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An Ovulation Tracking Application

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An Ovulation Tracking Application

**A Major Qualifying Project
Submitted to the Faculty of
Worcester Polytechnic Institute
in partial fulfillment of the
requirements for the Degree in Bachelor of Science
in
Computer Science
By**

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Abstract

The developing use of technology and applications for health and wellness tracking presents an opportunity for expansion and advancement in women's reproductive health tracking. Through current ovulation tracking application analysis, interviews, and surveys, this project explores the requirements for an effective ovulation tracking application. The three major features found to be fundamental for a successful ovulation tracking application were discretion, customization, and content. Based on these findings, a prototype iOS application was developed directly derived from the mentioned features.

Table of Contents

Abstract	- 2 -
Table of Contents	- 3 -
Table of Figures	- 4 -
1 Introduction	- 6 -
2 Background	- 10 -
2.1 Ovulation	- 10 -
2.2 Indicators and Prediction	- 11 -
2.2 Current Ovulation Tracking Applications and Wearables	- 14 -
2.3 Gender and Technology	- 19 -
2.4 Data, Security and Privacy	- 21 -
3 Methodology	- 24 -
3.1 Objectives	- 24 -
3.2 Assess Current Ovulation Tracking Applications	- 24 -
3.3 Design and Develop an Ovulation Tracking Application Prototype Through a User-Centered Design Framework	- 25 -
4 Results	- 26 -
4.1 Results of Online Survey	- 26 -
4.2 Results of Interviews	- 29 -
4.3 Application Prototype	- 32 -
5 Discussion	- 37 -
6 Future Suggestions	- 40 -
References	- 42 -
Appendix A	- 48 -
A.1: All interviews	- 48 -
A.2: Interview Questions	- 51 -
A.3: Survey Screenshots	- 52 -

Table of Figures

Figure 1: Kindara Application [20]	- 7 -
Figure 2: Flo Application [21]	- 7 -
Figure 3: Clue Application [22]	- 7 -
Figure 4: Apple released its first version of HealthKit with the ability to track and share an extensive range of health and wellness data points [4]. The goal was for it to be the only platform needed to track all indicators and data regarding health and wellness. There was no women’s reproductive health tracking available in the release.	- 8 -
Figure 5: Fertility cycle changes during a cycle [13]. This chart shows the spike then dip of estrogen during ovulation, and the spike of progesterone after ovulation.	- 11 -
Figure 6: Cervical mucus diagram [16]. Cervical mucus can fall under five different categories of consistency: dry, sticky, creamy, watery, egg white. Dry and sticky occurs after menstruation or ovulation. Sticky and creamy occurs during pre-ovulation. Watery occurs immediately before and during ovulation. Egg white indicates ovulation.	- 12 -
Figure 7: Basal Body Temperature Chart [18]. During pre-ovulation, BBT will drop at least 0.1 degrees Fahrenheit below the last six temperatures. Ovulation is indicated by a then sharp increase in temperature of 0.4 to 0.6 degrees Fahrenheit.	- 13 -
Figure 8: The Kindara indicator screen [20]. For increased accurate prediction of ovulation, the user must manually input their symptoms and indicators daily.	- 15 -
Figure 9: Kindara data chart [20] shows all logged indicators and symptoms of the user. The user can choose to share their chart within the Kindara community for advice, support, or comparisons.	- 16 -
Figure 10: The Flo symptom logger [21]. When a user has not logged their symptoms, Flo can notify the user as a reminder to update their symptoms.	- 16 -

Figure 11: The Flo calendar [21] has countdowns for menstruation, ovulation, and birth.	- 17 -
Figure 12: Clue daily data [22] has retroactive cycle reports detailing the past cycles.	- 17 -
Figure 13: The Clue calendar [22] uses colors to indicate when menstruation and ovulation have occurred.	- 18 -
Figure 14: A pie chart of the ovulation tracking applications the survey responses have used. Clue was the highest popular application, with Kindara and Glow tied for second. Almost a quarter of respondents indicated using an ovulation tracking application that no other survey responders used.	- 26 -
Figure 15: A bar chart of the ideal aesthetic for an effective ovulation tracking application. Over half of the survey responders stated that they did not want an application that either was pink or “cutesy”.	- 27 -
Figure 16: Drawing of ovulation tracking by the interviewee. Each line represents a month or cycle, while the blocks within the month show data recorded and predicted. Each month or cycle is lined up horizontally for the user to be able to compare their cycles easily and without changing screens.	- 31 -
Figure 17: Outline design for all screens within the application. Pink arrows indicate the available segues into other screens. Blue boxes indicate available changes to the user interface depending on the content of what the user has input.	- 33 -
Figure 18: Database Schemas	- 34 -
Figure 19: Main Screen	- 35 -
Figure 20: Settings Screen	- 35 -
Figure 21: Color Picker	- 35 -
Figure 22: Settings Colors Changed	- 36 -
Figure 23: New Symptom Screen	- 36 -
Figure 24: New Symptom Logging Method Screen	- 36 -
Figure 25: Alert Screen	- 37 -
Figure 26: New Alert Screen	- 37 -

1 Introduction

As mobile applications become progressively intertwined into people's everyday routine, they have the potential to improve our standard of living. Any smartphone user can now check the weather, count their steps, record their voice to text, and an endless number of other technological feats at their own convenience.

One dimension of this new and increasingly available technology is health and wellness tracking; it is becoming not only effortless, but also encouraged to follow one's physical health through technology. For example, there are applications that monitor the users heart through an EKG accurate monitor strapped to the users. In addition to having the capability to show analysis of the user's heart performance, these applications can also warn users of an impending heart attack or stroke, even days in advance [1]. Through the use and improvement of health and wellness technology, not only do they provide users with more insights about the functionality of their own body but can prevent premature deaths through imminent health danger prediction [1].

However, while tracking socially accepted health indicators (such as heart rate, weight, steps, etc.) are supported and encouraged in most societies, there still is a lack of acceptance and advancement specifically in the tracking of women's reproductive health. Socially stigmatized health indicators such as ovulation and menstruation can be essential information for those who are both trying and not trying to conceive. Just as steps taken and food-intake tracking can be a highly effective and indispensable tool for someone attempting to lose weight, ovulation and menstruation tracking can aid and be a vital

source of information for those attempting to gain a better understanding of how their own body works and what it needs.

Currently, there are a number of existing ovulation tracking applications available

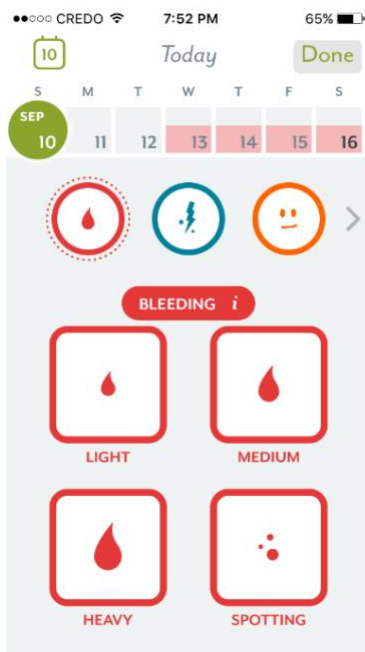


Figure 3: Clue Application [22]

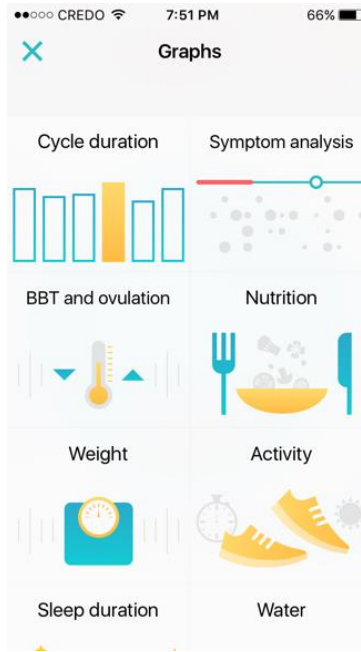


Figure 2: Flo Application [21]

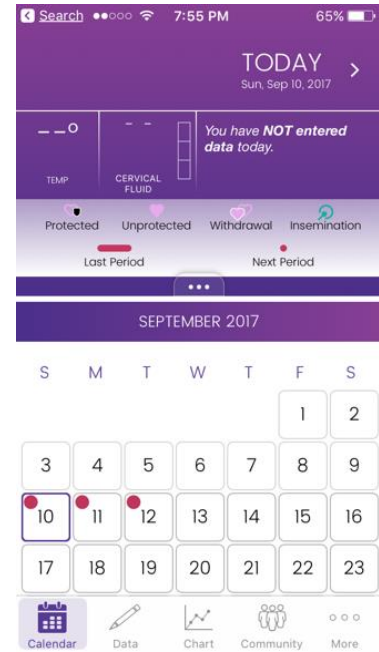


Figure 1: Kindara Application [20]

for both iOS and Android phones such as Kindara, Glow and Clue [2]. Yet, compared to the number of other health and wellness tracking applications available, ovulation and menstruation tracking applications are diminutive.

