cases must be hospitalized and about 0.5% are also treated in the ICU.

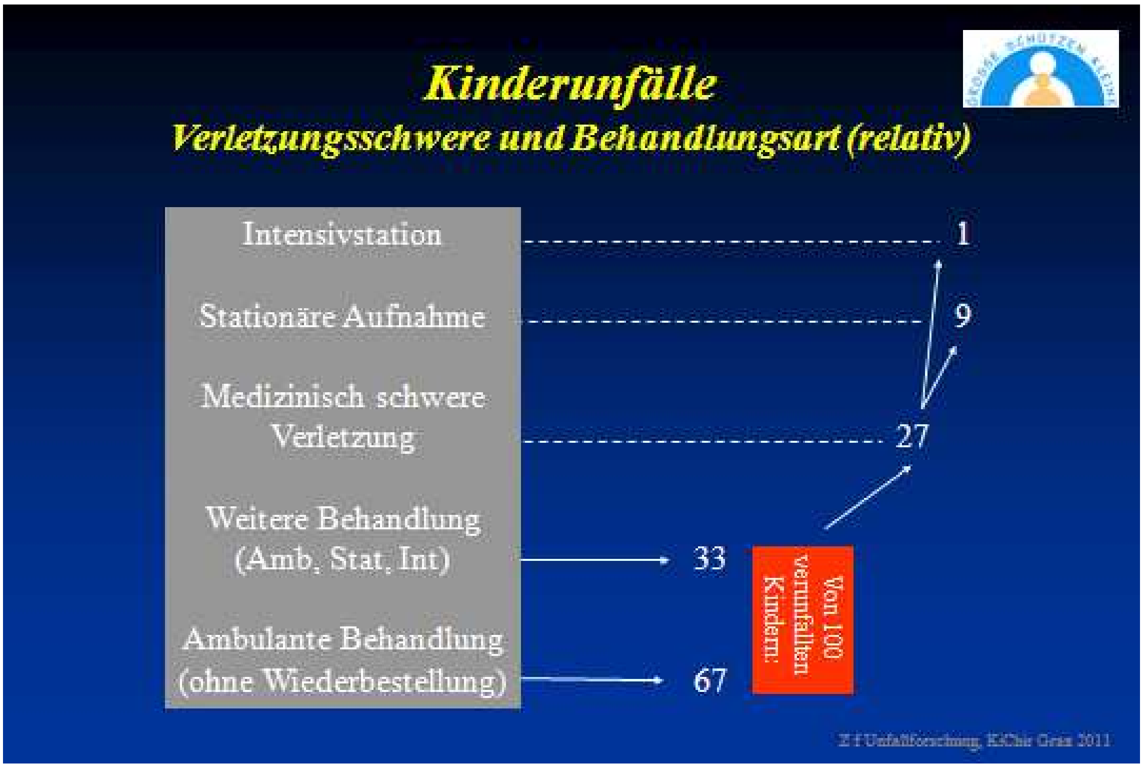


Figure 14: injury severity from accidents of children (Spitzer et al., 2009)

But injuries and necessary treatments are no basis on which to analyze the causes of accidents in detail and work out precautionary measures. In 2005, a database was installed which was connected within the MEDOCS system as an additional tool to capture more detailed circumstances of the accidents from treatments at the children's hospital.

The in-house experience, international developments in the accident classification and the need for a broadening the database now make an update and an upgrade necessary.

4. The System

Primarily it is important to ascertain the project requirements, the clinical environments and thus the technical environment and the end user.

4.1. Clinical Environment

To understand the whole system, it is important to have a look at the technical environment.

In order to display heterogeneous IT-systems of numerous hospitals, a system was developed by the KAGes, the governing body of the Styrian hospitals. This countrywide Hospital Information System, is called openMedocs, a customized SAP product. The core of openMedocs is the electronic patient record (EPR) system, which is use for patient management system. All documents and patient data are stored in this system.

Because very sensitive information about every patient is stored in this system, there has to be high data security, which is guaranteed by strict privacy policies. Due to this fact, the questionnaire for the patient reports cannot be easily integrated in Medocs. Consequently the questionnaire is designed and developed completely autonomously.

Therefore, it is necessary to know that the questionnaire will be a stand-alone system, which operates only on the frontend side. For that reason all necessary data for the development of the questionnaire, the questions, the answers, the structure and the logical interconnection, are stored locally on the touch-screen pc.

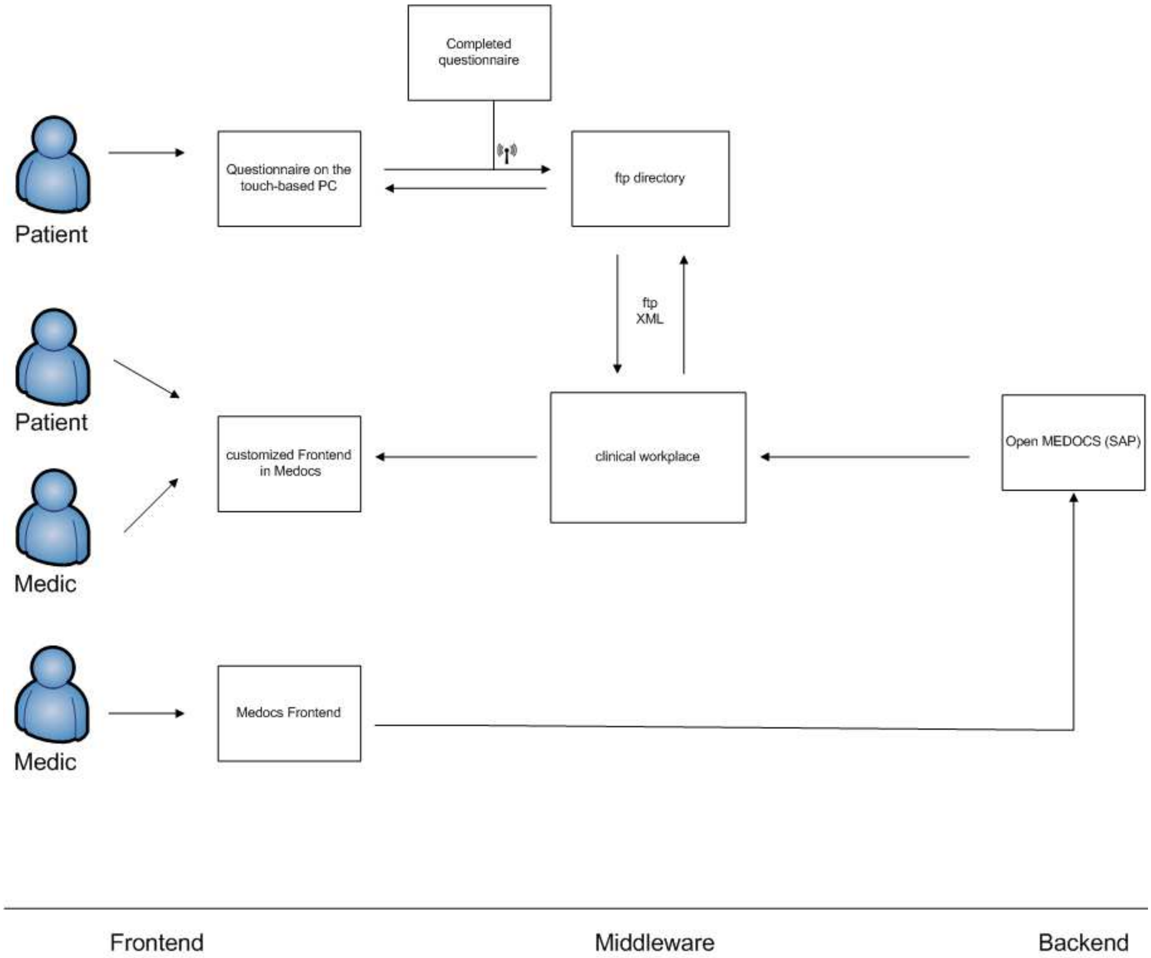


Figure 15: the system architecture

After the questions have been answered, the completed questionnaire is transferred into Medocs. The integration of the patient data into the Hospital Information System is based on an existing system from cancer research (Holzinger, 2002). Therefore, the same XML interface as the technical protocol can be used, so that the data collected from the questionnaire can transferred directly into the Medocs-System by using a remote function call. This XML file contains all the patients' answers, including the appending questions. All the obtained information is stored in Medocs and the medics may access the data of each patient at any time in the clinical workplace (see the system architecture in Figure 15).

4.2. The Device

The original goal of this work was to develop a mobile solution such as the MOCOMED project (Holzinger et al., 2011). As seen in related papers, the acceptance of mobile computing applications in health care is increasing. So a decision was made to implement this project on a tablet pc.

4.2.1. Mobile Solution

Today there are many available mobile platforms for tablets, such as iOS, Android, QNX or Microsoft. This posed the question, which tablet pc should be used for implementing this project.

A study by Strategy Analytics (Strategy Analytics, 2012) indicates that Apple no longer reigns alone over the tablet market. While, in the market, iPads are still involved with a respectable 57.6 per cent, last year Google caught up well. In the fourth quarter of 2011 Android held 39.1 per cent of the Tablet Operating Systems worldwide. In comparison, Windows or other tablets are far behind (see Table 1).

Global Tablet OS Shipments (Million of Units) and Market Share (%)	**Q4 '10**	**Q4 '11**	**Q4 '10**	**Q4 '11**
Apple iOS	7.3	15.4	68.2%	57.6%
Android	3.1	10.5	29.0%	39.1%
Microsoft	0.0	0.4	0.0%	1.5%
Others	0.3	0.5	2.8%	1.9%
Total	**10.7**	**26.8**	**100%**	**100%**

Table 1: Global Tablet Operating System Shipment and Market Share (Strategy Analytics, 2012)

As can be seen in Table 1, the two major competitors are the Apple's iPad and the Android tablet developed by Google.

These two designs represent two entirely different architectures and business models. While Google promotes freedom and flexibility with the Android, Apple controls almost everything. A big disadvantage when developing with iOS is the fact that the program will run only on the Mac OS X Operating Systems. On the other hand the big advantage of Google's Android is the fact that the operating system is platform independent; Android applications can be developed on three different operating systems; the program runs on Windows, Mac OS X and Linux. So it has received a great deal of enthusiasm from the public and development community. When developing an application on Android, the right platform version must be selected because no device can have an application running a platform version that is higher than the version on the device. However the version on the Android device can be different, depending on which Android device is being used. iOS does not deal with this problem because there is only one manufacturing company of iOS devices.

Of course, each platform involves strengths and weaknesses. In the paper from Shih et al. (2010), the author also starts a comparative analysis of Android versus iOS. Admittedly, this is an analysis of mobile phones; however, an objective comparison of tablets is not very different. On the one hand, it is mentioned that the iPhone will come out on top, like Microsoft Windows, "not because of its superior development platform, but rather because of its sheer penetration into hospitals and on home desktops with upwards of 90% of the world's PC market". But whether Android ends up being better than iOS is probably irrelevant, as long as Apple is good enough according to those who have experienced developing on it. The first successful entrant will be the market leader.

OS (Thousands of Units)	2010	2011	2012	2015
Android	2.512	11.020	22.875	116.444
iOS	14.685	46.697	69.025	148.674
MeeGo	179	476	490	197
Microsoft	0	0	4.348	34.435
QNX	0	3.016	6.274	26.123
WebOS	0	2.053	0	0
Other Operation Systems	235	375	467	431
Total Market	**17.610**	**63.637**	**103.479**	**326.304**

Table 2: Worldwide Sales of Tablets (Gartner, 2011)

In the past, many companies have tried to grab the first position but Apple has remained on the top. According to the forecast of Gartner (Gartner, 2011) 2012, Google’s Android will have 22.9 million worldwide sales of Media Tablets to End Users, while Apple’s iPad will have 69 million sales. In Table 2, you can also see that by 2015, these data are estimated to rise to 116.4 million tablets by Android and iOS will have 148.7 million devices in use.

Another recent operating system must not be ignored. Microsoft's forthcoming OS will have a strong tablet focus. So in the tablet market, Microsoft's Windows 8 OS is trailing at a distant third, as you can see in Table 2. In the past, in fact, Microsoft has not had much chance of success with tablets, but Windows 8 could change the course. The main reason for the successfulness is the fact that this operating system was developed especially for a tablet pc. The big difference to Android or iOS is that Windows 8 runs on both tablets and desktops. It offers the user a desktop UI and a touch-based UI, but not on the same time. The new user interface is designed and optimized for touch and works equally well with a mouse or a keyboard. Therefore, the big advantage is the consistent interface for tablet and pc, which neither iOS nor Android can offer their users. In addition, Windows 8 apps use the power of HTML5 and they are full-screen and touch-optimized. For this reason, the applications run on all work environments. It should be a single experience across a tremendous variety of PCs, whether x86 or ARM processor, whether tablet, laptop or pc. There will be tablets in different sizes with different orientations.

