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Using Machine Learning and Thematic Analysis Methods to Evaluate Mental Health Apps Based on User Reviews

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ABSTRACT The proliferation of smartphones has led to an increase in mobile health (mHealth) apps over the years. Thus, it is imperative to evaluate these apps by identifying shortcomings or barriers hampering effective delivery of intended services. In this paper, we evaluate 104 mental health apps on Google Play and App Store by performing sentiment analysis of 88125 user reviews using machine learning (ML), and then conducting thematic analysis on the reviews. We implement and compare the performance of five classifiers using supervised ML algorithms that are widely used for solving classification problems. The best performing classifier, with F1-score of 89.42%, was then used in predicting the sentiment polarity of reviews. Next, we conduct a thematic analysis of positive and negative reviews to identify themes representing various factors affecting the effectiveness of mental health apps positively and negatively. Our results uncover 21 negative themes and 29 positive themes. The negative themes fall under the following categories: *usability issues*, *content issues*, *ethical issues*, *customer support issues*, and *billing issues*. Some of the positive themes include *aesthetically pleasing interface*, *app stability*, *customizability*, *high-quality content*, *content variation/diversity*, *personalized content*, *privacy and security*, and *low-subscription cost*. Finally, we offer design recommendations on how the identified negative factors can be tackled to improve the effectiveness of mental health apps.

INDEX TERMS Health, machine learning, mental health, mobile apps, sentiment analysis, thematic analysis, user reviews, wellbeing.

I. INTRODUCTION

The proliferation of smartphones spurred innovation in healthcare over the years, leading to the rapid growth in mobile health (mHealth) apps. Through mHealth interventions, people are increasingly aware and are able to manage various conditions or diseases (such as diabetes, cardiovascular diseases, hypertension, etc.), including mental health conditions, and can effectively prevent or control them. For instance, specialized mHealth apps provide features for tracking symptoms, blood pressure, body mass index, heart-beat rate, sleep rate, nutritional values in foods, and much more [1]. mHealth apps offer users additional opportunities to share collected data with their healthcare professionals for

real-time monitoring, as well as personalize contents to suit their physical and behavioural characteristics [2].

Previous research in mental health interventions investigated the adoption of mobile applications in managing conditions, such as depression, anxiety, stress, eating disorder, psychotic disorder, etc. [3]–[8]. While adoption rate is moderate, there is insufficient research evidence to confirm the efficacy of mental health apps [7], [9] due to rapidly evolving technology [9]. Thus, it is difficult to determine the quality and safety of these apps [10]. However, content analysis of user reviews or comments is an option already adopted by researchers to assess both the benefits and challenges of mental health apps [11], [12]. Machine Learning-based sentiment analysis is another viable approach that offers insight into an mHealth app's effectiveness since negative opinions from users of a mobile app could highlight both quality issues and gaps. Positive opinions, on the other hand, considerably

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relate to the app's success in meeting users' expectations and needs. This approach has been adopted by only a few existing research in mental health domain to the best of our knowledge [13].

In this paper, we evaluate 104 mental health apps on Google Play and App Store by performing sentiment analysis of 88125 user reviews using machine learning approach. The contributions of our work are in three folds. First, we applied the machine learning (ML) techniques to determine sentiment polarity (*positive* or *negative*) of user reviews. We implemented and compared the performance of five classifiers using supervised ML algorithms which are widely used for solving classification problems. The algorithms include Support Vector Machine (SVM), Multinomial Naïve Bayes (MNB), Stochastic Gradient Descent (SGD), Logistic Regression (LR), and Random Forest (RF). We used the best performing classifier to predict the sentiment polarity of reviews. Second, to uncover more insights, we conducted thematic analysis of both positive and negative reviews to identify the factors affecting the effectiveness of mental health apps positively and negatively. Finally, we offer design recommendations on how the identified negative factors can be tackled to improve the effectiveness of mental health apps.

II. RELATED WORK

Over the years, research has applied sentiment analysis on mHealth app reviews and social media data to understand user opinions or perceptions. Greaves *et al.* [14] applied the machine learning (ML) technique to classify healthcare-related online comments into negative and positive sentiments to understand patients' perception about their care. Furthermore, Du *et al.* [15] extract people's opinions about Human papillomavirus (HPV) vaccines on Twitter using ML-based sentiment analysis. They leveraged the Support Vector Machine (SVM) algorithm to classify tweets. Chang *et al.* [16] used Weibo data to train an SVM classifier to determine whether a user is having suicide risk or emotional distress. Yadav *et al.* [17] utilized the convolutional neural network (CNN) approach to identify different forms of medical sentiments that can be inferred from users' medical conditions and treatments based on social media data. Lim *et al.* [18], on the other hand, leveraged a pre-trained sentiment analysis ML model, *SentiStrength*, to determine the sentiment scores of tweets. Pai *et al.* [13] performed sentiment analysis on Twitter comments using RStudio to assess user perception towards four categories of mHealth apps: fitness, diabetes, meditation, and cancer. They utilized their results in describing the causal relationships between accessibility and acceptability of mHealth apps. Furthermore, Park *et al.* [19] developed a gender detection model to understand how AIDS patients' online conversations differ along gender lines using sentiment analysis. Their model is based on the deep learning's CNN approach.

To uncover more insights, Nicholas *et al.* [11] conducted thematic analysis of user reviews for 48 bipolar disorder apps on Google Play and App Store. Their goal is to identify

unmet needs and understand user expectations. Similarly, Park *et al.* [20] identified three themes after conducting thematic analysis of 20 medication adherence apps with the aim of exploring users' perspective and experiences. Workewych *et al.* [21] also leveraged thematic analysis to detect themes that reveal mixed perceptions about traumatic brain injuries in sports using Twitter data.

In this paper, we utilized both machine learning-based sentiment analysis and thematic analysis to identify negative and positive factors affecting the effectiveness of mental health apps. In addition, we offer design recommendations based on the positive factors to address the negative issues.

III. METHODOLOGY

The main objective of this paper is to determine the various factors affecting the effectiveness of mental health apps positively and negatively. To achieve this, we employed well-known computational techniques which are summarized below:

- 1) We collected or mined user reviews for 105 mental health apps on both Google Play and App Store using Heedzy tool [22].
- 2) We applied natural language processing techniques to preprocess the data and prepare it for analysis.
- 3) We prepared ground truth data by automatically annotating reviews based on user ratings.
- 4) We vectorized the reviews (ground truth) using the Term Frequency-Inverse Document Frequency (TF-IDF) weighting technique.
- 5) We developed five supervised machine learning classifiers for predicting sentiment polarity (*positive* or *negative*) of reviews.
- 6) We trained the classifiers by performing a binary classification experiment with 10-fold cross validation using the vectorized ground truth data.
- 7) We used the best performing classifier to predict the sentiment polarity of unlabelled or unannotated reviews.
- 8) We conducted thematic analysis on positive and negative reviews using NVivo 12 (Plus Edition) qualitative analysis tool [23].

A. DATA COLLECTION

To identify eligible apps, we first performed a search on Google Play (for Android apps) and App Store (for iOS apps) using relevant keywords such as *anxiety*, *stress*, *depression*, *emotion*, *mental health*, and *mood*. We got a total of 183 and 254 apps from Google Play and App Store respectively as search results. Secondly, we excluded apps whose description does not relate to mental health, apps with less than five user reviews, and non-English apps. Afterwards, we collected 101715 user reviews for 105 eligible apps using the Heedzy tool [22]. If an app is published on both Google Play and App Store, we merged the reviews on both platforms. Table 1 shows some of the mental health apps and the corresponding number of reviews.

TABLE 1. Sample apps, supported platforms, and total reviews.