In a 2017 online Forbes article titled “Top 12 Health And Fitness Apps To Get You To Your Goals In 2017,” out of the 12 applications chosen, none offered or references women’s reproductive health and tracking [3]. Moreover, within its iOS 8 release in 2014, Apple unveiled its first version of HealthKit, a software platform that’s purpose was to be an all-encompassing health and wellness tracker via data collection from other various health and fitness applications. The four categories all tracking data fell into were Activity, Sleep, Mindfulness, and Nutrition. Indicators that could be tracked included but were not

limited to: steps taken, hours slept, carbs eaten, blood pressure and a multitude of other indicators. While HealthKit was exceedingly successful in tracking and analyzing all data collected, it remained negligent in at least one area of health and wellness tracking: women's reproductive health.

It then took Apple over one year to add menstruation tracking to HealthKit in its iOS 9 release. Moreover, throughout the year in-between releases, despite many articles and social media callouts regarding the lack of effort made for reproductive health tracking [5][6][7], Apple did not comment or issue an apology. The only mention of the addition of reproductive help was one line in the iOS 9 press release, regarding HealthKit as a whole: "iOS 9 APIs and tools for developers include: ... new HealthKit data points for reproductive health, UV exposure, water intake and sedentary state" [8]. This circumstance again highlights the absence of accessibility corresponding to a fundamental health category that directly affects half of the world's population.

While there are a number of available applications specifically designed for women's reproductive health tracking, they are still unfortunately deficient in the innovation, effectiveness, affordability and usability compared to other health tracking applications. There are a variety of different indicators per day to indicate when a woman will ovulate and menstruate, as well as a diverse array of reasons each individual is



Figure 4: Apple released its first version of HealthKit with the ability to track and share an extensive range of health and wellness data points [4]. The goal was for it to be the only platform needed to track all indicators and data regarding health and wellness. There was no women's reproductive health tracking available in the release.

motivated to track their reproductive health. The main motivators include wanting to be aware of how their body is doing, understanding their body's reactions to different phases of their cycle, to be prepared, to become pregnant, and for informed conversations with their healthcare providers [9].

To explore solutions to known limitations regarding women's reproductive health tracking, the objective of this project was to generate a prototype of an effective ovulation tracking application tailored for all individuals wanting to track their ovulation and menstruation. Such an app would create a solid framework to subsequently explore possible implementations for a Bluetooth wearable that could passively sync temperature and heart rate analysis, instead of manual input, in order to better predict ovulation.

In this report, in order to gain a better understanding of the needs and wants for an effective ovulation tracking application, we researched and analyzed currently popular ovulation tracking applications. Additionally, we completed literature reviews of topics comprising of ovulation, indicators and predictors of ovulation, gender and technology, and data and security. Once research and analysis of available ovulation tracking applications was complete, interviews as well as an online survey were implemented. All questions asked within the interviews and survey were actively derived from the previous literature reviews as well as based off of currently available applications.

The three main themes that continuously appeared throughout the interviews, survey, and literature reviews regarding an ovulation tracking application were a need for a discrete, completely customizable, and content sensitive application. After all key features for a successful ovulation tracking application were collected and analyzed, a prototype

was created based on the corresponding interview, survey, application analysis, and literature review findings.

Providing innovative and accessible technology for women's reproductive health has the power to empower women through their own bodies. And through empowerment comes improvement; creating a space for technology to stretch the boundaries of what society deems socially stigmatized offers a route where all health issues and indicators can be freely monitored, analyzed, and tracked. The more mainstream these issues become, the less stigmatized and more accepted they will become in society.

2 Background

2.1 Ovulation

During a woman's monthly menstrual cycle, there are two fundamental hormones regulating the cycle: estrogen and progesterone. During the follicular phase, which is the first half of the cycle (before ovulation), estrogen is highly prevalent. Estrogen aids ovaries in egg production in preparation for ovulation. Once in the luteal phase (the second half of the cycle) begins, estrogen levels drop, and progesterone increases and dominates until the onset of one's menstrual period [10].

After the ovaries produce an egg and the egg has matured, it is released from the ovaries and pushed down the fallopian tube. Once in the uterus, the egg is available for fertilization. If the egg does not get fertilized within 24 hours, menstruation occurs, which is when the egg dissolves, the uterine lining is shed, and the cycle begins again. The average

woman's cycle is around 28 to 32 days; however, many women have much shorter, longer or irregular cycles as well. Approximately 12 to 16 days following the first day of menstruation, ovulation is expected to begin [11].

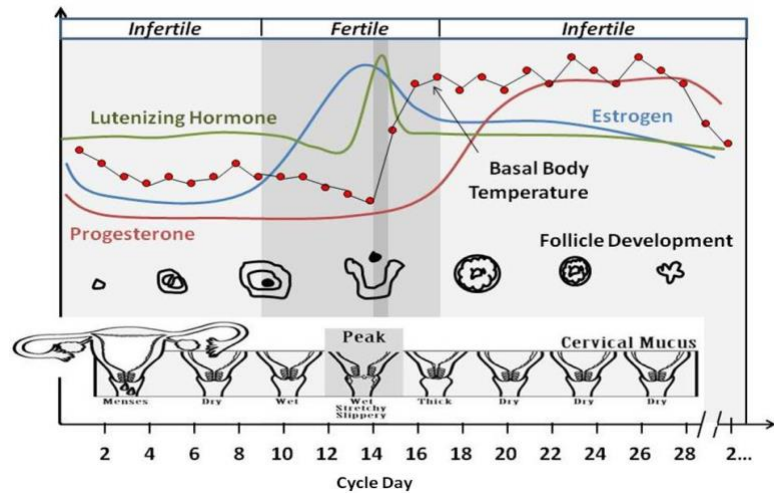


Figure 5: Fertility cycle changes during a cycle [13]. This chart shows the spike then dip of estrogen during ovulation, and the spike of progesterone after ovulation.

Amid a woman's

ovulation, she can become pregnant via sexual intercourse, artificial insemination or other medical procedures. Ovulation does not occur on the exact same day of each cycle [12]. Additionally, even with women who have highly regular cycles, stress, illness and disturbances of routine can alter the time of ovulation. As a result, for a woman to be able to predict when she can become impregnated, cycle tracking is required [11].

2.2 Indicators and Prediction

Since the early 1900's, there have been well-defined methods for ovulation prediction [14]. For example, a pelvic ultrasonography is a medical procedure that can accurately predict ovulation [15]. However, these procedures can be expensive, and require technology that one cannot obtain without visiting a hospital or clinic. As a result, cervical mucus scoring (The Inslar Score) and basal body temperature (BBT) fluctuation are two main variables used in independent ovulation tracking [14].

2.2.1 The Insler Score

Tracking the Insler Score is a reliable clinical indicator of the periovulatory period [15]. The Insler Score is quantitatively measured based on the appearance of the cervix, the volume of the cervical mucus, the stretch of the mucus, the degree of ferning that occurs, and the amount of viscosity of the mucus.

Around a day before ovulation, estrogen levels peak, which results in a change in cervical mucus. Peak mucus (the maximal Insler Score) is defined as “...mucus that stretches an inch or more, is clear in appearance, and has the sensation of lubrication” [17]. Moreover, the maximal Insler Score coincides with hormone surges, specifically the luteinizing hormone, which surges around 16 hours before ovulation.

If daily monitored, the Insler Score has been proved to be an accurate indicator of ovulation and follicular development compared to a daily real-time ultrasonography [15]. In a study of 95 menstrual cycles studied in 20 women, the maximal Insler Score was noted 24 hours before follicular rupture in 47.5% of the cycles, and 31% of the cycles on the day [15]. Overall, a key advantage of the Insler Score is that it is very easy to detect, the variation between women is small, and there is no technology required.

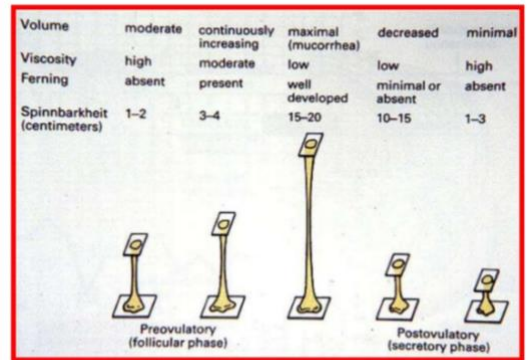


Figure 6: Cervical mucus diagram [16]. Cervical mucus can fall under five different categories of consistency: dry, sticky, creamy, watery, egg white. Dry and sticky occurs after menstruation or ovulation. Sticky and creamy occurs during pre-ovulation. Watery occurs immediately before and during ovulation. Egg white indicates ovulation.

