

# Android App Permission and Users' Adoption: A Case Study of Mental Health Application

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**Abstract.** The prevalent use of mobile devices makes mobile applications (apps) a promising approach to enhance mental healthcare. However, at the same time, users' information privacy and security becomes a serious concern due to the ubiquitous data collection of mobile device, especially when it comes to mental health information. With the exponential development of the current Android app market, hundreds of mental health apps are available to users. We are interested in how app permission, as the only information available about app privacy, is related to users' adoption of mental health apps. Considering that mental health is a broad field, this study focuses on one mental health condition: anxiety. A systematic search of anxiety apps was conducted on the Android app store. A total of 274 apps were collected and analyzed. In this study, we revealed the relationship between app permission and users' anxiety app adoption. We found that anxiety apps with more app permissions have higher installs. Also, certain app permissions are significantly related to the installation and rating of apps, such as the permission of in-app purchases, cameras, and location. This study provides a big picture of how app permission is connected with mental health app adoption. We believe this is an important step before we can identify which apps may pose higher risks for compromising users' information privacy and security.

**Keywords:** Information privacy · Security · Mobile device · Smartphone

## 1 Introduction

Recently, mobile technologies have advanced to the point that today's mobile devices function like handheld computers and are highly integrated into our daily lives. The prevalent use of mobile devices makes mobile applications (apps) a promising approach to engage users in beneficial activities or therapeutic sessions in the context of mental health [1]. While the majority of these mental health apps provide some level of confidentiality for their users' personal information, the information privacy and security of these mobile apps is still a vital concern, especially when it comes to the sensitivity of mental health information.

When using mobile apps for mental healthcare, users may be exposed more to information privacy risks and security breaches due to the "always-on" feature of

ubiquitous data collection [2]. For instance, users' information privacy can be compromised when third parties collect, store, and analyze their information without their consent and knowledge. Previous studies have indicated that patients are concerned about their information privacy while using mobile devices [3, 4]. Also, users' selection of apps can be affected by how they perceive the apps' risk to privacy and security [5, 6]. Users seem to prefer apps that collect less personal information [7].

From the user's perspective, information privacy represents a state of limited access to personal information [8]. However, when it comes to mobile privacy, users are often given no choice. For example, before app installation in the Android system, users can only see a dialogue of permission groups informing them what system function and data the app can access. In the iOS system, there is no privacy notice about apps although users can turn the app's access to personal information on or off after installation. The effect of these two mechanisms on users' information privacy protection is unclear. Prior research suggests that most Android users do not pay attention to the app permission dialogue [9–11]. Also, app permissions seem to have less of an effect on user adoption compared to other types of information (e.g., price, review, rating) [7]. Although the existing literature has indicated some important factors involved in users' decision-making processes for app adoption, the literature about mental health app adoption is scarce. To the best of our knowledge, no previous study has investigated how app permission, as displayed information of app privacy and security, is related to users' adoption of mental health apps.

To investigate the relationship between app permission and the adoption of mental health apps, we selected Google Play as our research site for two reasons. First, it is currently one of the leading app markets [13], and second, it exhibits the dialogue of information about app permission, which notifies users about app privacy and security. In addition, considering that mental health is a broad field, we focus this study on one mental health condition: anxiety, which is also one of the most common mental health issues among U.S. adults [12]. The aim of this study is to examine the relationship between different types of app permission and users' adoption of anxiety apps. As far as we know, this study is the first work focusing on examining the relationship between app permission and mental health app adoption.

## 2 Background

### 2.1 Mobile Privacy and Android App Permission

Information privacy has become one of the most concerning issues in mobile technologies due to the exponential use of mobile apps. According to Google Play [27], approximately 65 billion apps have been downloaded to users' mobile devices. The enormous number of apps downloads by users make the misuse of user data and the security breach of users almost inevitable. For instance, Felt et al. [11] found that around 93% of free Android apps had at least one potentially malicious data usage, such as accessing the camera to take pictures, and sending messages on the users' behalf.

Mobile apps often attempt to collect a wide range of user data stored on mobile devices for functionality purposes and to personalize advertising [14]. Android apps

can request access to mobile system functionality via the Android app permission system. To inform users which type of data may be accessed by apps, Google Play displays the permissions to the user at the time of installation. Nevertheless, it does not provide an explanation about how and why these permissions are requested. From the users' perspective, previous studies [9–11] found that only 3% of users had a full understanding of what access the permissions were requesting. In addition, most users do not pay attention to the permissions screen. That is, the majority of users do not have a comprehensive understanding about an apps' capacity to access personal data. The lack of adequate knowledge and attentiveness to app permissions could lead users to make inappropriate decisions, which may put users' information privacy at risk.

