

Research and Applications

Goals, life events, and transitions: examining fertility apps for holistic health tracking

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Received 11 June 2020; Revised 11 January 2021; Editorial Decision 9 February 2021; Accepted 15 February 2021

ABSTRACT

Objective: Fertility is becoming increasingly supported by consumer health technologies, especially mobile apps that support self-tracking activities. However, it is not clear whether the apps support the variety of goals and life events of those who menstruate, especially during transitions between them.

Methods: Thirty-one of the most popular fertility apps were evaluated, analyzing data from three sources: the content of app store pages, app features, and user reviews.

Findings: Results suggest that fertility apps are designed to support specific life goals of people who menstruate, offering several data collection features and limited feedback options. However, users often desire holistic tracking that encompasses a variety of goals, life events, and the transitions among them.

Discussion: These findings suggest fertility patients can benefit more from holistic self-tracking and provide insights for future design of consumer health technologies that better support holistic fertility tracking.

Conclusion: Fertility apps have the potential to support varied experiences of people who menstruate. But to achieve that, apps need to expand their support by offering ways for more users to perform holistic, personalized, and personally meaningful tracking, so they can derive long-term benefit from the data they collect.

Key words: Consumer health informatics (L01.313.187), holistic health (N01.400.350), fertility (G08.686.210), menstrual cycle (G08.686.605), women's health (N01.400.900)

INTRODUCTION

Fertility is a key to multiple important yet understudied issues related to female reproductive cycles such as menstruation, pregnancy, menopause, and reproductive diseases. These health issues are often stigmatized and entangled with taboos and, as a result, people may not receive proper treatment and care.^{1–4} Lately, “*female healthcare and pregnancy*”⁵ have drawn increasing attention in the consumer health technologies market, with around 28 000 mobile health applications (apps for short) available in app stores as of 2018.⁵ A large share of these apps focus on fertility.

Fertility is associated with multiple aspects of the health of people who menstruate (for purposes of this paper, this term is used to be inclusive to non-binary people, trans people, and women who menstruate). Menstruation is directly related to major life transitions such as from adolescence to reproductive years, (possibly) pregnancy, and menopause and it is also often associated with other physical and mental issues. These life transitions and events involve different needs. For example, previous studies have approached how technology can or should support individual fertility-related stages and needs,^{6,7} highlighting how these stages involve different goals.⁸

However, it is still unknown to what extent commercial systems support the needs of people who menstruate.

The goal of this study is to examine the design of consumer-facing fertility apps to understand how they support people who menstruate in their varied fertility-related goals. This study contributes to the areas of health informatics and design of fertility and mobile apps by describing: (1) what commercial fertility apps assume as people's main fertility goals, (2) how apps support intended and appropriated fertility goals, (3) challenges people may face when their fertility goals do not match app goals; and (4) how holistic tracking may better align with people's tracking needs.

Related work

Fertility is a critical factor for different life stages of people who menstruate. Adolescence, reproductive years, pre- and post-natal stages, and menopause are strongly related to changes in people's physical bodies and associated social and psychological factors.^{9–11} Fertility cycles additionally involve intricate changes in multiple hormones, and many cycle processes and their consequences on people's physiology are still unknown.⁹ Fertility is therefore connected to broader aspects that impact individuals' health and life quality. For example, 75% of people who menstruate experience premenstrual syndrome, or a combination of physical and emotional symptoms between ovulation and the start of the next cycle.^{12,13} Studies also suggest connections between menstrual cycles and onset of migraines,¹⁴ though symptoms potentially improve during pregnancy.^{3,14} Asthma, diabetes, epilepsy, irritable bowel syndrome, and rheumatoid arthritis have also been reported to be induced, exacerbated, or influenced by fertility.³

A growing body of research examines how technology can be designed to support the unique information and emotional needs and daily experiences of people who menstruate. Technology often aims to support menstrual health education because the health of people who menstruate is often entangled with social taboos¹ and proper education remains a challenge.^{7,15–17} People search for information about pregnancy,^{18–20} infertility,^{21,22} endometriosis,²³ and vulvodynia²⁴ online to make sense of their conditions,^{6,18,21} identify if their personal experience is *normal*,^{18–20} and manage stigma.^{6,22–24} Other studies explore the use of technology for social support, since stigma often triggers feelings of isolation and depression.²⁵

Self-tracking systems particularly have been widely used in multiple fertility-related contexts for keeping records of symptoms to identify cyclic patterns or support diagnosis,^{3,4,12,13,17} including monitoring menstrual blood loss²⁶ and triggers and patterns of nausea during pregnancy.²⁷ Lupton and Pedersen²⁸ describe people's use of pregnancy and parenting tracking apps seeking for information and reassurance around their changing bodies and child development. Similarly, Epstein et al⁸ report that people track menstrual cycles for various goals: to understand their bodies, to be prepared, to conceive, and to inform healthcare providers. However, studies have also described negative effects of self-tracking in fertility^{17,22} and used critical approaches to expose privacy issues by reviewing and questioning current products' data policies,²⁹ or to challenge normative characteristics of female bodies that technology can reinforce, such as technology presenting common experiences related to female bodies (eg, menopause) as problematic or isolating.³⁰

Mobile apps are currently the most popular self-tracking technologies for fertility. Like other self-tracking systems they are used to collect data,³¹ in this case, data related to fertility, such as period dates and other physical and emotional data. Apps also often pro-

vide feedback through visualizations, including predicting future periods, ovulation, and fertility windows. Studies analyzing fertility apps have primarily focused on evaluating the accuracy of predictions, finding that most apps do not explain how data are calculated, do not cite scientific literature, and have varying accuracy.^{32–35} Recent studies have also evaluated how apps may impact people's lives by scoring the quality of apps^{36–38} and examining apps' approaches to privacy and menstrual literacy.^{29,39} Studies have additionally discussed how fertility apps can stereotype the gender of the user,^{8,17,40} and examined the difficulty of communicating uncertainty in fertility predictions.⁴¹ This work elaborates on these studies to identify how people's planned, expected, and unexpected life stages, events, and transitions impact how apps support their tracking behaviors.