App	Platform	Total Reviews
PTSD Coach	Android and iOS	119
Happify	Android and iOS	1786
HeadSpace	Android and iOS	21605
Calm	Android and iOS	9012
MoodKit	iOS	302
Depressed	Android	494
Depression CBT Self-Help Guide	Android	360
Stop Panic & Anxiety Self-Help	iOS	766
Daylio	Android and iOS	17581
Mindfulness Daily	Android	500

B. DATA PREPROCESSING

Next, we prepared the data for analysis by performing the following preprocessing tasks using natural language processing (NLP) techniques:

- 1) Remove punctuation, special characters, and extra whitespaces
- 2) Reduce repeated characters (e.g., “toooo gooooo” becomes “too good”)
- 3) Remove numbers
- 4) Replace slangs with English words using online slang dictionaries [24], [25] which contain 5434 entries combined
- 5) Expand contractions (e.g., “oughtn’t” becomes “ought not”, “there’s” becomes “there is”, etc.)
- 6) Convert words to lowercase
- 7) Remove stopwords (e.g., the, an, will, shall, let, may, can, it, with, of, this, and, as, etc.)
- 8) Lemmatize words using the *WordNet Lemmatizer* (which is part of the *nlk* module of Python and uses WordNet [26] behind the scene) so that words can be converted to their root form (e.g., “better” becomes “good”, “regretted” becomes “regret”, etc.)
- 9) Remove duplicates

After preprocessing, the total number of reviews reduced to 88125.

C. DATA ANNOTATION

Next, we prepare ground truth dataset by annotating the reviews as either *positive*, *negative*, or *neutral*. On Google Play and App Store, each app user can assign a star rating on the scale of 1 to 5 (where 1 star represents *very dissatisfied* and 5 stars represents *very satisfied*). In our dataset, a total of 68247 reviews have user ratings (representing 77.4% of total reviews). Similar to the approach used by existing research [27], [28], we applied the criteria in Table 2 to automatically annotate reviews. Table 3 presents the number of reviews per sentiment polarity after annotation.

TABLE 2. Criteria for annotating reviews based on user ratings.

Rating	Description	Sentiment Polarity
1	Very dissatisfied	Negative
2	Dissatisfied	Negative
3	Okay	Neutral
4	Satisfied	Positive
5	Very satisfied	Positive

TABLE 3. Sentiment polarity and the corresponding number of reviews.

Sentiment Polarity	Total Reviews
Positive	57705
Negative	7051
Neutral	3491

D. DATA VECTORIZATION

Next, we applied the Bag of Words (BOW) approach which involves extracting unique words from our corpus (i.e., collection of user reviews in the ground truth dataset) and vectorizing each document (i.e., each review). We extracted unigrams and vectorized the documents using Term Frequency-Inverse Document Frequency (TF-IDF) technique since it considers both frequency and relevance when assigning weight to terms or words [29].

E. SENTIMENT CLASSIFICATION

Next, we develop machine learning (ML) models to classify user reviews into either *positive* or *negative* sentiment polarity since our goal is to identify positive and negative factors affecting the effectiveness of mental health apps. Our approach aligns with existing research which defines sentiment classification as a “*two-class classification problem, positive and negative*” [30] and also as a technique that “*determines whether a document or sentence is opinionated, and if so whether it carries a positive or negative opinion*” [31]. We implemented the models/classifiers using five supervised ML algorithms widely used for text classification problems. The algorithms are Support Vector Machine (SVM), Multinomial Naïve Bayes (MNB), Stochastic Gradient Descent (SGD), Logistic Regression (LR), and Random Forest (RF). We trained and evaluated each model on the vectorized documents by performing a 10-fold cross-validation experiment. We compared their performance using four evaluation metrics: *accuracy*, *precision*, *recall*, and *F1* score [32]. F1 score (or F measure) is a preferred measure since it is the harmonic mean of precision and recall, hence taking into account the impact of each class on the overall score.

To handle imbalance in our training set, we applied the *cleaning under-sampling* technique which reduces the majority class by randomly selecting samples without replacement [33]. Table 4 shows the number of reviews per polarity before and after the training set is balanced. Hence,

TABLE 4. Balancing training set for binary classification experiment.

Label	Original set	Balanced set
Positive	57705	7051
Negative	7051	7051

TABLE 5. Performance of classifiers.

Classifier	Metrics			
	Accuracy	Precision	Recall	F1
SVM	0.8939	0.8940	0.8939	0.8939
LR	0.8937	0.8938	0.8937	0.8937
MNB	0.8907	0.8908	0.8908	0.8907
SGD	0.8943	0.8945	0.8943	0.8942
RF	0.8769	0.8769	0.8770	0.8769

TABLE 6. Classification performance by sentiment polarity.

Classifier	Polarity	Metrics		
		Precision	Recall	F1
SVM	Positive	0.901	0.886	0.892
	Negative	0.887	0.902	0.894
LR	Positive	0.901	0.884	0.893
	Negative	0.888	0.901	0.894
MNB	Positive	0.883	0.898	0.892
	Negative	0.898	0.882	0.889
SGD	Positive	0.902	0.887	0.893
	Negative	0.890	0.906	0.897
RF	Positive	0.875	0.880	0.879
	Negative	0.880	0.877	0.878

the chance baseline for binary classification is 50% since the training set is balanced.

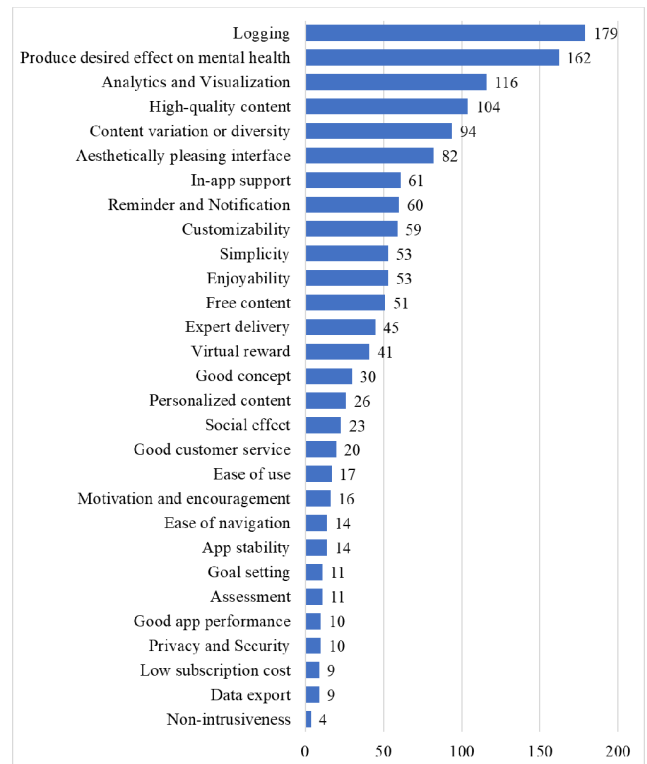
Finally, we used the best performing model to predict sentiment polarity for the user reviews that are not part of the ground truth dataset (n=19878).

F. THEMATIC ANALYSIS

Next, we conducted thematic analysis of both positive and negative reviews to identify the various factors affecting the effectiveness of mental health apps positively and negatively. We used the auto-coding functionality of NVivo 12 (Plus Edition) [23] to automatically detect themes in the reviews. The tool analyzes both the content and sentence structure, and then identify themes that occur most frequently.

IV. RESULTS

As shown in Table 5, all the five classifiers outperformed the chance baseline of 50%. SGD achieved the best overall F1 score of 89.42% overall, closely followed by SVM, LR, and MNB with 89.39%, 89.37%, and 89.07% respectively. Furthermore, Table 6 shows the breakdown of the overall performance of each classifier. SGD achieved a high precision and recall of 90.2% and 88.7% respectively for *positive* reviews. In addition, SGD achieved a high precision and recall of 89% and 90.6% respectively for *negative* reviews. Thus, the SGD classifier was able to correctly predict the sentiment polarity of the reviews with very low error rate.

**FIGURE 1.** Theme categories (y-axis) and the corresponding number of related themes (x-axis) for positive user reviews.

A. SENTIMENT PREDICTION

Next, we applied the best performing ML classifier (i.e., SGD) to classify the 19878 reviews that were not labelled. Based on the prediction results, 14318 reviews were classified as *positive*, while 5560 reviews were classified as *negative*.