2.2.2 Basal Body Temperature

Basal body temperature (BBT) is one of the most clinically and independently used aides in identifying the day of ovulation, especially for women who suffer from infertility [15]. While two to three consecutive menstrual cycles can occasionally be identical, four cycles are infrequent, and to have five identical cycles happens approximately only 0.15% of the time. As a result, BBT can be used for women with both regular and irregular menstrual cycles to inexpensively monitor ovulation from cycle to cycle [14].

Since the 1940's, there has been clinical evidence of a

correlation between BBT and ovulation through analyzing the BBT graph. There are two main predictors derived from a BBT graph: the nadir/low point and a sharp rise of temperature following the nadir. The nadir signals a nearing of ovulation and must be at least 0.1 degree Fahrenheit below the six previous temperatures as well as within three days immediately preceding a clearly two-phase shift. The subsequent sharp rise of temperature of 0.4-0.6 degrees Fahrenheit between two consecutive days suggests current ovulation [14]. BBT tracking can be very effective for women with standard temperature variations, however the more irregular temperature variations a woman has, the less effective BBT tracking becomes [14].

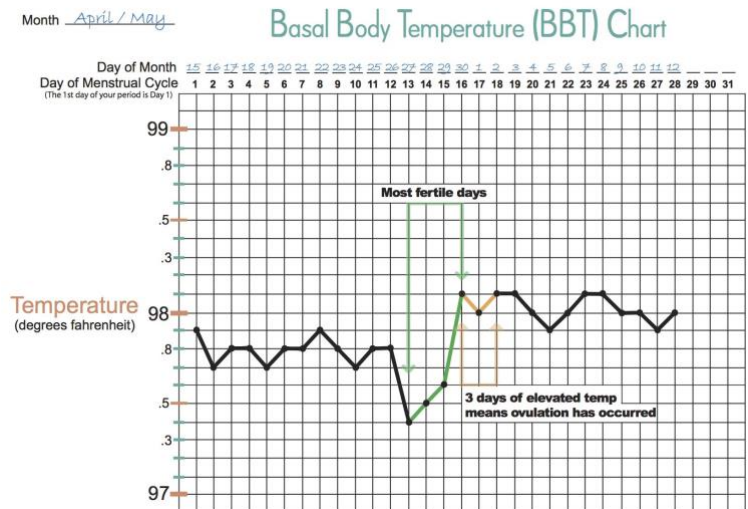


Figure 7: Basal Body Temperature Chart [18]. During pre-ovulation, BBT will drop at least 0.1 degrees Fahrenheit below the last six temperatures. Ovulation is indicated by a then sharp increase in temperature of 0.4 to 0.6 degrees Fahrenheit.

2.2.3 pH Levels

The pH levels of vaginal and cervical fluids can create either a suitable or harsh environment for sperm within the vagina, cervical canal and fallopian tubes. Sperm thrive in an alkaline environment (high pH levels) and deteriorate in one that is too acidic (low pH levels). As a result, if the vagina or cervix are too acidic, the sperm will be unable to swim into the fallopian tubes to fertilize the egg as the conditions are not favorable [19].

During most of a woman's cycle, her vaginal pH levels will range from 3.8 to 4.5, which is considered too toxic for sperm to survive for a prolonged period. However, during ovulation pH levels will spike to an average 7 to 14 range. Once in the alkaline range, sperm can survive up to 48 hours inside a woman's reproductive systems [19]. Consequently, measuring one's vaginal pH levels can be used as a method for tracking ovulation.

While pH testing kits and vaginal pH strips cost on average \$20 or less, there are still a myriad of outside factors that can alter the pH levels of a woman. Factors include stress, obesity, elevated or reduced hormone levels, age, dehydration, medications, diet and many more [19]. These elements can lower the pH levels of a woman, consequently creating a more difficult environment for one to track ovulation via pH levels. Overall, while pH monitoring and ovulation tracking can be accomplished with minimal cost and little technology needed, the large number of outside factors that can alter the pH levels of a woman can outweigh the benefits in many cases.

2.2 Current Ovulation Tracking Applications and Wearables

There are a multitude of current ovulation tracking applications on both the iOS platform and Android platform. Many of these applications allow manual inputting of

indicators ranging from mood, vaginal discharge, temperature, cramps, sexual intercourse, acne, nausea, fatigue, bloating and many more. Additionally, the user can manually input when they start and end their menstruation for the respective application to calculate an average cycle length as well as predict the next.

The mobile applications Kindara, Clue Period Tracker and Flo Period Tracker are three of the top-rated ovulation and menstruation tracking applications. All three of these applications feature prediction of ovulation as well as menstruation derived from active logging of symptoms and indicators.

2.2.1 Kindara

Kindara manually takes in data related to cervical fluid (none, sticky, creamy, egg white, or watery), sex (protected, unprotected, withdrawal or insemination), menstruation (light, medium or heavy), ovulation or pregnancy tests, and temperature. Additionally, Kindara sells a Bluetooth enabled oral thermometer that syncs with the mobile application. The user must manually check their temperature at specific intervals throughout the day. However, if the user misses a temperature check it is not possible for accurate prediction of ovulation and menstruation. For this reason, the thermometer is difficult to utilize as it requires a strict schedule that is cannot be flexible, overlooked, or forgotten about.

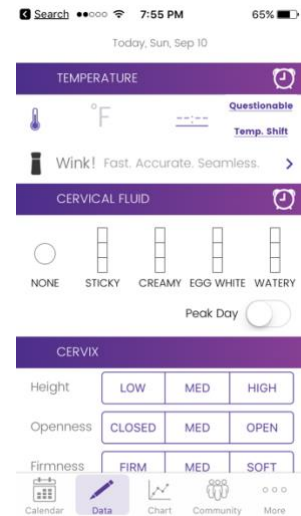


Figure 8: The Kindara indicator screen [20]. For increased accurate prediction of ovulation, the user must manually input their symptoms and indicators daily.

A major feature of Kindara is the access to the Kindara Community. Once data has been input into Kindara, it is possible to post a chart onto the discussion forum within the Kindara application. Moreover, any Kindara user has access to viewing any other user's

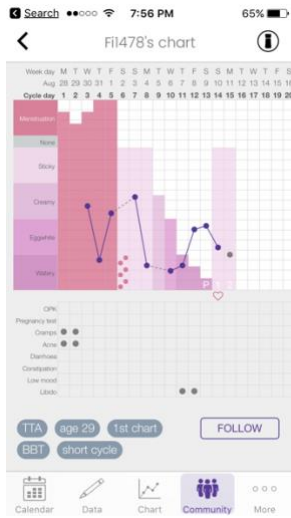


Figure 9: Kindara data chart [20] shows all logged indicators and symptoms of the user. The user can choose to share their chart within the Kindara community for advice, support, or comparisons.

chart that they have chosen to share with the community as well as comment on charts. There is a search function that can filter users based on different tags such as age, trying to conceive, or not trying to conceive.

Sharing and commenting on charts is a popular feature in Kindara for those wishing to participate in the Kindara community. Conversely, for those who do not want to partake in the community, the superfluous notifications and application pages are irrelevant and unnecessary. Additionally, the actual charts contain a large amount of data within a small (phone) screen that can be somewhat hard to decipher.

2.2.2 Flo Period Tracker

Flo creates a baseline user profile by asking several questions such as period regularity, spotting, and sexual activity. The user can additionally input a number of indicators manually, including weight, sleep, water consumed, sex and sex drive (didn't have sex, protected sex, unprotected sex, high sex drive or masturbation), mood (normal, happy, frisky, mood swings, angry, sad, or panicky), symptoms (fine, cramps, tender breasts, headache,

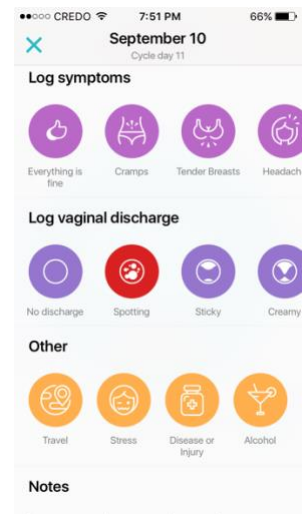


Figure 10: The Flo symptom logger [21]. When a user has not logged their symptoms, Flo can notify the user as a reminder to update their symptoms.

acne, backache, nausea, fatigue, bloating, cravings, insomnia, constipation or diarrhea), vaginal discharge (none, spotting, sticky, creamy, egg-white, watery or unusual), travel,

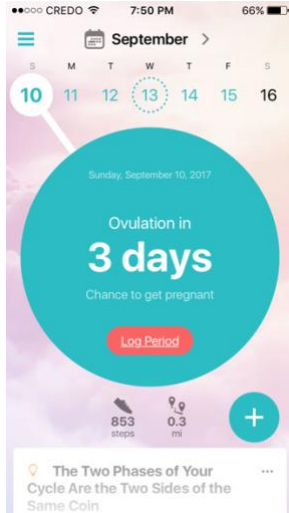


Figure 11: The Flo calendar [21] has countdowns for menstruation, ovulation, and birth.

disease or injury, stress, alcohol and basal temperature. Users can also link a Fitbit or their Apple Health App to Flo for better prediction services.