METHODS

App selection

Literature suggests fertility is a broader term that covers different aspects of individuals' reproductive cycles and health.^{9,21,40} Consequently, *fertility* was the keyword used to search for relevant apps in two app stores (ie, Apple App Store and Google Play Store). This search returned 524 apps in February 2019, as illustrated in Figure 1. To identify current, accessible, and widely used apps, metrics were used from the previous literature⁴² to select apps that: (1) focus on female fertility, (2) have an average rating ≥ 3 stars, (3) have had at least one update since 2017, (4) are free, and (5) have an English version. Poorly rated and paid apps were double checked and all had fewer reviews. For example, among the 94 Apple apps with less than 3 stars, 86 had 0 stars and 0 ratings. Since the focus was on consumer-driven apps used in everyday life, apps for clinical use were excluded, such as those to support in vitro fertilization treatments. After applying these metrics, star rating averages and number of ratings were used to assess app popularity and generate a ranked list for each app store. The 15 best and most rated apps were selected from this list. Three apps appearing in both stores were analyzed individually to determine if features varied by platform. Though Natural Cycles appeared among the 15 most popular Apple apps, its free version's offerings were very limited. To make a fair comparison, it was replaced it with another app (Monthly Cycles, the 16th app in the final list of Apple apps) from Apple. Natural Cycles' free version was still analyzed to the extent it was possible because it has received increased attention due to its recent FDA approval for birth control.^{43,44} With these inclusion criteria, a total of 16 apps from Apple and 15 from Google were analyzed (Table 1 lists the selected apps). There was considerable overlap in retrieval when using other search terms such as period or menstrual tracking. There were only two differences in the original 31 apps retrieved, suggesting *fertility* is an appropriated term.

Data collection

App store pages' content, app features, and user reviews were collected for each fertility app between April and July 2019. These three datasets helped to understand the technical promises presented, the functions offered, and people's experiences using the apps. The content of each app's page was copied to a file for analysis. All 31 apps were downloaded, test data was entered, and output observed. A complete review history was downloaded for each app at the Google store, but Apple's store policy only allowed accessing the 500 most recent reviews. In total, 70 685 reviews were collected (6313 from Apple and 64 372 from Google).

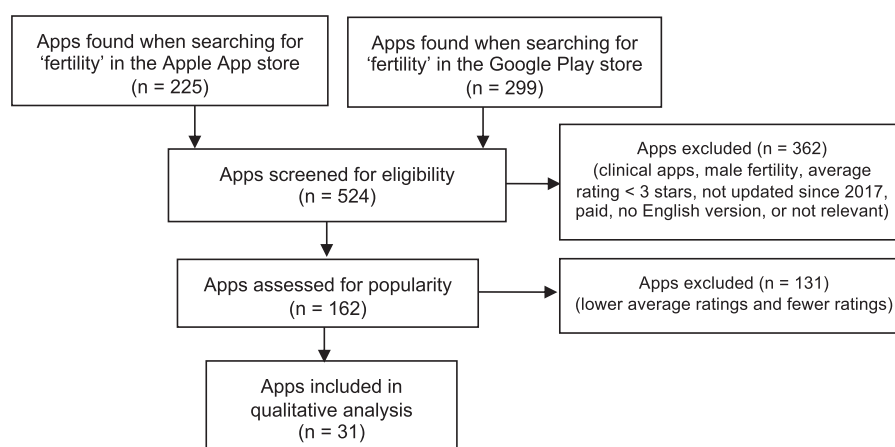


Figure 1. App selection process.

Table 1. Analyzed apps by platform, as of February 2019—name (average stars and number of ratings)

Apple App Store	Google Play Store
Flo (4.8 and 365K)	Period Calendar (4.8 and 4M)
Glow (4.7 and 29K)	Flo (4.9 and 795K)
Life (4.8 and 27K)	Clue (4.8 and 627K)
Clue (4.8 and 24K)	Period Tracker (GP) (4.5 and 334K)
Ovia (4.8 and 12K)	My Calendar (4.7 and 185K)
Cycles (4.5 and 7K)	Maya (4.7 and 173K)
Period Tracker Health Calendar (4.5 and 4K)	Pepapp (4.7 and 155K)
Kindara (4.6 and 3K)	Petal (4.8 and 140K)
Natural Cycles (4.8 and 3K)	Lilly (4.5 and 140K)
My Calendar (4.8 and 2K)	WomanLog (4.5 and 123K)
Ferdy (4.5 and 2K)	Period Tracker (Amila) (4.9 and 119K)
Dot (4.7 and 1.7K)	Woman Diary (4.6 and 94K)
Femometer (4.8 and 1.6K)	My Days (4.5 and 93K)
My Cycles (4.6 and 1.4K)	Period Tracker (Leap Fitness) (4.9 and 83K)
Premom (4.7 and 1.3K)	Ladytimer (4.5 and 72K)
Monthly Cycles (4.6 and 1.2K)	

Ethical and privacy issues were considered in using the reviews. Since they are intended to be seen by anyone who accesses app stores, it is reasonable to assume that reviewers expect their reviews to be public. Nevertheless, measures were taken to assure reviewer anonymity by removing reviewer and app names when using review quotes. When necessary, parts of quotes were deleted, rephrased, or paraphrased to ensure de-identification. Final quotes were searched for online to ensure the original reviews are not easily identifiable, and edited to ensure they were not a top search engine hit.