B. POSITIVE AND NEGATIVE THEMES

Next, we conducted thematic analysis on positive and negative reviews from both the ground truth dataset (see Table 3) and the newly classified dataset (using the SGD classifier). In total, there are 72023 positive reviews and 12611 negative reviews.

Using the NVivo tool, 5530 unique themes were detected in the positive reviews, while 1749 unique themes were identified in the negative reviews. We further reduced the number of themes after merging or categorizing themes that are closely related, and discarding themes that are generic or meaningless. As a result, 29 theme categories emerged for positive reviews (see Figure 1), while 21 theme categories emerged for negative reviews (see Figure 2). We refer to the theme categories in Figure 1 as “positive themes”, and the theme categories in Figure 2 as “negative themes” in the remaining parts of this paper.

Table 8 (see Appendix section) shows the positive themes, as well as their descriptions and corresponding sample reviews. The positive themes are: *aesthetically pleasing interface*, *customizability*, *free content*, *simplicity*, *low*

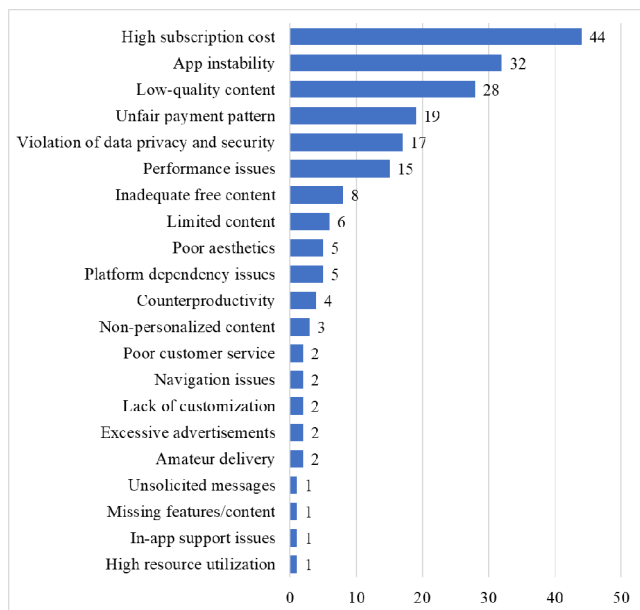


FIGURE 2. Theme categories (y-axis) and the corresponding number of related themes (x-axis) for negative user reviews.

subscription cost, ease of navigation, ease of use, enjoyability, app stability, motivation and encouragement, non-intrusiveness, produce desired effect on mental health, reminder and notification, social effect, in-app support, logging, analytics and visualization, good app performance, content variation or diversity, good concept, good customer service, high-quality content, personalized content, privacy and security, expert delivery, goal setting, virtual reward, assessment, and data export.

On the other hand, Table 9 (see Appendix section) shows the negative themes, including their descriptions and corresponding sample reviews. The negative themes are the following: app instability, low-quality content, unfair payment pattern, violation of data privacy and security, poor aesthetics, navigation issues, excessive advertisements, performance issues, counterproductivity, high subscription cost, poor customer service, unsolicited messages, amateur delivery, lack of customization, inadequate free content, limited content, high resource utilization, missing features/content, in-app support issues, non-personalized content, and platform dependency issues. In Section V, we discuss these negative themes and their implications, and then suggests design guidelines for addressing the negative issues based on the positive factors.

V. DISCUSSION

In this paper, we evaluated mental health apps to determine their effectiveness based on user reviews. Our empirical findings revealed that most of the reviews are positive. This means that most users found mental health apps useful and helpful. However, there are also issues that demotivate users from using these apps, including issues that poses major health risks. Further investigation through thematic analysis (see Tables 8 and 9 in the Appendix section) uncovered various

themes representing factors affecting mental health apps negatively or positively. In this section, we discuss the negative factors in detail, and then offer design recommendations based on the positive factors.

A. FACTORS AFFECTING THE EFFECTIVENESS OF MENTAL HEALTH APPS NEGATIVELY

As shown in Table 7, we further categorize the 21 negative themes (or factors) into usability issues, content issues, privacy and safety issues, cost issues, and customer support issues.

1) USABILITY ISSUES

Usability is the degree to which an app can be used by specified users to achieve their goals/tasks with effectiveness, efficiency, and satisfaction in a specified context of use [34]. Our findings reveal the various interface- and platform-related factors affecting the usability of mental health apps, thereby preventing users from completing their tasks successfully.

- i. *Poor aesthetics*: Research shows that there is a strong correlation between aesthetics and usability [35]. As a result, an app interface that is not visually attractive may be perceived as non-usable by users [36]. As shown in the sample comments below, users complained about the poor layout of interface elements, bad colour scheme, graphics and text rendering issues, and choppy animations of mental health apps. These issues influence users’ decision and make them to discontinue app usage, if not addressed.

“The layout of the application is very poorly designed...The pull-out menu looks gaudy. Please work on a better version!” [R3992]

TABLE 7. Negative themes and the corresponding category.

Negative Theme	Category
Poor aesthetics	Usability Issues
Navigation issues	
App instability	
High resource utilization	
Platform dependency issues	
Lack of customization	
Performance issues	
Low-quality content	Content Issues
Amateur delivery	
Inadequate free contents	
Limited content	
Counterproductivity	
Non-personalized content	Ethical Issues
Missing features/content	
Violation of data privacy and safety	
Excessive advertisements	
Unsolicited messages	Billing Issues
High subscription cost	
Unfair payment pattern	
Poor customer service	
In-app support issues	Customer Support Issues

*“I am using Samsung Note 3 and I am wondering why the **animation is choppy**.” [R20]*

*“... I think it is the **colors that put me off**. Lots of orange, and I really dislike orange...” [R197]*

- ii. *Navigation issues:* The choice of navigation components or controls within an app can affect ease of use [37], [38]. In other words, users with decreased cognitive capabilities will find it difficult to identify which controls (such as menus or buttons) will take them to the desired location. Based on our findings, users encountered difficulty accessing desired features or locations within the app due to missing or non-responsive navigation controls, redirection to wrong location, absence of shortcuts to desired location, etc. Below are sample comments from users:

*“**Terrible navigation**. The icon that looks like a menu button actually backs you out of the application.” [R4627]*

*“... **Navigation is awkward, links do not work**, not sure if I am missing something or that is just all there is. Giving two stars for positive intent, fix the application and I will give more.” [R8837]*

- iii. *App Instability:* Users rely on available app features or functionalities to achieve their goals. However, the presence of bugs can hinder task performance or lead to data loss which eventually render the app unusable, as shown in the comments below.

*“I like the meditations but for some reason when I start playing a session, it will **pause intermittently** and only resume when I touch the screen again. That kind of **defeats the purpose of meditating!** Please fix this bug.” [R3389]*

*“... the application **shown many bugs**... when it does load, it takes me back to the tutorial stage and my **progress is gone**...” [R32]*

- iv. *High resource utilization:* Consuming appropriate amounts and type of resources is critical for app efficiency and user productivity [39]. These resources, from mobile device standpoint, includes battery, internal memory, CPU, disk (memory card or SD card), and network [40]. Our findings revealed that users found excessive resource utilization (such as high battery and internal memory usage) by apps disturbing and unacceptable, as evident in the following comments:

*“Keeps up **eating up the battery**. Uninstalled and battery is back to normal... maybe great application but not for me” [R592]*

*“... The downside of having the application is that it has **taken all my memory on my phone** so I can no longer download updates. Do not know if I can continue with the application” [R479]*

- v. *Platform dependency issues:* While most developers build apps that run on Android and iOS platforms [41], fragmentation across (and within the same)

platforms is a major hurdle that affects app’s stability [42]. As a result, developers worry about supporting multiple versions of the same platform, as well as both platforms’ peculiarities in terms of user interface and experience, interaction metaphors, device properties and supporting tools during development. Therefore, many apps have issues working or rendering properly on certain devices or platforms due to developers’ inability to satisfy all dependencies (see comments below).

