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**Bachelorarbeit
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Systematic Development of mHealth Apps: Lessons Learned During Development of a Mobile Frontend for ePill

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Index of Abbreviations

app	abbreviation for Application
app user	the intended audience for the app
eHealth	"a paradigm involving the concepts of health, technology, and commerce, with commerce and technology as tools in the service of health" ¹ . Belonging to the field of telehealth. ²
ePill	a patient-centered health IT service which offers information on pharmaceuticals and aggregation of data in context
framework	can contain source code, tools and libraries, which together provide specific or common but abstracted functionality
frontend	visible user interface for the app user
HECAT	Health Education Curriculum Analysis Tool ³
HIT	abbreviation for Health Information Technology
IDE	abbreviation for Integrated Development Environment
mHealth	"medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices". ⁴ Also known as m-Health.
mHealth apps	"aim at providing seamless, global access to tailored health IT services and have the potential to alleviate global health burdens." ⁵
MVC	Model-View-Controller Architecture TODO: DEFINITION?
information security	Prevention from unauthorized access to information. In this context especially sensitive, personal information
OS	operating system
SDK	abbreviation for software development kit. Bundled software and tools for developing with or for a specified OS or Framework

¹ Martínez-Pérez, de la Torre-Díez, Isabel, López-Coronado (2013), p. 2

² cf. Martínez-Pérez, de la Torre-Díez, Isabel, López-Coronado (2013), p. 2

³ <http://www.cdc.gov/HealthyYouth/HECAT/>

⁴ World Health Organization (2011) cited by Martínez-Pérez, de la Torre-Díez, Isabel, López-Coronado (2013), p. 2

⁵ Dehling, Sunyaev (2013), p. 1

sensitive information	information, which is personal. Can be related to financial, health or otherwise personal relevant information ⁶
telehealth	delivery of medical- or health-related information or services via telecommunication technologies
usability	"extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" ⁷
use value	the utility of consuming a good or service
user interface	TODO: DEFINITION!

⁶ Suggested by Future of Privacy Forum, Center for Democracy & Technology (2011), p. 6, although the definition varies

⁷ Yeh, Fontenelle (2012), p. 64 as quoted from ISO 9241-11 (1998)

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1. Introduction

1.1 Research Problem

TODO: REVISE!

While it has become easy to develop a mobile health (mHealth) application (app), there is much more to it than just the aspects of the app's core functionality. Currently only very few guidelines, best practices and systematic development approaches for mobile app development can be found. And even less can be found for the specific area of mHealth apps.

Security leaks or even abuse of private and sensitive information can lead to great harm for the app user and to legal issues for the developer. Abuse of personal health related information can result in loss of reputation (e.g. sexual transmitted diseases) or financial drawbacks and decreased chances of employment (e.g. chronic diseases, genetic dispositions)⁸. With poorly developed apps, there is a chance of security leaks and hence for data abuse. Thus the risk for app users increases. A study⁹ has shown that only very few mHealth apps entail little or low risk for the app user. Self-publishing through modern sales channels like Google Play (<http://play.google.com>) or the iOS App Store (<http://appstore.com>) and the availability of easy-to-use Integrated Development Environments (IDEs) lower the barriers for entry. Even one-man developers or small teams are now able to easily publish apps with little development effort. Without fundamental knowledge of privacy and security aspects, there is an increase in the non-professional development of mobile apps with inadequate security aspects.

The usability, especially in critical situations, is another undervalued aspect in many non-professional developments. While fancy colors might look appealing to the developer himself, it might lead to confusion for the app user or even to a lack of operability for visually impaired people.¹⁰ Also the need for a intuitive user interface might not be considered as important as it should be.

