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Applying MVP Principles when Developing Mobile Health Applications

An Exploratory Study on Selected Mobile Applications and their Version History

Bachelor of Science Thesis in Software Engineering and Management

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Abstract— In an ever evolving and highly competitive mobile health application market, software developers and companies face the daunting challenge to streamline their development methods to be able to obtain and correctly interpret customer demands, in order to reduce wasted resources and reevaluate and improve their products to stay competitive within this volatile industry. This exploratory case study aims at identifying how mHealth developers deploy their products by applying build-measure-learn principles and how frequently a new minimum-viable-product is released; along with analyzing which factors that triggers the continuous development of their products, if any significant amount of changes are driven by user-experience issues, stability enhancements, legislative requirements, compatibility demands or emerging technological possibilities providing opportunities for extended functionality; as well as investigating which basic functionality that should be considered vital to implement in an initial version of a minimum-viable-product in this field.

Keywords— *minimum-viable-product; mvp; build-measure-learn; bml; lean software development; mhealth; ehealth; mobile application development; medical software; release frequency; continuous evolution*

I. INTRODUCTION

A. Purpose

It should be considered highly significant that supplying software development companies, active within any product field, has the ability to continuously deliver their products in order to capture customer demands and thus reducing waste of valuable resources in terms of time and money spent on implementing unwanted features and developing undesirable products [2]. This exploratory case study [15] aims to investigate how often mHealth products, packaged in the form of smartphone mobile health applications, are continuously updated and how the release and change frequency differs compared to other mobile application domains. Furthermore, we wish to identify the underlying causes driving the changes implemented in new versions of mobile health applications as well as which features that are necessary to include in a first version of a new mHealth product when initially released to the market. With this information we attempt to identify how ‘Lean start-up’ principles such as the build-measure-learn process is realized together with what functionality is required to deploy a

minimum viable product (MVP) within the mobile health applications domain [3][4].

By exploring what triggers the development of a new minimum viable product in the current mHealth market, in terms of which the most common set of new features and possible constraints on their continuous deployment are; the results of this study will be of interest for software engineers active within mobile health startup projects as well as software developers and business analysts operating in other parts of the eHealth domain, who wish to extend their current products to the mobile health applications market.

This investigation should be considered evidently important due to the growing size of the current mobile applications market [7] and the, as today, more than ever relevant utilization of information technology within the eternal human need of medical assistance [8].

B. Research Questions

- RQ 1: How frequent is the continuous development of a MVP of a mobile health application?

SRQ 1.1: Do the release frequency of minimum viable products differ between mobile health applications of different purposes?

We want to find out how often new versions of a minimum viable product of mobile health applications are released to the market and if the frequency differs between various mHealth applications targeted at different usage areas.

SRQ 1.2: Do the release frequency of minimum viable products differ between mobile health applications and mobile applications of other domains?

As with the former question, we want to find out how often new versions of a minimum viable product are released to the market within mHealth applications in general, but compared to other mobile applications of completely different purposes.

- SRQ 1.3: Do the change frequency of minimum viable products differ between mobile health applications of different purposes?

With this question we want to find out how often changes are integrated into a new released version of a minimum viable product of mobile health applications and if the frequency differs between various mHealth applications targeted at different usage areas.

- SRQ 1.4: Do the change frequency of minimum viable products differ between mobile health applications and mobile applications of other domains?

As with the previous question, we want to find out how often changes are integrated into a new released version of a minimum viable product within mHealth applications in general, but compared to other mobile applications of completely different purposes.

With these questions we wish to measure the frequency of continuous evolution of mobile health applications, i.e. how often an updated version of the minimum viable product is developed and deployed to the market. Additionally, we also wish to identify if mobile health applications are any different in terms of frequency of continuous development and deployment, compared to completely different mobile application domains.

- RQ 2: Which factors drive the development of updating a MVP of a mobile health application?
 - SRQ 2.1: Are the factors of the change of the minimum viable product rooted in user-experience issues, stability enhancements, legislative requirements, compatibility demands or emerging technological possibilities providing opportunities for extended functionality?

We wish to identify, label and categorize the driving factors of the change for a minimum viable product in the mHealth domain.
 - SRQ 2.2: Do the factors of the change of the minimum viable product differ between mobile health applications of different purposes?

In addition to finding out why a change is necessary for a minimum viable product, we want to investigate if any differences exist, regarding these findings, between various mHealth applications targeted at different usage areas.
 - SRQ 2.3: Do the factors of the change of the minimum viable product differ

between mobile health applications and mobile applications of other domains?

As with the previous question, we want to find out if any differences exist between the driving factors of change of a minimum viable product within mHealth applications in general, compared to other mobile applications of completely different purposes.

With these questions we strive to identify the underlying causes of continuous evolution of mobile health applications, i.e. what are the main reasons for deploying an updated version of the minimum viable product. Additionally, we also wish to identify if mobile health applications are any different in terms of factors driving continuous development and deployment, compared to completely different mobile application domains.

- RQ 3: What are the most common set of Minimum Viable Features (MVF) for a mobile health application?

- SRQ 3.1: Do the set of core Minimum Viable Features differ between mobile health applications of similar purposes?

We want to find out if there are any differences of which main features that must be initially implemented in mobile health applications, targeted at the same usage areas, from the first version release in order for the product to be considered viable.

- SRQ 3.2: Do the set of core Minimum Viable Features differ between mobile health applications of different purposes?

Following the previous question, we want to find out if there are any differences of which main features that must be initially implemented in mobile health applications, targeted at different usage areas, from the first released version in order for the product to be considered viable.

- SRQ 3.3: Do the set of core Minimum Viable Features differ between mobile health applications and mobile applications of other domains?

In addition to the two previous research questions, we want to find out if any differences exists of which main features that must be initially implemented in the first version release of mHealth applications compared to other mobile application domains in order for the product to be considered viable.

The purpose with these research questions were to determine which core features that are most commonly included in an initial MVP of different types of mobile health applications. We

considered this to be relevant since we wanted to investigate if any general differences exist between health applications developed for both different and similar purposes, as well as between mHealth applications in general and other mobile application domains, in terms of core functionality when developing an initial minimum viable product.

II. THEORETICAL BACKGROUND

A. Minimum Viable Product & Build-Measure-Learn

Many companies such as Google, Microsoft and Facebook has adopted an agile software development approach where both requirements and solutions develop gradually through collaborating self-organized and cross-functional teams [1]. In order to stay competitive on the software market it is vital that companies operating in this field has the ability to provide continuous delivery in order to bring and maintain customer value [2]. A minimum viable product (MVP) is in most cases the earlier versions of the product that is released for the market to obtain end-user opinions. The MVP is characterized by only having the minimum set of features, i.e. becoming viable for the end-users in order to solve the problem it was designed for [3].

momentum as well as ensuring the right strategy for their next version of the application by applying BML [4].

