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Exploring FemTech Affordances: A Computational Analysis of Fertility and Pregnancy Apps

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Short Paper

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Abstract

FemTech applications are mobile applications designed to promote women's health and wellness. They have gained increasing attention with a growing market share in the digital health industry. However, most of the existing products seem to be digital health apps with pink-themed design, but not oriented to female users or female-specific illnesses. To improve the understanding of FemTech apps, this study aims to explore the different types of affordances appearing in FemTech apps, through an analysis of user reviews of fertility and pregnancy apps. We applied topic modelling analysis on the data collected and extracted three types of affordances: instrumental, experiential, and empowerment. Our findings suggest that FemTech designers can consider these affordances to meet female users' expectations better and improve their experience. Furthermore, our study sheds light on the potential of FemTech in promoting female empowerment, which could inspire future research in this field.

Keywords: FemTech, machine learning, topic modelling, app reviews, affordance

Introduction

FemTech is an emerging discipline in digital health, which refers to a growing industry of software, diagnostics, services, and solutions that uses technology to address female health challenges(Faubion, 2021; Taylor, 2020). Today, with the wide adoption of mobile phones, a large percentage of FemTech solutions are delivered via mobile applications (apps), including detecting female illnesses, health behavior tracking, disease management, and health prediction(Krishnamurti et al., 2022; Taylor, 2020). This study adopts the definition of FemTech given by Faubion (2021), which limits FemTech to mobile digital services and solutions to help females achieve better health outcomes.

Many studies indicate that the high market potential of FemTech comes not only from investors' optimistic attitudes towards the field, but also from the high acceptance of digital health among its target users. According to The Economist (2021), global venture capitalists have invested nearly $1.2 billion in the FemTech sector through October 2021, double the amount invested in 2019. Numerous data also points to

FemTech's market share reaching around US$60 billion by 2027 (Global Market Insights, 2022). Furthermore, for a long time, women have been underrepresented and at a disadvantage in the digital health field, especially women from minority racial or ethnic backgrounds, who are more affected by gender inequalities in the general digital health design and therefore face less access and exclusion (Figueroa et al., 2021). Therefore, as an application focusing on women's health issues, FemTech is reasonably expected to be used to address gender disparity in digital health, and to improve women's health outcomes and quality of life.

Although the estimated market size of FemTech is boosting, and it is considered capable of bridging some gaps that are not addressed by biopharmaceutical and medical device industries yet, most so-called "FemTech" apps are not genuinely oriented by women's health expectations. They are only under the guise of "pink design", i.e., with pink color and other female-appealing user interfaces. Meanwhile, how to better design a FemTech solution that addresses the unique needs of female users is not clear. Some recent studies have proposed insights on how to improve FemTech to echo female's privacy concerns and uncertainty about the given medical advice from ethical and health perspectives (e.g., Jacobs & Evers, 2023; Krishnamurti et al., 2022), but there is limited research on what affordances FemTech products provide to users and how users perceive these affordances.

To improve the understanding of this emerging field in digital health, this research-in-progress study aims to explore the different types of affordances appearing in FemTech apps. Guided by IS affordances theory (Pozzi et al., 2014), we analyse user reviews of Fertility & Pregnancy apps in the Apple App store. We follow a computational inductive theory-building approach to identify the key affordances in FemTech apps that facilitate better health outcomes for women and empower them to address gender-specific health conditions.

Literature Review

FemTech

Throughout women's lifetimes, there are different health problems and physiological changes at different ages due to estrogen and progesterone fluctuation, making women's health issues unique. The term *FemTech* is initially proposed by Ida Tin, the inventor of the period tracking app Clue, in 2016. Now consisting of a broader range of digital health products designed for women's health risks and concerns, FemTech compensates for the field's long-standing disregard for women's disorders. FemTech used to have a very broad meaning, referring to all subjects that leverage technologies to support female health (McMillan, 2022), such as sustainable sanitary products and antimicrobial safepad (French et al., 2022). With the continuous digitization of health care and FemTech's consistent advancement in mobile technology, more academics are now willing to describe this term as internet-connected products and services designed to satisfy female health needs (Faubion, 2021; French et al., 2022). As mentioned earlier, the market value of FemTech has been highly anticipated by investors, however, this industry actually received only 3% of all health-tech funding in the global digital health scope (McKinsey & Company, 2022; The Economist, 2021). In other words, although the estimated market size of FemTech is boosting, it is still underrepresented compared with other digital health technologies.