A new and popular feature of Flo is the reminder option. A user has the choice to opt-in for reminders daily ranging from menstruation start and top, ovulation, or to take contraception. Additionally, a reminder to log symptoms and indicators can be utilized. Another popular feature is the ability to turn on

“pregnancy mode”, where a countdown till birth begins as well as other reminders relevant to pregnancy becoming available.

2.2.3 Clue Period Tracker

Clue can sync with the Apple Health App, Fitbit and the OURA ring to allow better ovulation and menstruation predictions. OURA is a ring placed on the user’s finger that tracks pulse and sleep cycles. Clue also allows the user to choose which indicators and symptoms they wish to track or ignore. These include bleeding (light, medium, heavy or spotting), pain (cramps, headache, ovulation or tender breasts), emotions (happy, sensitive, sad or PMS), sleep (0-3 hours, 3-6

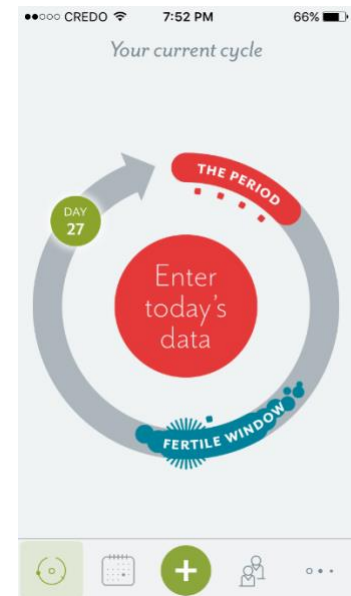


Figure 12: Clue daily data [22] has retroactive cycle reports detailing the past cycles.



Figure 13: The Clue calendar [22] uses colors to indicate when menstruation and ovulation have occurred.

hours, 6-9 hours or 9+ hours), sex (unprotected, protected, high sex drive or withdrawal), energy (energized, high, low, exhausted), weight, temperature, tags, collection method (tampon, pad, panty liner or menstrual cup), craving (sweet, salty, carbs or chocolate), digestion (great, bloated, nauseated, gassy) and many more.

Clue allows users to share their cycles through invitation.

This means that a user can invite someone to view their cycle or can request to view someone else's cycle. Clue additionally provides cycle analysis after each cycle and retroactive cycle reports as well.

2.2.4 Other Wearables

Currently, there are a limited number of dedicated ovulation tracking wearables that sync with mobile applications. The Ava bracelet is a bracelet worn solely at night that tracks nine different physiological parameters for ovulation tracking. These parameters include heart rate, skin temperature, sleep, data quality, perfusion, breathing rate, movement, heat loss and bio-impedance (response of a living organism to an externally applied electric current) [23]. Once awake, the user needs to take the bracelet off, connect it to the USB cable, open the mobile application and sync the device to the phone. For accurate ovulation tracking, Ava must be worn every night and synced every morning consistently. The Ava bracelet costs 199.00 US dollars [23].

Another wearable called the YONO is an earbud also worn at night for temperature and ovulation tracking [24]. Similarly, to the Ava bracelet, the user must manually sync the YONO every morning for accurate predictions. However, the YONO syncs via Bluetooth instead of through USB. Once data is synced the user must answer a variety of questions through the mobile application for accurate ovulation prediction. The YONO is not waterproof and must be cleaned thoroughly as ear infection is a risk. The YONO costs 149.99 US dollars [24].

2.3 Gender and Technology

Technology is an ever growing and quickly permeating factor of current society. As a result, technology has become increasingly intertwined and a significant influencer with other aspects of society, including the idea of gender and gender roles in society. Throughout history, human societies have always made distinctions between what male activities are and what female ones consist of, including the use and making of technology. Moreover, physical objects, including technology, are not only often designated as belonging to a particular gender, but also considered to have a gender in and of themselves [26]. For example, the majority of artificial intelligent (AI) software are named as women (Amazon's "Alexa", Microsoft's "Cortana", Apple's "Siri") [25].

2.3.1 Technology Historically Tailored for Men

Starting at birth, children have been traditionally contained within strict social boundaries related to their biological sex. As technology becomes a progressively more pervasive element of society, the deployment of technology to ensure appropriate gender

socialization deemed appropriate for a child's biological sex has become more and more utilized. As a result, in accordance with historically patriarchal societies, technology has functioned to exclude most women from activities related to technology that have been valued by their cultures [26]. A key example is that while women represent 50% of the total United States college-educated workforce, only 29% of the science and engineering workforce consists of women [27]. As women have been proven to be as capable as men in science, technology, engineering and mathematics [28], the disparity of women in STEM fields highlights the cultural idea that technology is a masculine skill that women should not participate in.

2.3.2 New Technology and New Norms

In the past and in many current societies, activities designated as feminine have been devalued as technology has functioned to express and enforce categories of gender. However, there has been a recent novel shift of how children and young adults have used technology to not only empower one's own gender, but also redefine the categories of gender at a deep social level. Young children previously learned what was acceptable and expected of them regarding what gender they were assigned at birth through observation of social behaviors and reactions of the adults they were surrounded by. For this reason, older adults who were not born in the era of ubiquitous access to technology most often cling to existing gender norms of their childhood. However, through technology, current children are more likely to observe ideas and people they do not personally know, and through this, rebel from societies pre-existing social norms of gender and identity cultures [26].

What previously was used as a method for gender constraints and hindrance, technology now is aiding in the social advancement of empowering self-identity and knowledge, regardless of gender. According to The Oxford Encyclopedia of the History of American Science, Medicine, and Technology's "Gender and Technology" entry:

As the next century began to take shape, a new element became increasingly important in the continuing discourse over the gendering of technology and technological knowledge. For the first time in human history, large numbers of people could directly access a range of sophisticated "personal" technologies through the marketplace [29]. Consumer devices ranging from telephones and automobiles to elective surgery gave individuals the unprecedented ability to challenge and manipulate existing gender norms. [26]

2.4 Data, Security and Privacy

Within mobile applications, there are many different methods of securing data, including local storage or remote storage. Local storage consists of all data being solely stored on the physical device, through either the phones internal hardware, or an external SD card. With local storage, there is no connection to the internet or external servers required. Remote storage options can be implemented in multiple ways. When implemented alongside local storage, it can be utilized to store backups of the data if the data is somehow wiped, or the phone suffers damage that results in loss of data.

Alternatively, remote storage can be implemented where all data is stored through a remote server, which the application then queries when data is added, deleted or updated. For real-time server queries, an internet or data connection must be allowed. Network

connection storage is most commonly utilized when there is a large amount of data that would not fit in a phone or the data is shared between multiple users [30]. Local storage is utilized most often when there is a limited amount of data or there is no internet connection available.

Both local and remote storage options have different security strengths and weaknesses. For local storage, in order to gain access to the data, an individual will likely need direct physical access to the storage [30]. Additionally, if the device is encrypted, proper authentication will be needed for an individual to obtain the data [30]. For this reason, when physical security of the phone is appropriate, there are minimal risks. However, if the phone is lost, stolen, or damaged, the data will also be at risk.

Contrary to local storage, remote storage offers great disaster recovery. Since the data is stored on servers instead of locally on the phone, data will not be lost if damage, theft or misplacement occurs [30]. However, as remote servers store the data of all users, they are more of an attractive target relative to hackers compared to one single phone data [30]. Consequently, effective provider security is more critical than physical phone security when it comes to remote storage.

2.4.1 Biometrics

Biometrics within mobile applications can signify any data derived from the user's own physical or behavioral body. For this reason, biometrics can be incredibly specific to the respective user: "Biometrics systems identifies the individuals based on the corresponding features thereby providing the authentication whenever needed with better security mechanisms. In addition to this it is used to distinguish the people in a large

gathering who are under observation” [31]. As biometrics cannot be stolen or presumed, it can be highly effective as a security measure for other private data. However, when biometric data is the private data needing protection, other security measures must be implemented to keep a user’s physical and behavioral fingerprints private.

2.4.2 Risks of Biometric Collection

The main risk involved with active collection of biometric data within a mobile application is the same as with any other confidential data; if it is stolen it can be used against the user in a variety of extortion methods. What makes biometric data more vulnerable than other personal information is that once stolen, it cannot be changed [32]. For example, if a credit card is stolen, the user can simply deactivate the card and get a new one. However, when the fingerprint data from an iPhone is stolen, the user cannot change their fingerprint; the individual that now has that data will always be able to utilize the user’s fingerprint against them. When personal physical or behavioral user data is targeted, the user will never be able to change their heart rate, temperature, facial expressions, or any other personally identifying data [32]. For this reason, biometric data must always be secured with functioning and effective data security measures.