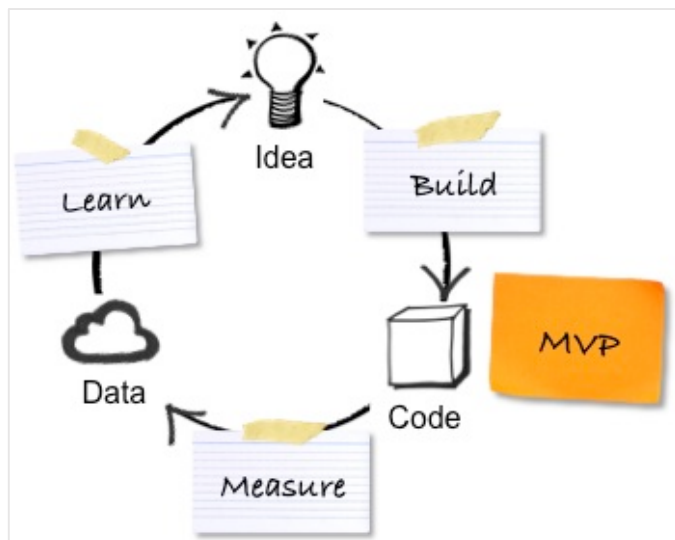


Figure 2. An illustration of the build-measure-learn process cycle [16].

B. mHealth

Electronic Health (eHealth) is a term that is used to describe the transmission, storage and retrieval of digital data in the health sector, combining electronic communication with information technology [5]. The term Mobile Health (mHealth) basically extends eHealth by describing such functionality utilized by the use of mobile smartphones and other mobile devices. Additionally, it is further defined as a concept including capturing, analyzing, processing and transmitting information related to health collected by sensory information or user input from portable devices running the intended and relevant mobile applications [6].

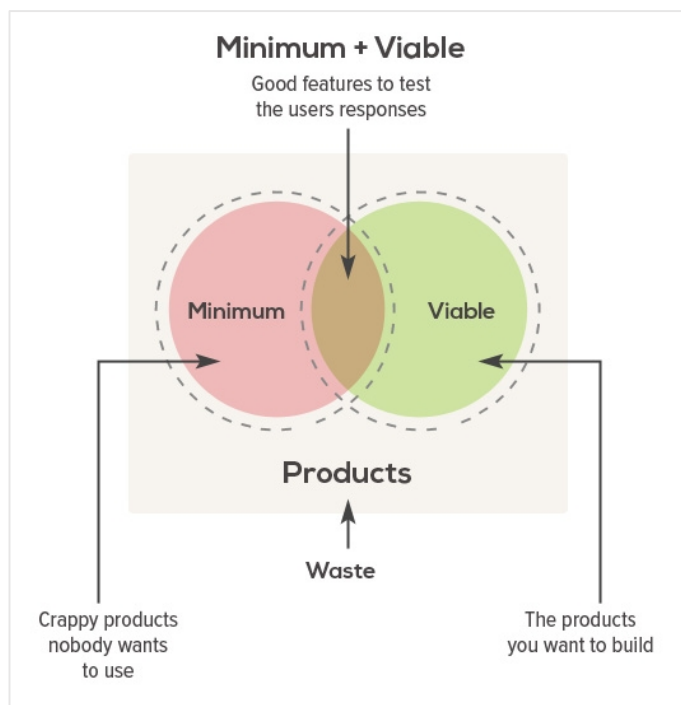


Figure 1. A representation of a minimum viable product, the intersection between the definitions minimum and viable [17].

When developing mobile applications there are companies that are applying the concept called “pivot or persevere” which means that before planning the next version of a mobile application release, a decision is made regarding to continue on the same path (persevere) or change the strategy (pivoting). In order to realize a MVP, companies utilize an activity called build-measure-learn (BML). First you build a MVP, then measure if the MVP leads to an advancement of the product, and lastly you learn by drawing a conclusion of the measurement of the MVP and decide whether to pivot or persevere. Using the aforementioned strategy enables companies to keep iteration

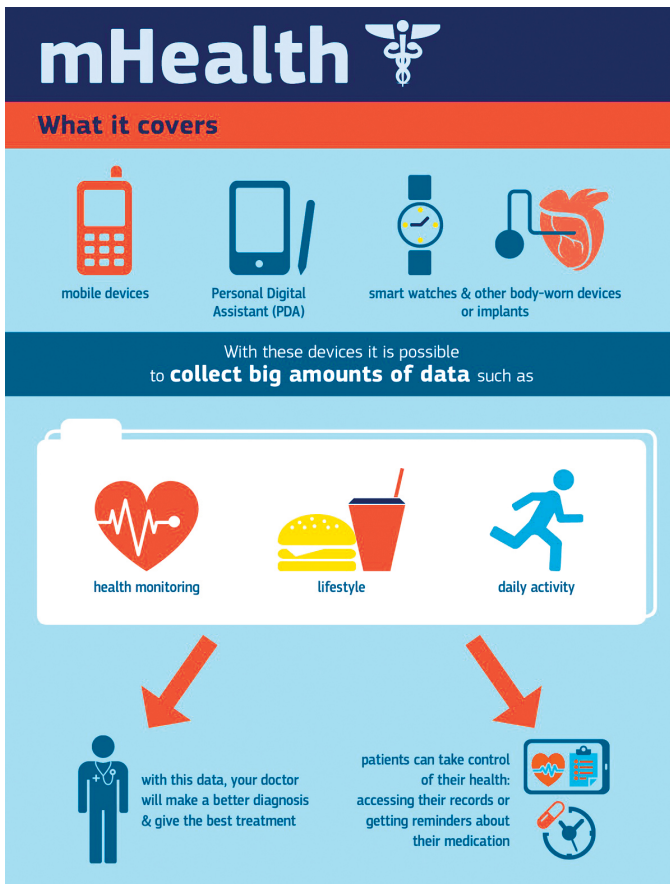


Figure 3. An illustration of the mHealth concept and what it covers [18].

C. The Current Mobile Applications Market

A significant increase of mobile applications has emerged since the year of 2000. As there are currently over 1 billion smartphones and more than 100 million tablets used daily around the world, indications of a big and growing market for mobile health applications are implied which should essentially be considered as a valuable possibility for new usage areas and business opportunities for mobile application developers, private smartphone-users interested in monitoring their health conditions, as well as medical patients, entrepreneurs and professionals from the entire healthcare industry [7]. As of 2015 there are approximately 165 000 mobile health applications running world-wide [8].