All, Android OS, Apple iOS and Window 8 OS have their advantages, so all are equally strong contenders. Indeed, the size of sales is important, but not always the ultimate deciding factor. None the less, an objective comparison between the operation systems is very difficult.

It is clear that different users from various societies will have different needs. Ultimately for an operating system it will never be easy to satisfy the needs of a large multicultural and diverse society. So the challenge in this work is the question of which operating system is best suited for a hospital.

For the decision on which device shall be used, it is important to know the end users. One should decide, for example, on the technical features you wanted in the developed app. Do you want to develop a system for basic users or will the app be complicated and quietly run in the background to help the users with their tasks? If it is the latter, iOS is not the best choice, for instance. Understanding which technical features each mobile device provides will help in the decision of the right OS.

In contrast to Google, Apple has shown an interest in Enterprise solutions. So Apple specially builds in enterprise features for the iPad. Furthermore, Apple collaborates with different hospitals to help them to integrate the iPad into the clinical workflow. The big disadvantage of Google is their openness. If a hospital wants to upgrade their Android version of their tablets, it is not certain whether the customized apps will work on the new hardware. That is one big reason why Android is not a good option for hospital and enterprise solution. Another reason for preferring iPads instead of Android tabs, is the current state of iPads in hospitals; there are a numerous pilot studies and current examples of the use of an Apple device in hospitals (Apple, 2013). For example, Ottawa Hospital uses more than 1000 iPads for physicians and health care providers. Another hospital, the California Hospital, also use more than 100 iPads in their hospital system. Also the Australian's state government launched a $500,000 pilot program to use an iPad in hospital settings. All the testing of Apple's iPads in hospital settings further separates it from Google's Android or other platforms, such as Windows 8. This again reflects the very different philosophy of the operation systems.

Some market researchers are convinced that Windows Phones will get ahead of Apple's iOS in 2015. This will allow Windows Phone to surpass Apple to retake the market's second rank behind Android. Also tablet PCs will get more and more end-users. Despite these forecasts, a tablet PC with Windows 8 was not taken into consideration for this project. Due to the fact that there are very few and untested tablets on the market, this operating system isn't proper for the use in a sensitive environment like a hospital.

Due to these above facts the enormous enthusiasm in the medical world for the iPad is comprehensible. However, with the tremendous growth of Google's Android, the market dominance of the iPad will clearly diminish. Most devices from Google, e.g. the Galaxy Tab 10.1, run the most popular Android 3.0, which makes the device high-performance and effortless in multitasking. On the other hand, Apple iPad 2 runs iOS 4.3, which makes fast browsing and programming of the device.

When we look at the device itself, at the hardware rather than the software, there are small but nice differences, which are important for the use in a hospital. The big handicap of Apple is the fact that a developed iOS application can only be operated on one device, namely the iPad. In contrast, an Android application can be used on different devices. Acer, HP and Sony, as well as Samsung, run Android. Depending on which device is finally used, the screen size can also diversify. Especially when a device is used in the ER, the display size is important in deciding whether the application emerges as successful or not. Good handling, weight and depth are no less decisive. The Galaxy Tab 10.1 has a 10 inch display and Apple iPad 2 has a 9.7 inch display, the Galaxy Tab 10.1 weighs lightly less than Apple iPad 2. The big difference here is the depth, namely the Galaxy Tab measures approximately 0.43 inches, while the iPad2 measures only 0.34 inches. Consequently, the resolution of both devices is relatively more or less the same. Hence, there is not much to compare.

If the end-users, in this case the patients of the Pediatric, are not technically-savvy at all; the Apple iPad is the best choice because it is very easy in handling. On the other side, Apple simplifies things where a lot of simple computer features are impossible. Because of the strict and clearly specified tools, Apple restricts a lot of things, whereas Android tablets are much more flexible and customizable.

In conclusion, Apple's iPad is a highly refined and an adapted device for hospital use. One could almost say that Apple has revolutionized computing. But it may not be the device most likely used by medics to access patient records in the future.

4.2.2.Problems

The field of application for the developed questionnaire will be the emergency department.

A mobile questionnaire can add value by replacing handwritten documentation, providing more accurate and complete documentation with a reduced risk of manual errors. In this thesis, not all the features of a tablet pc are utilized, because only one self-developed application will be employed on the device.

There is no literature or further studies about the best screen size, the ideal weight or the optimal battery life for an effective handling in a hospital. The only way to avoid the decision as to which device is the best for the use in an ER is to test both in real life. Therefore a test phase started (see Figure 16).

For this work, only the handling and the easy practicability is important. The emergency department is a place of speed and hectic activity.

Figure 16: Testing a mobile solution (Photographed by author)

Due to turbulences, confusion and the continuous arrival of new patients, the mobile solution showed several disadvantages during the experimental testing phase in real life.

- **Keeping track of tablets and incidental theft**

Because on the one hand, new patients permanently arrive in the hospital and on the other hand, a waiting patient is called into the doctors' office or patients leave the emergency room after the treatment, it is very difficult to keep track of the distributed tablets. Although the secretary can hand out the device to a particular patient, but it is possible for another patient to take the device after this patient has answered the questionnaire. This also makes the accidental removal of a tablet from waiting room easier.

- **Falling down**

A very great problem of the mobile solution is doubtless the possibility that the device can easily fall or be dropped. The tablet pc will be used at the Department of Pediatric Surgery, a very hectic and chaotic environment. There are many children who can't keep their seats or fidget.

- **Get wet**

Because of the chaotic environment it is also easily possible that drinks or something near it are spilled on the device.

4.2.3.Kiosk Solution

Therefore it has been decided that the developed questionnaire will not implemented as a mobile solution.
To avoid exactly these disadvantages described above, the new designed interface will be implemented on a kiosk system. To keep the input as simple as possible simple the input device is a touch screen monitor as a fixed installation in the Department of Pediatric Surgery in Graz, because the touch screen technology is the most natural input device of all. Moreover, it is important that especially children can easily learn how to handle them. The finger as natural input is the "[…] most commonly and effectively used for simple applications where any person can easily use without prior experience or instructions" (Holzinger, 2002).

An HP TouchSmart PC (see Figure 17) was chosen to test the prototype application. This touch screen PC is an All-in-One solution, so that it can be operated both with keyboard and mouse and the fingers.

Figure 17: HP TouchSmart Elite 7320 All-in-One Business PC (HP, 2013)

The operating System in use was Windows 7 Professional 64. The other technical details and specifications are listed in Table 3: HP TouchSmart Elite 7320 specifications

Processor	Intel® Pentium® G630 (2.70 GHz, 3 MB cache, 2 cores)
Chipset	Intel® H61
Memory	2 GB 1333 MHz DDR3 SDRAM
Display	54,6cm (21.5") diagonal widescreen full HD WLED; viewing angle: 160° horizontal, 160° vertical
Display resolution	1920 x 1080

Table 3: HP TouchSmart Elite 7320 specifications (Picture taken by me)

4.3. The waiting room of the emergency department

Confusion, frustration, uncertainty, annoyance and anxiety are feelings that often fill the waiting rooms. This study (Yoon et al. 2010) aspires to an understanding of the patient’s experiences in the waiting room of an emergency department. In principle, waiting times are never pleasant. If there is an uncertainty, a long waiting time can cause fear or distrust between the patients and the staff of the hospital. Waiting times can feel like an eternity, which again worries the patients and causes frustration. Patients also “might feel anxious and nervous about what the doctor will do or say” (Yoon et al. 2010). The hospital staff thinks that the waiting phase is less important to patients and so this time is not considered as part of their work. But this is not at all the case, as the study shows. “This lack of interaction affects the patients’ level of anxiety.

The uncertainty as to when they will receive medical care causes uninterrupted awareness among the visitors, which likely increases the anxiety“.

In such situations, the importance of clear information and communications between patients, their families and the medics, is shown in these studies (Tseng et al. 2011, O’Neill et al. 2004). “Literacy and stress affect people’s ability to read, understand and act on health related information” (Tseng et al. 2011). Furthermore, it is shown that the lack of information leads to stress and problematic behavior. In the studies of Tseng et al. (2011), an information board is used to present specific medical information more effectively. With a fun and interactive approach, this project can engage with introduction videos, games or key word section more effectively in medical procedures. The goal of this project is to inform, to educate and to ease anxiety, which is especially important for this paper. As this project shows, it is possible to calm patient’s nerves with a fun, interactive, age-adaptable, mobile system because environmental conditions affect patient’s behavior.

Maister (1988) found in his study that patients who were given information about their waiting times are less likely to be anxious about the wait. To give patients information is positively related to their satisfaction. If patients already feel involved by the doctors during the waiting time, this waiting phase is no longer recognized as such, this again made the patients feel more at ease. These methods may be a useful distraction not only for reducing stress, but for influencing patients’ perceptions of satisfaction.

Due to the aforementioned facts, the redesigned questionnaire of this project is used during the waiting time in the emergency room. The future workflow of the redesigned patient report is presented in Figure 18.

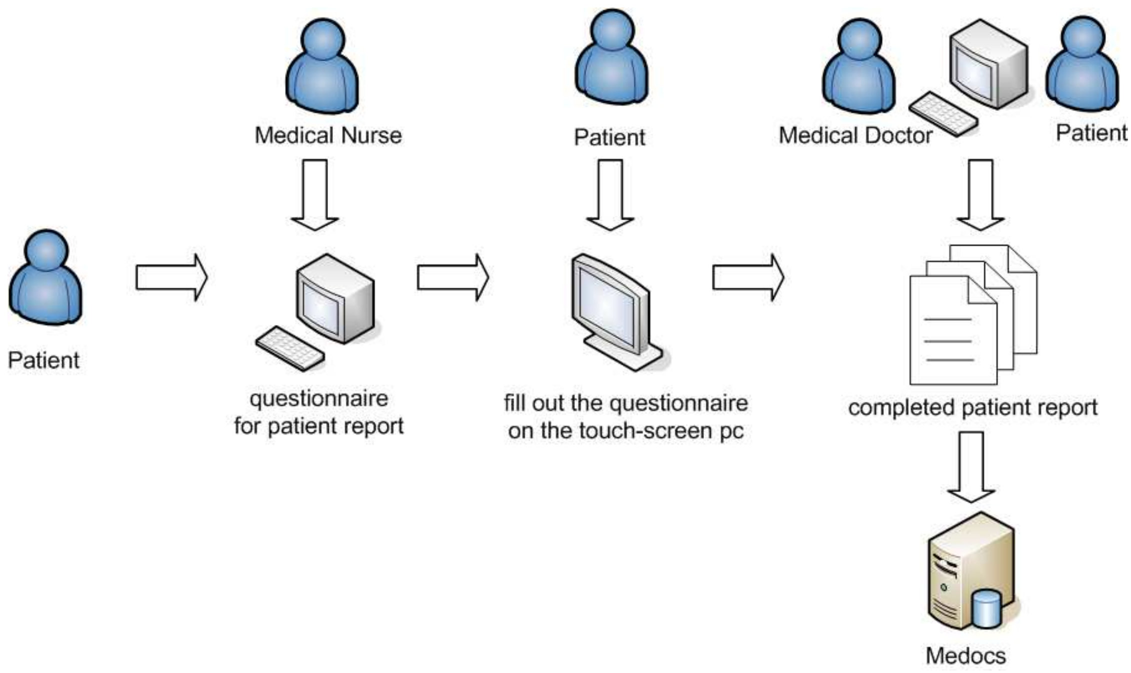


Figure 18: Future workflow of the patient report

A patient's first station on arriving at the Pediatric is the registration desk. As usual, the secretary there types the data of the injured child in the system. If the injury of the young patient derives from an accident, a patient report has to be generated. But patient reports should not be filled out by the nurse or the medics later, it should be filled out by the patient. For this reason, an application will be developed for a touch-screen pc. This touch-screen pc is permanently installed in the waiting room of the emergency department of the Pediatric Graz, where the patients should fill out the questionnaire during the waiting time in the hospital. At this terminal, a list of the waiting patients, who have been registered by the secretary, is displayed. Before the questionnaire is displayed, the user has to login into the application with his so called e-card. This authentication is necessary for data security reasons, so that the answers of the filled out questionnaire can be assigned to the right patient. The data thus obtained are directly transferred into the countrywide Hospital Information System in such a way that the medical doctor can see the answers of the questionnaire of each patient. Thus, it is possible that medic and patient can discuss the results of the questionnaire during the treatment before these data are definitely saved into the openMedocs.

On the one hand, this new flow process gives the patients the sense of reducing the waiting time and so minimized anxiety, stress and frustration. On the other hand, this workflow provides the opportunity for patients to be involved in the health care process.

An important term in this context is the word patient empowerment. Real definitions of patient empowerment are hard to find. But you can say, that this term describes the situation that patients are animated to take an active part in their own health management. In Table 4, the key tenets of patient empowerment can be seen.

Patients cannot be forced to follow a lifestyle dictated by others.
Preventive medicine requires patient empowerment for it to be effective.
Patients as consumers have the right to make their own choices and the ability to act on them.