2.4.3 Benefits of Biometric Collection

Biomedical collection can provide countless benefits to both the users as well as the population. Similarly, to other data collections systems, once data begins to be collected, different analyzing and learning opportunities can begin. Specifically, for ovulation tracking biometrics (temperature, heart rate, etc.), the more data collected from a variety of women

can directly aid in the mass learning of the trends, cycles and outliers of ovulation cycles [33]. As there are a large array of factors that can affect a woman's ovulation cycle, the more data that is collected, the better generalizations can be made relative to how to predict a woman's ovulation correctly and accurately [11]. This can become an iterative process, whereas more data is collected, the generalization can be more and more fine-tuned, while continuously updating as more data is collected [33].

3 Methodology

3.1 Objectives

- Assess current ovulation tracking applications.
- Design and develop an ovulation tracking application prototype through a user-centered design framework

3.2 Assess Current Ovulation Tracking Applications

3.2.1 Semi-Structured Interviews

To gain a clear understanding of the current market of ovulation tracking applications, two women were interviewed about their menstruation/ovulation application usage. The two women interviewed were chosen by convenience sampling. Both interviews were conducted in person and were semi-structured, focusing on what they liked and disliked of the current available applications. Additionally, what each user would ideally want, need, and not want for a new ovulation tracking application were queried. Following

the flexible nature of this interview type, other topics including look, price and extra features were brought up as necessary. See a complete list of interview questions in Appendix A.2.

Each interview lasted approximately 10-15 minutes. Notes were taken for the first interview, while the second interview was recorded. See the consent form in Appendix A.1.

3.2.1 Online Survey

An online survey was implemented through Google Forms with the same questions as the interview. All responses were solicited through Twitter and Facebook. The former was open to the public, while the latter was only privately seen. The survey was qualitative with 13 total responses. See Appendix A.3 for screenshots of the survey.

3.3 Design and Develop an Ovulation Tracking Application Prototype Through a User-Centered Design Framework

3.3.1 User-Centered Design

Once all interviews and surveys were assessed and logged for needs, likes and dislikes for an ovulation tracking application, development of an application prototype took place. Major focus was on developing a structured framework that has the capacity for new features to be easily implemented in the future, especially Bluetooth syncing for temperature and heart rate. All features and functions developed were directly inspired and derived from the survey and interview results, as well as literature review analysis. This method resulted in a user-centered design that is both innate and functional.

4 Results

The online survey provided an array of requirements that the application both should include and not include. A total of 12 individuals participated, with the majority of answers being either long answer or short answer texts. This survey style provided the participants a space to elaborate on their answers if they felt the need to. As a result, analyzing the survey was completed manually instead of through code as most answers were unique and specific to each respective participant. The in-person interviews provided a general outline of what the application should look like and do, especially aesthetically.

4.1 Results of Online Survey

Of the 12 responses analyzed, 100% had used an ovulation tracking application, while 17% used two. The ovulation tracking application Clue was the most popular application, with 31% of responders stating they had or are still using Clue at this time. Eve and Ava were the two least used applications, with both only being used by 8% of responders respectively.

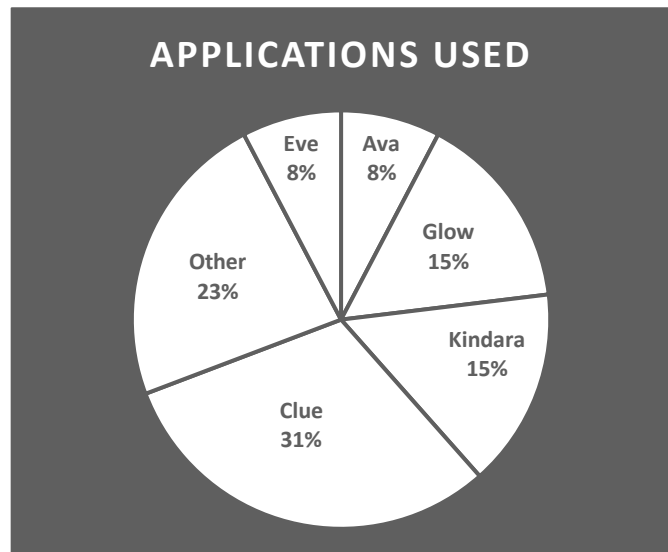


Figure 14: A pie chart of the ovulation tracking applications the survey responses have used. Clue was the highest popular application, with Kindara and Glow tied for second. Almost a quarter of respondents indicated using an ovulation tracking application that no other survey responders used.

A key finding from this survey was that while 90% stated they could easily understand the applications charts, 75% of responses stated that they wished the

application was more customizable to their needs, goals and wants. Additionally, in response to the questions regarding what users like and dislike about their current ovulation tracking application, an overwhelming portion of responses stated that a major issue they had was that most ovulation tracking applications are pink and “cutesy,” as well as focus solely on pregnancy. This highlights a need for a customizable application that can change aesthetically for each individual user, in addition to having different goal states within the application.

Another key finding was that while most current ovulation tracking applications have some form of community and/or chat system built within the application, most responses stated that they disliked this feature and viewed it as unnecessary for an effective ovulation tracking application.



Figure 15: A bar chart of the ideal aesthetic for an effective ovulation tracking application. Over half of the survey responders stated that they did not want an application that either was pink or “cutesy”.

4.1.1 Requirements, Likes and Dislikes

Derived from the responses, a complete list of requirements, likes and dislikes for an ovulation tracking application were created. Requirements for the application are as follows:

- Simple UX
- Symptom tracking: Heart rate, basal body temperature, sleep, menstruation, flow, PMS, pregnancy test, exercise
- Medication tracking and alerts
- Customizable –discreet and not “girly”
- Data analysis and prediction (color coded)
- Export, import, edit and delete data
- Custom notes and symptom option – ability to annotate data
- No typing required, button clicking only
- Customizability of notifications of menstruation and ovulation (on/off frequency)

Likes for an application are as follows:

- Menstruation and ovulation prediction precision
- Data analysis
- Export to spreadsheet/doctor
- Tracking key dates
- Informative about ovulation and menstruation
- Easy to use – innate
- Symptoms tracking and data

- Simple design
- Mood represented as emoji's

Dislikes for an application are as follows:

- Can't export, share data (for doctors, partner, self, etc.)
- No tutorial
- Focus and emphasis solely on pregnancy
- Chats with community
- No miscarriage category
- Important information not in main page
- Not intuitive
- Too many notifications
- Too much data needed to be input manually

4.2 Results of Interviews

The two in-person interviews consisted of the same questions asked in the online survey. However, as the interview style was semi-structured, this allowed for natural deviations to questions as needed, due to the flexible nature of this interview style. Both participants are from convenience sampling.

4.2.1 Interview 1

The first interview took place on the 13th of October 2017, at Worcester Polytechnic Institute. The interviewee has one child and has used multiple ovulation tracking

applications in the past, which makes her an appropriate and insightful candidate to interview.

The interviewee attempted to use three different ovulation tracking applications in the past, but ultimately never continuously used any of them. When asked why she never committed to using an application, she stated: “I didn’t stick with it because of privacy concerns. I didn’t want to display to the world that I was tracking my pregnancy. The UI was overly complicated, as well as the calendar. Instead I kept track of things in my head.” This highlights a key finding of the online surveys as well; women would actively choose to not use an ovulation tracking application, rather than potentially reveal to strangers that they are tracking their ovulation and menstruation.

Having tracked her own ovulation manually, she knew exactly what would and would not be helpful in an ovulation tracking application designed for all women. The interviewee stressed the need for an application that was careful with what language was used throughout the application. Specifically, to not have language based on the assumption that the user is solely attempting to get pregnant. As some women involuntarily are either successful or unsuccessful at getting pregnant, the language used in the application must be neutral as these scenarios can be extremely sensitive.

Moving on to how the interviewee imagines an effective visual representation of ovulation and menstruation tracking, she stated that a fundamental feature would be the ability to see when the window of ovulation moves per cycle. See Figure 15 for reference.