D. Lean Software Development

The Lean development (LD) approach stems from the Japanese automotive manufacturer Toyota and was developed during the 1950s, it was originally called Toyota Production System (TPS) and it was developed in order to specify value, as well as coordinate the value-adding actions, execute these actions upon request without interruption and the aim of improving continuously [12]. A customized principle of this approach was presented in the book "Lean Software Development: An Agile Toolkit" by Mary Poppendieck and Tom Poppendieck (2003). This book presented how to apply accepted lean practices and transfer those to agile software development. Accordingly, there are seven steps to achieve this:

1. Eliminate waste - find out exactly what the customer wants, everything else is considered waste.
2. Amplify learning - Try out several solutions in order to find the best solution
3. Decide as late as possible - In fast evolving markets it is better to have the option to change rather than decide early on, facts are better than speculations.
4. Deliver as fast as possible - If the speed is not up to par, you cannot delay decisions nor get reliable feedback. Since the development cycle usually consists of: design, implement, feedback and improvement, more can be learned the shorter those development cycles are. Having speed also ensures that you deliver value to your customer today when they need it and not tomorrow.
5. Empower the team - Involves the developers of the specifications of the technical decisions in order to establish a good product, let the developers make the decisions instead since they know best because they are the ones doing the software development. This is realized by having daily meetings, visible charts, continuous integration and testing of the software which gives the developers the tools to communicate and make decisions on their own of what needs to be done. This enables to release refined versions of working software in iterations.
6. Build integrity in - When the software does what the intended users expects it to do, furthermore, it should then run smoothly and also have the ability to evolve meaningful into the future as well as has a high rate of usability and purposefulness.
7. See the whole - when developing a product, it is common that the person that has expertise in a certain area of the development tries to allocate most resources performance-wise to that area (e.g., backend or frontend), making the overall performance of the product suffer [13].

E. MVP and Release Frequency

In today's development of mobile applications, it is vital that the delivery of those applications are developed and delivered as fast as possible to quickly generate a return of the financial investment made. Therefore, Lean approaches has been adopted for the development of minimum viable products (MVP) which focus and prioritize a core set of features of each iteration of the mobile application [9][10]. Hence, the release frequency of these applications does impact on not only financial gains, but factors such as product quality and customer satisfaction [11].

III. METHOD

A. Data Collection

In the process of gathering the data necessary to answer our research questions we used Apple iTunes as a library to search for mobile applications based on a specific filtering criteria. We decided to collect data regarding different applications targeted at a variety of medical and health-related conditions, namely;

diabetes, diet/calorie guidance, woman's health and pregnancies and a few other miscellaneous medical usages. Additionally, we decided to inspect the version history of applications from other domains, such as from financial/banking services, fitness coaching, entertainment and utilities, in order to map out if any general differences exist regarding release of new minimum viable products between our samples of mobile health applications and the other mobile apps. We exclusively selected applications with a full version history available, which enabled us to compare and study the changes of each version of the application and deduct the minimum viable product, its core features and reasons for continuous deployment.

B. Data Analysis - How frequent is the continuous development of a MVP of a mobile health application and which factors drives it?

In order to get a good overview of the mobile applications from the various domains we created a data spreadsheet which enabled us to document and categorize those applications in a systematic way. The classifications consisted of:

- App domain

The domain from which the application belongs to was classified as either usage related to specific medical health conditions, such as: diabetes, diet/calories, woman's health and pregnancy, or other miscellaneous medical domains with applications we found interesting for this study; and non-medical related domains, such as tool/utility, entertainment, finance and fitness. Although fitness-related apps could be associated to health-related usage, we decided to distinct this category from the other medical/health apps we used in this study since we do not consider it to be directly related to any medical condition and should thus not be included in our interpretation of the concept of mHealth applications.

- Date of first release of MVP

The date of the initial release of the first MVP for every application, which was not only necessary in order to estimate the lifetime, e.g. for how long an application has been available on the market, but also to understand how the perspective of time could affect any differences between various applications minimum viable features dependent on current technological possibilities.

- Date of latest version

The date of the latest released version of the application, equally necessary as the date of the first release, to estimate for how long an application has existed for customer usage.

- Lifetime

The total lifetime in days that an application has existed, necessary to understand how frequently the MVP has been updated into a new market release.

- Number of versions

The total amount of MVP versions released for every application, necessary in order to measure the release ratio and average amount of changes implemented in every release of a new MVP.

- Average days between new releases

A representation of how often a new MVP version has been released to the market.

- Release ratio

A new version is released when there have been one or more changes implemented into the mobile application and there is an increased version number, e.g. "Version 2.0" from the previous "Version 1.9". For each application we divided the total amount of released versions with the number of days of its existing lifetime. Using the following formula:

$$R = \frac{V}{D_2 - D_1}$$

Where V = The total number of released versions, D₁ = The date of the first released MVP and D₂ = The date of the latest released MVP: A higher figure represents a more frequent continuous delivery of released versions of a MVP. This gave us a value we refer to as a "release ratio", a figure representing how often a new release have been historically deployed, and thus giving us insight in how often a new minimum viable product is developed and delivered to the market.

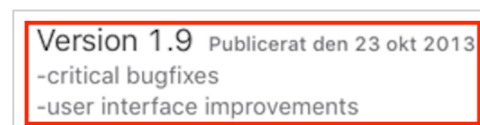


Figure 4. An example of a complete version release.

- No of changes

The total amount of changes implemented during the full lifetime of an application. This data was necessary in order to measure the amount of changes that is implemented on average in every release of a new MVP.

- Change/Release ratio (Average amount of changes per new release)

We consider any altering of the mobile application to be a change compared to the previous version. We estimated the mean amount of changes per each new release of every application. This ratio value gave us insight in how many changes are realized in every iteration of deploying a new minimum viable product. Using the following formula:

$$R = \frac{C}{V}$$

Where C = The total number of implemented changes and V = The total number of released versions: A higher figure represents a higher mean amount of changes implemented in newly released versions of the MVP.



Figure 5. An example of a change implemented within a release.

- Driving cause of the change

We analyzed every change made in each updated version of the minimum viable product in an attempt to identify the main causes and purpose for the change. Every change was then classified to be rooted in at least one of the seven categories specified below. We later found out that some changes did not fit into any of the following classifications and if the cause were insignificant to our research, we classified it into the miscellaneous category “Other”. Additionally, some changes were broad enough to be considered to relate to more than one purpose. The different classifications we used to analyze the drivers of the change were:

- User-Experience related

If the change affects the user's experience of the application in any way such as a new graphical user interface, updated FAQ, different colors or extended customizability, etc.

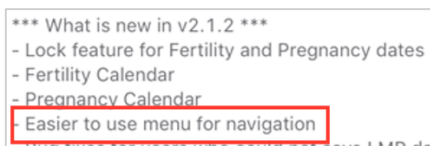


Figure 6. An example of a change driven by user-experience improvements.