There is some skepticism of the industry. The current design of FemTech is not women-centered, making its industry positioning vulnerable, being challenged by general digital health technology. As claimed by Roetman (2020) and McMillan (2022), the male gaze and the lack of female perspective inevitably emerge throughout male-dominated realms, and the result of this situation is that women's real needs are being overlooked. As FemTech relies on IT and information systems to fulfill its functions, it also falls into a male-dominated field. Consequently, ignoring women's fundamental health needs and leading to negative value orientations, could very likely occur in the design and use of FemTech. Moreover, privacy protection is another serious problem faced by FemTech artifacts. The data collected by FemTech is sensitive for females such as period cycle date and reproductive plans, so the data protection for FemTech should be more stringent. However, according to the research of Erickson et al. (2022), FemTech is encountering threats from third parties' misuse and abuse due to their promotional and marketing purposes, and few of FemTech has encryption to protect users' data which means user's personal information is viewable to everyone with proper network analysis tools.

As a result, rather than merely copying the design characteristics of general digital health, FemTech, as a digital health technology designed exclusively for women, should thoroughly react to target users' demands and provide high-quality expert support. While it is acknowledged that existing FemTech apps rely mostly on manual entry of body data, and incorrect or incomplete input of body data will result in the application's incapacity to effectively analyze body conditions (Rosas, 2019). Hence, whether some female severe illnesses may totally rely on FemTech for successful monitoring and prevention merits more discussion.

Technology Affordances

The concept of affordance was first introduced by Gibson (1977) in the field of psychology. Affordances of a subject (e.g., environment and objects) are what it offers to the other subject (e.g., people and animals). Humans directly interact with objects by perceiving what the objects offer to them and achieve the results of the interaction, such as operability and usability (Gibson, 1977). Further research suggests that affordances can be created and influenced by both humans and objects (Stoffregen, 2003). When the affordance is the interaction results, it may change since the factors (i.e., humans or objects) that influence the interaction can vary (Chemero, 2003).

In the field of Information Systems (IS), the two sides of the interaction are humans and IT artifacts. Humans choose to interact with IT artifacts only because they perceive the positive affordances (Leonardi, 2011). Affordances are not the same as the features of IT artifacts (Markus & Silver, 2008); instead, they are enabled by the feature when humans interact with IT artifacts (Volkoff & Strong, 2017).

The affordances of mobile apps have also been investigated in the IS literature. Sundar et al. (2012) identified three affordances of modern media surfaces: navigability, interactivity, and customization. Kaptelinin and Nardi (2012) classified Human-Computer Interaction (HCI) affordances into two categories: instrumental affordances, such as handling, and supplemental affordances, such as maintenance. Technology is seen as a mediational instrument that helps to realize the interaction between humans and objects, so there exists an affordance of operation between humans and technology, which is described as handling. Fang (2019) identified five app affordances for branded mobile apps, including visibility, persistence, interactivity, association, and selectivity, which aim to promote brands and establish user loyalty. Lee et al. (2021) argued that virtual role-playing games had three affordances: achievement, socialization, and immersion. Although there is a lack of IS affordance studies in the context of digital health, previous research has identified affordances in the context of general wellness management, such as promoting goals, comparing oneself to others, coaching, and nurturing (Alshawmar et al., 2021). Researchers also proposed a list of generic affordances of mHealth, including perceived connective, perceived utilitarian and perceived hedonic affordances (Liu et al., 2021).

Despite the different terms and contexts, existing literature has pointed to two major categories of affordances that facilitates users to achieve fundamental health goals (*instrumental affordances*) and enrich their experience with digital apps (*experiential affordances*). The affordances of FemTech are rarely studied, but it has been addressed that FemTech products could assist females in realizing birth control by helping users understand their fertility pattern (Sudjic, 2018). Thus, as a digital mediation, it is expected that FemTech can provide users with instrumental and experiential affordances to further enhance females' health outcomes. In this study, we aim to explore the instrumental and experiential affordances provided by FemTech apps.

Methodology

In this study, we followed a computational theory-building approach (Miranda et al., 2022) to apply topic modelling analysis on FemTech app reviews and identify key topics that are related to the expression of affordances and specific features.

In app reviews, users reflect their experience of using an app or particular feature. Hence, app reviews are not only plain using descriptions, but reflect on the interaction between users and the IT artefact—that is, the affordances. In particular, our study focuses on the Fertility & Pregnancy FemTech apps, as they are the most common types of FemTech apps in the market. Fertility and pregnancy are the most popular category of FemTech apps, with more than 100 million active female users track and manage their bodies via these apps (Kresge et al., 2019), therefore allowing us to obtain a sufficient number of reviews for analysis. Existing FemTech research also pays attention to mobile apps that assist women with fertility issues, and

these studies have indeed identified areas for improvement in these types of mobile apps, such as ethical concerns and behavioral problems embedded in these kinds of FemTech apps (e.g., Erickson et al., 2022; Hendl & Jansky, 2022).