*“Always running smoothly on my iPhone but since I switched to Samsung I have been **fairly disappointed**, tonight the **application won’t open** and continuously says its **force stopping**...” [R1056]*

*“The meditations are great, but every few times I use the application it **crashes** and I need to delete the application, redownload it, relogin, and then click through all the introductions again.” [R29]*

- vi. *Lack of customization:* Customization has been shown to enhance users’ self-agency and self-determination [43], [44], thereby influencing continuous engagement with the app. In other words, users will become less motivated and eventually discontinue app use if they are unable to customize/modify the interface or features according to their preferences or taste. As shown in the sample comments below, users are unable to change narrator’s voice (e.g., from male to female) or customize their virtual character (or avatar).

*“Please update. I would like to customize my **avatar**.” [R9791]*

*“Great concept but you **cannot change the narrators voice**...” [R7118]*

- vii. *Performance issues:* Users also complained about the time lag in getting response during app usage. For example, users expressed their frustrations regarding slow loading time and intermittent freezing or unresponsiveness of the interface while scrolling through features or performing target behaviour (e.g., watching meditation videos or playing in-app games), as shown in the comments below. This may be due to the need to download app dependencies or stream contents from the internet or insufficient phone resources (e.g., low internal memory).

*“New version **loads really slow** and **requires internet for most applications**. Liked the previous version better. New version **gets hung up on the opening logo** and **takes over a minute before you can access any program**...” [R800]*

*“**Freezes a lot**. Will not let me watch videos or listen to meditations” [R77]*

*“Recently it is been **scrolling slowly and choppy**. I tried restarting the application and shutting down all background apps but it still persists...” [R323]*

2) CONTENT ISSUES

Research has shown that most mental health apps are lacking in terms of content quality [45]–[47]. Specifically, these apps do not comprehensively address the domain of interest (e.g., bi-polar disorder, depression, anxiety, etc.) with respect to information dissemination, as well as adopting evidence-based preventive and treatment guidelines for self-management. Based on our findings, users of mental health apps complained about low-quality content, delivery of content by amateur coaches or trainers, inadequate free content, counterproductive content, limited content, missing features or content, and non-personalized content.

- i. *Low-quality content:* Users expressed their frustrations over off-topic, basic/regular, and impractical contents, as shown in the sample comments below. In addition, some contents do not consider the abilities of their target audience, thereby rendering them unhelpful. These issues reflect the dearth of evidence-based interventions and clinically validated treatment techniques in most mental health apps [48]–[52] which, in turn, can have adverse effects on patients [53]. Below are some of the user comments:

*“...Also, some of the **courses disappointingly never actually address their supposed topic**, instead just going through the regular meditation technique with no variation or explanation of how to apply it to the particular topic.” [R109]*

*“Just no. I have no interest in listening to a soothing voice explaining what anxiety is, how it effects millions blah blah blah. I thought it was going to be an actual practice to end anxiety, **not a lecture on what anxiety is**. I am here looking for a tool to deal with anxiety – good bet I already know what anxiety is. I am already going through it. I already know millions suffer from it, I already know it is normal, **why would I need to be told this?** Why would anyone?...” [R203]*

*“...The **task descriptions were not created in full or logical sentences**. Was not really a game but more of a to do list which you could just tick off without doing any of it. Uninstalled application within five minutes of having it.” [R738]*

*“There are **no closed captions for the hearing-impaired population**, so I am 100% unhappy...” [R773]*

- ii. *Amateur delivery:* The non-involvement of mental health professionals (e.g., therapists, psychologists, counsellors, psychiatrists, etc.) in the delivery of app contents to users is another issue apparent from

our findings. Users either do not like the presentation style of the coaches or feel they are insensitive to their individual needs. As shown in the sample comments below, users complained that their instructors mumble, lose pace, present with offensive/condescending/robotic voice, behave rudely or immaturely, and are unresponsive.

*“The trainer of this application is **not lucid to his words**, I had to pay more attention to what he says rather than focusing on meditation. Also, he talks so fast.” [R93]*

*“...Be careful using this application. **These people are not professionals, and some are very unprofessional**. I was connected with a listener that told me I was narcissistic and selfish for having children.” [R192]*

*“The actual meditation is great, if you do not pay attention to the voice guiding you through the meditation. She **sounds like a high school PE teacher on her first day**...reading the requirements, but **not familiar with them**. It is very distracting.” [R54]*

- iii. *Inadequate free content:* Most users of mental health apps rely on free contents, especially if they are unable to afford subscription costs or need to explore (or try) the contents prior to purchase. Hence, locking up most or all contents behind the subscription wall will prompt people to look elsewhere for apps that can satisfy their needs. This further poses the risk of being exposed to clinically unproven contents that will worsen the health condition of users, since only few mental health apps reveal the source of their contents or follow best practices [45]. The sample comments below reveal users’ frustration regarding this issue.

*“The **free portion of the application is too limited in terms of content**. The price is way too high for me to subscribe. Likely a good application if you can afford it.” [R622]*

*“Free to download the application but **zero free content** once you get it opened. What a bummer. Deleted immediately...” [R31]*

*“...The reason I gave it 3 stars instead of 5 is the fact that they **do not offer many free sessions or a free trial**. I would be interested in purchasing a subscription, but I have no way of truly testing out the application” [R665]*

- iv. *Limited content:* Users are unable to choose from diverse contents, thereby feeling constrained and bored (see comments below). For example, some mental health apps only provide video-based contents (e.g., unguided breathing videos) which can be tiring/boring over time. Evidence has attributed lower assessment scores of mental health apps in information and

engagement to the lack of comprehensiveness and diversity in contents [54].

“Do not waste your time or money on this one. Meditations are all the same, no real variety or creative insight...” [R57]

*“...It seems ridiculous that I pay more for an application with **such limited content** than I do for Spotify or Netflix.” [R3772]*

*“...I would like to have some cool meditation practices that focus more on the analytical side of meditation, and to have more different types of meditation, but no, **everything is similar and boring...**” [R9]*

- v. *Counterproductivity*: The reason users engage with mental health apps is to get relief from their mental health issues. However, our findings revealed that users experienced deteriorating conditions after using some of these apps, as shown in the sample comments below. This further reinforces imminent concerns regarding the content of mental health apps, and the need for clinical validation and compliance with evidence-based best practices or guidelines before releasing these apps for public use.

*“Hated it **made my head hurt really bad** and then my **throat started to hurt** when I swallowed and now I might not be able to go to Harry potter land in London tomorrow morning...” [R903]*

*“...The streak system built into the software is a **huge source of anxiety** for myself and a number of other users I have spoken to...” [R2932]*

- vi. *Non-personalized content*: Research has shown that mental health apps that do not personalize user experience are less helpful [55]. This aligns with our findings, as users complained about some apps' generic content which made it unsuitable and unhelpful for their condition (see sample comment below).

*“I do not see it as that helpful. After the first session, I have noticed it only **gives generic responses**, no matter what issue you have. So what seemed like was caring about me the first time, turns into seeing me as just another john. So I do not feel any better than before.” [R210]*

- vii. *Missing features/content*: Users of mental health apps complained about the unavailability of certain features or content crucial for their motivation and self-management practices. For example, analytics that leverage usage or behavioural data (such as mood tracking data) to provide valuable insights to users about their health issues and improvements over time is missing in some apps (see sample comment below). Other missing content/features include tracking mood within certain hours instead of daily, help/tutorial content, turning-off “obtrusive”

notifications and background music, saving typed texts as draft to avoid losing them, etc.

*“...Nevertheless, it is **missing a lot of actionable content that can be done with the data**. For example, change in behavior through time, what affects your happiness and what affects your sadness the most.” [R837]*

3) ETHICAL ISSUES

Lack of openness about how some mental health apps collect and use personal and health-related data, as well as prioritization of marketing (for revenue generation purpose) over healthy living has raised ethical concerns among users. Research has shown that user privacy, confidentiality, and safety are not guaranteed in mental health apps [56], and this may be due to the lack of consistent and clear ethical guidelines for mHealth apps generally [57], [58].