⁸ cf. Dehling, Sunyaev (2013), pp. 6-7

⁹ cf. Njie (2013), pp. 19-20

¹⁰ cf. Badashian et al. (2008) p. 108

Knowledge of data privacy acts and laws is a premise for a legal, safe and fair development for the developer and the app user. Multiple layers of data privacy laws in Europe on international, national and state level require a certain legal knowledge.¹¹ Also the benefit of and the need for a privacy policy seems to be ambiguous for many non-professional developers.¹²

This lack of guidelines for mobile app development and of specific guidelines for privacy and usability sensitive apps is only superficially considered by most of the literature. The beforehand highlighted aspects usability and information security are just two of multiple possible requirements. Current research seems not to state which specific requirements, if any, mHealth apps distinguish from other apps or which are needed to be more accented.

1.2 Objectives of this Thesis

TODO: REVISE!

The purpose of this thesis is to discover, identify and report issues and challenges of the development of mHealth apps by developing a mobile frontend for the ePill system (developed by the University of Cologne, <http://epill.uni-koeln.de>). ePill is a patient-centered health IT service which offers information on pharmaceuticals and aggregation of pharmaceutical data in context.

During the development of a mobile frontend for ePill, all requirements can be addressed more easily than in a completely theoretical context. As a side effect, a mobile app for ePill will increase the accessibility for the ePill system in general and thereby increase the possible user value. Especially in critical situations in which one does not have one's desktop computer at hand, a mobile easy-to-use app can be of value.

The experiences made during the development refer to general mobile app development,

¹¹ cf. Directive 95/46 of the European Parliament and of the Council (October, 24th 1995), Directive 2002/58 of the European Parliament and of the Council (July, 12th 2002) cited by Future of Privacy Forum, Center for Democracy & Technology (2011), p. 16

¹² cf. Njie (2013), p. 20

but also to the specific development of mHealth apps.

Mainly this thesis aims to describe the planning and the development process and discuss all discovered issues and challenges for planning and developing mHealth apps. One sub-objective is to give a short overview about the state of research on guidelines and important factors of mHealth app development. Subsequently, this thesis aims to highlight specific characteristics of mHealth apps and focus on them during the development as well in the conclusion.

2. The ePill System

2.1 The System in general

The ePill system (<http://epill.uni-koeln.de>) was developed by the University of Cologne to improve the readability and comprehensibility of instruction leaflets of medical drugs. Additionally ePill aims to provide further information on adverse reactions and interactions of different medical drugs. ePill emphasizes an easy readability and access to informations.

There are three major functions covered by the system: Searching for pharmaceuticals, display information on pharmaceuticals and supplementing services.¹³ The search enables the user to find corresponding pharmaceuticals depending on specified parameters in the underlying database. As an extend, the display functionality enables the user to read the leaflet information in an optimized fashion. Finally supplementing services are provided to refine the displayed information (e.g. select the level of detail of the displayed information), linking pharmaceuticals as well as other information and aggregate pharmaceutical information (e.g. interactions).

An integration and personalization depending on the current user's health records was not implemented due to the arising privacy and trust challenges.^{14, 15}

The system uses a Model-View-Controller (MVC) architecture¹⁶ and utilizes a relational database (MySQL) **TODO: CITE!** as persistent data storage.¹⁷ The data is organized in an atomic way. Products are any pharmaceuticals, whereas they contain specific molecules, which themselves may have specific adverse reactions with other molecules.

With this atomized organization of the pharmaceutical information, it becomes more easily to compare different pharmaceuticals and have very consistent information about

¹³ cf. for this section Dehling, Sunyaev (2012), p. 2

¹⁴ cf. Kaletsch, Sunyaev (2011) cited by Dehling, Sunyaev (2012), p. 2

¹⁵ cf. Kaletsch, Sunyaev (2011), pp. 5-6

¹⁶ cf. Dehling, Sunyaev (2012), p. 3

¹⁷ cf. Dehling, Sunyaev (2012), p. 5 for this and the following two sentences

molecules and adverse reactions for different pharmaceuticals.