- Performance optimization

A vital part of an application is great performance, whether it is a more effective calculating algorithm or utilizing the hardware in a more efficient way. Speed and performance is highly significant and every increase of it adds value and advantages to the user in the form of saved time and efficiency when conducting actions and interactions within the application. Every change that were considered to be related to performance optimization were classified to this category.

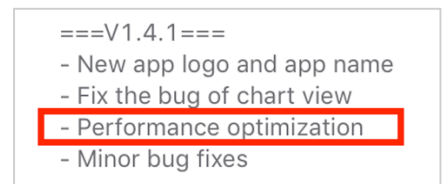


Figure 7. An example of a change driven by performance optimization.

- Bug fix/Stability enhancements

The last thing anyone using software wants is an unexpected crash, making bug fixes and stability enhancements critical in order to maintain a good user-experience and reputation of the application. Every change related to bug fixes and stability enhancements were classified to this category.

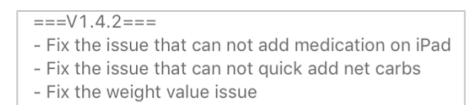


Figure 8. An example of changes classified as bug fixes/stability enhancements.

- Legislative causes

This classification was supposed to be used for changes that had been implemented because of legislative causes. Furthermore, the classification was included based on our initial assumption that there might be judicially regulatory demands and constraints on applications interacting with human health conditions.

- Compatibility

This classification specifies changes with a sole purpose to ensure that the application runs as intended by the developer and supports the current mobile platform operative system and other features that the application requires to run properly.



Figure 9. An example of a change related to compatibility improvements.

- New features already possible with previous technology

Changes introducing and utilizing new features that had been supported and possible with previous technology but not yet been implemented and taken advantage of within the application, were classified to this category.


```

===V1.4===
- iOS 5 compatibility improvements
- Fix the bug of password feature
- Fix the bug of backup & restore feature
- Add unit "µg" in medicin module
- Fix the crash in science module

```

Figure 10. An example of a change classified as a new feature already possible with existing technology.

- New features made possible with new technology

As opposed to the previous classification, these were changes utilizing and taking advantage of new features that had been introduced and enabled by the use of new technology, either software- or hardware-related, and implemented within the application.

```

iPad Pro Support
• Cycles looks gorgeous on the big screen!
3D-Touch Support

```

Figure 11. An example of a change classified as a new feature made possible with new technological opportunities.

- Other

This is a category that we only used for changes that were of minor significance to our research and could not be allocated to any other cause of change categories.