Data analysis

App store page content, app features, and review data were scanned to understand what fertility apps claim to support, how they are designed, and users' attitudes and perceptions toward them. Because people often described in their reviews challenges as relating to changes in their goals or life stages, these themes were chosen to be further investigated. The three datasets were then analyzed with this focus.

One researcher open coded⁴⁵ all text on app store pages. Example of codes included: list of indicators, contraception, conception, period tracking, pregnancy, support for pattern visualization, interfaces. The main themes identified based on this analysis were (1) fertility goals, (2) available health indicators, (3) types of feedback, and (4) claims of control. For the feature analysis, two researchers downloaded and analyzed each app by entering four months of fertility data to observe apps' visualizations and other feedback, a time frame used in previous fertility studies.^{32,38} All available health indicators were entered, including common variations (eg, regular and irregular cycle length) to understand app output. The researchers annotated the offered features, including what and how data is entered in the app, what visualizations are available, what data is shown in the visualizations, what (if any) are the options for setting and changing goals.

Based on this initial analysis, a codebook was created to analyze user reviews to focus on goals, app interaction, and fertility experiences described in prior work^{6,8,16,23,25,39,47} and the positive and negative perspectives in each review (eg, reviews describing how users liked the app vs reviews describing challenges).⁴⁶ Specifically, codes for goals included conceiving, avoiding conception, period tracking, pregnancy, changing goals, and goal mismatches. App interaction codes encompassed tracked indicators, offered feedback, reactions to indicators, and reactions to feedback. Other fertility experiences referred to adolescence, menopause, miscarriage, breastfeeding, and endometriosis. Since most app reviews focused only on general app experience (eg, "Easy for use. I love it"), searches were specifically conducted for reviews covering 12 fertility-related terms (eg, *fertility*, *conception*, *TTC*, *miscarriage*, *menopause*, *endometriosis*, *pcos*, *breastfeeding*, *pregnancy*, and variants of these terms), that identified 3433 relevant reviews (1075 from Apple and 2358 from Google). These reviews were then iteratively coded by two researchers. First, the two researchers coded the same 500 reviews and compared their results, resolving disagreements through discussion. Then the researchers split the remainder reviews and coded them separately, meeting frequently to discuss the analysis. Themes were identified when reaching a point of data saturation⁴⁸ (around 2000 reviews), but all 3433 reviews were coded.

After coding, findings from all datasets were compared to identify possible mismatches among apps' claimed goals, actually supported goals, and needs and desires reported by users.

Table 2. Main aspects of app store pages

App store pages description	Summary	Examples
Support for multiple fertility goals (26 out of 31 app store pages)	Apps most commonly describe supporting goals of period tracking (PT—29 apps), trying to conceive (TTC—21), trying to avoid conception (TTA—9), and pregnancy tracking (PgT—7). According to apps' pages, these different goals can be supported through tracking multiple health indicators.	<i>"Whether you are concerned about conceiving, birth control and contraception, or regularity of period cycles"</i> [A3] <i>"predicts menstrual cycles, helping women to get pregnant or avoid pregnancy"</i> [A21]
Available health indicators to track (31 out of 31 app store pages)	Of the 31 app store pages, 29 emphasize support for tracking several health indicators, highlighting extensive lists of possible indicators. Two apps emphasize a limited list of indicators, describing that users only need to track period dates.	<i>"Comprehensive Health Tracking"</i> [A1] <i>"Track over 30 health categories and start to see the patterns in your health"</i> [A22] <i>"no need for extensive charting and daily temperature taking"</i> [A14]
Feedback (31 out of 31 app store pages)	All apps provide feedback to users. Feedback includes predictions for next periods, ovulation, and fertile window and is often provided through visualization of tracked data. App store pages frequently suggest it will be easier for people to see patterns and variations in their cycles through visualization, particularly calendars.	<i>"See fertile days and variations in your cycle at a glance"</i> [A5] <i>"vital information at a glance"</i> [A17]
Encourage users to exert control over their bodies (16 out of 31 app store pages)	10 apps use expressions such as <i>take control</i> apps, while 6 others emphasize how users can end the <i>guesswork</i> by using their app. Fertility apps suggest that they can help people understand or control their <i>cycle, fertility, reproductive health</i> , or even their overall <i>health</i> .	<i>"All women, even those with irregular periods, can rely on this health tracker"</i> [A26] <i>"take full control of your health with the app"</i> [A11] <i>"shows you the science behind your menstrual cycle"</i> [A31]

RESULTS

Results show that fertility apps aim to be comprehensive, which their app store pages reflect by focusing on four main aspects, summarized in Table 2: (1) support for different fertility goals, (2) available health indicators to track, (3) types of feedback offered, and (4) enabling people who menstruate to take control over their bodies. Apps are named A1 to A31 to preserve anonymity.

These descriptions suggest that apps support multiple goals by providing data tracking features and feedback based on data. App descriptions suggest that taken together, these activities can support people who menstruate improve their control over their bodies. The following sections report results on aspects intended to support control: goals offered by the apps, data tracking features, and typical forms of feedback.

Intended and supported fertility goals

Goals for using fertility apps are mostly visible in three places: app store pages, onboarding process, and configuration settings (Figure 2).

Among the 31 apps analyzed, 18 include an onboarding process. However, only 14 of them ask users' goals during this process (Figure 3), with all 14 including the goal of trying to conceive (TTC). Although period tracking (PT) was referenced on all 31 app store pages, only 8 apps include it as a goal. Only two apps include all four goals of TTC, PT, trying to avoid conception (TTA), and pregnancy tracking (PgT) in the onboarding process.