2.2 The Web Application

The web application of the ePill system introduces itself highly customizable to the user. It offers the user the choice between a default view, a customizable view and an expert view. The default view aims to provide all necessary information in a compact way. The customizable view offers more choices for the elements to be displayed. The expert view activates all options for the most detailed information level. The pharmaceutical informations to be displayed can be fine tuned for every view. ePill offers four different presets varying from only the most basic up to all available information. These presets can be further customized by afterwards selecting or deselecting items. Additionally the font-size can be set to normal, bigger and biggest to support visually impaired users.

Three columns shape the layout. The leftmost column contains the main navigation for searching, pharmaceutical listings, basic functionality like help pages and settings as well as extended functionality like interactions research and adverse reaction lookup or pharmaceutical comparisons. The centered column contains the current content. This column has tabs, which can be assigned different contents. With this tabular layout, e.g. multiple, different search queries can easily be switched and held in parallel. The rightmost column can be used to dynamically display or hide specific information. Depending on the beforehand selected view, the left or right columns are hidden or visible. The website also offers the user on the pharmaceutical detail page to explain any term as well as a shortcut to the page's top.

The specific content layout is very consistent. Headlines are made salient and the arrangement of common sections are congruent. Changes in settings are apply with no delay and without a page reload. Any changes are applied congruent with the chosen layout and other related settings.

Although this web application is not optimized for mobile application and designed with a desktop computer in mind, this web application can be accessed by nearly any modern mobile computing device, like a smart phone or a tablet, and can therefor categorized as

a mHealth application. This assumption is important to the following section, to clarify the differences between this web application and the mobile client, because with this assumption we can categorize on the same level and focus on the essential differences.

3. What is mHealth?

3.1 Definition

TODO: MORE DETAIL!

mHealth, also known as m-Health, is an abbreviation for mobile health and is a refinement of eHealth (or e-Health, an abbreviation for electronic health), which itself belongs to the field of telehealth.¹⁸

eHealth is defined as "a paradigm involving the concepts of health, technology, and commerce, with commerce and technology as tools in the service of health".¹⁹

Telehealth means the delivery of medical- or health-related information or services via telecommunication technologies.

mHealth in detail is defined as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices".²⁰ The introduction of smart phones like the Apple iPhone or any Android device led to a greater audience and the evolution of mobile tablets further increased the audience for mHealth purposes. A study²¹ relied on the Health Education Curriculum Analysis Tool (HECAT)²² to group different mHealth apps together. This study illustrates the distribution of apps in different categories. As Tab. 3-1 illustrates, most of the available apps in 2011 in the Apple App Store in the United States of America belonged to the Physical Activity area, whereas drug-related and safety-related apps (like ePill) are the least two.

¹⁸ cf. Martínez-Pérez, de la Torre-Díez, Isabel, López-Coronado (2013), p. 2

¹⁹ Martínez-Pérez, de la Torre-Díez, Isabel, López-Coronado (2013), p. 2

²⁰ World Health Organization (2011) cited by Martínez-Pérez, de la Torre-Díez, Isabel, López-Coronado (2013), p. 2

²¹ cf. for this and the first following sentence West et al. (2012)

²² <http://www.cdc.gov/HealthyYouth/HECAT/>

HECAT content area	n	%²³
Physical Activity	1108	33.21
Personal health and wellness	962	28.84
Healthy eating	651	19.51
Mental and emotional health	414	12.41
Sexual and reproductive health	243	7.28
Alcohol, tobacco, and other drugs	131	3.93
Violence prevention and safety	96	2.88

Tab. 3-1: HECAT Content Area App Distribution (N = 3336)²⁴

From February to May of 2012, a Study by d'Heureuse et al. (2012) found several ten thousands of apps in the Google Play Store as well as the Apple App Store just in the "Health" categories.²⁵ This study shows the potential of mHealth for a broader healthcare supported by mobile devices. From March to May of 2012, the total number of apps increased by an average of 6.4% (Google Play Store) and 4.5% (Apple App Store) per month.²⁶

3.2 mHealth App Categories

Although the Tab. 3-1 listed categories for mHealth apps, it focusses on content and less on the specifics for mHealth apps on other possibly important topics, such as information security or usability. Other literature focusses on data practices and privacy risks with a more technical aspect²⁷. Njie (2013) concludes that most of the mHealth apps deal in any way with directly or indirectly (e.g. via usage behavior) with sensitive information. Therefor ten levels of privacy risks were developed and a sample of 43 mHealth and fitness apps were assigned to the different levels. Tab. 3-2 illustrates the characteristics of every level as well as the distribution of the 43 analyzed apps.