Table 4: Key tenets of Patient Empowerment (Picture taken by me)

“Patient empowerment is considered as a philosophy of health care that proceeds from the perspective that optimal outcomes of health care intervention are achieved when patients become active participants in the health care process” (Monteagudo et al., 2007).

This paper (Baird et al., 2011) takes a step further towards the traditional physician-patient relationship and describes a possible patient-centered care solution. Personal Health Records provide patients with an entirely new and patient-centric possibility to manage medical records and medical information. The study of this paper shows that patients are very interested in playing an active role in their health care.

So it is not surprising that the concept of patient empowerment is growing in popularity and application. It’s a powerful instrument for health care change. “For some experts, redefinition of the traditional patient is probably the biggest driver of change in healthcare” (Monteagudo et al., 2007).

The empowerment is not exactly defined. There are different levels, because patients have different ideas about what it means to take charge and to be empowered. Some simply want to give information about their condition, while others want to have full control over all medical decision-making.

Patient empowerment has been considered as a potential tool. “During last years a wide number of eHealth tools and applications have claimed to support patient empowerment. They range from using generic phone, e-mail, or SMS services to dedicated Internet Health Portals and Interactive Web services, as well as healthcare specific applications such as Personal Health Records, e-Prescribing, and Chronic Care Management Systems based on mobile e-care” (Monteagudo et al., 2007).

In my thesis I also involve patients in the new process flow of the developed questionnaire. Because of this, as a nice side effect, medics are freed from filling out the patients records. Therefore it is possible that physicians can do their actual medical work again.

5. Prototyping

Since users are involved in the interaction with different applications, assessing the usability of interfaces is a necessary part of HCI development.

5.1. Redesign of the accident categories

In analyzing the problem of the current system and, as a consequence, to develop a user-centered design, I received assistance from the Bärenburg. In cooperation with the Bärenburg, a WHO-based patient questionnaire, which delivers information about the location, mechanism, cause and other important facts about the accident, will be developed.

Many problems in the existing SAP System occurred, because of false and difficult to understand accident categorization. Therefore, the whole categorization will be redesigned to make a completely new structure of the categories of the one hand and on the other hand to make it easily understandable.

The detailed categorization is specified in a WHO (ICECI) document. The core modules presented are separated into:

- core (intent, mechanism of injury, activity when injured,...)
- violence (previous suicide attempt, type of conflict,...)
- transport (mode of transport, role of the injured person,...)
- place (indoor/outdoor, part of building, ...)
- sports (type of sport, countermeasures, ...)
- occupational (economic activity, occupation)

The newly developed application should be created as a questionnaire, which will guide the patients through the categories. Therefore, in cooperation with the Bärenburg, questions and answers are defined (see Figure 19).

Welcher Sport war es? (Quereinstieg Schulsport)

- Ballsport (Fußball, Volleyball, etc.) (->Quereinstieg von Spielplatz!)
  Was hat Ihr Kind gespielt?
  - Fußball
  - Volleyball
  - Basketball
  - Handball
  - Tennis
  - Anderes Ballspiel
- Wassersport
  Wo/wobei ist es passiert?
  - Beim Schwimmen
  - Beim Turmspringen
  - Bei der Wasserrutsche
  - In der Umkleidekabine
  - Ausrutschen im Badebereich
  - Beim Bootfahren, Segeln
    ->Trug das Kind eine Schwimmweste? ->JNW
  - Beim Tauchen (mit Taucherflasche)
  - Ertrinkungsvorfall (-> gehe zu)
  -
- Wintersport
  Was hat Ihr Kind gemacht?
  - Schifahren
    -> Trug das Kind einen Helm? JNW
    ->Trug das Kind einen Rückenpanzer? JNW
  - Snowboarden

Figure 19: Example of some questions with their answers

Based on this categorization, the questionnaire is developed in German. However, to make the questionnaire as user friendly as possible, questions should be linked logically with each other. Thus the user has to answer different questions depending on his previous answers.

5.2. Mock-Ups

Designing an application is considerably different for a tablet pc than for a desktop computer or even more than for print media. Especially the screen size plays an important role in efficient design. The development of software for tablet PCs is further complicated by the transition from the large screens and familiar input devices of the desktop computer to small, pocket-sized screens and the limited interaction techniques of mobile devices. An application should be beneficial and should help end-users to achieve a particular goal. “While it is difficult to make devices with small displays usable, there is also the fundamental challenge of making them useful” (Holzinger et al. 2007). It is also important to develop a user centered design. Since the developer is aware of the personas of the end-users, acceptance of the application promotes its success.

Developing Mock-Ups is necessary to developing a first screen design on paper without needing to cover all functions or technologies of the application. “One of the main advantages is that paper mock-ups encourage the end-users to come up with more suggestions, since the mock-ups are obviously easy to change” (Holzinger et al. 2007).

In order to design and develop the questionnaire for the patient reports, it is important to know which factors affect the acceptance of a new software tool. “[…] users must know and understand the interface, and then they can use it” (Chao 2009). So it is important that users clearly understand what to do for the desired objective. Adding less formats and actions for solving the functions quickly is often better, because less is more.

In order to start with the design phase, it’s necessary to know the sequence of events. Figure 20 shows the different screens, which are important for the questionnaire application.

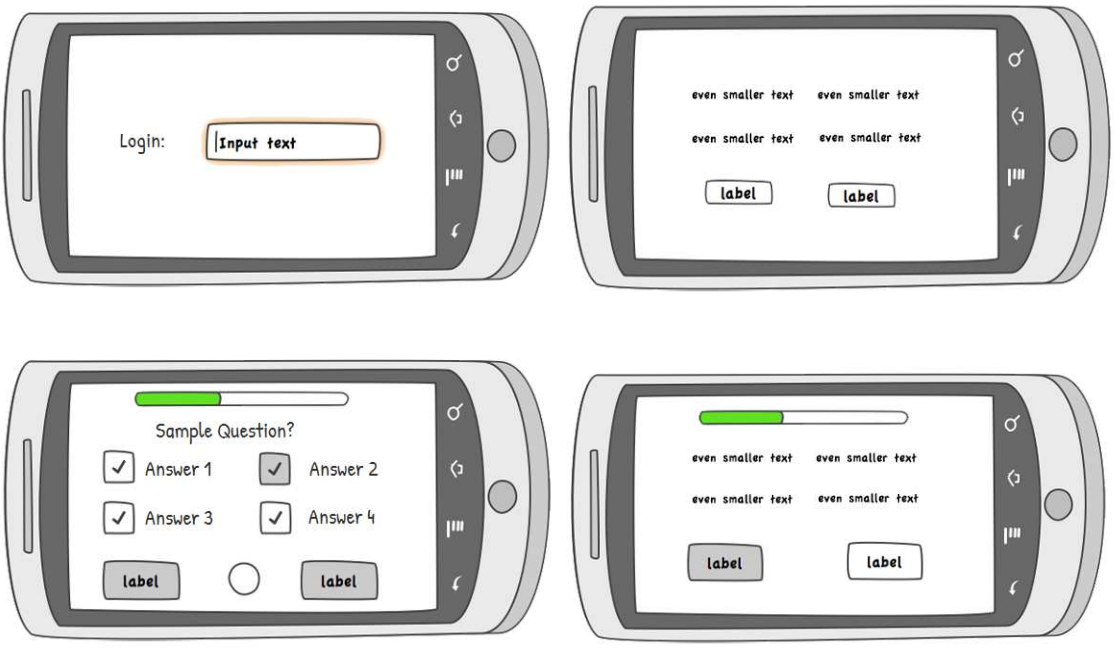


Figure 20: Sequence of events

First, the application needs a login screen to clearly assign each questionnaire to the correct patient report. The second screen displays general information about the questionnaire and offers the patient the choice of language, German or English, in which to answer. After the patient has chosen the favored language the main screen appears, which will be discussed more precisely later. On the main screen, the patient has to answer all questions to reach the last screen, where a button appears to save all their answers.

It's not a new theme that UCD is very important for a successful interface, as the paper (Hong et al. 2010) demonstrates. So for example, the paper from Chao et al. (2009) lists some design principles of usability for human computer interfaces. Also in the paper of Holzinger et al. (2007), there are some guidelines for UCD, which I considered in designing the Mock-Up for the patient report questionnaire.

It is important that the most relevant information is displayed first. For that reason, in the newly designed questionnaire the answers are ordered by the frequency of accidents. Because of the small screen size the questions and answers are short and easy to understand. For simplification of reading it is crucial to use only sans serif fonts like Tahoma or Verdana. Not only the font and font size are meaningful for a successful design, also the proper use of color is very important. Black fonts on white background are simple and are most often the best. A good design always has a consistent color scheme within the whole application and groups the information by using colors. End-users are confused by using too many colors together, so it is important to know that it is best to keep it simple by using only a few colors. Due to the fact that humans always make errors, the application should prevent and tolerate such user errors. Therefore, each application should have a "back" button, because every end-user action must be reversible. According to Holzinger et al. (2007) every implementation should ask for confirmation whenever there is an action which causes a change. So in my designed questionnaire, the end-user must choose the right answer by clicking on the "answer" button, but does not get to the next question automatically. The end-user has first to click on the button "next" before seeing the next question. Such data flow prevents an unexpected choice of a wrong answer. Even thought the application should still be simple, it is important that a help button is available. Many end-users feel comfortable when they know that a help function is available. Of course, it is easier to select a predefined answer instead of a text entry. Besides, a general selection control is automatically analyzable by computers. Therefore, in the questionnaire for the patient report, there are only answers which the user must select and there are no questions with free text entries. In Figure 21, you can see the created design of the questionnaire, according to the above described facts.

Figure 21: Design of the questionnaire

For a good usability the primary key is a good navigation. One of the main reasons for the unfilled patient reports was the lack of structure of the data and so the lack of navigation. Also, the study from Schumacher et al. (2009) shows that thirty-five percent of their test persons listed problems with screen navigation as the most common usability issues.

Since the questionnaire will be developed for the Pediatric, the design of the interface has to focus on children, because well-designed software can insure children enjoy using it by providing a suitable interface. The international standard ISO 9241-11 defines usability as qualities of a product with the goal of effectiveness, efficiency and satisfaction in a particular environment of use (ISO9241).

In this paper, the big challenge is the wide range of ages of patients of a Pediatric. A child of four years definitely has other interests of design than children of nine years, just as children of thirteen years or children of seventeen years. Also the degree of cognitive ability, mind and body development in young children are different from adolescents or adults. Moreover, adolescents' experiences of using computers should not be underestimated (Chang 2008).

5.3. Implementation

The design and the development of the questionnaire will be implemented in
HTML/PHP and CSS.

5.3.1.Tools and Materials

The main development was done on a Toshiba laptop connecting to a 21" monitor, running Windows 7 Home Premium 64-bit operation system. The prototype application was implemented in Aptana Studio 3 using XAMPP 1.7.7 with PHP 5.3.8 as the development environment. The tool Aptana Studio 3 allows developers to implement and test their web applications with support for the latest browser technology specs such as HTML5, CSS3, JavaScript or PHP using a single environment. A screenshot of the code editing view can be seen in Figure 22. All graphics have been made with Adobe Photoshop CS4 Extended.

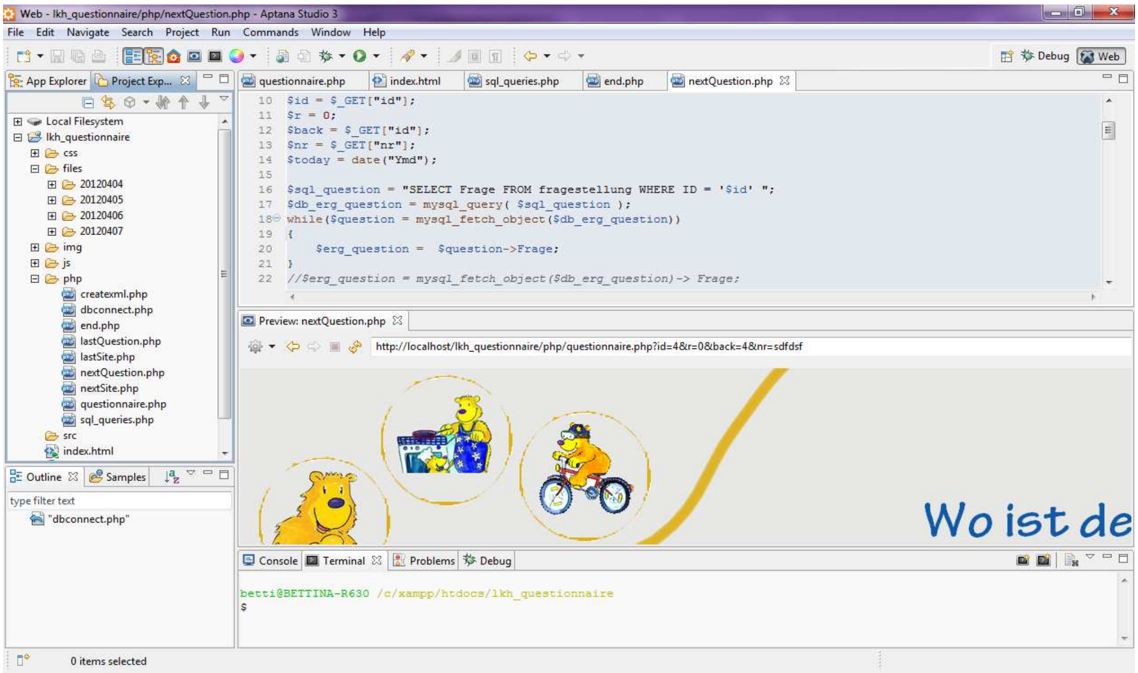


Figure 22: Aptana Studio 3

The database used for the developed questionnaire, which stored all questions and their appending answers, is saved locally on the touch screen computer. A MySQL database by Oracle Corporation is used with the phpMyAdmin to handle the administration of MySQL with the use of a web browser.