We conducted our data analysis following Nelson's (2020) framework of computational grounded theory. In step 1, we collected and cleaned the data and established the initial LDA analysis model to obtain the preliminary results. According to Blei (2012), an LDA method could be chosen in this study because it has proven to be highly effective in identifying latent topics within large textual datasets. LDA's notable features, including scalability, robustness, and interpretability, make it an ideal tool for analyzing text data in various contexts. In step 2, we refined our LDA model regards to the analysis results from step one until the generated topics could be identified and summarized. Then, we exported the refined model and conducted data analysis again. The analysis results help us to categorize the topics hiding behind the user's app reviews. Guided by the technology affordance theory, we summarized the topics and further classified them according to different digital affordances in step 3. In this research-in-progress paper, we reported our preliminary results from steps 1 and 2, and complete results would be reported after step 3.

Data Collection

We first used the computational scrap method to filter all English-language FemTech Fertility & Pregnancy relevant apps based on our search terms shown in Table 1 from six Apple app store categories that are related to female health. Within them, the returned search results were further filtered by checking whether the apps' descriptions consisted of the required description terms or not. All search categories and terms are shown as Table 1.

iOS-APP Categories	Search Terms	Description Terms
education, food-drink, health-fitness, lifestyle, medical, social networking	"period", "fertility", "ovulation", "menstrual", "pregnancy", "menstrual cycle", "track my cycle", "period track", "period calendar", "sexual education", "sexual health", "femtech"	"woman", "women", "girl", "female", "females", "fertility", "pregnancy"

Table 1. Search Categories and Terms

For each selected app, we exported all the "most helpful reviews" of these apps. If an app has more than 100 "most helpful reviews", we select the top 100 reviews. 4633 customer review data of the 142 apps were kept for further analysis.

Data Cleaning and Preparation

In the process of cleaning the text data, we only kept the titles and body text of the app reviews. Then, we processed the data by removing non-English characters, stopwords, spaces, and by converting the text to lowercase and tokenizing it. After that, we tagged the vocabularies of all reviews and filtered all words that could reflect users' expected affordances, which are nouns, verbs and adverbs, because we would like to identify how FemTech users interact with these apps. Since the sentiment analysis is not included in our research scope, we removed the adjectives, such as "good" and "great", to focus on the affordances analysis. These cleaning and processing steps were performed by the natural language processing library spaCy, which minimized the shortcomings of manual operations. Once this step was completed, we imported the organized text into the designed LDA model for topic modeling analysis.

Data Analysis

Topic Modelling by LDA

Topic modelling is an algorithm based on machine learning methods, which could be used to categorize and summarize the underlying thematic structure in large volumes of textual information. This method not only

solves the heavy workload that coders may face when dealing with large datasets, but also helps researchers to more easily discover topics that are difficult to be manually recognized (DiMaggio et al., 2013).

For conducting the analysis based on the topic modelling algorithm, in this study, we follow Blei's (2012) statements on the intuition behind LDA that textual data is composed of multiple topics, every vocabulary that composes the large document belongs to a certain topic, and the fitted topics could be confirmed for their validity through illustrative interpretation. Therefore, since LDA has the capability to generate topics in large text data, we import this method to analyze the implied topics in the content of reviews on fertility & pregnancy apps. By categorizing and summarizing these topics and conducting further coding work, we have discovered the major affordances of the apps.

We use the visualization tool pyLDAvis to compare the results generated from topic numbers from 10 to 50. The model which leads to results with higher interpretability, better consistency, better distribution and less overlapping in topics is selected for coding and further analysis. According to the visualization result, the LDA model with topic number 44 is chosen (Figure 1). By interpreting the terms generated by each topic, we assign labels to the topics and the most relevant ones are shown in Table 2.