These results suggest that apps primarily focus on conception, which is reflected in app reviews. Reviews for apps mentioning conception are generally favorable. Users often indicate they achieved their goal during

app use, some report abandoning it once conception was successful (eg, *"I have been using [A6] for more than a year to TTC and now I feel very funny to delete the app since I am pregnant!"*), while others report resuming app use when TTC a second child (eg, *"I used this app when we were TTC our son some years ago, and today I am using it again while we try for a second child"* [A1]).

Other people use apps continuously to support multiple goals: *"I used this app for five years. In the beginning I successfully avoided pregnancy, and now I am on my second pregnancy"* [A8]. Nineteen apps allow users to change their goals in settings within the apps. Six apps do not ask goals in the onboarding process, only allowing to change to a pregnancy-specific mode within the app later.

Tracking fertility: comprehensive and long-term driven

Most apps offer a vast list of health indicators to track including those directly related to fertility such as period dates as well as broader ones, such as diet and exercise. Sixty-two unique types of indicators apps offer to track (mostly manually) were identified, ranging from 2 to 34 per app (mean = 13.93 and median = 14). Table 3 lists all identified indicators.

The health indicators in fertility apps often support multiple phases of a regular fertility cycle (eg, menstruation, pre-ovulation, fertile days, post-ovulation), but most indicators focus on fertility or pregnancy. Of the 17 indicators present in 10 or more apps, 7 relate primarily to fertile days or aiming to become pregnant (temperature, cervical mucus, ovulation, intercourse, cervical observations, and pregnancy test), while 2 are closely related to menstruation (period dates and flow). Two indicators relate to avoiding pregnancy (intercourse protection, contraceptive). Three indicators are primarily associated with general health (weight, sleep, and exercise), while

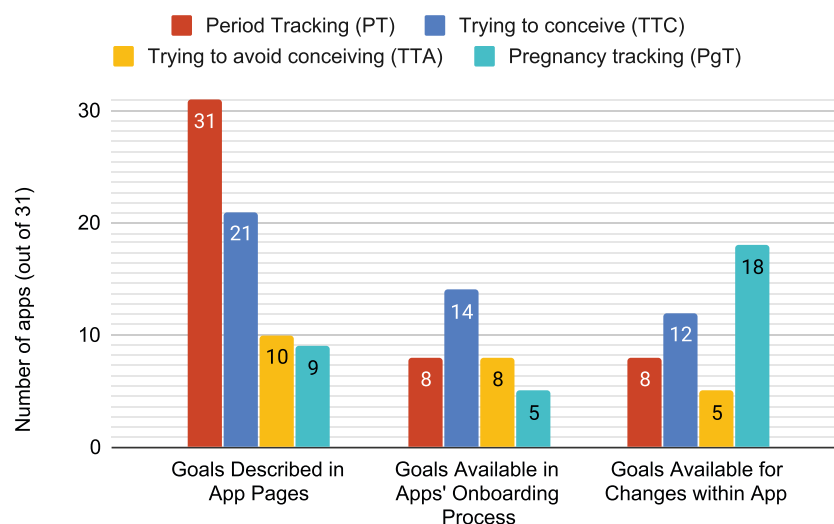


Figure 2. Goals within apps.

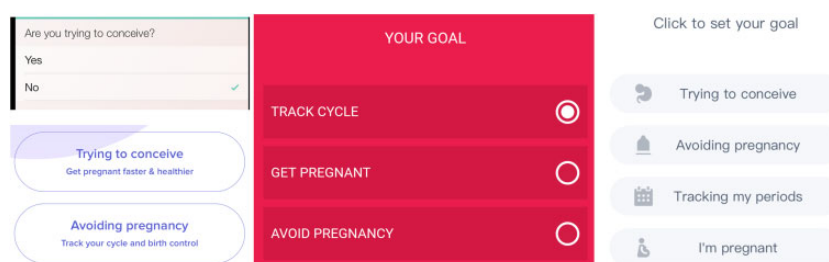


Figure 3. Examples of goals question in the onboarding process.

four flexibly relate to fertility or general health depending on the context (medication, notes, symptoms, and mood). For example, people could use mood indicators to monitor premenstrual impacts, but also as a more general indication of their health. Individuals can track all these indicators across the fertility cycle.

Users' reviews express desiring a similarly vast and varied list of indicators. Many users highlight how they enjoy "how extensive tracking is" [A1]. Some reviewers request the ability to track more, frequently asking for additional indicators. Requested indicators are often associated with periods or general symptoms (eg, "I wish I could track other things such as headaches, hunger, mood, cramps, and etc. I currently use another app to capture these other data" [A31]). In addition, people's health circumstances often lead to other suggested indicators. For example, a user with diabetes and TTC wished to also track insulin levels to avoid complications around her glucose level:⁴⁹ "the app should include the option to track sugar levels for woman with diabetes and TTC. We should be allowed to track our insulin level within the app" [A1]. Another user who is pumping wished to track how her menstrual cycle influenced milk production: "I know that moms who are solely pumping are a minority, but [if] things like milk production in ounces [...] appeared as a line in the fertility graph, I would be able see how ovulation and menstruation actually affect my milk output" [A1]

Data over long-term tracking

Reviews revealed that many people use fertility apps as data storage tools, so they can "have all my information in one spot so I can look

back on" [A6]. For example, users like the feature of uploading pictures of Ovulation Predictor Kits (OPK) because "the app saves the strips' photos, so you are not holding them for weeks!" [A15]. Additionally, some users felt that storing long-term data could be useful to prepare for goal changes: "I believe that when I am ready to have a child, it will be easy to switch the goal and see my most fertile days because I have logged so much data already" [A31].