5.3.2.Structure and Application flow

The first step in the implementation is to develop a HTML/PHP skeletal structure. Because the questionnaire will be dynamic, adaptive and especially react to users interaction the questions cannot fix integrated in the HTML file. Depending on which answer the patient clicks, a different question will appear. Thus a database has to be built. So I created two tables; one table contains all possible questions and the other one is filled with all potential answers. With simple SQL queries one question after the other with their appending answers are read from the local stored MySQL database and displayed on the screen.

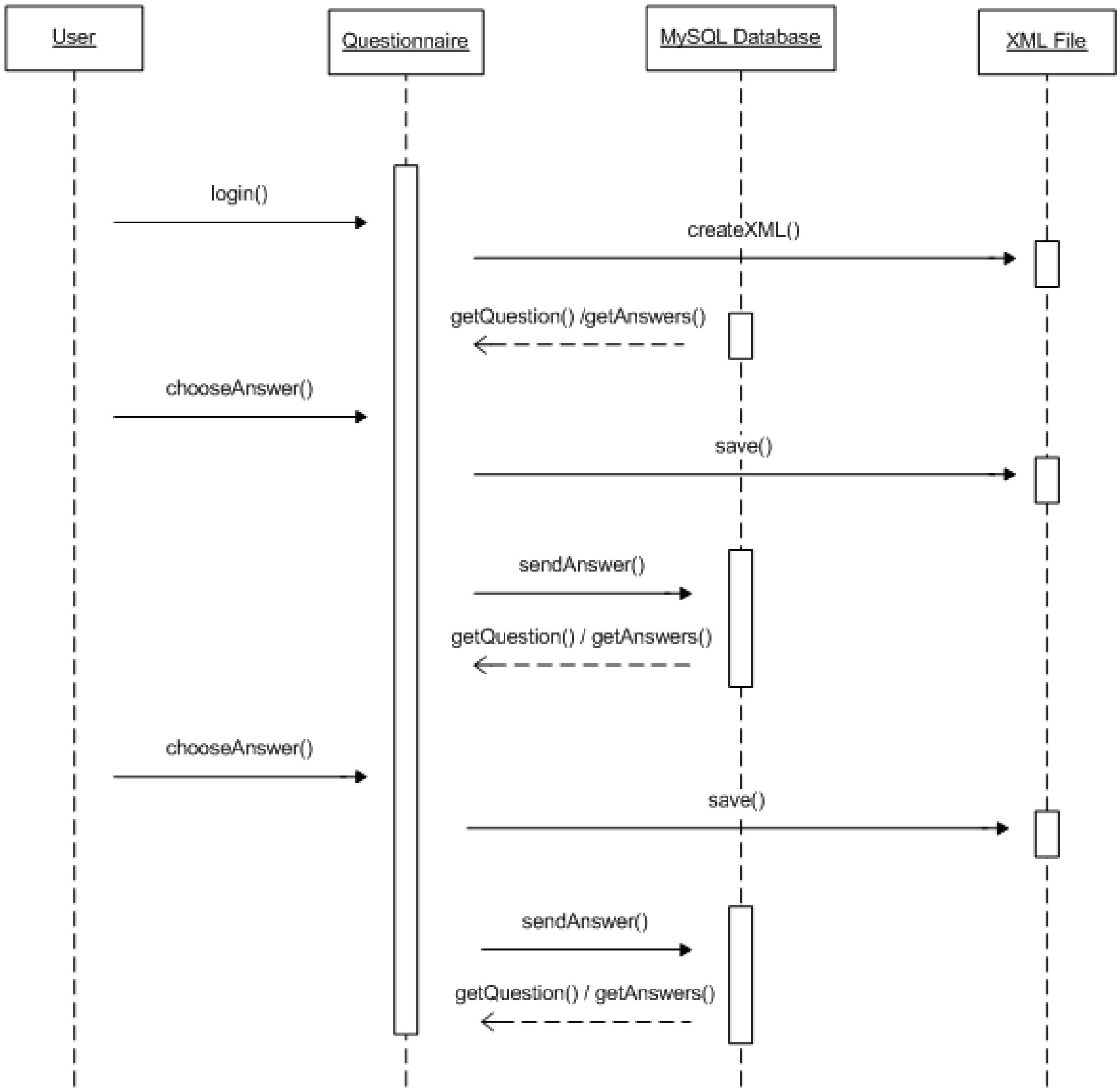


Figure 23: Application Workflow

The first screen a user sees on the touch based pc is the login screen. Before the questionnaire appears, the patients have to login to the system with their eCard. As soon as the application has read the data on the eCard an XML file is created in the background, as can be seen in the Figure 23. The name of the XML file is the social security number of the patient, so that every document can be assigned to the right patient. At the beginning, this file only contains the date and time of the creation. At the same time that the XML file is stored local on the pc, the application sends a MySQL query to the database, so that the predefined first question with their appending answers appear on the screen. After the patient has chosen an answer and has clicked on the button, which is named nextQuestion, another query is sent to the database. The MySQL database again sends the next question with the answers back to the users' screen. At the same time, the data containing the chosen answer are sent to the database with another PHP script, where the corresponding question and the ID are saved into the XML file, which was created at the beginning of the questionnaire. This process is repeated until the patient has come to the end of the questionnaire.

The code snip, seen in Table 5, makes sure that the start site of the questionnaire appears within 10 seconds, so that the next patient can login into the system and fill out the questionnaire.

```
…

1 <meta http-equiv="refresh" content="10;

2 http://localhost/questionnaire/start.html">

…
```

Table 5: Get to the Start Site of Application

5.4. The logic in the system

To develop a quasi-intelligent system, it is important to have logic in your application. The new system for collecting patient accident cases should save time and resources. Therefore it is important, that the patient can answer the questions easily and quickly.
The complexity and variety of accident mechanism make a clear classification almost impossible. There are too many accident mechanisms und locations so that a fixed questionnaire has too many questions to cover all possible accidents to get to the target. So, for example, it is impractical to digitize a paper based questionnaire.

5.4.1.Computer Intelligence

To solve this problem, a quasi-intelligent questionnaire has to be developed. “Hierarchical decomposition does not work for complex adaptive systems” (Rouse 2007). Also this questionnaire cannot be addressed through hierarchical decomposition. “Traditional software engineering approaches offer limited support” [] for such systems. In order to handle such complexity, new engineering challenges, such as intelligence, adaptiveness and seamless integration have to be solved.

But before one can develop a quasi-intelligent system, it is important to know what computation intelligence actually is.

However, attempts to find definitions of intelligence still provoke heavy debates. Wikipedia defines the term *intelligence* as followed: The term comes from the verb *intellegere* from Latin, which means *to understand*. The Latin term is a compound noun composed of *inter* (inter-) and *legere* (to chose), which can mean *to choose a way in some possibilities* (Wikimedia Foundation Inc., 2012). Also the Chinese word for the noun intelligence means *the ability to know and say out*. So one can say, that intelligence is “a kind of reasoning ability […]” (Huang et al., 2010).

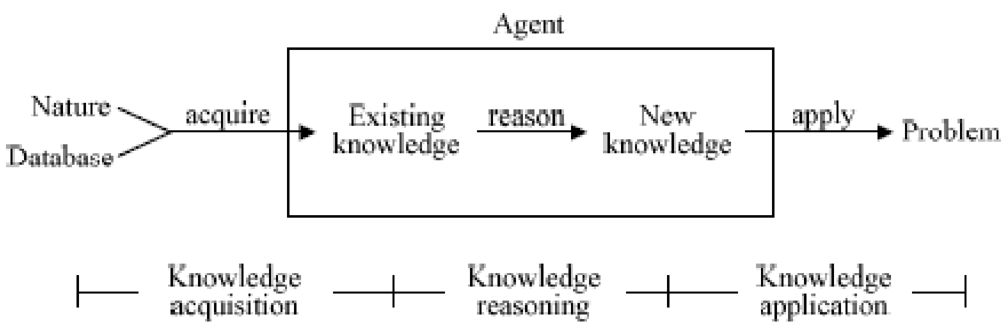


Figure 24: Intelligence composed of three processes about knowledge

Figure 24 shows the process of knowledge. There you can see that intelligence has three actions on knowledge, to perceive, to reason and to apply. In the center of Figure 24 is the knowledge reasoning process, the key of intelligence. “Because the truck of intelligence is knowledge and the key of intelligence is reasoning, to be concise and profound: intelligence = knowledge + reasoning” (Huang et al., 2010). Summing up, one can say that intelligence is about cognizing facts, summarizing rules and creating forward theories.

But now another question arises: can computers be intelligent? “This is a question that to this day causes more debate than the definitions of intelligence” (Engelbrecht, 2007).

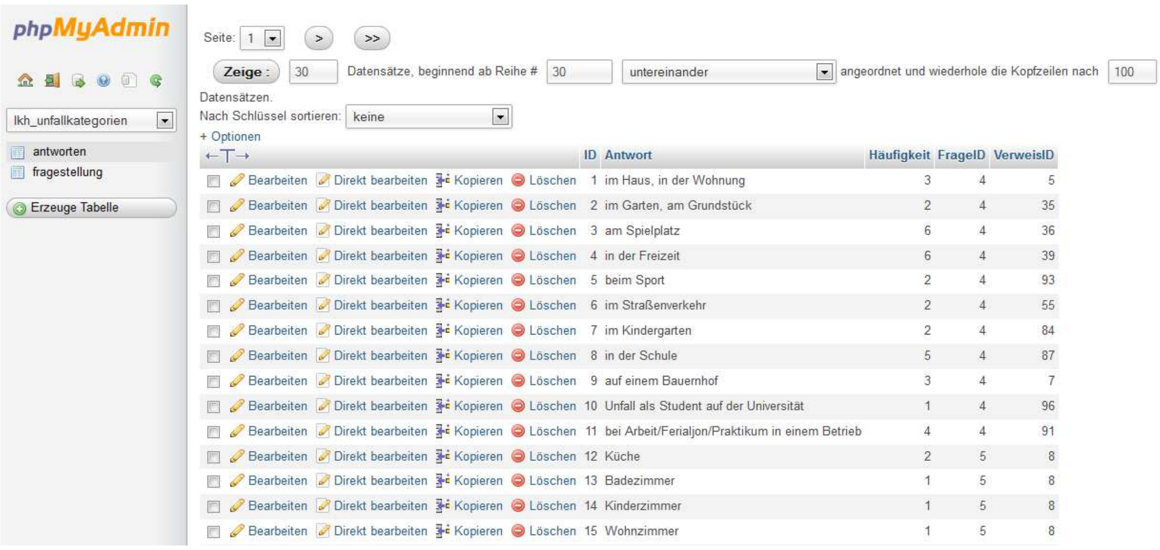
The idea, of course, is not new. That software engineering is very knowledge-intensive, is nothing new. Also, that software processes are human centered has already been discussed. The CI exploits exactly this process. Thereby, the CI technology uses “various mechanisms of interaction with humans and processes domain knowledge with intent of building intelligent systems” (Pedrycz, 2002). Future software systems will be adaptive and use intelligent interfaces.

In order to obtain the target even in a complex system as fast as possible, the developed application has to apply some rules. Because, the system has to display a different question depending on the answer the patient has chosen. In addition, an answer has to relate to more than one question, which it makes possible to get to the same answer on different ways. So you can say that intelligent systems should be able to perform rationally to seek the best solution for their designed objectives. “From the user perspective, this means delivering context-aware human-like services with minimal user effort” (Sterling et al., 2005).

That intelligent systems are already used in medicine today this project (Dogantekin et al., 2010) shows. It also makes clear that it is not easy to handle large and complex data without intelligent adaptive systems, because traditional programming languages don’t support descriptions of certain types of behavior. Another example of the integration of AI techniques in the medical area is the project of Cavazza et al. (2003). In his paper he describes the development of a virtual patient for the use of training applications in the field of cardiac emergencies.