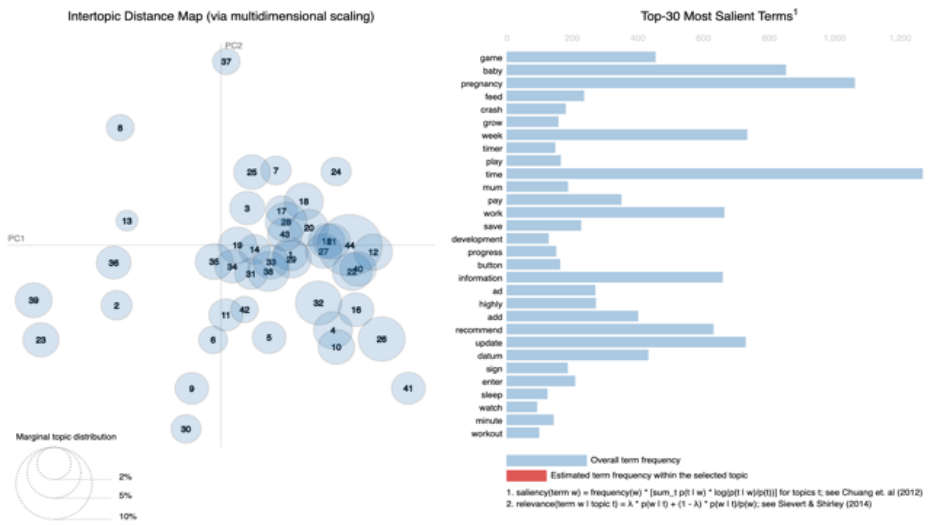

Figure 1. Visualization of Topic Modelling Results

Topic Number	Sample Topic Terms	Topics
6	"button", "wheel", "alarm"	Interactivity
38	"sign", "look", "scroll"	
33	"use", "resolve", "work"	Usability (reliability)
8	"info", "password", "process"	Usability (accessibility)
16	"glitch", "time", "ad"	Usability (unreliability)
35	"error", "log", "issue"	
27	"timer", "time", "minute"	Tracking
37	"cycle", "track", "update"	
11	"guidance", "description", "answer"	Guiding
36	"game", "try", "love"	Gamification

Table 2. Results from Topic Modelling

Table 2 indicates that the analysis identified a major topic related to app interface design, with the most frequently used words being "button" and "alarm". Users emphasize the importance of interacting with

these design features, such as “sign” and “scroll”, to achieve the intended interactive purposes. Therefore, topics 6 and 38 are labelled as "Interactivity". Topic 33, with terms like “use”, “resolve”, and “work”, prove that FemTech is reliable and useful in addressing users' health concerns. Topic 8 includes terms like “password” and “process”, indicating that FemTech has design features that facilitate user access. However, some users express their dissatisfaction with current FemTech, using terms like “glitch”, “error”, and “issue” to highlight its unreliability and the need for further usability improvements. As a result, Topic 33 is labelled as “Usability (reliability)” and Topic 8 as “Usability (accessibility)”. Topics that contain complaints are marked as “Usability (unreliability)”. It is unsurprising that many frequently mentioned terms, such as “cycle”, “minute”, and “track”, relate to tracking bodily states since most users adopt Fertility & Pregnancy FemTech apps for this purpose. Therefore, topics 27 and 37, which contain the most relevant terms related to state tracking, are labelled as “Tracking”. Additionally, some topics are found to be related to app design features such as guidance and gamification. Therefore, topic 11, which contains terms like “guidance”, “description”, and “answer”, is labelled as “Guiding”, and topic 36, which contains terms like “game”, “try”, and “love”, is labelled as “Gamification”.

Identifying Additional Topics

During the model training process, although some generated topics might not be interpretable, some terms with high weights caught our attention, such as “remind”, “community” and “nurturing”. Therefore, in addition to LDA-generated topics, we further analyse some significant terms which have not been explained by the emerged topics. In particular, we retrieved the app reviews where these terms appeared and interpreted the meaning of the reviews with the affordance lens.

For term “remind”, there were 145 reviews mentioned this term, and most of them expressed the reminding function of Fertility & Pregnancy FemTech apps. In these reviews, some expressed their love for the reminder functions, while others expressed their wish for a reminder function. For example: “*I especially love the alerts to remind me if my period has started or ended to then support predictions thereon.”* All these reviews indicate that FemTech apps have great contributions to satisfying users’ health needs for reminding. Thus, we conclude that *reminding* is another topic that needs to be included in the analysis.

The term “community” appeared in 116 reviews. Most of them showed a positive attitude towards the community support that FemTech apps provided. Especially, many apps’ communities could not only offer peer support for fertility and pregnancy-related concerns, but also users could achieve some other daily socialization support from community members. For example: *“The community is really good and everyone is really understanding and open - good for any awkward or embarrassing questions you might not want to ask your doctor.”* Thus, it is imperative to include *peer-support* for the analysis.