Given the value of storing long-term data, many users complain about data loss. For example, one user dealt with unexpected loss of long-term data from different stages of life: "After six years of using this app, I now have lost everything! I tried to import my data to my new phone, but it is all gone. I lost all my notes of my miraculous pregnancy, my unpredictable periods information, and the lovely chats I had in the groups. I am upset because I need to start over again! Off to get a new app" [A21].

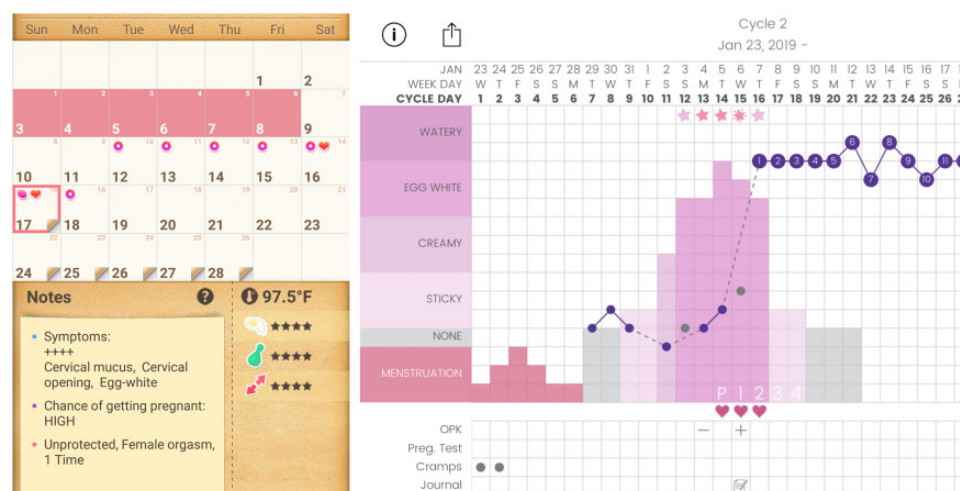
Main feedback: visualizing tracked data

Apps most commonly provide feedback to users through calendars (31) and temperature graphs (21), although some apps include other forms of feedback (eg, reminders, raw data lists, or line and bar graphs). Figure 4 shows examples of the most common forms of feedback.

Calendar and temperature graphs emphasize dates and ovulation, as described in Table 4. Although many users comment how they like being able to see their data through calendar and temperature graphs, user reviews highlight that these visualizations do not fully support peoples' fertility goals.

Table 3. Health indicators offered by the apps

Indicator	# Apps	Input mode	Implied periodicity
Period	31	Manual	Monthly
Intercourse	30	Manual	By occurrence
Symptoms	26	Manual	By occurrence
Mood	26	Manual	By occurrence
Temperature	26	Manual (23)/manual + synchroni- zation (3)	Daily
Notes	26	Manual	Vary
Cervical mucus	22	Manual	Daily
Weight	21	Manual	Vary
Flow	21	Manual	Monthly (3–7 days)
Ovulation	21 (19 OPK, 9 selection)	Manual (18)/manual + computer vision (3)	Monthly (10–20 days)
Intercourse protection	20	Manual	By occurrence
Contraceptive	17	Manual	By occurrence
Medication	15	Manual	Vary
Pregnancy test	15	Manual (12)/manual + computer vision (3)	Vary
Cervical observations	12	Manual	Daily
Sleep	11	Manual (9)/manual + synchroniza- tion (2)	Daily
Exercise	10	Manual	Daily
Others	Alcohol (8), disease (7), water (6), pregnancy (5), blood pressure (5), custom indicator (5), spotting (5), meditation (4), diet (4), orgasm (4), insemination (3), smoking (3), pain (3), stress (3), doctor appointment (2), location (2), sex position (2), fern test (2), collection method (2), craving (2), digestion (2), hair (2), skin (2), stool (2), energy (2), mental (2), motivation (2), social (2), party (2), travel (2), lochia (2), fertility, caffeine, vaginal sensation, treatments, events, progesterone test, lab results, waist, chest, hips, pulse, breasts, habit, and headache		

**Figure 4.** Calendar and temperature graph visualizations.

App descriptions often suggest that people can collect different types of data to compare their fertility cycles and see “*variations in your cycle*” [A5] or “*patterns in your health*” [A7]. Users’ app reviews indicate they generally have these goals (eg, “*I am terrible in memorizing patterns of symptoms from one month to the other and this app does it for you*” [A1]). However, calendars and temperature graphs offer limited support for such goals.

People’s goals for understanding their symptoms and mood are not particularly well-supported by fertility apps. Although 26 of the 31

apps present these indicators (only period and intercourse appear more often), only five apps included visualizations that enable seeing how they and other non-TTC indicators relate to cycle days, periods, ovulation, and fertile days. Users suggest wanting to compare their mood and symptoms by cycle: “*It could include a better way to monitor monthly mood and symptoms on a graph, so you could see whether the same moods appear at the same time in the cycle, and not just days*” [A23]. Despite apps’ focus on conception, even some users who are TTC complain they do not support identifying and understanding patterns of