The developed questionnaire is not as complex as, for example, a virtual patient from Cavazza et al. (2003). Therefore, for the practical example developed in this paper, this logic can be defined in a database. There are two different tables; one table contains all possible questions and the other one is filled with all potential answers.

In Figure 25, one can see that the quasi-intelligence is implemented in the database. Each answer is linked with the corresponding question, with the following question and with a variable, which counts the frequency a user clicks on this answer.



ID	Antwort	Häufigkeit	FrageID	VerweisID
1	im Haus, in der Wohnung	3	4	5
2	im Garten, am Grundstück	2	4	35
3	am Spielplatz	6	4	36
4	in der Freizeit	6	4	39
5	beim Sport	2	4	93
6	im Straßenverkehr	2	4	55
7	im Kindergarten	2	4	84
8	in der Schule	5	4	87
9	auf einem Bauernhof	3	4	7
10	Unfall als Student auf der Universität	1	4	96
11	bei Arbeit/Ferialjon/Praktikum in einem Betrieb	4	4	91
12	Küche	2	5	8
13	Badezimmer	1	5	8
14	Kinderzimmer	1	5	8
15	Wohnzimmer	1	5	8

Figure 25: Logic in the System

First of all, the front-end interface starts by displaying the first defined question (with ID 4) and its corresponding answers, which are defined in the fourth column (FrageID) of the first table. In this way, all questions with their answers can be displayed with simple MySQL queries. The exact statement you can see in Table 5 in the first line.

If the patient now chooses an answer and clicks on the button to move to the next question, the script sends another MySQL query (Table 6, line 3 and line 4). In this process, the script checks up the last column (VerweisID) of the chosen answer of the user to obtain the new ID of the following question. Once the ID of the next question is known, with the MySQL query defined above, the next questions and the appending answers can be selected from the database and displayed on the screen.

```
…
1 $sql = "SELECT Frage FROM fragestellung WHERE ID = '$id'";
…
3 $sql = "SELECT VerweisID FROM antworten WHERE Antwort = '$answer'
4 AND FrageID ='$id' ";
…
6 $sql_answer = "SELECT Antwort FROM antworten WHERE FrageID = '$id'  7 ORDER BY Häufigkeit
DESC";
8 $sql_plus = "UPDATE antworten SET Häufigkeit = Häufigkeit+1 WHERE
9 FrageID = '$id' AND Antwort = '$answer' ";
…
```

Table 6: Sample MySQL queries

Because the newly developed application should make input less difficult, the interface has to display the answers chosen most often by users first. Therefore the database includes an extra column, which stores a variable for each answer with the frequency of users' clicks. You can see that in the third column of the first table in the database (Figure 25).

The line 8 in Table 6 shows the correct MySQL statement to update the counting variable Häufigkeit (frequency). Whenever a patient clicks on an answer followed by the button to move to the next question, this variable is updated. The display of answers can therefore be sorted according to frequency using a simple MySQl query (Table 6, line 6 and line 7) in descending order.

Because the application is developed simply, the described logic in the database is enough to simulate the quasi intelligence in this system.

Testing

The test phase is as important as the development process itself. So the software testing phase is an essential process that comprises part of the software development lifecycle.

Testing the developed software is so important because it is the process with the intention to find bugs in the software.

Software testing should be done in every step of the development process. Because it is very difficult to correct the bug at the last stage, especially if there is a small error, which has crept in at the beginning of development.

In this thesis, the test phase proceeded in three phases. In the first phase the system was tested by me with debugging tools. This is an absolute technical analytical testing method. Thereby correctness testing and reliability testing are the two major areas of this testing method. In the second phase of testing, the system rather than the software was tested. For the correct working of the system, the right links between questions, the right definitions of each question, I was supported by experts from the Bärenburg. In the third testing phase, the system was tested in real life. In this last phase, patients tested the application in real situations in the ER in the Pediatric Surgery of Graz.

5.5. Xdebug and Firebug

Software testing is the process of testing the functionality and correctness of software by running it. The first step of the test phase is to find errors by running the program.

Therefore I used the tool Xdebug. This tool is a PHP extension, involved in the PHP engine, which provides debugging and profile capabilities.

With the tool Xdebug it is possible to identify recursions and allow code coverage analysis. In addition, Xdebug allows the display of complete traces when an error occurs. As you can see in Figure 26, additional information about used parameters, user defined functions, function name, script name and line numbers are also displayed.

(!) Notice: Undefined index: id in C:\xampp\htdocs\lkh_questionnaire\php\sql_queries.php on line 7				
Call Stack				
#	Time	Memory	Function	Location
1	0.0008	360744	{main}( )	..\questionnaire.php:0
2	0.0014	367856	include('C:\xampp\htdocs\lkh_questionnaire\php\sql_queries.php')	..\questionnaire.php:9

Figure 26: Xdebug

Using the method, it is essentially easier to find the error.

A further functionality of Xdebug is the possibility of getting all lines of a script, which are really run with the request xdebug_get_code_coverage().

Because the developed application also includes HTML and CSS files, I used the tool firebug to inspect these files. With this Firefox add-on it is possible to get an overview about the structure of a website and about its parameters. Especially CSS values can be checked and, if necessary, changes can be made very easily and quickly.

In addition, the Firefox add-on can be used to inspect JavaScript files, because it also includes a powerful JavaScript debugger that lets you stop executions at any time and you can see what each variable looked like at that moment.

Figure 27: Firebug

As one can see in Figure 27 the displayed errors are describes concisely, so that the developer can easily fix the bug.

5.6. Expert Review

After the system was tested for robustness, it had to be tested for correct functionality.

Because the view of a developer is always different to a user's view, it is important to test the software from the point of view of a user as well. Usually users don't care which libraries, components, databases etc. the application uses internally. Also, users do not distinguish between problems concerning underlying components and errors of the application itself. Therefore, the user is not interested in hearing that it is not the developers fault; a solution is required. So it is the job of developers to select proper underlying components and to ensure that these underlying libraries or databases work correctly.

For this reason, I started expert review phases, because this method tends to produce qualitative results and require fewer participants than controlled experiments. A few usability experts can find a large percentage of a system's usability problems.

- **Participants**

Participants were medical scientists of the University Hospital at Graz, Austria, recruited from the paediatric surgery, who are all members of the staff of the Bärenburg. These users are domain experts, because they use the collected data from the questionnaire for statistic evaluations every day. Besides, the staff of the Bärenburg had defined the WHO conformed questions and answers of the questionnaire. For this reason, they know the working flow and also they had experiences with usual accidents, so that they know which data are important for statistics.

- **Procedure**

For the expert review, the developed questionnaire was installed on a touch screen pc, which was also used for the third test in real life in the Pediatric Surgery of Graz. This testing phase was carried out in a period of two weeks in an office of the Bärenburg. In that time the participants could test the software time-independent. Under the supervision of Dr. Peter Spitzer, the main contact of the Bärenburg, all participants could complete the questionnaires within two weeks in their own time.

Each test person received some sample use cases (Table 7: Sample Use Case) of most often occurred accidents. The exercise was to fill out the questionnaire with the sample use cases.

	Use Case 1.01
description	an adolescent was hurt by playing football during training lessons in school
place	in school
actors	other adolescents and the teacher
trigger	hurt by playing football

Table 7: Sample Use Case

Immediately after the pilot test, the participants had to give feedback on the procedure of using the questionnaire. For this reason, I implemented the SUS questionnaire into the questionnaire system, so that the ten questions of the SUS are displayed after the end of the developed patient questionnaire system.