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===V1.4.1===
- New app logo and app name

```

Figure 12. An example of a change unrelated to the other classifications and less significant to our topic of research.

These classifications have provided us with the possibility to understand what the drivers of change of the MVP are for mHealth applications and other different mobile applications along with information of how often a new version of a MVP is released in the different domains.

C. Data Analysis - What are the most common set of Minimum Viable Features (MVF) for a mobile health application?

In order to obtain the necessary results to answer this research question our initial plan was to further investigate the medical applications used in our sample to identify which set of features were provided in the current MVP and subtract them off if they were discovered to be implemented at any given point of time documented in the available version history. By using the following formula:

$$f = \{x \mid x \in a \wedge x \notin \{r - r_0\}\}$$

Where x represents the set of features included in the application a , but not included in any of the releases r other than

the initially released version r_0 . This would give us a set of core minimum features for every application and the next step would be to compare these features between the other applications of the same purpose i.e. providing usefulness for the same medical conditions; those with a different medical purpose and; the applications of totally different domains. During this phase of our research we realized that the collected sample would be insufficient to analyze in order to obtain the desired results to answer these research questions. This was however unfeasible due to various constraints that we discovered, generally identified as:

- The initial MVP deployment of the different applications were spread during a too large span of time. Some applications were a few years older than the others of the same domain or usage area, making the core initial MVF between different apps irrelevant to compare due to the fast paced evolutionary nature of the smartphone application market.
- The version history of the different applications varied a lot in level of detail, making it very difficult or, even impossible in some cases, to accurately identify which features were included in the first MVP of certain applications, ultimately making a fair comparison unfeasible.

Hence, we decided that another sample of applications would be necessary in order to conduct this data analysis. Another filtering criterion would be desirable, including only applications with an initial MVP release from the same time period and with a highly detailed feature specification, or entirely new applications with only one MVP version released to the market. This analysis would preferably also require a larger sample than the one used for the other analysis, in order to reduce validity threats and produce more accurate results representing the most common set of MVF for a mHealth application in the current market. Given these constraints we concluded that the aforementioned research questions edged out of scope for this research project and furthermore we decided to leave this topic open for future studies.

D. Validity Threats

We have only included applications that had a full version history available, both in order to categorize what type of change that has been made and how the application has evolved throughout time, but also to enable us to be as unbiased and fair in a comparison with the other applications in our population sample as possible when drawing conclusions. However, there is a risk that by not systematically include all applications that fit our inclusion criteria, nor possibly not having the ability to access full version history data of every application, our conclusions and theories might be inaccurate and not represent the factual case. Furthermore, different developers and companies have different ways of describing their application updates and changelogs, thus since there is no official "version history template" there is a lack of uniformity and the detail

level of each update varies a lot making it hard to do an accurate comparison in some cases.

Another concern may be that we, as researchers, interpret the cause of the change differently when analyzing, which jeopardizes making the conclusions and correlations consistent and accurate. It should also be taken into consideration that the lifetimes of the gathered applications are different; some have a long lifespan while others are short lived which might give a distorted view of how often an application is updated and which technologies that are currently available and might be supported or not. The framework for deciding what change can be mapped to which cause is not always obvious, some changes can be mapped to more than one cause and overlaps several categories of change, which might cause inconsistent end results and inaccurate conclusions. In summary, the general threats to validity in our research consists of:

- The assessed version history might not be fully complete for some of the applications, i.e. other updates might exist unknown to us, and thus not included in our data samples.
- Different level of details in the version history of different apps.
- The classification of change drivers might be interpreted differently between the researchers.
- Some changes can be mapped to more than one cause.
- More general classifications of change drivers might exist.
- The applications in our collected sample have existed during different time periods.
- Using only one source for data gathering, i.e. one smartphone app market, might render deficient results.

IV. RESULTS

A. Sample Distribution

The sample consisted of mobile applications classified into the following eight different categories, the dispersion of the mobile applications is presented in the table below:

TABLE I. SAMPLE DISTRIBUTION OF MOBILE APPLICATIONS

Category of mobile applications	Number of applications
Diabetes	4
Diet/Calories	3
Miscellaneous medical	3
Woman's health/Pregnancies	4
Utility	1
Entertainment	1
Finance	2
Fitness	3

Total number of mobile applications	21
-------------------------------------	----

In this report we have analyzed 21 mobile applications from eight different sectors, which were deemed to be sufficient and appropriate for the sake of finding out the MVP of a mobile health application.

The pie chart in Fig. 13 represents the different domain areas used in this study and the proportion of their respective shares of the sample population. Diabetes and women's health are predominant with 19% each, this because of the complete and well documented version history we found of these apps. At the other end of the spectrum, the non-medical domains such as entertainment as well as utility applications only represent 4,8% each of the total samples used in the study.

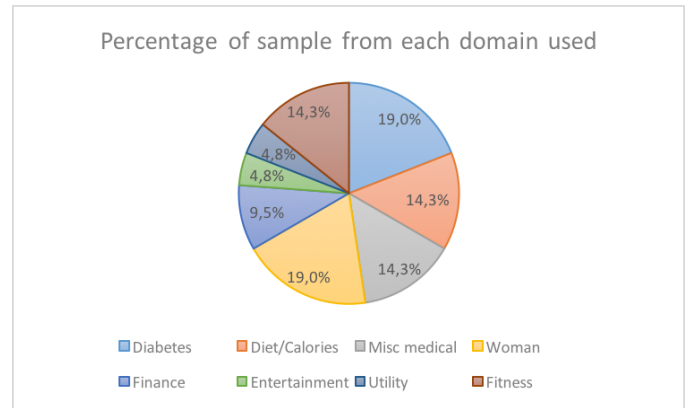


Figure 13. Domain origins of the total sample of applications used in this study.

B. Do the release frequency of minimum viable products differ between mobile health applications of different purposes?