Table 4. Main ways to visualize tracked data

Visualization	Description	Positive perspectives	Negative perspectives	Examples
Calendar view	Calendar views emulate paper calendars by aligning menstrual cycles to days. This visualization displays predictions for periods, ovulation day, and/or fertile window in calendar cells. It is often possible to see more tracked indicators by clicking on each day's cell.	App users enjoyed how predictions on calendars helped them see their fertile window "at a glance" [A22], as the app pages advertise.	Limiting the visualization to calendar months limits full cycle analysis, as a cycle may span months. Many users wanted to compare between cycles to identify patterns, which the visualization does not easily support.	<i>"I really like the calendar feature—it makes it easy to track sex and my cycle [...] and any changes in my body: from mood to fatigue and acne. It is helpful to identify patterns" [A6]</i> <i>"now you have to scroll month by month [to analyze the visualization], and it can get burdensome when you have some years of data in between pregnancies" [A8]</i>
Temperature graph	Temperature graphs are used to identify ovulation [21] by visualizing days (x-axis) against a person's basal body temperature (y-axis). Unlike calendars, they usually do not offer predictions into the future; instead, they display current and past cycles. Temperature graphs often only show health indicators directly related to conception such as temperature (21 apps), period days (19), intercourse (13), cervical mucus (9), OPK results (6), and pregnancy tests results (3).	Allows users to see multiple days of data at once, including temperature and other indicators. Temperature graphs primarily help support goals of TTC or TTA because the patterns displayed mainly help identify fertile days.	As graphs tend to only show a limited set of indicators, users often cannot rely on them to analyze other aspects of their fertility goals, particularly symptoms and mood. They also have limited or no use if users do not track temperature or do not have a TTC or TTA goal.	<i>"I got pregnant! It helped me in understanding my body! From things such as cervical mucus, cervical changes, to tracking basal temperature. The graphs are easy to understand" [A8]</i> <i>"we do not want to conceive so soon. [...] Observing my temperature values increase and decrease really helps me" [A31]</i> <i>"The app allows us to add other symptoms and observations, but it does not display them on the graph, making it a useless feature" [A9]</i>

symptoms throughout the cycle: "If you are trying to get pregnant, this app is very plain. I use this and several other apps and while this one has a few features to track symptoms, it does not explain how they correlate to your cycle" [A29].

All app visualizations analyzed are pre-defined and not customizable, so users cannot choose which indicators they want plotted, analyzed, or correlated within a cycle. Only two apps allow users to partially define what indicators appear within the calendar days. Graphs are not customizable and pattern analysis features are uncommon, showing only one indicator at a time.

Users' experiences using fertility apps

Fertility spans the life of people who menstruate, being key to multiple life stages and events. However, this analysis revealed that apps generally do not adequately support users apart from their reproductive years, during which apps often presume people have conception goals. Even their support for conception-related health events lacks support for many peoples' needs. Table 5 lists quotes supporting these findings, referenced in Q1–18.

Support for conception-related events

Many user reviews complain about how apps support pregnancy, miscarriage, and breastfeeding, events that are directly related with conceiv-

ing. Of the 31 apps, 18 allow users to indicate pregnancy in the app and often offer a pregnancy tracking mode, which was positively reviewed by the users (Q1). However, similar to previous literature reports,⁸ many users also note that although they enter in the app that they were pregnant, some apps kept warning them their period was late or changed predictions as the person was having a very long cycle (Q2–3).

Not all pregnancies come to full term: 20% of all pregnancies are estimated to end in a miscarriage.⁵⁰ Only 5 apps among the 31 offer some level of support after a miscarriage, for example by allowing registration of a miscarriage, providing articles and supportive messages, providing guidance for tracking after a miscarriage, and resetting or stopping predictions and emails. Some users comment that apps, even ones that offer support for TTC, do not offer an option to input a miscarriage (Q4), or even impact predictions in unexpected and potentially irreversible ways when a miscarriage is tracked (Q5). Additionally, apps' pregnancy messages, if not configurable, could serve as a reminder of miscarriages (Q6). Finally, even when pregnancy comes to term, other events can interfere with app use and fertility cycles. For instance, some users expressed that apps did not support their needs while breastfeeding post-partum (Q7).

Support for other life stages

Reviews suggest that apps tend to lack support particularly for the initial menstruation cycles during adolescence or the increased irregularity dur-

Table 5. Users reviews regarding apps' support for life stages and fertility-related events

Conception-related events	
Pregnancy	(Q1) "I love this app's pregnancy mode. It was my 1st pregnancy and it guided me through it" [A16] (Q2) "It would be good if you could tell the app you are pregnant. I keep receiving these almost panicked notifications about how late my period is" [A17] (Q3) "I do not believe I can continue using this app without reinstalling it and losing my data, because now my average period length will be very off [A7]
Miscarriage	(Q4) "I lost two pregnancies and I cannot track that in the app, which completely messes up cycle predictions. No app, I did not have a sixty days cycle. I had a miscarriage!" [A15] (Q5) "after having an early miscarriage, the app changed not only the future, but also the data for past months! So now I do not know whether my period is late or not. Thank you so much for that" [A2] (Q6) "I lost my baby and I became severely depressed. I reported my miscarriage in the app in order to stop the daily e-mails, which served as a daily reminder of my baby's death" [A1]
Breastfeeding	(Q7) "I really like this app to plan for pregnancy, but now that I am using it after conceiving, it keeps saying it cannot track because my periods are irregular. I want to tell the app that I know! I had a child and then I breastfed for two years. Now I need the app's help until I get regular again" [A14].
Other life stages	
Adolescence	(Q8) "The app always asks 'did you have sex? It is the perfect time to make love with you partner today' [...] I am still a teenager and I am still not thinking to have sex" [A4].
Menopause	(Q9) "I am going through pre-menopause, so this app has been a blessing!" [A12] (Q10) "I wish there were more symptoms specific to my condition, but I know this app is not for people in the peri-menopause stage" [A2] (Q11) "When I missed a period, I was not able to add this to the tracker" [A13] (Q12) "I am looking for something that allows me to distinguish levels, such as spotting, light, and heavy, because I track pre-menopause" [A18] (Q13) "I would like additions for tracking night sweats, sleeplessness, hot flashes" [A18]
Reproductive years' experiences not involving conception	
Fertility changes	(Q14) "I began to use this app to track my moods alongside my cycle. [...] I discovered that my moods were difficult to control during ovulation. I told my doctor and he made me a prescription of a medication that I have been using for a year so far, and the things are much better now" [A12]
Support for diagnosis	(Q15) "when I was not getting pregnant, I looked for a doctor and I was able to tell exactly what my body was doing and I was then diagnosed with PCOS" [A1] (Q16) "I would give this app more stars if it mentioned adenomyosis and endometriosis with the description of how painful periods are NOT normal. Millions of women worldwide suffer from unexplained pelvic pain. It took me 15 years to be diagnosed!" [A26]
Diverse genders and sexualities	(Q17) "I personally track my ovulation to deal with mittelschmerz pain, but I do not ever need to track cervical mucus or basal body temperature because me and my partner are not capable of conceiving. So, please give me a way to turn these things off!" [A13] (Q18) "even though these [gender and sexuality] aspects may not have a direct effect on our cycles, I believe this app is about accurate data, but there are data that I cannot input" [A11]