Additionally to the SUS feedback of the participants, I had the automatically created XML files from the questionnaire. In order to see whether the use cases have the same meaning as the XML files, I have simply to compare the input with the output. In Figure 28, one can see the created XML file from the sample use case in Table 7: Sample Use Case.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<patient>
  <date>Erstellt am 06.04.12 21:47</date>
  <answers>
    <id>4</id>
    <question>Wo ist der Unfall passiert</question>
    <answer>in der Schule</answer>
  </answers>
  <answers>
    <id>87</id>
    <question>Wann ist der Unfall passiert</question>
    <answer>beim Schulsport</answer>
  </answers>
  <answers>
    <id>48</id>
    <question>Welcher Sport war es</question>
    <answer>Ballsport</answer>
  </answers>
  <answers>
    <id>49</id>
    <question>Was hat Ihr Kind gespielt</question>
    <answer>Fußball</answer>
  </answers>
```


Figure 28: Sample XML File

- **Results**

This pilot test showed the first difficulties with the developed system.

The design of the input mask was based on no knowledge or experience. Therefore, this trial had to be stopped after only a few passes. The structure of the database could not do justice to the complexity of the different approaches of the entered accidents of the participants.

In addition to the database structure, some user input options also needed to be improved. Due to the problem that it was not possible to read the e-card with a card reader, the patients have to enter their social security number in an input field to login into the questionnaire system. First of all it was very difficult to key in the social security number in the login mask within the virtual keyboard. The numbers of this virtual keyboard were too small. Therefore, the virtual system keyboard was completely deactivated and own input buttons for the entry field were implemented. As you can see in Figure 29, using these buttons for the input of the social security number are more user-friendly.

Figure 29: Login screen for the questionnaire

Additionally, there had to be a validation of the entered numbers, so that all completed questionnaires can be assigned to the patients. Furthermore, it should not be possible to fill out the questionnaire more than once per day.

Field reports from the project of the cancer research clinic also shows that patient that are in stressful situations do not see logical systems as clear as others. Therefore it is very important that the developed questionnaire is implemented to be as resistant to failure as humanly possible.

The Figure 30 shows the result from the system usability scale, which was implemented at the end of the questionnaire. As you can see, neither the positively worded questions nor the negatively worded questions were answered clearly. Both average values are in the middle.

Thus, it is not surprising that the so-called SUS Score is short of 55% (54.38%). But is this a good or a bad SUS score? Tullis and Albert suggest in their paper (Tullis et al., 2008) that an average SUS score under about 60% is relatively poor, while one over about 80% could be considered pretty good.

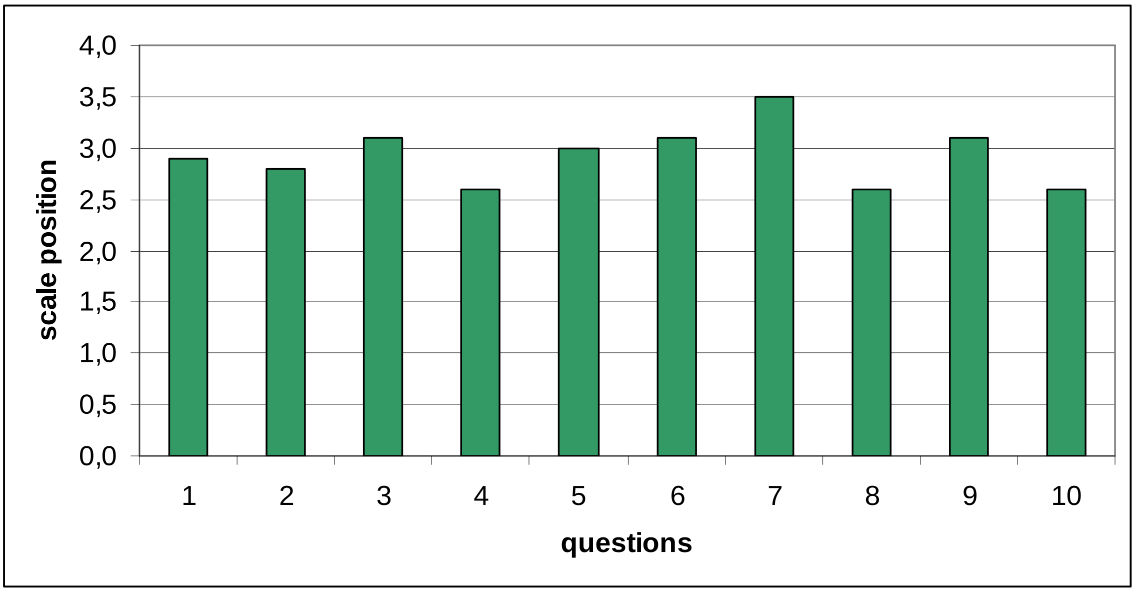


Figure 30: Result of the SUS in the pilot test (question/scale)

Apart from the usability of the questionnaire, the correctness of the results is important. In order to test whether the questionnaire is working properly or if the links have been set correctly, the individually created XML files have to be compared to the use cases. Overall, the result shows that most created XML files reflect the sample use cases. But on closer inspection, particular accidents cannot be answered with this implemented logic. For example, the accident described in Table 7 could not be answered with this implemented questionnaire, because some links were not consequentially connected.

The written feedbacks from the participants also reflect these findings. The main problem found in this testing phase were not errors of the implementation itself or design errors, the poor rating of the SUS questionnaire resulted from the inconsequential connection between the questions and some usability errors.

The purpose of this test was to pre-test and receive feedback on the developed questionnaire to increase the validity and reliability as well as possible.

- **Discussion**

Because of this bad result from the System Usability Scale (see Figure 31), I have had to adapt the patient questionnaire for the following testing in the paediatric surgery.

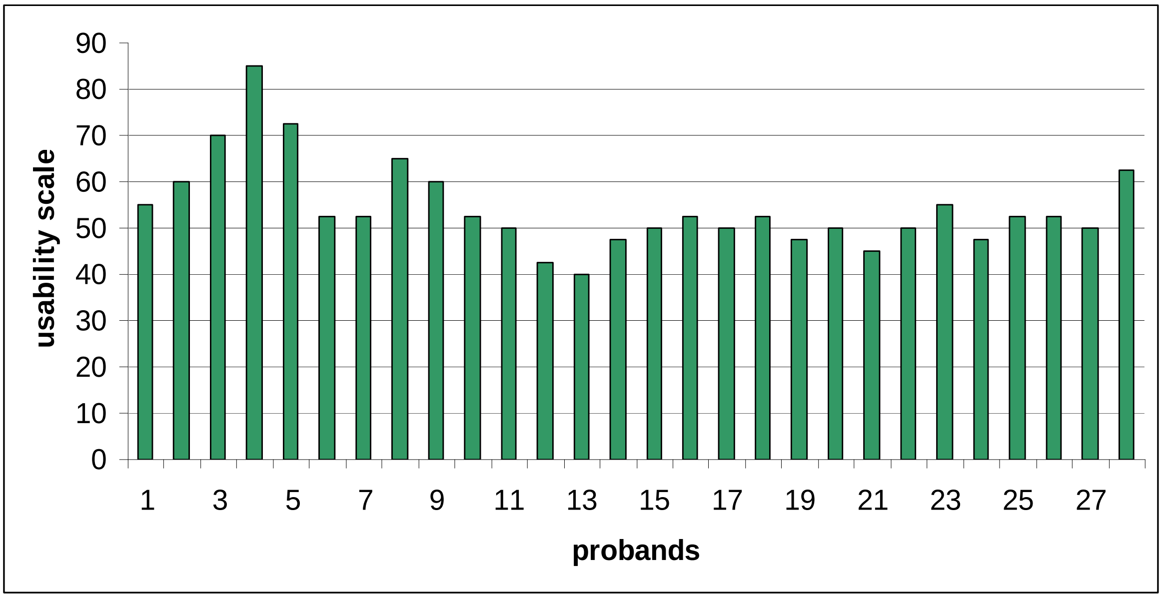


Figure 31: Result of the SUS in the pilot test (participants/usability scale)

Because such a result is not acceptable for a further testing phase, the main problem had to be fixed. The discovered results of all accidents were correct, so no changes in the design or the structure of the questionnaire were made. As the aforementioned results show, it was very important to change the query logic.

Therefore, the total questions were divided into three levels. In order not to complicate the questionnaire unnecessarily, all three levels were completely decoupled from each other. So there is one level for the questions relating to accident mechanisms, one level for the questions relating to accident locations and the last level for general questions.

Furthermore, all answers were newly ordered and the font size was increased significantly. Besides this, the answers were subdivided for easier and faster findings. After this restructuring, 200 case histories of real accidents of the Pediatric Surgery could be successfully entered.

In Figure 32 one can see the newly structured questions with their answers.

Figure 32: New structured questionnaire

5.7. Evaluation in real life

After the tests with simulated accidents, it was time to test the designed and developed interface in real life in the Pediatric Surgery in Graz.

For the evaluation of application, there are different evaluation methods, which are used in different designing phases with different purposes. These methods can be classified into inspection methods and testing methods. The evaluation methods can also be classified according to their purpose:

- Exploratory: This evaluation method will answer the question of how an interface is used and what it is used for.
- Predictive: This method shows user performance based on an interface design.

- Formative: The purpose of this evaluation is to illustrate a design feedback by listing problems and show recommended solution.
- Summative: This evaluation method provides an assessment of an interface often in the form of numerical data which is statistically analyzed.

Figure 33 shows these sample evaluation methods according to their purpose and type.

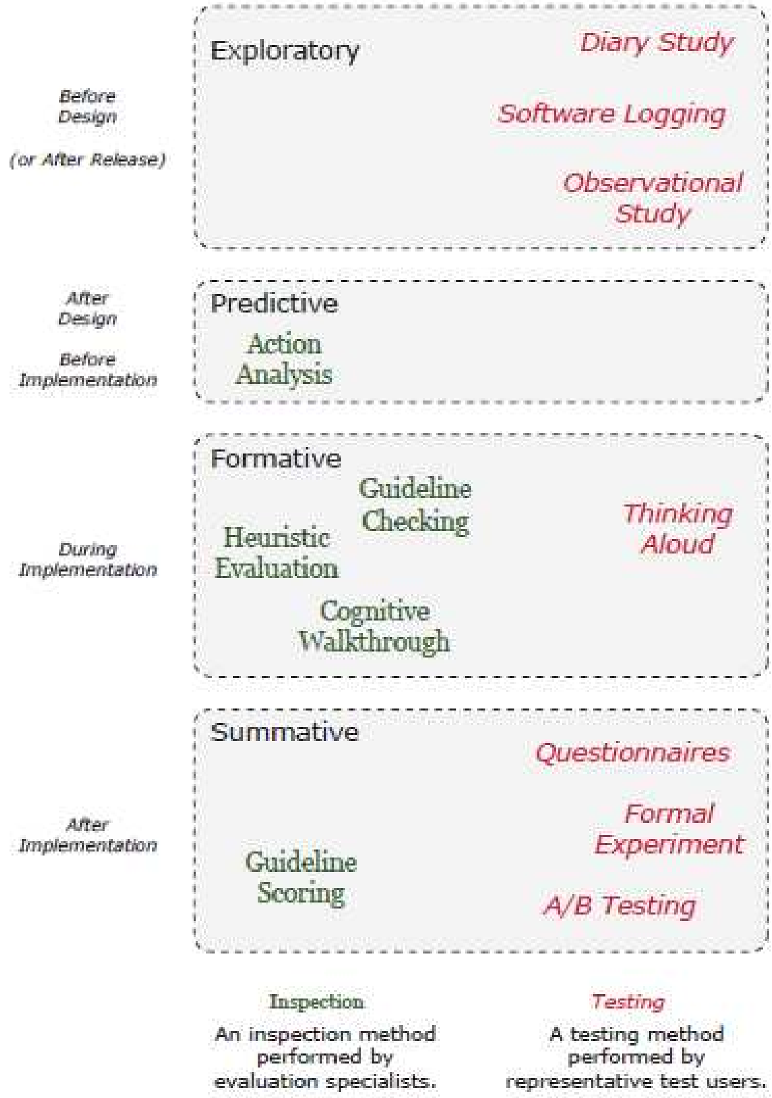


Figure 33: Evaluation methods (Andrews, 2006)

For the testing phases in the Pediatrics Surgery, the formative and the summative methods are important. Contrary to the expert testing phases, the tests in real life are in accord with the testing methods.

Usability measures should be taken as early as possible in the development of an application. Also, testing phases should be part of the whole development phase and cannot be seen in isolation.

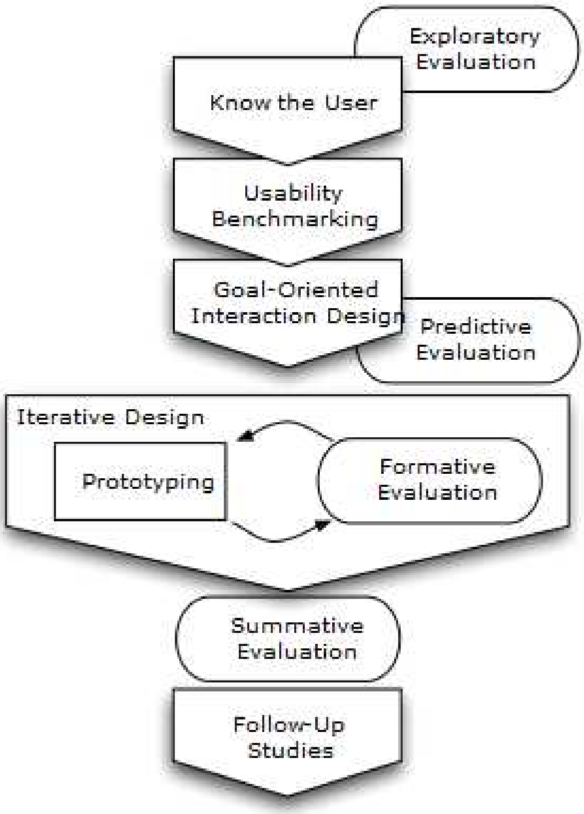


Figure 34: Usability engineering lifecycle (Andrews, 2006)

As apposed to the usability engineering lifecycle, as one can see in the Figure 34, I combined the formative with the summative testing phase. Thus making it possible to find both usability problems and quality of the interface in only one testing process.

Evaluation Methods	Testing Subject	Method	Purpose
Formative evaluation	Prototype (during implementation)	Thinking Aloud usability testing	Find usability problems
Summative evaluation	Final application (after implementation)	Questionnaire (SUS)	Quality of an interface

Table 8: Formative and summative testing

The questionnaire was transferred a touch screen computer, installed in the ER in the Pediatric.

5.7.1.Thinking Aloud Test

A thinking aloud test is a technique implemented to test the usability of an interface. Therefore, this thinking aloud method is the most common test for trying to detect usability problems. Especially in software development this method is often used (Holzinger, 2006).
Thereby, the test users are asked to verbalise their thoughts, so the observer can hear what the users think during their test of the interface. The users should so tell us what they want to do or what decisions they make and why.

In the test phase, after the users are asked to fill out a consent form a basis introduction to thinking aloud tests are given to them, so they will know what to expect. All users test the interface on a designated laptop, which is monitored by an examiner. After finishing the test phase, all users are asked to fill out a questionnaire (SUS) and answer a few interview questions.

- **Participants**

Because the application will be used in the Paediatric Surgery in Graz the target subjects of this questionnaire will be patients. Both injured children and their chaperons will be users of this interface. Because of this fact, the users cannot be limited as to age or computer experience.

Therefore the test users of this thinking aloud test will be adolescents and parents.

- **Test Environment**

The test environment which will be used is shown in Table 9.

Room	Paediatric Surgery in Graz
Hardware	Intel® Core ™ i5, 4GB RAM
Operating System	Windows 7 Home Premium
Web Browser	Internet Explorer 9.0 (64 Bit)
Monitor Resolution	1366 x 768
Monitor Size	13.3"

Table 9: Hardware and software environment for the thinking aloud test

- **Recording Equipment**

Because the testing questionnaire is not too complex, no recording equipment, such as video, audio or screen recording software is needed.

To collect the thoughts of the test users the observer only makes notes and includes the result of the questionnaire and the interview after the test phase.

- **Test Tasks**

The only task the users have to do is to fill out the questionnaire. Because the test phase takes place in real life, example tasks have not been defined. The test persons only have to fill out the questionnaire with the facts about their accidents.

Figure 35: Real life testing in the Pediatric Surgery in Graz (Photographed by author)

- **Interview Questions**

After the patients filled out the questionnaire about their accidents, a few patients were requested to answer some questions about the interface.