Although the term “nurturing” was only mentioned in 3 reviews, some valuable reviews helped us to notice the potential *self-nurturing* affordance provided by FemTech. For example: *“I love that this app it allows me the space to capture ways that I have nurtured myself through the month and to deeply reflect on how I have been living within my cycle. It is simple to use and beauty-full to look at.”*

Results Discussion

As in most of the mHealth and wellness management studies, salient instrumental affordances were identified in FemTech apps from our analysis, which was shown to support users' development and management of their own health. In particular, our result shows tracking, guiding and reminding are the most significant affordances identified. These affordances could be realized during users directly interact with FemTech apps, so they have a strong functional directionality and could be directly enabled by the features of FemTech apps.

Our analysis also reveals multiple experiential affordances of FemTech apps, which focuses on better user experience and engagement with the apps. Some specific affordances include interactivity, usability, and gamification. Experiential affordances focus more on users feelings and usage experience, and they provide hedonic value to users when interacting with the apps.

Fertility & Pregnancy FemTech, which specifically serves women’s reproductive and maternal health, also provides additional empowerment affordances to users. Female empowerment is explained as the effort to help females have greater control over their health, self-development and social status by providing them

opportunities, resources and power (Mosedale, 2005). From the data analysis, we surprisedly identified peer-support and self-nurturing affordances. For fertility-related FemTech technologies, they enhance females' self-surveillance by digitalizing body status, which allows females to better manage their health status during pregnancy (Mishra & Suresh, 2021). Some FemTech apps claim that they would support female users' empowerment, such as better understanding and control over self-body and protect females' ownership towards fertility (Hendl & Jansky, 2022). These affordances truly serve females, allowing them to benefit not only in health, but also to achieve further progress in such as personal growth and self-confidence, which certainly enhance females' quality of life and empowerment. A summary of the preliminary findings is shown in Figure 2 below.

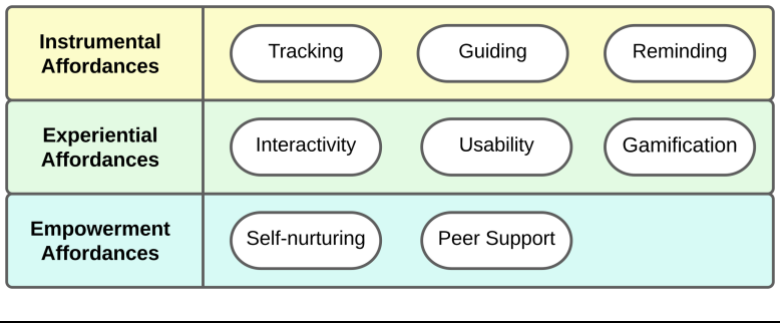

Figure 2. Preliminary Findings

Potential Contribution and Next Step

In this research-in-progress study, we identified major affordances of FemTech from users' reviews of Fertility & Pregnancy FemTech apps. We found that in addition to instrumental and experiential affordances, empowerment is an important category of affordances in FemTech products. Prior research also pointed out the potential value of FemTech is to provide a female-oriented digital health management space (Lupton & Maslen, 2019). Despite the identification of self-nurturing and peer support in the data, we also found that empowerment affordances are less reflected in users' reviews. One possible reason is that existing FemTech solutions are not oriented to provide empowerment affordance to users, thus, fewer users have experienced empowerment affordance through interacting with the apps.

As a research-in-progress project, the study has its limitations. First of all, app reviews are highly subjective, and the quality of review content varies greatly. Since the amount of data we collected is large, it could help us to make some amends for this issue. Second, regarding the data selection, we only chose the FemTech app related to fertility and pregnancy. We may extend our analysis to other types of FemTech, such as menopause management and female-specific fitness apps.

This study not only helped us to better understand the development status of the FemTech industry and users' attitudes and expectations of FemTech apps, but also revealed the enormous potential of FemTech in female empowerment. Two implications are proposed by this study. First, our findings can influence the current design of FemTech products. Our study could prompt the FemTech industry to re-evaluate product design and place greater focus on features that provide empowerment affordances, enabling the industry to better meet the needs of female users and deliver a more empowering user experience. Second, this research can transform the current landscape of digital health. Our study highlights the potential of FemTech in empowering females, supporting the initiative of women-oriented digital health. The findings urge policymakers and professionals to prioritize the needs of women in the digital health realm and support the development of more empowering and inclusive solutions.

The next step of the study involves analyzing and coding the features of the selected apps and establishing the connection between features and affordances. We will especially focus on the features that could lead to empowerment affordance. Our findings hopefully could help FemTech industry to examine the feature design and rethink how to truly serve females based on the above-given affordances.

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