²³ Apps could be added to multiple categories

²⁴ cf. West et al. (2012), p. 5, Table 2

²⁵ cf. d'Heureuse et al. (2012), p. 20, Figure 5

²⁶ cf. d'Heureuse et al. (2012), p. 20

²⁷ cf. for this and the following three sentences Njie (2013), pp. 13-14

As stated by Istepanian, Jovanov, Zhang (2004), another categorization is possible. They categorized mHealth applications into administrative connectivity, financial connectivity or medical connectivity.²⁸ Because of the lack of smart phones and a far lesser availability of mobile devices in 2004 compared to today, this article cannot take the recent development in mobile devices into account. Nevertheless the categorization is still appropriate. The administrative connectivity handles appointments, electronic patient records and any non-financial transactions, the financial connectivity handles all financial transactions like purchases, billing or any financial services.²⁹ The third connectivity, the medical connectivity, handles mobile monitoring and diagnostics.

There are there different sub-categories for mHealth applications: The content, the information security risk-level and the overall connectivity function. For the content-category as well as the connectivity-category, multiple assignments are possible. Combined these sub-categories form a specific grouping of mHealth apps. Depending on the categorization in the privacy risk, one can easily take care for precautions. With the categorization into a HECAT content area, one can identify the target audience more precisely as well as with the help of the connectivity category.

3.3 Classification of the ePill Web Application

ePill is to be categorized in the beforehand mentioned HECAT content areas mainly as "Alcohol, tobacco, and other drugs", because of the purpose to inform about (medical) drugs. Additionally, ePill informs about adverse effects and interactions, so it also belongs to the content area of "Violence prevention and safety".

The ePill web application is not connected to any electronic patient records, nor does it store any user related information, like the last searched pharmaceuticals. But it does not utilize SSL-encryption. Therefor it might not be collecting information or storing

²⁸ cf. Istepanian, Jovanov, Zhang (2004), p. 6

²⁹ cf. for this and the first following sentence Istepanian, Jovanov, Zhang (2004), p. 13

³⁰ cf. Njie (2013), p. 13

Level	Risk	Characteristics	%
9	Highest	address, financial information, full name, sensitive or embarrassing health (or health-related) information, information that a malicious actor could use to steal or otherwise cause a user to lose money	40
8	High	geo-location	
7	Medium-high	DOB, ZIP code, any kind of personal medical information	
6	Medium	risk evaluated to be between level 5 and level 7	32
5	Medium	email, first name, friends, interests, weight, information that is potentially embarrassing or could be used against a person (e.g., in employment)	
4	Medium	risk evaluated to be between level 5 and level 3	
3	Medium-low	anonymized (not personally identifiable) tracking (e.g., app usage), device info, a third party knows the user is using a mobile medical app	28
2	Low	risk evaluated to be between level 3 and level 1	
1	Low	any kind of anonymized data that does not include medical health-related data or personally identifiable information	
0	No		0

Tab. 3-2: Privacy Risk Levels of mHealth Apps (N = 43)³⁰

anything, but third parties could collect user specific information by monitoring. Setting this information into context with the risk levels developed by Njie (2013), the ePill web application could be categorized as level three, if SSL-encryption would be utilized. If that would be the case, third parties could retrieve browser and OS specific information, but not data sent and retrieved with each request like pharmaceutical information. Without encryption, all data sent and retrieved is visible to possible eavesdropper. With information about searched pharmaceuticals, one could assemble a overall picture of the ingested drugs and therefor extrapolate possible diseases. Still, all data is anonymized. Having in mind, that ePill still is in early prototyping and assuming, that the SSL-encryption will follow, the risk is more of a medium to low level. Dealing with only anonymous data and protecting them with encryption leaves only very less room for serious risks. We would therefor categorize ePill in terms of privacy risk levels as a level two.