- Opening Question
    - "What do you think? How was it?"
- Standard Questions
    - "What's your first impression of the system you filled out before?"
    - "Was it easy to fulfil the task?"
    - "What was the biggest problem?"
    - "Do you find the navigation well-structured and self-explained?"
    - "What do you think about the design of the questionnaire?"
    - "Was it easy to read the text?"
- Individual Questions
    - "Were the questions clear to understand?"
    - "Were there any problems to find the right answer?"

- “Were the questions easy to answer?”
- “Were there any problems in the structure / logic of the questions?”

- Test Materials

After completion the test, it is common practice to give the user a post-test questionnaire. The SUS (System Usability Scale), a standard feedback questionnaire, will be used for this test.

- Results

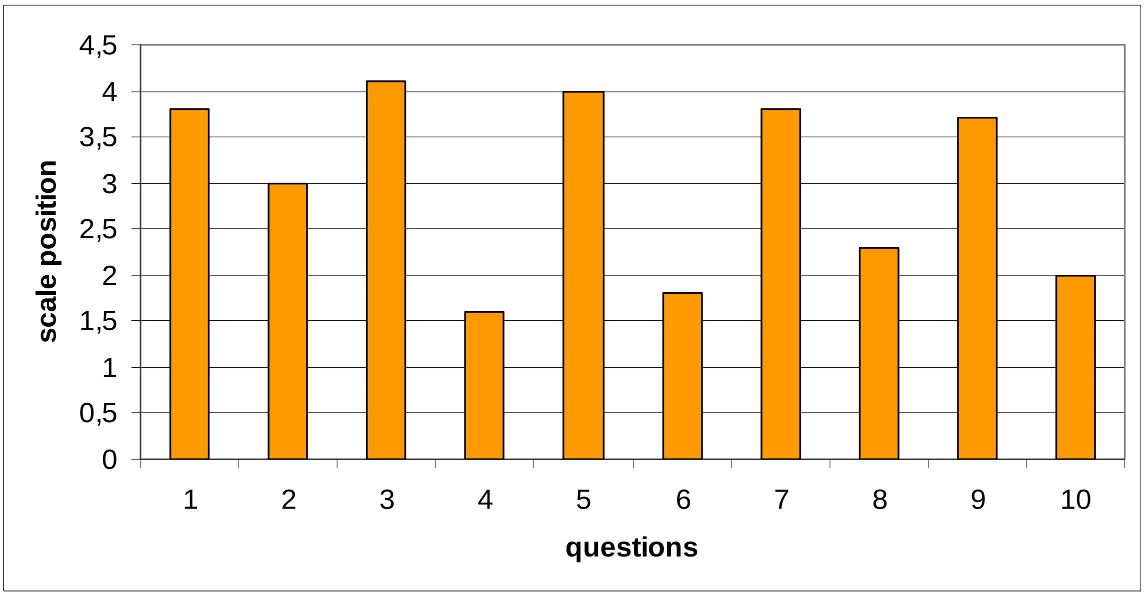


Figure 36: Result of the SUS in the real life test (participants/scale position)

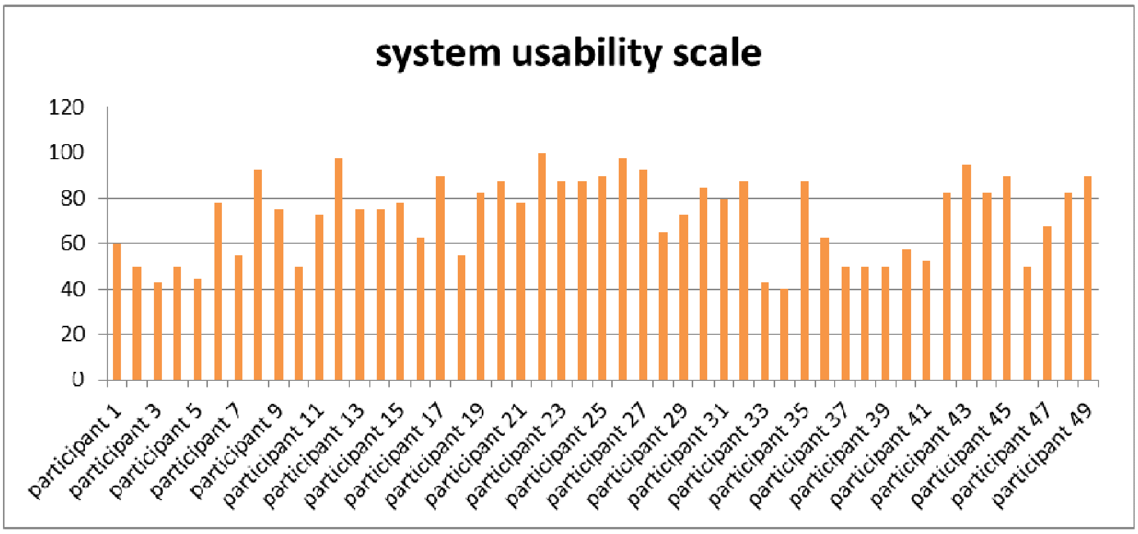


Figure 37: Result of the SUS in the real life test (participants/usability scale)

A comparison between the results from the pilot test and from the real-world testing at the Paediatric Surgery shows that the usability scale from the real-world test is higher than in the pilot test.

The following figure (Figure 38) shows that on the one site the scale of the positive questions is higher and on the other site the scale of the negative questions is lower in the pilot testing phase than in the real testing phase.

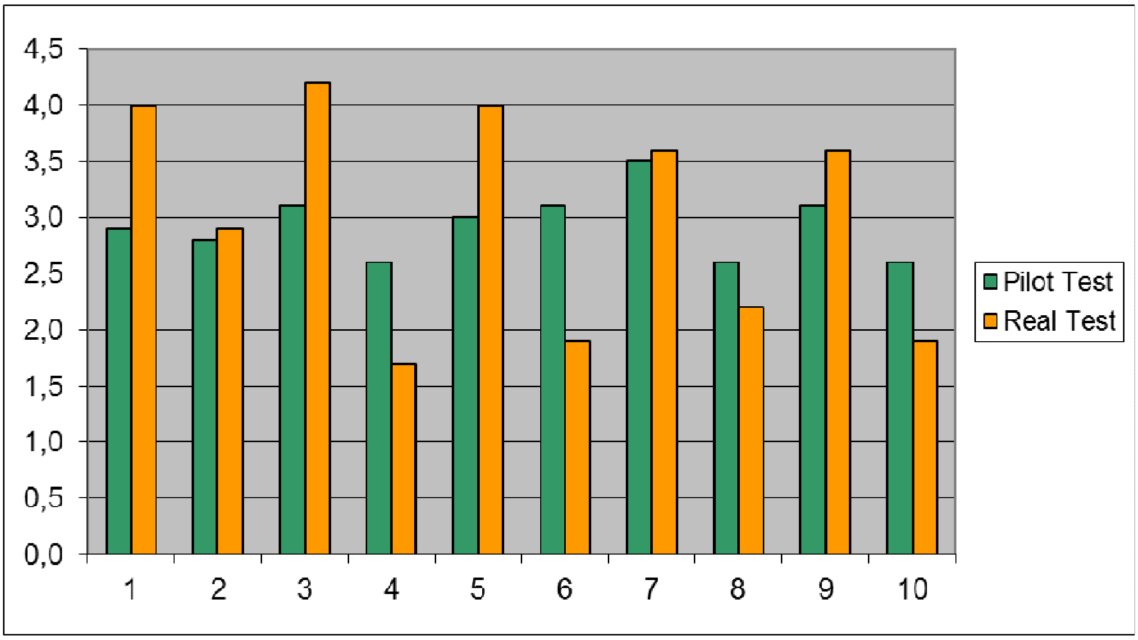


Figure 38: Comparison between results from pilot test and real life testing

This fact is also reflected in the average usability scale. In the pilot test, the scale is between 40 and 85, resulting in an average scale of about 54.4. In the real-world test this scale is between 38 and 100, consequentially, there is an average usability scale of exactly 71.99.

The findings of this test phase can be summarized in the following Figure (Table 10).

Immigrants showed great reluctance and refusal
Parents were too excited, since her child was injured. These people wanted to complete the questionnaire in any case.
When patients were called to go into the treatment room, the entry was just cancelled and they hurried into the treatment room.

Table 10: Main Findings of the real testing phase

This result shows that the completion of the questionnaire does not make major problems, but for the patients, it is not always clear what they have to do while they answer the questions.

Due to the hustle, as I mentioned before, some questions will be misread and / or misunderstood.

Thus it quickly emerged that the installation of this questionnaire tools is impossible in this time period.

6. Executive Summery and Conclusion

On average, up to 40 patients per day are taken to the emergency room of the Department of Pediatric Surgery in the country hospital in Graz. To ideally meet these child and adolescents needs, as much data pertaining to the accident of each patient as possible must be collected during anamnesis. To date, children and their escorts were asked to answer questions about their accident during the treatment, while the attending physician took notes.

This procedure for collecting accident data has some drawbacks: 1^{st} the face-to-face interview and the extra notes of the responses during the treatment restrict the doctors in their principal duty, 2^{nd} the notes are usually left until the end of the clinic time and so 3^{rd} had to be entered into the database manually at the end of the work day. 4^{th} due to lack of time and its not very user-friendly input form, the data are often incomplete or even empty, which results 5^{th} in a lack of available, statistically valuable, data about the accidents.

During the project QIMQ, a touch-based computer system was developed using the "User Centered Development (UCD)" method. The patients are now included into the process of collection data. Therefore, in the waiting room of the emergency department, they fill out the application on a touch-based computer for the newly developed, newly categorized, finger-based questionnaire immediately after registration. This procedure puts the patient in the treatment process early on, which can calm the children and their escorts down. Because of this, they get distracted, which again reduces subjective waiting time ("patient empowerment"). After completion of the questionnaire, the data are immediately transferred to the hospital's internal system called openMEDOCS. These data are already visible on the clinical workplace (KLAP) the moment the patient comes into the surgery to the attending physician. After signing off the answers of the completed questionnaire by the physician in charge, these data are permanently stored with the patient data.

Mobile devices, recently especially tablet PCs, with small screens and minimal facilities for interaction find increasing use in complex human activities for accessing and processing information. Therefore the QIMQ project was evaluated at the end of the master's thesis in different areas: New categorization and structuring of data, user friendliness of the guided questionnaire and applicability in the emergency room.

In order to be able to evaluate the completeness of the categories, their structure and the quasi-intelligently linked possible answers, an expert review was conducted by the employees at the Bärenburg. Because all volunteers were familiar with the accident mechanisms, this testing phase enabled us to reveal missing or incorrectly linked questions and answers very quickly and easily. During a period of one month, 108 examples of accidents were evaluated to test the quasi-intelligence navigation through all questions. To test whether the links within the questions are logical, there was a collected feedback session once a week to find missing links, so that I could correct wrongly linked questions or answers as soon as possible. Now, due to the restructuring, almost all accidents can be classified into their right categories or subcategories, which resolved the problem, which existed until now, that the majority of accidents were classified under the category "other". The great advantage of the restructuring of the accident data is the consequent WHO - standardization, which particularly facilitates the comparison with other countries.

To evaluate the usability of the developed questionnaire a standardized evaluation combined with a self-developed German version of the System Usability Scale (SUS) was performed (10 questions with a 5-value scale). The questionnaire was installed in the waiting area of the emergency room on a touch-based computer and could be completed there. 58 patients participated in the evaluation. From these 58 subjects only 49 patients (about 85%) completed the followed questions of SUS. Subsequent analysis revealed a SUS of 71.99 (min: 50, max: 100).
This value indicates that QIMQ is simple and satisfactory usable, but not always very clear. Especially questions like "I think I need assistance from another person to fill in the questionnaire." were rated by most very low and so with approval. One reason could

be the existing bustle and agitation in such troubled areas, such as an emergency hospitalization. Indeed, completing the questionnaire offered distraction and reduce the waiting time, but it seemed that the patients are not able to concentrate totally on the questionnaire.

Especially for a system, which will be used in real processes of hospital, an evaluation of the applicability in the emergency is very important. For the testing phase, therefore the touch-based computer with the installed questionnaire was constructed in the Department of Pediatric Surgery in Graz.
During a period of four weeks, the patients were able to complete this survey in the emergency room three times a week from around 8:00 to 11:00 o'clock.

Because, in primary care, children, young people and especially their chaperons are always under pressure, under stress or just concerned, we have decided that only patients who came to follow-up examinations are preferred to complete the questionnaire. To advise children and their parents of the questionnaire, and to minimize inhibitions against this new system in the test run, they were assisted from a staff member of the Centre for Accident Research (pediatric nurse). Although this employee actively went to the patients and their parents and asked them to complete the questionnaire, only 10 per cent completed it.

Weak point:
In order to provide a complete collection of accident data and to permit the attending doctors to know how the accident happened shortly before the actual treatment, it has to be ensured that each patient fills out the questionnaire in the waiting room in the emergency department to the best of their knowledge. However, as we have seen in the evaluation, both the children and young people themselves, and especially the accompanying persons, mostly parents, are too hectic and panicked, as that this can be ensured.

Recommendation:

Due to the condition in which patients are when they come to the emergency room, they cannot be expected to deal with a system they do not know. This project has shown that it was not possible to shift the input of accident data to the patients. Indeed the evaluations show that the system has proven itself; however, the environment was not optimal. Therefore, in the future, the focus should not be moved to the beginning of the chain of treatment before the treatment room, as planned in the design of the project, but as usual remain with the attending physicians. But how the developed questionnaire can be integrated in the clinical workplace (KLAP) needs to be tested and implemented accordingly in the course of a new project.

7. Lessons Learned

The area of health care has been a new experience to me. Although my educational background is focused on informatics, this thesis was very interesting, because the thematic is situated in the interface of informatics and health care. I have gained an excellent overview over the electronic patient record, the computerized documentation system in the Pediatric Surgery in Graz and the situation in the emergency room.

Furthermore, the multidisciplinary work with medics, computer scientists and health-informatics specialists at the Bärenburg and the Steiermärkische Krankenanstalten GesmbH offered important and interesting insights into various areas of medical informatics.