The horizontal bar chart in Fig. 14 illustrates the release ratio between the different mHealth applications analyzed in this study. According to our findings, minimum viable products of diet/calorie apps as well as diabetic apps are more frequently released in new versions than the other medical domains used in our sample.

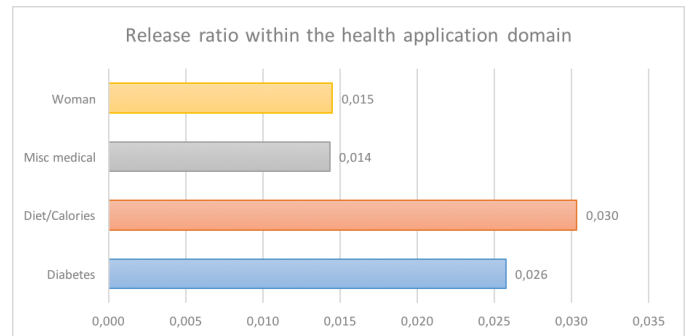


Figure 14. The release ratio of the various medical applications used in this study.

Based on the release ratio formula: $R = \frac{v}{D_2 - D_1}$

Where V = The total number of released versions, D_1 = The date of the first released MVP and D_2 = The date of the latest released MVP: A higher figure represents a more frequent continuous delivery of released versions of a MVP.

C. Do the release frequency of minimum viable products differ between mobile health applications and mobile applications of other domains?

The horizontal bar chart in Fig. 15 illustrates the average release ratio between the mHealth applications and the other mobile application domains analyzed in this study.

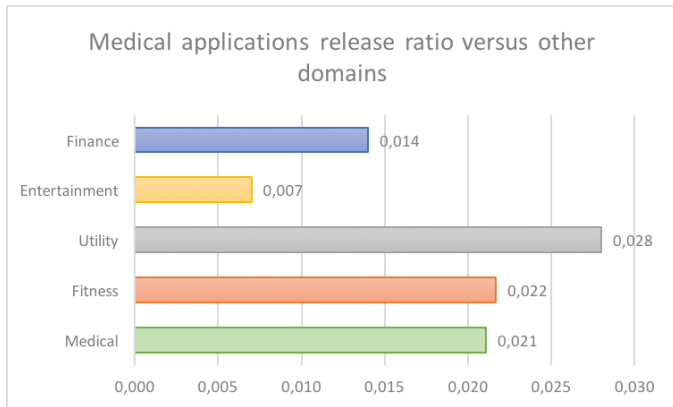


Figure 15. The release ratio of the medical applications domain and the other applications used in this study.

Based on the release ratio formula: $R = \frac{V}{D_2 - D_1}$

Where V = The total number of released versions, D_1 = The date of the first released MVP and D_2 = The date of the latest released MVP: A higher figure represents a more frequent continuous delivery of released versions of a MVP.

D. Do the change frequency of minimum viable products differ between mobile health applications of different purposes?

The horizontal bar chart in Fig. 16 represents the average number of changes per release of each health application domain in this study. Diabetes applications had the most changes with 2,84 changes per release, while women’s health applications had the lowest amount of changes with 2,67 changes per release.

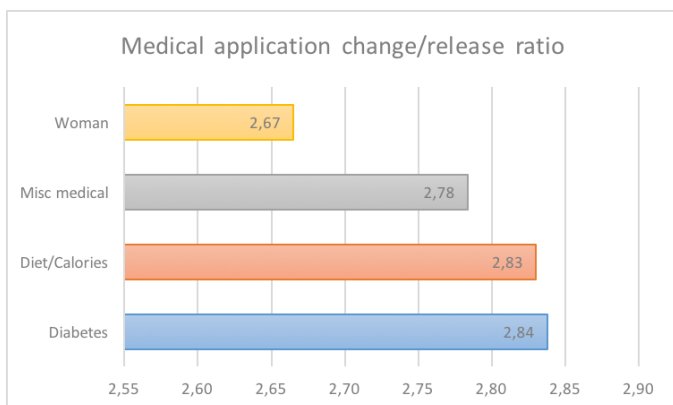


Figure 16. The average number of changes per release of the various medical applications used in this study.

Based on the change/release ratio formula: $R = \frac{C}{V}$

Where C = The total number of implemented changes and V = The total number of released versions: A higher figure represents a higher mean amount of changes implemented in new released versions of the MVP.

E. Do the change frequency of minimum viable products differ between mobile health applications and mobile applications of other domains?

The chart in Fig. 17 represents the average number of changes per release in the medical domain compared to the other domains. We can see that the medical applications had slightly more changes with 2,78 changes per release in contrast to the utility applications used in this study which had 2,25 changes per release.

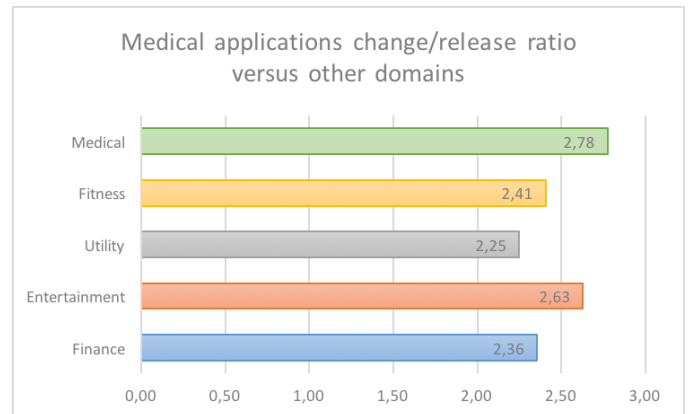


Figure 17. The average number of changes per release of the medical applications domain and the other applications used in this study.

Based on the change/release ratio formula: $R = \frac{C}{V}$

Where C = The total number of implemented changes and V = The total number of released versions: A higher figure represents a higher mean amount of changes implemented in new released versions of the MVP.

F. Do the factors of the change of the minimum viable product differ between mobile health applications of different purposes?

The bar chart in Fig. 18 represents the proportion of minimum viable product causes of change within the different categories of medical applications. We can see that women’s health applications had the most user-experience changes with 32,3% compared to diabetes applications which had 17,6% user-experience related changes. Furthermore, the diabetes applications were predominant in performance optimizations with 8,8% compared to women’s health applications which represented 3,4%. When it comes to bug-fixes we see that the diabetes domain had the highest frequency of those with a figure of 35,3% compared to the least prominent domain, which was the miscellaneous medical applications with 30,4%. Compatibility related changes occurred most in the diabetes applications with a figure of 7,6% compared to miscellaneous medical applications that had 3,8%. Diet and calories applications had the most changes related to new features which consisted of 28,2% of the total amount of changes compared to the women’s health applications which had a figure of 23,8%.

Moreover, new features enabled by new technological possibilities were most common in the diet and calories applications, these changes represented 3,9% while diabetes applications represented 2,4% at the other end of the spectrum of these changes. The changes that were classified as the miscellaneous ‘other’ category were insignificant and of such a small quantity and therefore left out of numerical representations within the bar chart diagram. Furthermore, we did not discover any changes at all being related to legislative constraints and thus this classification is left out from visual presentation in the diagrams.

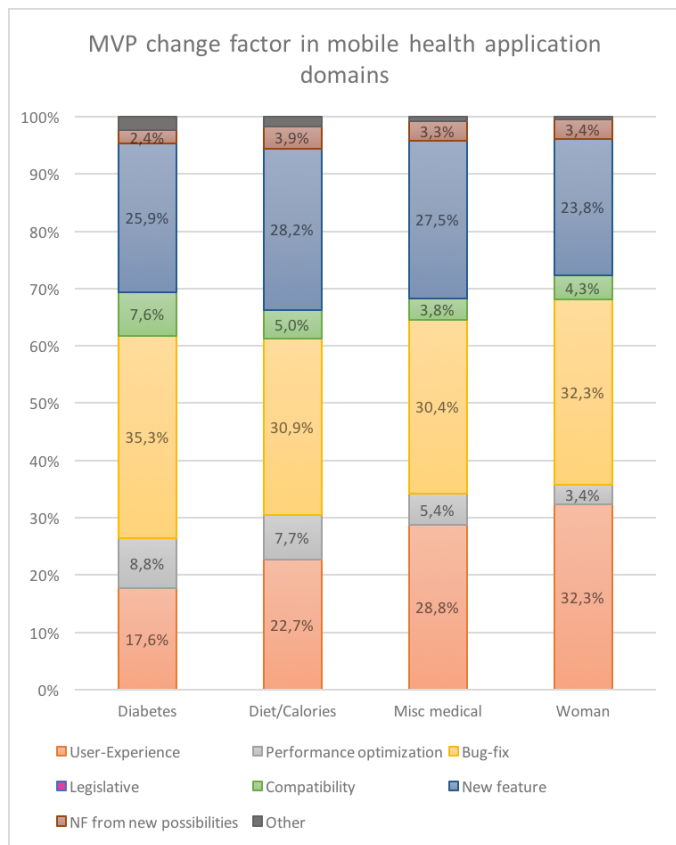


Figure 18. A representation of the minimum viable product cause of change of the various categories of medical applications.

G. Do the factors of the change of the minimum viable product differ between mobile health applications and mobile applications of other domains?

The bar chart in Fig. 19 represents the proportion of minimum viable product causes of change within the different application domains. We can see that fitness applications had the most user-experience changes with 46,6% compared to the medical applications domain which had 27,4% of user-experience related changes. Moreover, performance optimization was predominant with 10,3% in finance applications compared to utility applications which represented 3,7%. When it comes to bug-fix related changes we see that the utility domain had the highest frequency of those with a figure of 44,4% compared to the least prominent domain, which was the finance applications with 14,4%. The compatibility related

changes occurred most in the entertainment applications with a figure of 26,2% compared to finance applications that had a rate of 7,2%. Furthermore, finance applications stood for most of the changes related to new features which consisted of 30,9%, compared to the utility applications which had a change rate of 3,7% in this aspect. Additionally, new features enabled by new possibilities were predominant in the fitness applications, these changes represented 5,5% while finance applications represented 2,1% at the other end of the spectrum of these changes. The changes that were classified to be driven by the ‘other’ category were entirely from the medical app domain with a figure of 1,4% as no other domains fit into this category with the applications from the population we chose.

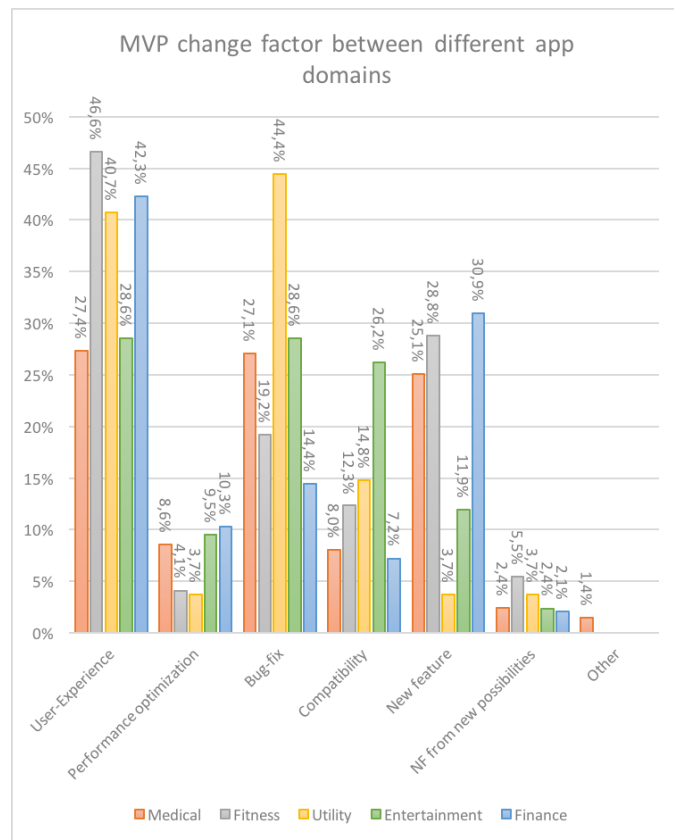


Figure 19. A representation of the cause of change of the MVP in the medical applications domain and the other application domains used in this study.

V. DISCUSSION

A. How frequent is the continuous development of a MVP of a mobile health application?

Our initial assumption was that the diet and calorie applications had more changes than the diabetes applications among the medical domain, this because of the complex nature of the disease [14]. However, Fig. 16 shows opposite results, that among our sample population of the medical domain, the diabetes related applications had the highest average number with 2,84 changes per release compared to women’s health domain which had the lowest average number of 2,67 changes per release. With this said it is arguable that the changes per release -frequency of minimum viable products does not differ