- i. *Violation of data privacy and security*: Users perceive most mental health apps as not trustworthy [46]. As shown in the sample comments below, users are wary of apps that covertly compromise their privacy by revealing sensitive data to third parties or using it for unauthorized purposes (e.g., marketing). There is evidence that almost half of mental health apps either lack privacy policies or fail to provide clear and concise information on data collection, sharing, and use [59], [60].

*“...’By using this application, you accept that Google Admob can use your emotional data to target you with advertising’: The reply is hypocritical. What is relevant is the link to Google Admob’s privacy policy which is directed towards publishers not end-users. It is **completely untransparent what happens with the emotional data of end-users**. This makes your business model unethical. It is very likely that you **sell emotional data of people**, who try to improve their health...” [R773]*

*“... Claims it is confidential but asks for a lot of **personal information. I do not trust it.**” [R455]*

- ii. *Excessive advertisements and unsolicited messages*: As shown in the sample comments below, users complain about distracting and disruptive advertisements, such as those hindering task performance (see [R890]) and erasing data (see [R900]). In addition, users receive spam email messages after creating an in-app login account (see [R531]). All these reflect a misuse of their personal information. Users also think app developers care more about making profits than people's health (see [R233] and [R900]).

“The ads are distracting. I cannot focus on the task with flashing, blinking ads at the bottom.” [R890]

“The ads erase entries, therefore worthless in the midst of crisis. Programmers are putting profit over people...” [R900]

*“This is a **money grabbing application** this makes me more stressed and I hate how ads pop up nearly every second. Please fix” [R233]*

*“I like the application okay, but it **sends me email spam** and there is no way to unsubscribe. When I replied to the spam and asked to be unsubscribed, it was undeliverable. Really **annoying for an application that is supposed to help you feel calmer!**” [R531]*

4) BILLING ISSUES

Research has shown that most people download and use free mental health apps [61]. In addition, commercial developers of mental health apps offering direct-to-consumer services have difficulty acquiring enough users and sustaining their business in both short and long-term [62], [63]. This is due to the high subscription cost and billing patterns of paid apps, as revealed in our findings.

- i. *High subscription cost:* Paid apps offer premium contents or features to potential subscribers who are willing to pay the associated fees. Most people are unable to afford these fees or unwilling to pay, as they feel the cost is too high for the values the apps provide (see sample comments below).

*“Sorry, the **cost is ridiculous**. Yes, I get the idea of ongoing use but it is still an application. Paying \$95 is just too much.” [R3998]*

*“... living on a fixed income due to a disability means I **cannot afford the monthly/annual subscriptions**. It is too bad that something that could be so helpful to the disabled community is priced so out of reach. Perhaps the company can think of ways to help.” [R89]*

*“The **subscription should not cost as much as it does**, there are many other free meditation apps that are just as good and have more content.” [R1935]*

- ii. *Unfair payment pattern:* Users shared their concerns about the payment pattern employed by some paid apps which makes subscription unaffordable or inconsiderate. For example, users condemn: (i) yearly payment plan without hope of complete ownership, (ii) recurring monthly payment plan for all contents rather than payment per content pack, (iii) lack of one-time subscription that lead to lifetime access. Below are sample comments:

*“It says 4.99 a month for 1-year subscription which I would happily pay at 4.99 a month, but **not all in one go at 60 for the year. Why can't you set up monthly billing instead of annual,***

you would get a lot more people paying for the application” [R182]

*“... However, rather than a monthly subscription I really **wish you could pay per pack** - that way I am making a one-time payment to use only the program I feels is relevant to me. I would be much more willing to pay for the service if that were an option.” [R566]*

5) CUSTOMER SUPPORT ISSUES

Users also expressed their frustrations regarding inadequate or lack of support during app usage. Evidence shows that lack of adequate support can hinder user adoption of technology, including mobile apps [64], [65].

- i. *Poor customer service:* Users complained that app developers or support staff are either unreachable, unresponsive, or unable to resolve (or slow in resolving) issues. Below are sample comments:

*“... My stuff was totally wiped out and **customer service is nonexistent**. .. Tried to reach customer service, but the **application does not actually send messages to customer service**. I paid for this application and now I am sorry that I did.” [R1098]*

*“... I paid the subscription of \$12.99... But then I was suddenly locked out of all the content past the limited free trial. I contacted their support. They **did not resolve the problem...**” [R2746]*

*“... However, the worst part is **total lack of customer support**... I have sent three emails and have been **waiting for over a week, and still absolutely no help**, just the canned ‘we will get back to you within 24-72 hours’...” [R9220]*

- ii. *In-app support issues:* Self-help resources, such as frequently asked questions (FAQs), interactive tutorials or user manuals are also missing in some apps (see sample comment below).

*“I could not figure out how to use the add emotion and add statements or customize this program in any way. There is **no help within the program to assist someone trying to use it**. I am going to uninstall this from my device and look elsewhere.” [R1645]*

B. ADDRESSING THE NEGATIVE FACTORS: DESIGN RECOMMENDATIONS

To address the negative factors discussed above, we propose the following design recommendations based on the 29 positive themes in Table 8 (see Appendix section) which are factors that contribute to the effectiveness of mental health apps.

1) DEVELOPERS SHOULD CREATE APPS THAT ARE USABLE

Usability is crucial for increasing user adoption of mHealth apps [66]–[68]. Therefore, to create mental health apps that

are usable, developers should consider the following recommendations based on our findings:

- i. *Aesthetically pleasing interface*: The user interface should be visually attractive and consistent with respect to colour, font, layout, graphics, and animation. Research shows that an aesthetically pleasing interface will capture users' motivation and interest and situate them in the interaction [69].
- ii. *Simplicity*: The user interface should be simple and straightforward. The minimalist design approach is a major way of achieving simplicity [70].
- iii. *Ease of use*: The app should require less effort to learn and use. The interface should be intuitive; in other words, objects of interaction (icons, graphics, menus, buttons, etc.) should be familiar to users without ambiguity. There is evidence that ease of use significantly influence continuous adoption of mHealth apps [71].
- iv. *Ease of navigation*: App features should be easy to locate. This can be achieved by implementing a linear task flow, clearly labelled and limited number of navigation elements (buttons or icons), as well as easy-to-find home screen [72].
- v. *App stability*: App should be free of bugs and crashes. This can be achieved by conducting rigorous testing using various screen sizes, device types, and mobile platforms. In addition, user testing should be carried out with select target audience for a specific period to ensure the app works as expected before deployment.
- vi. *Good app performance*: App should be highly responsive during user interaction. Time lag between every user request and response should be very minimal or negligible. Offline access to content should be available as an option for users.
- vii. *Customizability*: App interface should be customizable to fit user preferences. Users like to have control over the appearance of an interface [73], such as changing the colour or theme, background image, layout, etc. They also want app features to be flexible and modifiable, such as enabling/disabling push notifications, changing narrator's voice, disabling background music, turning on/off video subtitles, etc. Research has shown that customization offer psychological gratifications to users [74] and improves their sense of agency and engagement levels [75].

2) CONTENT OF APPS SHOULD BE OF HIGH QUALITY, COMPLETE, ACCESSIBLE, AND EVENTUALLY IMPROVE THE HEALTH OF USERS

The main purpose of mental health apps is to deliver therapeutic interventions that lead to improved psychological well-being of users. Based on our findings, developers should adhere to the following recommendations when creating app content:

- i. *High-quality content*: Research has shown that evidence-based content can effectively supplement

medical care [76]. In other words, app content should be based on evidence-based strategies or practices within the target domain (such as stress or anxiety). In addition, involving mental health professionals in content creation is crucial to increase user engagement and achieve desired outcome [46], [77].