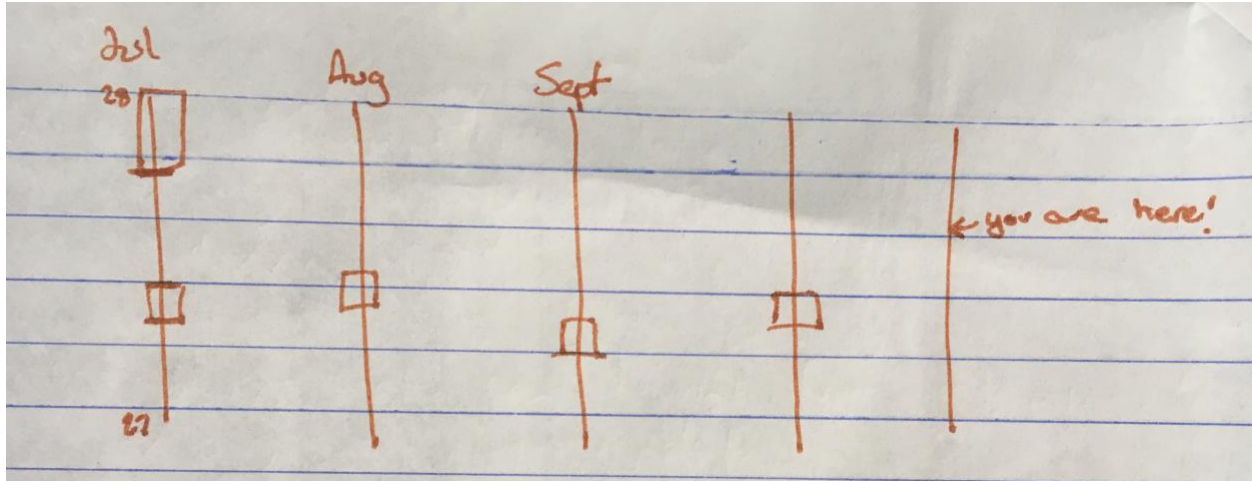


Figure 16: Drawing of ovulation tracking by the interviewee. Each line represents a month or cycle, while the blocks within the month show data recorded and predicted. Each month or cycle is lined up horizontally for the user to be able to compare their cycles easily and without changing screens.

The interviewee further explained her drawing, stating that each month or cycle is shown side by side with pointers indicating where ovulation began or when menstruation began. Through this chart, it would be not only possible, but easy for users of all ovulation and menstruation knowledge to compare their cycles on their own.

Overall, the interviewee provided a multitude of insightful and important advice regarding a successful ovulation tracking application.

4.2.2 Interview 2

The interview took place on the 13th of November 2017, at Worcester Polytechnic Institute. The interviewee was pregnant at the time of the interview, making her an ideal candidate with a new perspective.

Similar to the first interview, she used to use two different ovulation tracking applications, but no longer does. Her main reasons for discontinuing use of each application was due to the amount of manual input each application required to effectively

predict her ovulation and menstruation. Additionally, neither application synced with her personal calendar, which she used as her main source of notifications.

During pregnancy, medications can be vital to the health of both the fetus and mother; proper administration of medication requires accurate dosage during specifically scheduled intervals. If medications are taken improperly, it can have a severe effect on either the fetus, mother or both. As a result, having a notification service that effectively monitors, tracks and reminds the mother of medication alerts is extremely important. The interviewee stated that while one of the ovulation tracking applications did track medications, it did not have reminders or alerts as to when she should take her medication, which was the decisive factor resulting in her discontinuing use of said application.

Another key detail pointed out during the interview was that for women who are attempting to conceive, ovulation tracking applications should take into consideration that each woman is simply human; sometimes it is not possible to adhere to the strict timings needed for conceiving. Even though the point of an ovulation tracker is to know ovulation timing, an application's reminders can increase emotional pressure and increase stress. For these reasons, the interviewee suggested that the application have on/off switch for notifications regarding timing of ovulation and when would be best to try to conceive.

4.3 Application Prototype

All features of the application prototype were directly derived from the interview, survey and literature reviews findings. A complete outline of the prototype was completed before development began. Once the outline was finalized, development of an iOS

application began. All code was in the Swift 4 language, utilizing Xcode as the Integrated Development Environment (IDE).

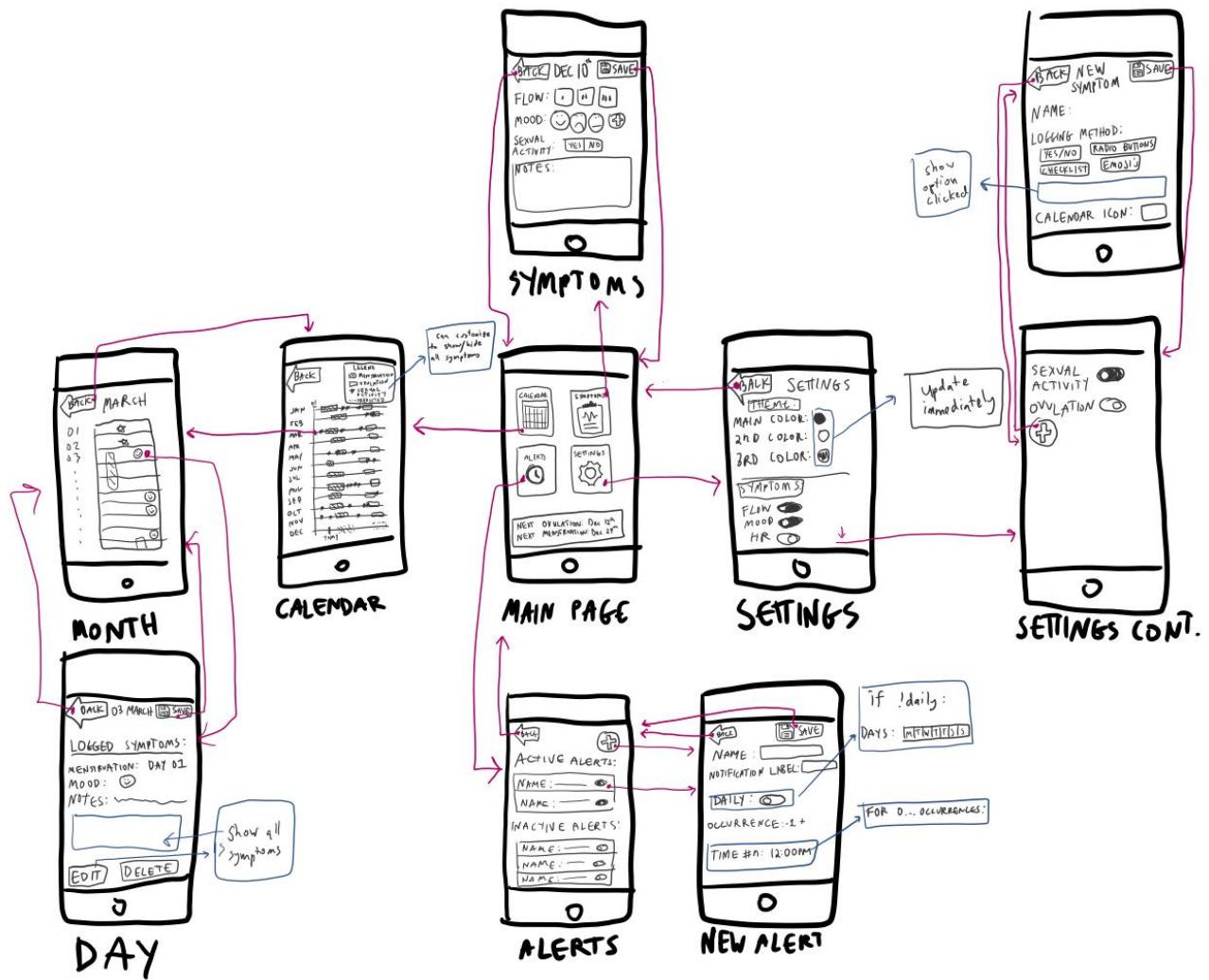


Figure 17: Outline design for all screens within the application. Pink arrows indicate the available segues into other screens. Blue boxes indicate available changes to the user interface depending on the content of what the user has input.

All main functionality was developed and completed for the main page, alerts page, new alert page, settings, and new symptom page. AlertItem, SymptomItem and DayItem database tables were implemented for functional persistence as well as User Defaults for persistent application color settings. See below for the schemas of each table.

AlertItem	SymptomItem	DayItem
UUID: String	UUID: String	UUID: String
name: String	name: String	date: Date
title: String	loggingMethod: String	symptoms: [SymptomItem]
body: String	loggingNames: [String]	notes: String
everyday: Bool	calendarIcons: [String]	logged: Bool
weekdays: [Bool]		
times: [Date]		

Figure 18: Database Schemas

Below show quotes from the interviews and survey regarding what individuals liked and disliked about current ovulation tracking applications as well as what they would ideally require in a new application.