between the mobile health applications of different purposes used in our research, in any significant way.

The same result is repeated in Fig. 17 where we can see that the medical domain had the highest average number with 2,78 changes per release compared to the utility domain which had the lowest average number of 2,25 changes per release. Based on this result we can draw the conclusion that the change frequency of minimum viable products does not significantly differ between the mobile health applications and the mobile applications of other domains used in our research.

In Fig. 14 we can see that there is a difference in release frequency of a minimum viable product in the mHealth domain, diet and calories mobile applications has the most frequent updates (0,030) among the mHealth applications of our research compared to miscellaneous medical which has the least frequent updates (0,014).

When we categorized the mobile applications we discovered in the version history of the diet and calorie applications that they had often integrated and utilized Apple's HealthKit that was introduced in iOS 8, which is a tool that allows developers, with the permission of the user to access health data such as how many calories the user has burnt. One could imagine that there are new functions and updates released from HealthKit frequently and might explain the more recurrent updates compared to the other miscellaneous medical applications which did not in our study utilize Apple's HealthKit.

Fig. 15 illustrates that there is indeed a difference in terms of release frequency among mHealth applications versus the other mobile applications in our study, the medical applications had an update rate of 0,021 compared to the utility applications which had the most frequent update rate with a value of 0,028. However, since we only had one utility application it is hard to generalize about the findings, additionally the difference was very slight.

As seen in the horizontal bar chart in Fig. 16 there is a slight difference in the amount of changes per release in mHealth applications of different purposes used in this study, ranging from an average of 2,67 changes per release for women's health/pregnancy applications till 2,84 changes per release for diabetes applications. As stated earlier, there is not a huge difference in changes per update between the different mHealth applications of different purposes in our study, suggesting that the change frequency is quite similar.

Fig. 17 depicts that there is a difference of the change frequency between mHealth applications and other mobile applications used in this study, where medical applications had an average of 2,78 changes per release compared to the lowest average value of the finance applications which had 2,36 changes per release. This result suggests that there is a difference between the mHealth domain and the other mobile applications of our sample, although the range is quite narrow.

B. Which factors drive the development of updating a MVP of a mobile health application?

Based on the results in Fig. 18 we can conclude that the greatest intervals and biggest gaps of causes of changes within medical applications of different purposes lies within the categories user-experience and performance optimization. Women's health applications had 32,3% user-experience related changes compared to diabetes applications that had only 17,6%. Regarding the performance optimization of diabetes applications, the figure was 8,8% while women's health applications had a value of 3,4% in our study.

Regarding the noticeable deviating amount of user-experience related changes in women's health apps, one possible assumption might be that within the women's health apps collected in our sample, many were highly user-interface-based pregnancy monitoring apps basically consisting of graphical visualizations of fetal growth development. Additionally, these applications presented a significantly lower amount of changes driven by performance-optimization, which also might be due to the fact that they mostly consist of more illustrative functionality and probably less calculating, thus containing algorithms of less complexity, with that being said, graphical rendering could obviously imply high performance demands as well.

Furthermore, we can see an even pattern in changes driven by bug-fixes and stability enhancements between all mHealth domains, ranging from representing 30,9% of all changes in the diet/calorie apps to 35,3% in diabetic apps. A possible hypothesis could be that the amount of changes driven by bug-fixes and stability enhancements correlates in parallel to the amount of, and the complexity of features that a mHealth application provides. However, in contrary to this theory, the two mHealth application domains with the highest rate of total new features added, happen to be those with the most diverse amount of bug-fixes, namely diabetic and diet/calorie apps, with 33,5% respectively 33,2% of all MVP changes being directly related to added functionality.

Diabetes apps had the highest amount of compatibility related changes, one reason for this might be that these apps are granted extended possibilities from new hardware components, such as Apple Watch™ being released as smartphone accessories, presumably containing sensors for blood pressure monitoring, as well as for input of other body-related data. As opposed to this theory, however, these apps scored the lowest on the classification of changes being driven by new features made possible from new technology with 2,4% making this assumption more questionable.

By looking on the results presented in Fig. 19, we can conclude a diverse amount of MVP change drivers between all domains. In an attempt to answer whether the factors of the change of the minimum viable product differ between mobile health applications and mobile applications of other domains, we can conclude that mHealth applications got very close results to entertainment apps in amount of changes driven by incentives such as; user-experience improvements,

performance optimizations, stability enhancements and new features made possible from new technology. A major validity threat to these findings would however be that our sample only consisted of one entertainment app and a larger sample would be necessary in order to draw a more accurate conclusion. On the other hand, these two categories had very diverse results regarding the amount of changes driven by compatibility necessities, where financial apps had the closest figure to mHealth applications; as well as new features implemented with existing technology, where none of the other domains were considerably indifferent to mHealth, but with fitness apps being closest with a difference of 3,7%.

In order to further analyze what these findings actually mean and thus, conclude if the factors of the change of the minimum viable product differ between mobile health applications and mobile applications of other domains, it would be necessary to study the driving factors of the change of a MVP with a more in-depth investigation of every domain included in our sample, together with researching the technological possibilities available for the current mobile application market.