- ii. *Content variation/diversity*: Content should be diverse and not of a single type. For instance, content can cover a wide range of topics and presented in different ways - e.g., using video, text, audio/voice or gamified interaction. This help arouse users' interest and increase their engagement with the app in both short and long-term.
- iii. *Expert delivery*: Due to the sensitivity of health-related issues, only experts in the target domain (e.g., psychiatrists, therapists, psychologists, clinicians, etc.) should deliver the content to (and interact directly with) users who are also patients seeking treatment.
- iv. *Free content*: Most people install mental health apps because they offer free content [61]. Also, most users want to engage with the content first before making a decision to purchase or not, hence the term "free always wins" [66]. Thus, therapeutic and evidence-based content will not be widely accessible to users/patients unless it is free. App developers should ensure that users continue to access content that will improve their health, as denial of access will only expose them to harmful/inaccurate content elsewhere that will worsen their health.
- v. *Personalized content*: Content should be tailored to individual user and should continue to adapt to their changing needs. Developers can leverage demographic data, health history, medical assessment results, and usage/behavioural data to provide content that is relevant for each user. Research shows that personalized content is critical for mental health apps [78] due to the shift in healthcare from electronic health (eHealth) to intelligent health (iHealth) driven by precision or personalized medicine [79].

3) APP DEVELOPERS SHOULD PROVIDE FEATURES THAT SUPPORT USERS IN PERFORMING THEIR TASKS

Based on our findings, app developers should provide the following functionalities or features in their apps:

- i. *Logging* – for tracking moods, daily activities, etc.
- ii. *Goal setting* – allow users to make commitments by setting goals which, in turn, increases their motivation [80].
- iii. *Social effect* – allow users to interact with each other and health professionals to share their experience.
- iv. *Analytics and visualizations* – for tracking progress, and benchmarking against set goals.
- v. *Reminders and notifications* – useful for reminding users to take medications, complete therapies, or suggesting important content that can improve their condition.

- vi. *Virtual reward* – rewards (such as badge, coins, trophies, stickers, etc.) can motivate users [81] and result in high satisfaction and self-efficacy with respect to the ability to achieve current and future goals [80].
- vii. *Assessment* – pre- and post-intervention assessment or quizzes within the app can help users gauge improvement in their health condition and can also drive content recommendation based on users' stage in the treatment/recovery process.
- viii. *Data export* – users should be able to download their textual or visual data in different format (e.g., PDF) for the purpose of sharing with desired recipients (e.g., family doctor or specialist).
- ix. *Enjoyability* can be achieved through gamification which is also capable of motivating and encouraging people to take charge of their health [82].

4) APP DEVELOPERS SHOULD OFFER LOW-COST SUBSCRIPTION PLANS AND ENSURE FAIR BILLING PRACTICES

Developers should balance profit-making/income generation and helping people recover from mental health conditions. Research has shown that most people who own smartphones and willing to use them to monitor their health conditions are under 30 years of age (i.e., young adults). In fact, most people with mental illness are young adults [83]. In addition, most young adults are likely students and fresh workers who may not be able to afford high cost of subscription. This aligns with evidence that most students download free mental health apps [61]. Furthermore, people in low-income countries will have difficulty subscribing due to financial constraints. Most people that can afford to subscribe also want complete ownership rather than recurring/unending payments. Therefore, app developers should create flexible and affordable subscription plans (with necessary fee waivers) that cater for everyone, especially young adults and people with financial challenges.

5) DEVELOPERS SHOULD ASSURE DATA PRIVACY AND SECURITY

Data protection, as well as transparency in data transmission and usage, is one of the major areas of concern for mental health app users due to the sensitive nature of mental health issues. To gain users' trust, app developers must be open and clear about what data leaves users' mobile devices, how data is stored (whether encrypted, anonymized, or plain), who can access the data, what data is sold and to whom, and the steps taken to ensure personally-identifiable information remain confidential [84]. These details should be readily available (and written in simple and unambiguous language) as data privacy and security policy statements within the app. In addition, app developers should encrypt and de-identify sensitive data in their back-end systems, and also during transmission of data to third-party entities after obtaining users' consent.

6) APP SHOULD NOT INTERFERE WITH USERS' DAILY LIFE OR PRIMARY TASKS UNNECESSARILY

Users prefer apps that are non-intrusive but support them in performing their tasks. In other words, technology, such as mental health apps, should integrate or blend with users' daily lifestyle rather than disrupt it [85]. Therefore, developers should avoid interrupting users with in-apps advertisements (or ads), frequent push notifications or reminders, background processes that drain critical phone resources quickly (such as battery, internal memory, and mobile data), etc.

7) APP DEVELOPERS SHOULD PROVIDE ADEQUATE AND RESPONSIVE IN-APP AND EXTERNAL SUPPORT TO ENABLE USERS COMPLETE THEIR TASKS SUCCESSFULLY

Users of mental health apps require varying degree of support, depending on the severity of their conditions, as well as their proficiency level or experience with mobile technologies. For example, some users may require one-on-one conversation with medical experts regarding health issues, while others may need developers' help to resolve technical issues. Power users may be able to figure out the panacea to certain issues by leveraging background knowledge or by reading in-app tutorials/FAQs. Thus, developers should provide diverse user support mechanisms, such as instant messaging feature (to connect users with health professionals or customer service agents), in-app contact form, and easy-to-understand tutorial/help feature. Chatbot, driven by artificial intelligence (AI), is also important to provide real-time support to users, but should be able to connect users to humans (i.e., health professionals, customer service representatives, or developers) where necessary.

VI. CONCLUSION AND FUTURE WORK

We performed sentiment analysis using machine learning (ML) approach to understand users' opinion regarding mental health apps with the aim of uncovering positive and negative sentiments. Specifically, we implemented and compared the performance of five ML classifiers, and then used the best performing classifier, with F1-score of 89.42%, to predict the sentiment polarity of user reviews. Afterwards, we conducted thematic analysis of both positive and negative reviews to identify the factors affecting the effectiveness of mental health apps positively and negatively. Based on the positive factors, we offered recommendations to app developers on how the negative issues can be addressed to improve app effectiveness.

As part of future work, we plan to extend our approach to apps in other domains to uncover their strengths and weaknesses, and then offer design suggestions that app developers and researchers can adopt to improve the quality and effectiveness of their apps.

APPENDIX

See Tables 8 and 9.

TABLE 8. Positive themes, description, and sample reviews.

Theme	Description	Sample reviews
Aesthetically pleasing interface	User interface is attractive, with good design layout, colour, animations, and graphics.	<p>"...has been my go-to application for mindfulness for over a year now and I absolutely love it! Amazingly colorful and minimalistic design coupled with simple, yet highly insightful animations make my experience so delightful every time..." [R310]</p> <p>"I think this application worth a try if you want to become the best version of yourself. Beautiful application interface, beautiful animations." [R9201]</p>
Customizability	App content and user interface can be customized by users	<p>"... There is a breathing section that you can customize for your own breath, you can customize your background and sounds that play." [R55]</p> <p>"As a user with a diagnosis, this application is the best customizable mood tracker around." [R611]</p>
Free content	App features are free to use or try	<p>"Searched for an actual free application for a while and they always want to charge you to get premium after a few sessions. This application is totally free and I completely LOVE it!!" [R2884]</p> <p>"I have used this application for only a few days so far. I have liked all the voices, meditations... I am using the trial version but may gladly pay for it once I explore it some more." [R6412]</p>
Simplicity	App features/contents are easy to understand and straightforward	<p>"Nice simple application that has helped me get back into meditating" [R805]</p> <p>"Great minimalistic application. Simple enough to use daily, but perfectly effective..." [R1114]</p>
Low subscription cost	Premium contents/features are affordable or cheap	<p>"...Premium is a great price for what you get (emojis, auto backup, no ads, notifications whenever). Only \$2.50 or \$3.00 AUD." [R247]</p> <p>"Fantastic content at a great price. The bedtime stories are my favourite I cannot believe how well I sleep after listening to them." [R308]</p>
Ease of navigation	App features are accessible easily and quickly	<p>"...Easy application navigation with a good-looking, minimalistic theme." [R92]</p> <p>"It does what it says it does. Simple menu, easy navigation, and a truly serene and calming experience" [R150]</p>
Ease of use	Users are able to perform intended tasks seamlessly	<p>"I love the ease of use. This is a very helpful tool for my life." [R410]</p> <p>"I have used the application since it is first version. The application is easy to use. Very helpful for yourself & your doctor." [R177]</p>
Enjoyability	Users find the app features/contents enjoyable or fun	<p>"I am new to meditation and this application helped me get started and stay on track. It is fun and easy to use, and makes it less daunting." [R2382]</p> <p>"...there are plenty of activities and games to make this an enjoyable application for me." [R942]</p>

TABLE 8. (Continued.) Positive themes, description, and sample reviews.