ing menopause. For adolescence, similar to prior findings⁸, some teenage users found it inappropriate when apps focused on conception (Q8). Only 10 apps ask user age during the onboarding process, even though this information can additionally help towards conception goals.

Most reviews are positive concerning menopause, with people benefiting from tracking their cycles when their periods became irregular (Q9). However, users recognize the apps were not developed for menopause (Q10) and try to adapt them to support their needs. Menopause users also describe some problems with app support to their specific needs, such as not being able to track missed periods, the intensity of symptoms, or symptoms more directly related to the menopause experience (Q11–13).

Conflating reproductive years with conception

While fertility apps are praised for supporting the goal of TTC, many users were disappointed by this limited focus: "I wish they would allow us to customize more since not every woman wants to be a mother, but every woman has to deal with that period of the month" [A29]. As this user describes, many people do not have conception goals during reproductive years.

Although periods are often more regular during reproductive years, people with periods often have *irregular* experiences. People may face temporary changes in their cycle, and tracking can help identifying them (Q14). Reviews suggest people want to use fertility apps to monitor their cycle regularity and "to track

inconsistencies” [A30]. To other people, *irregularities* may be part of their regular experience, such as people facing fertility issues, polycystic ovary syndrome (PCOS), and endometriosis. Apps can support identifying and managing these issues by recording data useful for diagnosis (Q15). However, apps can also normalize particular experiences and ignore others (Q16).

Fertility apps also often make heteronormative assumptions about users’ genders or sexuality.⁸ Participants who did not fit these assumptions noted that their data needs were not being well-supported (Q17–18).

DISCUSSION: FERTILITY AND HOLISTIC TRACKING

This study revealed that fertility apps are generally supportive of goal-oriented uses, particularly TTC. This aligns with traditional uses of self-tracking technology.³¹ However, people also want to use these apps in a more holistic way: to support multiple goals, different life stages and events, and transitions between them. For example, it would be common for a person to start to use a fertility app as a family planning tool, transitioning from avoiding pregnancy to trying to conceive, and then to early parenthood with breastfeeding and other activities, ideally without deleting the app or losing data.

First, although apps typically support only a subset of possible fertility-related goals (eg, TTC or PT), people often use fertility apps to track other health factors influenced by fertility, such as moods, glucose, and pumping. Second, fertility spans over most of the life of people with periods, with intrinsic transitions. Fertility inherently encompasses three important life stages: adolescence, reproductive years, and menopause. Similar to a recent study,³⁹ this study found some of these life stages, especially around menarche and menopause, are largely missing in the current fertility app design, which primarily focuses on conception. But even conception itself is entangled with multiple life transitions: from TTA to TTC, being pregnant, miscarriage, and breastfeeding. These transitions are entangled with broader changes in peoples’ lives requiring users to collect and analyze their data across different stages and events holistically. Some transitions can be planned (avoiding or trying to conceive), some can be expected (from teenage to reproductive years to menopause), and others just happen (eg, miscarriage). Finally, the reproductive years are not constant nor homogenous: it is typically the longest fertility stage of the lives of people with periods, so it is unreasonable to assume fertility will be constant during this time (eg, changes in birth control methods can impact the menstrual cycle). It is also unreasonable to assume that every person with periods will have the same experiences. People have different genders and sexualities, have health conditions affecting fertility (eg, PCOS and endometriosis), and use different conception methods (eg, IVF and egg/sperm donation), and more. These differences suggest that, although other self-tracking domains also strongly benefit from holistic tracking, fertility may intrinsically require it. For example, food tracking often includes different goals such as to manage weight,⁵¹ understand IBS symptoms,⁵² and recover from eating disorders.⁵³ However, it is less likely for a person to experience all of these food tracking goals throughout their lifetime, while people typically pass through many goals, life-stages, and events when tracking for fertility. Biological changes do alter people’s food goals, such as changing metabolism, but common biologically-influenced changes in fertility goals can be more drastic and happen in a shorter time (eg, from TTA to TTC, to breastfeeding, and to TTA again potentially in a rel-

atively short time). Thus, fertility app users may need a holistic approach because their goals and situations change more frequently in response to factors inside and outside of their control. Supporting different goals, life-stages, and events can all benefit from the same self-tracked data, but this analysis shows apps are still focused on goal-directed uses, particularly the ones society still associates with women (ie, conceiving).