Although ePill does not fit absolutely in any of the connectivity categories, it fits best into the medical connectivity. Because of the aim to provide pharmaceutical (therefor medical) information, it belongs definitely to the medical connectivity category.

Concluding this categorization, we would suggest to categorize the ePill web application as a low privacy risk, drug- and safety-related medical connectivity mHealth application. The ePill web application lacks a optimization for mobile devices but all categorizations match their definition. The HECAT content area is by definition not limited to mobile devices and privacy risks are in many ways the same for mobile apps and web applications.

3.4 Why is a special Focus on mHealth Apps warranted?

mHealth apps differ in some way from general (mobile) applications but also from eHealth applications. While mHealth apps can be used in many different situations and with very different intentions, the special focus on e.g. equality of all users and accessibility for all possible users are not as important for other areas of mobile apps as they are for mHealth apps.

mHealth apps are defined to "aim at providing seamless, global access to tailored health IT services and have the potential to alleviate global health burdens."³¹, which means, that they should be accessible by mostly all possible users, whereas other types of apps do not necessarily need to be accessible by any user. We want to stress, that accessibility does not only mean usability (especially for elderly people), but also e.g. different social layers or cultures.

Furthermore, mHealth apps deal with medical- or health-related information and have therefor to deal wit sensitive information and are to address privacy risks and concerns. As pointed out by Njie (2013) and already referred to in Tab. 3-2, many mHealth apps deal with highly sensitive data and have serious privacy risks. Dehling, Sunyaev (2013)

³¹ Dehling, Sunyaev (2013), p. 1

illustrate the possible damages through leaks, manipulation or loss of information.³²

To address these concerns and issues in a mHealth project, they need to be made clear and experiences must be shared as well as interpreted. The following chapter will present all experiences made during the development of a mobile frontend for ePill in a structured way. We will list all theoretical preconditions, outline the analysis as well as the implementation of the mHealth app. Afterwards we will validate the product and give an overview about the lessons we learned.

³² cf. Dehling, Sunyaev (2013), p. 7

4. The Development of the mobile Client

4.1 Preconditions

4.1.1 Norms for mobile Apps

4.1.2 Best Practices

4.1.3 Internal requirements

4.2 Analysis

4.2.1 Assignment of a mHealth App Category

The mobile app does not differ from the web application in terms of privacy risks, content or connectivity because it has exactly the same functions and does also not store any data and serves the same purpose for connectivity.

We plan to implement every request to the server to be optimized for SSL-encryption as soon as the server is capable of accepting and responding with SSL-encryption.

Therefor we would suggest to categorize the ePill mobile application as a low privacy risk, drug- and safety-related medical connectivity mHealth application.

4.2.2 The different Operation Systems

Android

iOS

Windows Phone 7 and 8

other

4.2.3 Possible Frameworks and Technologies

Xamarin

Vaadin

HTML 5, jQuery mobile and Phone Gap

Completely native

4.2.4 The Choice for Framework XYZ

4.3 The Planning Process

4.4 (The Design Process)

4.5 The Implementation Process

4.6 Validation of the mobile Client

5. Lessons Learned

6. Conclusion

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Erklärung

Hiermit versichere ich an Eides Statt, dass ich die vorliegende Arbeit selbstständig und ohne die Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe. Alle Stellen, die wörtlich oder sinngemäß aus veröffentlichten und nicht veröffentlichten Schriften entnommen wurden, sind als solche kenntlich gemacht. Die Arbeit ist in gleicher oder ähnlicher Form oder auszugsweise im Rahmen einer anderen Prüfung noch nicht vorgelegt worden.

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