Theme	Description	Sample reviews
App stability	App works as expected without bugs, errors, or crashes.	<p>"...Guided meditation feels very positive and powerful. Stable application does not crash." [R736]</p> <p>"...Have used it for 6plus months and have yet to find a bug. Really well thought out." [R7]</p>
Motivation and encouragement	Users are encouraged or motivated to perform target behaviour that improves their mental health	<p>"Inspiring and motivational application. Very helpful for tracking medication and therapy" [R7261]</p> <p>"...There are so many coping methods, and Flitz is just so encouraging and cute! The daily quotes and encouragement...were so great" [R1540]</p>
Non-intrusiveness	App content is not disruptive, disturbing, or annoying to users	<p>"No muss, no fuss, just you and a great un-intrusive and zen-like tool for learning and aiding your meditation practice. Highly recommend it." [R772]</p> <p>"Great for positive self-reflection, without being intrusive." [R11]</p>
Produce desired effect on mental health	Users perceived an improvement in their mental health after app usage	<p>"It works REALLY GOOD! After an exercise, I feel calm and like yeah. I love this application." [R439]</p> <p>"This application is so relaxing! When I first saw it in ads, I thought I will never get this. But one day I decided to try it. And thank goodness I did! And I love how it is for all ages." [R1912]</p>
Reminder and Notification	App reminds users to perform their tasks or notifies them about relevant information	<p>"This application makes me so happy! Love my reminders throughout the day and the reminder to meditate..." [R374]</p> <p>"...This application has been really helpful in guiding my meditation and reminding me to be mindful throughout the day with push notifications. I recommend this application to everyone..." [R8774]</p>
Social effect	Users can interact (and share their experiences) with other app users	<p>"This online community has helped me and allowed me to help others! I get to talk and listen to people who are going through similar to exactly what I have been through or am going through..." [R3]</p> <p>"This application is very great! You can have one-on-one chats and group chats to help you with your problems, and you can do several activities to help yourself in recovery." [R2448]</p>
In-app support	Users receive guidance and suggestions that draw them closer to their goals. This also includes support from virtual agents within the app.	<p>"The short daily instructions help me deepen my meditation continually and at a good pace...A very good investment for my personal growth and sanity!" [R350]</p> <p>"... whenever I am low or feeling lonely and I do not know who to share with or who could help... I can share with this cute intelligent penguin and the breathing practices and everything else that it suggests help me a lot." [R69]</p>

TABLE 8. (Continued.) Positive themes, description, and sample reviews.

Logging	Users utilize in-app diaries or journals to log their activities or moods.	<p>“Great application for mood tracking and short-form journaling. Love that you can just tap icons to log what you have been up to.” [R182]</p> <p>“It is a great little application, keeping track of my mood with the activities that contribute to it has been very helpful.” [R42]</p>
Analytics and Visualization	In-app analytics and visual representations of data (e.g., charts) allow users to track their progress in real-time or over a specified period	<p>“Easy to keep a watch on mood. The graphs are very impressive and reveals a lot” [R442]</p> <p>“... The analysis tools provide great insight into correlations that may assist in self or guided therapy.” [R4009]</p>
Good app performance	App performance in terms of response time is good	<p>“The information provided in each interaction is applicable and relatable. No performance problems.” [R3342]</p> <p>“This application quickly became an essential. Educational, fast, very effective.” [R10030]</p>
Content variation or diversity	App offers variety of contents from which users can choose	<p>“...I love that they have different meditations focused on different things such as anxiety or stress or physical health...” [R2225]</p> <p>“... Variety of meditations for different purposes, along with a new meditation posted daily. Highly recommended.” [R664]</p>
Good concept	Users find the apps’ design concept, idea, or metaphor interesting	<p>“Such a smart idea to encourage people to meditate just 10 minute a day...and I really like the style of meditation...Love this application.” [R501]</p> <p>“Though I thought I understood basics of meditation before trying, the short animations use sticky metaphors that make the process crystal clear. The application makes it possible for me to stick to a daily schedule.” [R445]</p>
Good customer service	Users receive timely help or assistance from app designers or support team when they need it	<p>“Customer service response was quick and effective. Happy to have the application working as normal on my phone once more...” [R600]</p> <p>“Since the new update I cannot even open the application to use. I reinstalled the application and it now works great and thanks to the developer for a fast response.” [R691]</p>
High-quality content	App content (videos, sessions, courses, etc.) are of high quality	<p>“I came here to write that this application has great quality. The starting courses are very helpful and progresses at just the right pace.” [R7737]</p> <p>“I love the tone and the voice quality, and the videos are charming and well done.” [R39]</p>
Personalized content	Contents are tailored or personalized for individual users	<p>“...Soothing, not annoying voice, and once done, a full personalized plan for coping with anxiety.” [R688]</p>

TABLE 8. (Continued.) Positive themes, description, and sample reviews.

		<p>“I love this application so much. I love that each meditation or breathing practice is tailored for what you are feeling at the time...” [R5003]</p>
Privacy and Security	App provides data privacy and security options that enhance users’ trust	<p>“...The application is also well run logistically, with security to protect your anonymity. Thanks for this application” [R117]</p> <p>“I read the terms of service especially concerning privacy and was left with a very positive impression, which led me to download the application...will consider buying it.” [R318]</p>
Expert delivery	Contents are carefully created and delivered by knowledgeable or skillful coaches/trainers	<p>“It has changed my life. The instructor’s voice and knowledge make it easier to beginners or experts to find joy in each session.” [R7346]</p> <p>“As someone who has been meditating for over 15 years, I find this application very thoughtfully and skillfully constructed.” [R8838]</p>
Goal setting	App allows users to set goals	<p>“It has lots of meditation options (in terms of time limit and the goal you are trying to reach e.g. falling asleep or practicing gratefulness) so it can fit perfectly into anyone’s life. I recommend it to everybody.” [R10]</p> <p>“...this application presents a fantastic way to get comfortable with meditation: (1) I like that the packs help you focus on a specific goal over the course of several sessions...” [R68]</p>
Virtual reward	Users receive virtual rewards in the form of trophies or points as they complete required milestones	<p>“I like the process used to gain more headspace. The tracking and reward system help to keep me motivated to continue. Highly recommend.” [R420]</p> <p>“You can keep track of how often you meditate, and it has cute reward stickers as you complete different goals.” [R447]</p>
Assessment	Users answer quizzes or questions that assess the state of their mental health	<p>“I love how the thought diary helps you take yourself through the steps of CBT... The quiz has helped me share my progress with my psychiatrist. All-around, one of the best apps I have used.” [R768]</p> <p>“Absolutely wonderful application...The assessment at the end of the 2weeks I will get based on my answers to the in-depth questions everyday will be what gives me the courage to finally ask for help. Thank you for this tremendously helpful application.” [R103]</p>
Data export	Users can access and download logs, assessment reports, and other data that can be useful for healthcare providers	<p>“Very nice that you can export thought diary entries and email them to a therapist...” [R2110]</p> <p>“I use it with clients to track mood. Works great. Love the exportable graphs and reports.” [R9005]</p>

TABLE 9. Negative themes, description, and sample reviews.