Designing for holistic tracking

Ideally, holistic tracking should include long-term, extensive, but flexible data tracking. This study’s results indicate people value the capability of storing long-term data, but they typically do not want to track all available health indicators at once. Instead, they prefer personalized tracking for their current and individualized needs. Currently, users have limited control over data collection: they can choose what to track but only within the possibilities offered by the apps. Beyond offering extensive lists of indicators, app developers could learn from flexible tracking configuration tools⁵⁴ offering people the possibility of creating their own fields and defining how they will track them (eg, selection, quantities, and text). Because such extensive customization may be burdensome to some users, app developers should keep offering the current default data collection options for users who do not wish to configure their tracking and examine how to make such options as inclusive as possible. As these findings indicate, people may also appropriate apps initially designed for fertility tracking to manage their overall health. Although they were not the focus of this study, current mainstream health tracking apps (eg, Apple Health⁵⁵ and Fitbit⁵⁶) have begun to include the ability to track fertility indicators such as menstruation. These apps can aggregate data from multiple apps or incorporate and integrate tracked data about other health aspects such as diet and activity. Although such initiatives may suggest recognition of fertility as an important health factor and efforts to support holistic tracking, such apps tend offer more limited options of fertility data collection and limited visualizations analyzing such data than the ones offered by apps dedicated to fertility. Therefore, it might be useful for fertility apps to support tracking of custom and non-fertility indicators that might be influenced by fertility cycles, such as mood, physical activity, and sleep. Doing so may support people who menstruate to track and see their overall health holistically, giving them the opportunity to connect their patterns of behaviors with fertility cycles if they desire.

Broader discussions have approached the difference between “data about me” and “my data:” people often have limited control over their own personal data generated through interactions with digital infrastructure.⁵⁷ Similarly, fertility apps enable people to generate extensive data about themselves, but tend not to give people enough control over these data or how to visualize them. They usually cannot manipulate these data the way they want or choose how to analyze, compare, and visualize data at different levels of detail. The feedback they receive is pre-defined and often generic. Tracking feedback might be provided in two ways to support holistic tracking. First, tracking tools should provide a full view of the cycle (besides the current monthly view) and allow cycle-to-cycle comparisons to allow people to compare their cycle length, symptoms, mood, and other indicators across cycles. Second, people should be able to reconfigure feedback to their specific goals. For example, the frequently included temperature view assumes that people will measure temperature daily and input the data. However, the burden of doing so may make it only worthwhile for those with

TTC or TTA goals. Customizable graphs can provide more support for users with a variety of goals, supporting pattern recognition by allowing users decide the type of graph and plotted indicators. Fertility apps can draw inspiration from information visualization studies focused on democratization of visualization tools^{58,59} and self-experimentation research aiming to support users' exploration of personal data.^{52,60} Both can provide insights for visualizations that allow users to experiment^{52,61} and make sense of their "*personally meaningful data*."⁵⁹ For example, customizable graphs can be built from building blocks⁵⁸ provided to users so they can generate their own visualizations and associations of health-related events, indicators, symptoms,^{52,61} or contextual information.⁶⁰ Finally, apps should enable people to further customize their interfaces to better match their different goals and transitions between them. For example, apps could confirm a person's current goal when they do not track periods for some time (which might indicate pregnancy, for example). Apps could allow users to indicate a miscarriage and halt references to the lost pregnancy, and also allow resetting predictions. To do so, apps could leverage data from before the pregnancy, taking care to avoid interpreting the miscarriage as a very long cycle. Apps could also provide ways for users to configure predictions (eg, people TTA may want more conservative predictions, while people TTC may need more accurate ones⁸) and allow users to hide and add indicators and visualizations to match their needs.

Limitations

Leveraging user reviews to investigate people's needs and challenges has inherent limitations: they provide only snippets of people's experiences and may be biased toward people who are willing to share their experiences. This method was used to assess user real-life experiences related to many different fertility stages, goals, and events (eg, TTC, breastfeeding, and miscarriage) at a scale and provide enough description of how the app landscape supports them. It was a practical way to capture these experiences over time in ways other methods may not. Future laboratory or field studies of peoples' experiences with these apps can provide further understanding of people's lived experiences with app use under the specific circumstances a person is experiencing. Finally, although the keyword *fertility* used to select eligible apps is a broad term, other keywords produced similar results. The differences were minor and the divergent apps were excluded to keep the data set consistent.

CONCLUSION

Fertility influences and is influenced by many health aspects and spans major transitions in the lives of people who menstruate. Although most fertility apps emphasize comprehensive support for multiple goals, they mainly support goal-oriented uses such as TTC. However, people want to use these tools in more holistic ways, storing long-term data and using these data for different life-stages, goals, life events, and transitions among them. Consequently, there are design modifications that can better accommodate these needs in more flexible ways, allowing better ways for people to meet their goals, and derive longer term benefit from the data they collect.

FUNDING

This work was supported in part by the University of California, Irvine Donald Bren School of Information and Computer Science through the 2020 Exploration Award. It was also partially sup-

ported by the National Science Foundation through grant IIS-1850389, awarded to Daniel A. Epstein. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Science Foundation or other funding bodies.

AUTHOR CONTRIBUTIONS

MCF provided substantial contributions to the conception or design of the work and to the acquisition, analysis, and interpretation of data for the work; drafted the work; and revised it critically for important intellectual content. TH and AT provided substantial contributions to the acquisition, analysis, and interpretation of data for the work and drafted the work. DAE and YC provided substantial contributions to the conception or design of the work and to the acquisition, analysis, or interpretation of data for the work; and revised it critically for important intellectual content. All authors provided final approval of the version to be published and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

ACKNOWLEDGEMENTS

We gratefully thank Sean Victory and Zhaoxian Hu for the excellent work in generating the lists of apps from both stores and support in the initial stages of this study.

CONFLICT OF INTEREST

The authors have no competing interests to declare.

DATA AVAILABILITY

The data underlying this article cannot be shared publicly for the privacy of individuals who wrote the reviews. The data will be shared on reasonable request to the corresponding author.

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