4.3.1 Main Features and Interview and Survey Quotes

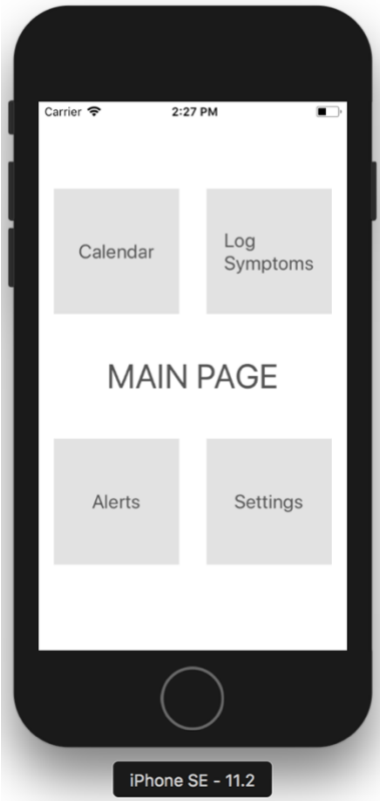


Figure 19: Main Screen

- “...easy to use”
- “...not overly girly”
- “... a simple app UI/UX”
- “...no group chats and ‘community’”
- “...chat room features feel irrelevant and send me too many notifications”
- “I just want simple, basic, clean!”
- “I like having a period app that’s not overly girly, pink, and embarrassing to pop open.”
- “...not overly ‘feminine’”
- “Clean and clear”
- “...minimalist would be ideal”
- “Just a nice clean interface that is easy to use”
- “no ads”
- “No cutesy text trying to get me to conform to the idea of being a mom”
- “I also really disliked the features that were so hyper focused on pregnancy.”

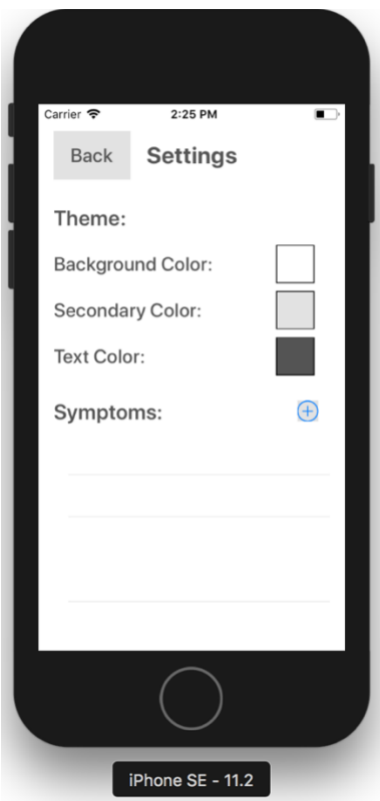


Figure 20: Settings Screen

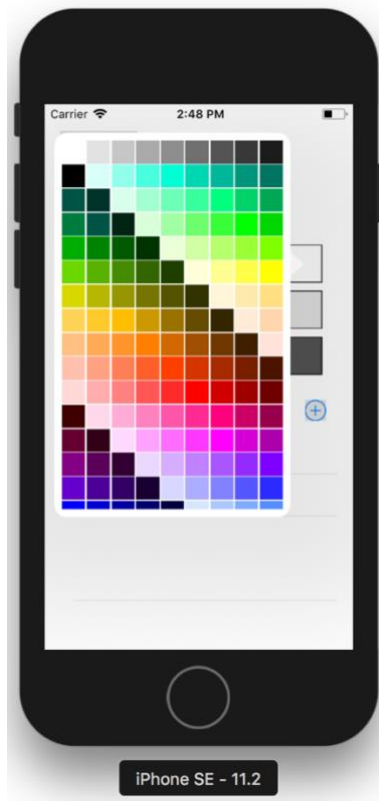


Figure 21: Color Picker

- “...customizable, not ‘cutesy’”
- “...low key, NOT PINK”
- “I definitely want something that either has customizable color or is gender-neutral.”
- “Anything full of pink hearts and flowers is just cheesy and off-putting”
- “...customizable in terms of what I do and don’t want to see.”
- “Not really looking like an ovulation tracker is appealing as I don’t want something pink or covered with babies on my phone”

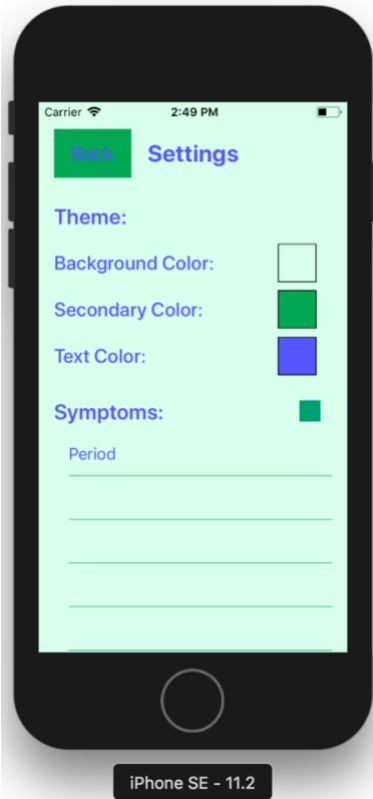


Figure 22: Settings Colors Changed

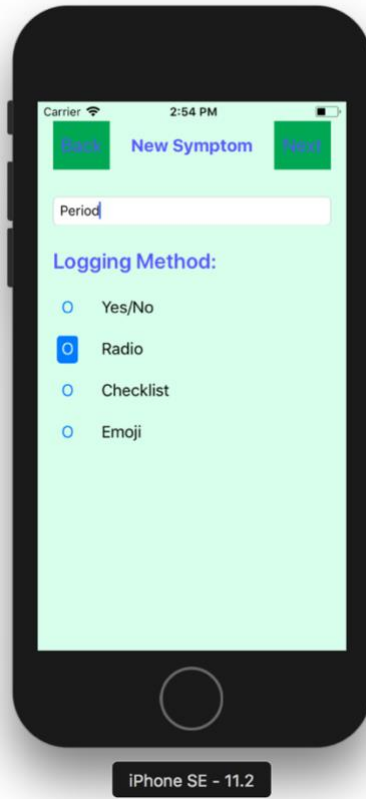


Figure 23: New Symptom Screen



Figure 24: New Symptom Logging Method Screen

“There was no way to categorize a miscarriage in the app”

“...keep track of key dates”

“I also don't like how if you're trying to conceive or trying to avoid it still gives you the same icons for fertile days, etc. It should be a little more customizable for those who aren't trying.”

“...customizable notes”

“...ability to track other symptoms”

“Track symptoms with emoji's”

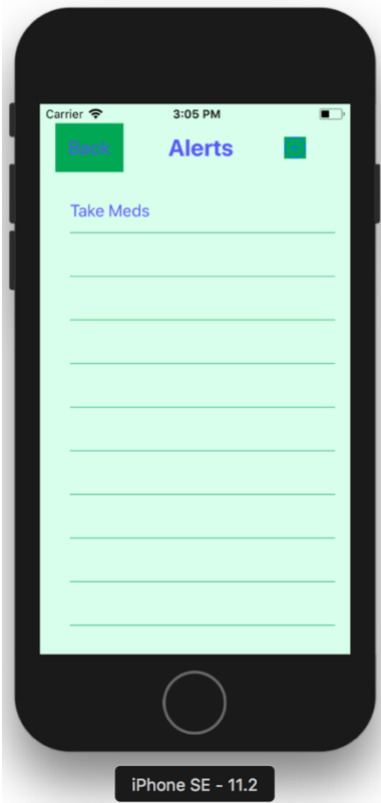


Figure 25: Alert Screen

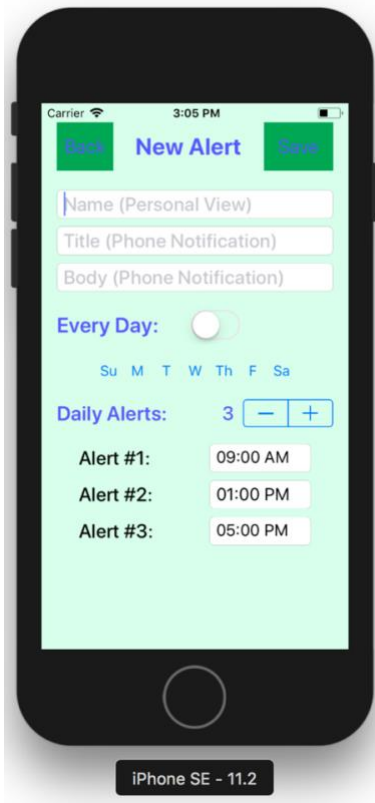


Figure 26: New Alert Screen

“...push notifications”

“...medication reminders”

“... it will remind me of things.”

“Keep track of when and how to take meds”

“Something discreet so if I am inputting on the train or at work it isn’t really obvious what it is”

“Simple design”

5 Discussion

The original objective of this project was to create an ovulation tracking application that passively took in Bluetooth data in order to accurately and precisely predict ovulation. However, once the literature reviews, survey and interviews were analyzed, it was clear that a user-centered ovulation tracking application needed to be created first. Moreover, the literature reviews highlighted the lack of frameworks regarding Bluetooth in conjunction with an ovulation tracking application, while the survey and interviews emphasized the need for simply an ovulation tracking application that met the standards and requirement for all women.

The only established framework created for iOS that is capable of syncing with an Arduino and Bluetooth was written in 2014 and in the Objective-C language, while this project was written in Swift 4. Alternatively, there is a working framework for Android that syncs with Bluetooth and Arduino, however, the code is likewise four years old, and contains several soon to be obsolete functions similarly. The lack of Bluetooth to smartphone frameworks was surprising, yet a large enough roadblock that the main objective needed to be adjusted.