Theme	Description	Sample reviews
App instability	App behaves abnormally due to bugs or errors	<p><i>“Not so much anymore. application crashes every time I try to use it and I am unable to restore some previously purchased tracks onto my new iPhone. So frustrating, especially since these tracks were paid for... Please update!” [R118]</i></p> <p><i>“Great meditation, awful application bugs...if the application worked correctly, I would give it 5 stars. But I have consistently had connectivity problems, it will not remember which meditation in a series I am currently on, and none of the animations included with the basics package ever worked...” [R33]</i></p>
Low-quality content	App contents failed to satisfy users or meet their expectations	<p><i>“Do not bother, unless you can afford to pay \$13 a month; just for really bad meditation music.” [R300]</i></p> <p><i>“Wishy washy meditations are useless, esp when they clearly have no idea about the idiocy of making assumptions after you have just asked for someone to self-assess.” [R2101]</i></p>
Unfair payment pattern	Users express displeasure over the billing or payment process, such as the absence of one-time payment plan or paying only for the content required	<p><i>“Why should those who are already scrambling to make yearly payments have to pay forever, while those who are not burdened with financial need can buy it once and have it forever? Yearly payments should contribute to the lifetime fee. Once we pay it four times, we should earn lifetime access.” [R1310]</i></p> <p><i>“The pricing is not to my liking and I doubt I will ever subscribe. I would much rather do one-time payments and OWN the meditation I want instead of paying \$13/month for the same content over and over again...” [R22]</i></p>
Violation of data privacy and security	Users perceive the app as undermining the privacy and security of their data	<p><i>“Access to calendar, covertly creates reminders which then get displayed on lock screens etc. about one's private matters such as their mental health!!” [R990]</i></p> <p><i>“...The privacy policy is unacceptable. I had to install it to say this here. Read it and decide before you install. Meditation is yours. Let no one sell it to you for full telemetry milking.” [R7625]</i></p>

TABLE 9. (Continued.) Negative themes, description, and sample reviews.

Theme	Description	Sample reviews
Poor aesthetics	App is not visually attractive due to poor rendering of graphics, text, colour scheme, or animation, as well as poor/complex layout of controls	<p><i>“The user interface is so ugly and overwhelming” [R3844]</i></p> <p><i>“First activity, balloons, had most of the words almost unreadable because the letters were too small or bad color on the balloons” [R1087]</i></p>
Navigation issues	Difficulty in navigating to a desired location within the app	<p><i>“Difficult interface with unclear directions and lousy with grammatical errors. Waste of \$5.” [R401]</i></p> <p><i>“New version of the application is barely functional. The navigation is worse and cannot do basic things like replay an exercise. Previous one worked fine.” [R80]</i></p>
Excessive advertisements	Users are often disturbed or distracted with advertisements within the app	<p><i>“Too bad that this application ads literally everywhere and annoying” [R13]</i></p> <p><i>“You guys should probably add the fact that you added countless annoying ads not only to our feeds but to our profiles as well to the patch notes. This bullshit is misleading...” [R101]</i></p>
Performance issues	App is slow to respond to user inputs	<p><i>“...One star is missing due to poor application performance. When you press the notification of application it takes almost 30 secs to open it. Which should be in milli secs.” [R1900]</i></p> <p><i>“Terribly slow and laggy application” [R10023]</i></p>
Counterproductivity	App has negative effect on users rather than the desired effect	<p><i>“...I have bipolar 1 so I know. The meditation videos background music is dinging and really makes my head hurt.” [R618]</i></p> <p><i>“Vent is a toxic application. It is full of hate and judgment. Not many people on vent are helpful at all! And some are there just to be lurkers and sexually harass people!!” [R779]</i></p>
High subscription cost	App's premium features are expensive, thereby discouraging users from using them	<p><i>“Yes, this is a fantastic application, but the monthly subscription cost is just too high. It is too bad that Andy and the developers of this application who seem to care so much about my mental wellbeing, are clearly more interested in making money.” [R46]</i></p> <p><i>“Giving every overpriced greedy subscription application a 1 from now on. I used to never give bad ratings and will gladly pay for an application because developers need to make money too. However, developers have gotten greedy. they do not need \$10 or more per month for an application to support it...” [R15]</i></p>

TABLE 9. (Continued.) Negative themes, description, and sample reviews.

Theme	Description	Sample reviews
Poor customer service	Users' inability to get required assistance from customer representative, agent, support team, or app developer	<p>"The application is flawed...Customer service loses credibility when they try to explain it away as if that is just the way it is or has to be...I am extremely disappointed...Customer service turnaround time is horrible as well. I sent over my original concern on a Saturday and it took them 4 whole business days to respond..." [R113]</p> <p>"I have contacted customer support three times over the past week and have not received a single response. My pack is not loading and no one will help me despite my best efforts to get in touch..." [R719]</p>
Unsolicited messages	Users are spammed with emails or excessive notifications	<p>"...While checking it out I made the dire mistake of giving them my email. The daily spam is terrible! Multiple obviously-marketing emails a day and there is a waiting period to unsubscribe" [R66]</p> <p>"Do not download this application unless you want your calendar filled with rubbish notifications." [R811]</p>
Amateur delivery	Content is delivered by low-skilled, unprofessional or incompetent instructors	<p>"... The speaker does not have a soothing voice at all... I tried the 'falling asleep' meditation and felt like there was this loud woman yelling at me in the dark. Way too unsettling ..." [R201]</p> <p>"Used this confusing application out of desperation and got an unsympathetic, unprofessional listener that typed 'you are dumb' to me. I am not trying this application again and discourage anyone else from using it either. Thoroughly disappointed and much more upset than before. Do not use it." [R994]</p>
Lack of customization	Users are unable to customize features to meet their needs (such as selecting preferred voices for meditation)	<p>"...However, I would love a choice of meditation voice. The 'Andy' bloke, for some reason, I find his voice very irritating. I cannot bare the bits where there are videos of him. He looks cocky and he has a face I want to punch. Sorry, he may be a very nice man in real life." [R5023]</p> <p>"Cannot customize the med reminders (I have WEEKLY meds)..." [R1944]</p>

TABLE 9. (Continued.) Negative themes, description, and sample reviews.

Theme	Description	Sample reviews
Inadequate free content	Free contents that are usable are almost non-existent. Users have to pay or subscribe to access helpful contents.	<p>"...The only free meditation after a while turn out to be a 1-minute breath exercise! Totally Lame!" [R237]</p> <p>"... I could not find a single unlocked meditation to even attempt to look at whatever this application had to offer" [R461]</p>
Limited content	Contents are generally insufficient (or lack varieties) to make significant impact	<p>"This application makes me feel stupid...I seem to be watching a lot of video and little meditation" [R194]</p> <p>"Dumb...all it gives you is suggested activities" [R6631]</p>
High resource utilization	App excessively consumes phone resources (e.g. battery, storage space, etc.)	<p>"One 13-minute meditation and my phone went dead from 30% battery. I could play my Spotify for hours with that battery life!" [R84]</p> <p>"Enough with the apps that suck internal memory & cannot be moved to the ext. SD card!" [R424]</p>
Missing features / content	App lacks certain features required by users	<p>"No background meditation music. What are you guys thinking?" [R500]</p> <p>"My phone will vibrate when it is finished, now I am anxious anticipating that!! I played it for a few seconds, discovered there is not even a progress bar..." [R3111]</p>
In-app support issues	Users are unable to access instructions or guide that would help them perform the target behaviour	<p>"What is this. It cannot play the instruction video. How am I supposed to start then? Ugh" [R8730]</p> <p>"Absolutely the worst application I have ever tried to use...No instructions on how to use. No tutorial for use and navigating is impossible!" [R541]</p>
Non-personalized content	Contents are not tailored to individual users	<p>"... I cannot do my personalised meditations anymore. I paid for this application but now I cannot use it! This is unfair! I am going to have to look elsewhere. Not happy!" [R808]</p> <p>"I understand the people that created this may have done it with good intentions of trying to help people, but it really is generic. I do not see how it can really help anyone with heavy issues..." [R7467]</p>
Platform dependency issues	App does not work well on certain platforms	<p>"Does not work on Nexus 7 tablet. Now I am even more depressed" [R16]</p> <p>"Application says it cannot get a connection. Tried Facebook sign up instead, tried reinstalling, rebooting my phone, 3g and Wi-Fi. This application is simply broken on my device - Samsung Galaxy Nexus with Cyanogenmod 10." [R94]</p>

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