Moreover, the software development process at the Bärenburg, the child safety house at the university hospital at Graz where I worked on this thesis, has provided important input for the development of the implemented medical quasi-intelligent questionnaire prototype for the collection of patient accident reports. Also the team meetings with a professional team have been a valuable experience.

Although such cooperation cause some difficulties, so it was not always easy to arrange a common date or to find joint solutions for the same problem. However, such little things are the reason for time lags in the whole project.

The greatest aspect I have learned in this work is the fact, that test phases and different ideas and opinions are very important.

At the beginning of the master thesis, we had the idea to develop the questionnaire on a mobile device, such as a tablet pc. Recently, there has been an increasing interest in using mobile phones or tablet PCs. So it is not surprising that mobile devices play an increasingly important role.

Medical doctors and nurses work in an environment which requires high mobility. Therefore the usefulness of handheld computers in medicine is respected, even among patients. Thus it is not astonishing that mobile devices are also used in medical care systems. Because of these facts, the new interface developed in this thesis should be implemented on a tablet computer. Just as with the project at the dermatology patients and medics can derive advantage of mobile devices. In this project a method is implemented, which collects data by filling out a questionnaire by patients using tablet PCs.

Therefore I developed mock-ups for a mobile device and tested the idea in real life scenario. During this test phase I found out that in this case a mobile solution is not the best option. Also the medics, who are daily confronted with the situation in the ER, advised me against a mobile solution. Because of several disadvantages shown in the test results of the evaluation of the designed mock-ups and the opinion of the medics, I decided to develop the quasi-intelligent questionnaire on a touch computer, which is installed in the Paediatric Surgery in Graz.

Thanks to this thesis, I gained an excellent insight into the working environment with all the pros and cons. However, the experience with the medical sector has sparked my interest in medical informatics. Thus I can imagine doing further work in this area.

8. Outlook and Future Work

Although a great deal of research has already been conducted in the field of human-computer interaction for medical applications, there is still a long way to go until new concepts and user-centered design are applied to the development of the commercial products currently used in hospitals.

In Austria, the acquisition of absolute numbers of accident events based on projections form the basis of Austria's target group interviews in a few hospitals. Due to the collection of data across multiple steps (paper, interview, anonymization) and different input into the system, it ultimately follows that the data is of low quality. In addition, the Pediatric Surgery is not included in the acquisition.
The prototype application developed in this master' thesis should be understood as a basis for further projects in this area.

If the survey does not take a high priority, an integration of the questionnaire is not possible in an acute care clinic. This is mainly because parents with injured children have trouble concentrating on things other than the child. The only goal for parents is to see the doctor and thus to relieve the pain for the child.

The prototype application could be improved in many ways.
The questionnaire mask is perfect to capture the accident in a greater depth of information and data quality with a few clicks. However, the input cannot be done at the beginning of the outpatient process by the parents themselves.
Therefore, the current system which is included in Medocs must be replaced by the present upgrading questionnaire. In order for accurate and reliable statistical accident data to be collected, it must be integrated into the hospital's medical system, Medocs.
Based on the results from the testing phase in the emergency room, it is clear that the input of accident data will again be carried out by medical professionals. Through the employment of responsible persons who work at the registration desk of the ambulance, a standardized quality for input can be guaranteed.

The final version permits an automated insertion of keywords in the text during the input process, providing the doctor with the medical history to scroll through in the treatment room.

To obtain accident data area-wide, this system has to be integrated in both outpatient and inpatient operation. Thereby, the idea with the mobile solution can be reinitiated.

Because of the connection of Medocs to other departments and hospitals, this data collection can be integrated in all KAGes hospital in Styria. In a further step, it is conceivable to import the available data from the EU-funded IDB (Injury Data Base).

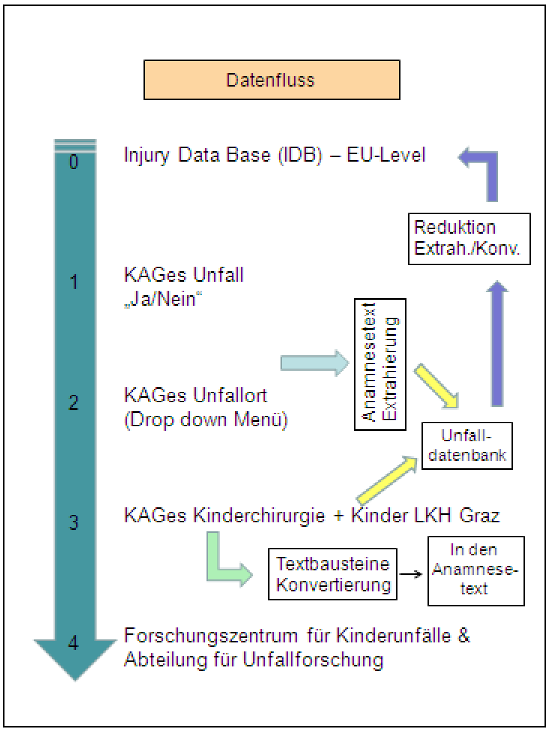


Figure 39: Data flow diagram of acciendent data in the future (Picture taken by Dr. Spitzer)

Through the use of an automatic evaluation mask, the finished model enables effective and efficient use of accident data.

9. List of Figures

10. List of Tables

11. References

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Appendix I: SUS Questionnaire

	überhaupt nicht einverstanden 1	2	3	4	völlig einverstanden 5
01. Ich denke, ich würde dieses System gern regelmäßig nutzen.					
02. Ich fand das System unnötig komplex.					
03. Ich fand, das System war leicht/einfach zu benutzen.					
04. Ich glaube, ich bräuchte die Unterstützung einer fachkundigen Person, um das System nutzen zu können.					
05. Ich fand, die verschiedenen Funktionen in diesem System waren gut integriert.					
06. Ich fand, es gab zu viel Inkonsistenz in diesem System.					
07. Ich könnte mir vorstellen, dass die meisten Leute sehr schnell lernen würden, dieses System zu nutzen.					
08. Ich fand das System sehr umständlich zu nutzen.					
09. Ich fühlte mich bei der Benutzung des Systems sehr sicher.					
10. Ich musste viele Dinge erlernen, bevor ich anfangen konnte, mit dem System zu arbeiten.					

Appendix II: SUS results of the evaluation in real life

	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Question 7	Question 8	Question 9	Question 10	SUS
Participant 1	3	3	4	3	3	2	3	2	3	2	60
Participant 2	3	3	3	3	3	3	3	3	3	3	50
Participant 3	3	4	2	3	4	5	4	3	2	3	42,5
Participant 4	2	3	4	2	3	3	4	3	2	4	50
Participant 5	3	4	2	3	4	3	2	3	3	3	45
Participant 6	1	3	5	1	2	1	5	1	5	1	77,5
Participant 7	4	3	4	3	4	3	5	4	2	4	55
Participant 8	5	3	5	1	5	1	4	1	5	1	92,5
Participant 9	1	4	5	1	4	1	4	1	4	1	75
Participant 10	4	4	4	1	5	1	1	5	1	4	50
Participant 11	4	4	1	1	5	1	4	1	4	2	72,5
Participant 12	5	1	5	1	5	1	4	1	5	1	97,5
Participant 13	4	1	4	1	5	1	2	4	4	2	75
Participant 14	4	2	5	1	4	4	5	1	1	1	75
Participant 15	3	5	5	1	5	1	4	2	4	1	77,5
Participant 16	3	3	5	2	4	2	2	4	4	2	62,5
Participant 17	5	5	5	1	5	1	5	1	5	1	90
Participant 18	4	2	4	2	3	4	1	4	3	1	55
Participant 19	4	4	5	1	4	1	4	1	5	2	82,5
Participant 20	4	5	5	1	5	1	5	1	5	1	87,5
Participant 21	5	5	5	1	5	1	3	3	4	1	77,5
Participant 22	5	1	5	1	5	1	5	1	5	1	100
Participant 23	5	3	5	1	5	1	4	2	4	1	87,5
Participant 24	4	2	5	1	2	1	5	1	5	1	87,5
Participant 25	5	1	1	1	5	1	5	1	5	1	90
Participant 26	5	1	5	1	4	1	5	1	5	1	97,5
Participant 27	5	1	5	1	5	1	5	1	2	1	92,5
Participant 28	5	5	5	1	5	1	1	3	5	5	65
Participant 29	5	1	5	2	2	3	5	3	2	1	72,5
Participant 30	5	4	5	1	4	1	4	1	5	2	85
Participant 31	3	4	5	1	4	1	4	1	5	2	80
Participant 32	5	3	5	1	5	1	4	2	4	1	87,5
Participant 33	4	1	4	5	2	5	3	5	3	3	42,5
Participant 34	5	3	3	5	1	3	2	5	3	2	40
Participant 35	5	3	5	1	5	1	4	2	4	1	87,5
Participant 36	5	3	2	3	4	2	4	3	3	2	62,5
Participant 37	3	3	3	3	3	3	3	3	3	3	50
Participant 38	4	4	4	1	5	1	1	5	1	4	50
Participant 39	4	4	4	1	5	1	1	5	1	4	50
Participant 40	4	2	3	3	4	5	1	2	4	1	57,5
Participant 41	4	1	3	5	4	4	4	4	3	3	52,5
Participant 42	5	3	5	1	5	1	4	2	4	3	82,5
Participant 43	4	1	5	1	5	1	4	1	5	1	95
Participant 44	5	3	5	1	4	1	4	2	4	2	82,5
Participant 45	4	3	5	1	4	1	5	1	5	1	90
Participant 46	3	3	3	3	3	3	3	3	3	3	50
Participant 47	4	1	3	2	1	5	5	1	4	1	67,5
Participant 48	4	3	5	1	4	2	4	1	5	2	82,5
Participant 49	5	4	5	2	5	1	5	1	5	1	90
SUS	4,04	2,90	4,18	1,73	4,02	1,92	3,63	2,29	3,69	1,94	71,99

Appendix III: Overlook about the Patient in the Pediatric Surgery at Graz

Analyse der Monatstage 1 bis 31 (n=9.297)

Regelmäßige Verteilung

Tag

		Häufigkeit	Prozent	Gültige Prozente	Kumulierte Prozente
Gültig	1	304	3,3	3,3	3,3
	2	284	3,1	3,1	6,3
	3	319	3,4	3,4	9,8
	4	312	3,4	3,4	13,1
	5	280	3,0	3,0	16,1
	6	330	3,5	3,5	19,7
	7	321	3,5	3,5	23,1
	8	305	3,3	3,3	26,4
	9	310	3,3	3,3	29,7
	10	306	3,3	3,3	33,0
	11	316	3,4	3,4	36,4
	12	318	3,4	3,4	39,9
	13	286	3,1	3,1	42,9
	14	301	3,2	3,2	46,2
	15	347	3,7	3,7	49,9
	16	316	3,4	3,4	53,3
	17	296	3,2	3,2	56,5
	18	276	3,0	3,0	59,4
	19	307	3,3	3,3	62,8
	20	309	3,3	3,3	66,1
	21	302	3,2	3,2	69,3
	22	339	3,6	3,6	73,0
	23	302	3,2	3,2	76,2
	24	300	3,2	3,2	79,4
	25	313	3,4	3,4	82,8
	26	284	3,1	3,1	85,9
	27	298	3,2	3,2	89,1

	28	326	3,5	3,5	92,6
	29	244	2,6	2,6	95,2
	30	274	2,9	2,9	98,1
	31	172	1,9	1,9	100,0
	Gesamt	9297	100,0	100,0	

Analyse der Tageszeit (n=9.297)

Uhrzeit Stunde

		Häufigkeit	Prozent	Gültige Prozente	Kumulierte Prozente
Gültig	0		,4	,4	,4
	1		,2	,2	,5
	2		,1	,1	,6
	3		,1	,1	,7
	4		,1	,1	,9
	5		,1	,1	,9
	6		,1	,1	1,1
	7		,4	,4	1,5
	8		2,2	2,2	3,7
	9		4,7	4,7	8,4
	10		6,6	6,6	15,0
	11		7,2	7,3	22,3
	12		7,4	7,4	29,7
	13		7,1	7,1	36,8
	14		6,5	6,5	43,3
	15		8,2	8,3	51,5
	16		8,6	8,6	60,2
	17		8,0	8,0	68,2
	18		9,1	9,1	77,3
	19		7,5	7,5	84,8
	20		6,9	6,9	91,7
	21		4,5	4,5	96,2
	22		2,6	2,6	98,8

	23		1,2	1,2	100,0
	24		,0	,0	100,0
	Gesamt		100,0	100,0	
Fehlend	System		,0		
Gesamt			100,0		

Geschlecht (n=9.297)

Geschlecht

			Prozent	Gültige Prozente	Kumulierte Prozente
Gültig	M		57,2	57,2	57,2
	U		,1	,1	57,3
	W		42,7	42,7	100,0
	Gesamt		100,0	100,0	

Wochentag (n=78.676)

Wochentag

		Häufigkeit	Prozent	Gültige Prozente	Kumulierte Prozente
Gültig	SUN	9285	11,8	11,8	11,8
	MON	12314	15,7	15,7	27,5
	TUE	11905	15,1	15,1	42,6
	WED	12222	15,5	15,5	58,1
	THU	12009	15,3	15,3	73,4
	FRI	11858	15,1	15,1	88,5
	SAT	9083	11,5	11,5	100,0
	Gesamt	78676	100,0	100,0	

Behandlungen pro Tag (N=7.195)

Durchschnitt pro Tag 47 (Jan bis Mai 2012)

Range zwischen 1. Jänner 2012 und 31. Mai 2012: 17 (war 1. Jänner) und 77