VI. SUMMARY

The purpose with this exploratory case study was to identify how mHealth developers deploy their products by applying build-measure-learn principles and how frequently they release a new minimum-viable-product, but also to analyze which factors that triggers the continuous development of those products.

In this study we have shown that there are differences in terms of both release frequency, the number of changes per release and the driving factors of the change of a minimum-viable-product, not only between the various mHealth applications included in this study but also between those applications combined and compared to the other mobile application domains that has been examined and assessed in our sample. Furthermore, we have introduced and explained concepts such as minimum-viable-product, the build-measure-learn process, lean software development which are all central subjects applied in this research topic.

By finding and categorizing mHealth applications of different usage areas and comparing those to mobile applications from other domains we have tried to establish which factors that drives the development of a minimum viable product, how often it is released and how many changes that are implemented on average in the different mobile application domains. The dispersion of the different domains is presented in tables and diagrams to visualize the results and help answer our research questions.

There are however threats to the validity of our findings, which has been taken into consideration within the discussion of the results, and further research is necessary in order to draw more accurate conclusions.

VII. FUTURE WORK

In order to draw more accurate conclusions and correlations, and to the greatest extent reduce bias, a larger sample of applications from the various domains would be needed, as well as this could provide enough data to conduct suitable methods for statistical analysis, thus improving the accuracy of the results. Moreover, even more domains could be included to get a better and fairer overview of what triggers the development of a minimum viable product for the mobile health market. Means of realizing this could be the use of data triangulation which means that we use data from many different sources to get a more complete and a broader picture. By using both Google Play Store, Apple iTunes and contacting a variety of mobile software development companies from different domains we can draw better conclusions. Furthermore, we could use methodological triangulation with the use of different data collection methods such as well formulated surveys and oral interviews, as well as data gathering from the online mobile application stores, this in turn would yield both quantitative and qualitative data.

A. *What are the most common set of Minimum Viable Features (MVF) for a mobile health application?*

Since we did not, as we initially intended, manage to collect the data necessary to properly analyze the core minimum viable features (MVF) of the different mobile application domains targeted in our study: this undiscovered area would be a worthwhile topic of future research in the subject, needful in order to answer our third set of research questions “*What are the most common set of Minimum Viable Features (MVF) for a mobile health application?*”.

B. *How is unwanted functionality detected and dealt with for a Minimum Viable Product of mobile health applications?*

Another aspect that would be interesting to look into in future research of this subject would be to further study how the first step in the concept of ‘Lean Software Development’: eliminating waste, is applied by mHealth developers. Which initial features are considered unwanted by the users of mobile health applications, how are they detected and how quickly are they eliminated from the MVP?

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APPENDIX I. DATA MAPPING SCHEME

Collection date	App name	Developer	App domain	Date of first release of MVP	Date of latest version	Number of versions	Lifetime (days)			
2016-04-06	Diabetes App - blood sugar control, glucose tracker and carb counter	BHI Technologies, Inc.	Diabetes	2010-08-21	2013-11-14	9	1181			
2016-04-06	DiabetesGuru	Shore Innovation HB	Diabetes	2014-03-05	2015-05-27	8	448			
2016-04-06	Glucose Buddy	Azumio Inc.	Diabetes	2008-10-28	2012-10-04	20	1437			
2016-04-06	mySugr Diabetes	mySugr GmbH	Diabetes	2015-02-23	2016-03-24	25	395			
2016-04-06	Get Moving	Epic Pixie KB	Diet/Calories	2014-01-10	2015-11-03	18	662			
2016-04-06	Lark - Personal Weight Loss Coach & 24/7 Nutritionist	LARK	Diet/Calories	2014-09-29	2016-03-30	21	548			
2016-04-06	Running for Weight Loss interval training plan, GPS, how-to-lose-weight tips by Red Rock Apps	GRINASYC CORP.	Diet/Calories	2013-07-26	2016-03-18	25	966			
2016-04-06	MotionX 24/7	MotionX	Misc medical	2012-02-29	2014-11-11	19	986			
2016-04-06	Radiology Assistant	BestApps BV	Misc medical	2010-07-31	2014-12-04	24	1587			
2016-04-06	Vision Test	Rocktime Ltd	Misc medical	2010-07-08	2014-01-13	12	1285			
2016-04-06	Cycles - Period tracker with fertility calendar and reminders for both of you.	Perigee	Woman	2013-02-14	2016-03-15	16	1125			
2016-04-06	iPregnant Pregnancy Tracker Free (iPeriod's Pregnancy Companion)	Winkpass Creations, Inc.	Woman	2011-10-27	2015-02-05	10	1197			
2016-04-06	Natural Cycles, the fertility monitor	NaturalCycles Nordic AB	Woman	2013-12-12	2016-03-17	25	826			
2016-04-06	Pregnancy Due Date & Fertility Calculator, Tools and Baby Kick App	BabymedLLC	Woman	2009-07-18	2015-08-26	14	2230			
2016-04-06	Clips - Copy and paste anywhere with widget and keyboard	Clean Shaven Apps	Utility	2014-10-07	2015-12-17	12	436			
2016-04-06	SVT Play	Sveriges television AB	Entertainment	2010-02-01	2016-03-08	16	2227			
2016-04-06	Avanza	Avanza Bank AB	Finance	2010-07-19	2016-03-11	19	2062			
2016-04-06	Nordea Mobilbank - Sverige	Nordea Bank	Finance	2012-10-29	2015-12-12	22	1139			
2016-04-06	CARROT Fit - 7 Minute Workout, Step Counter & Weight Tracker	Grailr LLC	Fitness	2014-01-24	2015-04-20	12	451			
2016-04-06	The Johnsons & Johnson Official 7 Minute Workout App	Johnson & Johnson Health and Wellness Solutions, Inc.	Fitness	2014-01-03	2016-02-29	13	787			
2016-04-06	Workout (7 Minute Body Fitness Exercise)	Yellow Lab, Inc.	Fitness	2013-05-24	2014-01-16	5	237			
Average days between new releases	Release ratio	No of changes	Change/release ratio	User-Experience	Performance optimization	Bug-fix	Compatibility	New feature (NF)	NF from new possibilities	Other
131,2	0,008	31	3,44	2	1	16	5	7	0	1
56,0	0,018	23	2,88	4	4	5	3	7	0	1
71,9	0,014	63	3,15	15	8	15	4	21	1	2
15,8	0,063	47	1,88	9	2	24	1	9	3	
36,8	0,027	42	2,33	13		12	1	14	3	
26,1	0,038	79	3,76	32	3	22	3	22	1	
38,6	0,026	60	2,40	22	3	18	5	11	1	1
51,9	0,019	74	3,89	27	14	5	9	19	0	
66,1	0,015	51	2,13	17	6	18	7	5	0	
107,1	0,009	28	2,33	6	4	9	3	8	0	
70,3	0,014	63	3,94	16	8	13	5	22	4	
119,7	0,008	22	2,20	5	1	9	5	5	0	
33,0	0,030	54	2,16	19	6	10	3	11	3	5
159,3	0,006	33	2,36	4	0	13	2	14	1	
36,3	0,028	27	2,25	11	1	12	4	1	1	
139,2	0,007	42	2,63	12	4	12	11	5	1	
108,5	0,009	42	2,21	25	2	7	3	7	1	
51,8	0,019	55	2,50	16	8	7	4	23	1	
37,6	0,027	40	3,33	18		5	5	12	3	
60,5	0,017	22	1,69	9	3	7	3	5	1	
47,4	0,021	11	2,20	7		2	1	4		