After thorough analysis and examination of the survey and interview data, it was apparent that while the most-used ovulation and menstruation applications do function correctly and provide the results that some women require, overall there are three areas that all applications are deficient in: sensitivity, discreetness, and customizability.

Women's reproductive health is innately a sensitive topic as it is so personal and intimate to each individual woman. Furthermore, for women who are either attempting to become pregnant but are unable to, or for women who become pregnant when that was not the goal, both situations are extremely delicate sensitive matters that need to be dealt with in an appropriate matter within an ovulation tracking application. For example, one survey response about what they disliked about current applications stated that there was no miscarriage button on her application, so once she had a miscarriage the application continued to count down the days until her due date until she had to manually delete the pregnancy and data associated with that. This is an exceptionally distressing and poignant example of current applications failing to understand and provide the necessary sensitivity within their applications for women who do not fall under the two typical pregnant or not pregnant categories.

As women's reproductive health unfortunately is still, to some extent a socially taboo subject to mention in common conversations, women still necessitate an ovulation tracking application that is discreet and ambiguous to other people. According to the first interviewee, one main reason she stopped using ovulation tracking applications was due to the highly discernable look of all the applications she attempted to utilize. Additionally, over half of the survey responses mentions a dislike for all current applications being pink, "girly", "flowery" or not discrete enough. For this reason, it is vital to create an application that is discreet and not condescendingly "feminine".

Similarly to a need for a discrete application, the survey and interview analysis indicated a need for customizability of all features within the application as well. Ovulation tracking applications are meant to be utilized daily for accurate prediction, and as a result, must be tailored to each individual in order to create a user experience that is pleasant, easy to use, and also encouraging to use again. As a result, for an ovulation tracking application to be completely successful, it must be adaptable for all different women.

The work that Epstein et al. [9] accomplished in 2017 regarding the design of personal informatics tools through an analysis of menstrual tracking applications was a major influencer on the direction that this project took. Specifically, Epstein et al. [9] found that women track their menstrual cycle for various reasons, application designs have the potential to create feelings of exclusions in relation to sexual minorities and gender, and lastly, current applications only cater to one specific type of stereotypical woman, disregarding other stages of a woman's life (young adulthood, pregnancy, and menopause). These three findings gave a solid framework for this project to then explore what was needed in order to create a successful ovulation tracking application that catered to

different goals, was inclusive, and was tailored for all life stages of a woman. Through this, discreetness, customization, and content sensitivity were found to be the three major features needed to accomplish these objectives.

It should be noted that it was beyond the scope and objectives of this project to incorporate how ovulation applications are used effectively and ineffectively as a birth control method. The extent of this project was to understand people's desires regarding ovulation tracking applications. As a result, it was not investigated how the applications were being used for health-related reasons, to prevent pregnancy, to conceive, or for any other reasons.

6 Future Suggestions

Due to time constraints, the finished product of this project was a prototype of an application. For this reason, the Calendar view as well as the Symptom view would be the first and main suggestions as the next steps needed in continuation of this application development. See Figure 17 for the suggested layout of the Symptoms and Calendar views. As the database tables for the SymptomItems and DayItems have already been implemented, the Symptoms and Calendar views only need to be populated with the existing table data.

Once the basic user interface is complete and a framework is created, enabling Bluetooth to passively collect data for better ovulation prediction would be the next step for a successful application. The main steps in order for this suggestion to be completed would be to create a timer that would on a set interval take the users temperature and add

it to the symptoms column within the current DayItems row. Once syncing is achieved, then implementation of a formula to detect ovulation would be needed. See Chapter 2.1 and 2.2 for extensive research and analysis on how to predict ovulation.

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Appendix A

A.1: All interviews

**Please read over the below consent form. No need to sign the form. By returning the questionnaire you agree to participate in this research study.

Informed Consent Agreement for Participation in a Research Study

Investigator: Alexandrina Agloro, Lane Harrison, Gina Gonzalez-Roundey

Contact Information: ggonzalezroundey@wpi.edu

Title of Research Study: Ovulation Tracking Application

Introduction: You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience because of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study: Currently, there are no wearable heart rate and temperature monitors that can passively sync with an Android application. This study will be assessing what users want and need in a respective application as well as creating an application that has the functionality of taking in Bluetooth data from a wearable.

Procedures to be followed: This interview will take approximately 10-15 minutes and I will be asking you question related to other ovulation tracking applications as well as your thoughts on what a new application should comprise of.

Risks to study participants: None.

Benefits to research participants and others: None

Record keeping and confidentiality: Only I, Alexandrina Agloro and Lane Harrison will have access to your records. No personal identifying information will be stored. Records of your participation in this study will be held confidential so far as permitted by law.

However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you.

Compensation or treatment in the event of injury: This research does not involve any risk of injury or harm, thus there is no compensation available. You do not give up any of your legal rights by signing this statement.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact: See top of page for contact

information. IRB Chair: Professor Kent Rissmiller, Tel. 508-831-5019, Email: kjr@wpi.edu.
University Compliance Officer: Jon Bartelson, Tel. 508-831-5725, Email: jonb@wpi.edu.

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

_____ Date: _____
Study Participant Signature

Study Participant Name (Please print)

_____ Date: _____
Signature of Person who explained this study

A.2: Interview Questions

- Which ovulation tracking applications do you use?
- What do you like about it and what do you dislike?
- Which features do you think are vital to the application?
- Can you easily read and understand your charts?
 - What would you like your charts to look like? (feel free to draw and snap a picture to send)
- Are there any features you wish were not included?
- What kind of aesthetic (look, style, color) are you interested in for an ovulation-tracking app?
- Is there anything specific about an ovulation tracking application that would make you consider downloading one?
- Would you be interested in an ovulation tracking application that passively takes in your vitals?
 - If yes, what features do you think are necessary for said application?
[Analyze, store, edit, delete, import/export]
 - If not interested in passive collection of vitals, why not?
- What is the maximum effort you are willing to put into an ovulation tracking application?
- No effort, some effort, a lot of effort?

A.3: Survey Screenshots

Ovulation Tracking Application Questionnaire

Informed Consent Agreement for Participation in a Research Study
Investigator: Alexandrina Agloro, Lane Harrison, Gina Gonzalez-Roundey

Contact Information: ggonzalezroundey@wpi.edu

Title of Research Study: Ovulation Tracking Application

Introduction: You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study: Currently, there are no wearable heart rate and temperature monitors that can passively sync with an Android application. This study will be assessing what users want and need in a respective application as well as creating an application that has the functionality of taking in Bluetooth data from a wearable.

Procedures to be followed: This questionnaire will take approximately 10-15 minutes and we will be asking you questions related to other ovulation tracking applications as well as your thoughts on what a new application should comprise of.

Risks to study participants: None.

Benefits to research participants and others: None

Record keeping and confidentiality: Only Gina Gonzalez-Roundey, Alexandrina Agloro and Lane Harrison will have access to your records. No personal identifying information will be stored. Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or its designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you.

Compensation or treatment in the event of injury: This research does not involve any risk of injury or harm, thus there is no compensation available. You do not give up any of your legal rights by signing this statement.

For more information about this research or about the rights of research participants, or in case of research-related injury, contact: See top of page for contact information. IRB Chair: Professor Kent Rissmiller, Tel. 508-831-5019, Email: kjr@wpi.edu. University Compliance Officer: Jon Bartelson, Tel. 508-831-5725, Email: jonb@wpi.edu.

Your participation in this research is voluntary. Your refusal to

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

By clicking the submit button below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

Which ovulation tracking application(s) do you use?

Your answer _____

What do you like and dislike about your app(s)?

Your answer _____

Which features do you think are vital to the application?

Your answer _____

Can you easily read and understand your charts?

Your answer _____

What would you like your charts to look like? (feel free to draw and snap a picture to send to ggonzalezroundey@wpi.edu)

Your answer _____

Are there any features you wish were not included?

Your answer _____

What kind of aesthetic (look, style, color) are you interested in for an ovulation-tracking app?

Your answer _____

Is there anything specific about an ovulation tracking application that would make you consider downloading one?

Your answer _____

Would you be interested in an ovulation tracking application that passively takes in your vitals? (Meaning, it collects your

for an ovulation-tracking app?

Your answer

Is there anything specific about an ovulation tracking application that would make you consider downloading one?

Your answer

Would you be interested in an ovulation tracking application that passively takes in your vitals? (Meaning, it collects your information without effort on your part)

- No
- Yes

If yes, what features do you think are necessary for said application? [Analyze, store, edit, delete, import/export]

Your answer

If no, why not are you not interested?

Your answer

What is the maximum effort you are willing to put into an ovulation tracking application?

- No effort
- Some effort
- A lot of effort
- Other: _____

Any other comments?

Your answer

SUBMIT

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