## 2.2 Mobile App Adoption

A substantial amount of studies have identified a variety of factors that can influence users' app adoption, including prices, ratings, reviews, rankings, installs, titles, descriptions, functions, and privacy issues of apps [6, 7, 15–22]. Furthermore, the search ranking of results is a significant factor of users' adoption [25], which can influence app adoption. Although app adoption is a complicated decision-making process, users often apply the simple "take the first" heuristic approach. This approach is mainly dominated by the most accessible information, such as price, ratings and rankings of apps [7, 22]. Even though prior research has pointed out that users would prefer the app to collect less personal data [7, 26], how app permissions affect users' app adoption remains unclear, especially when it comes to mental health apps. Since mental health apps can collect sensitive personal information (e.g., mental health state, health conditions, daily routine), we are interested in whether app permission is related to users' adoption of mental health apps.

## 3 Method

### 3.1 Anxiety Apps Search and Selection

To imitate the users' app search process, we used keyword search strategies to identify apps that most likely would be adopted by users seeking anxiety-related apps. This is similar to the approach employed by Ramo et al. [23]. Based on DSM-5 [24], we first identified three main keywords related to anxiety disorders including: anxiety, fear, and avoidance. Each term reported 250 results on Google Play. We dropped the term "avoidance" because its search results did not yield the result of anxiety-related apps. To identify other potential keywords, we performed a search for the word "anxiety" on the website UrbanDictionary.com. Twenty-seven commonly used terms were listed. We selected two of the words most compatible with anxiety and fear, which are "anxious" and "worry." We used four keywords as our final search terms on Google Play, including: anxiety, anxious, fear, and worry. The term "anxiety" was our primary search term and the other three keywords were used for supplementary searches.

A two-phase app search was conducted. Our first app search was conducted on Google Play between July and September 2016. Researchers collected the information

for all of the apps and selected the anxiety-related apps based on the apps' descriptions. A second round of app searches by keyword was conducted on October 7, 2016. Twenty-four new apps were identified and 14 apps no longer existed. A total of 274 apps were chosen for analysis.

### 3.2 App Permission

According to the list provided by Google Play [28], there are 138 types of system permissions that Android apps can request. App developers can also create their own app permission request if there is a need. Although many app permission requests are available to developers, only certain types of app permissions are commonly requested by most apps, such as in-app purchase, location, and Wi-Fi connection. Users can review these app permission requests before they download the app. Google Play categorizes their system permission and only displays 16 common groups of app permission. Additional app permission requests fall under the 'Other' category. To identify app permissions, we included these 16 types of app permission requests and added other app permissions by manually reviewing the 'Other' section of apps, which resulted in 11 additional app permission requests. Table 1 provides the full list of app permissions identified in this study.

**Table 1.** List of app permission request

App permission group	Other app permission
1. In-app purchases	17. Storage
2. Device & app history	18. Receive data from Internet
3. Cellular data settings	19. Control vibration
4. Identity	20. Prevent device sleeping
5. Contacts	21. View network connections
6. Calendar	22. Change your audio settings
7. Location	23. Full network access
8. SMS	24. Modify system settings
9. Phone	25. Run at startup
10. Photos/Media/Files	26. Google play license
11. Camera	27. Manage access to documents
12. Microphone	
13. Wi-Fi connection information	
14. Bluetooth connection information	
15. Wearable sensors/activity data	
16. Device ID & call information	

### 3.3 Indicators of App Adoption: App Installs and Ratings

We collected two types of observational data as indicators of app adoption from the app store, which are: app installs and ratings. We reassigned a number to the installs because we could only access the approximate range of installs on Google Play, instead of the exact number. Based on the range of categories, the number of installs ranges from level 1 (<10) to level 12 (>1000000). The mean of anxiety app installs is 6.42 and the average rating is 3.43 (SD = 1.61).

### 3.4 App Price, Review, and Ranking

We also collected the price and number of anxiety app reviews. App ranking on the search results page is defined by an algorithm and may be customized based on individuals' preferences. To collect the average mean ranking for each app, three researchers manually searched web browser apps by keyword and recorded their rankings between October 7 and October 11, 2016.

## 4 Results

### 4.1 Overview of Anxiety App Permission

The average of app permission requests is 5.84 (SD = 4.01). As exhibited in Fig. 1, approximately 80% of anxiety apps request full network access permissions, which is followed by 'view network connection,' 'storage,' and 'photos/media/files.' Forty percent of apps request permissions to prevent the phone from going into sleep mode. These results suggest that many anxiety apps provide functions that require Internet access, data storage, or constant operation. Around 30% of apps request 'phone' and 'device and app information,' which indicates that these apps may access users' phone numbers and that the phone number is connected by calls, web bookmarks, and browsing history. Seventeen percent of apps request permission to access users' contact information, location, and identify users' accounts on the device. Approximately 10% of apps request permission to access the camera and microphone. Also, very few apps request permission to access the log history of the device and app, SMS messages, and calendar schedule. No apps request permission for 'cellular data settings,' 'Bluetooth connection,' and 'wearable sensors/activity data.' Thus, we exclude these three types of permission in our analysis.

### 4.2 Anxiety App Permission and App Adoption

We investigated the relationship between anxiety app permission requests and their adoption by correlational analysis. As shown in Table 2, the permission requests of 'in-app purchase,' 'control vibration,' 'prevent device from sleeping,' 'view network access,' and 'run at startup' have a significant positive correlation with app install and rating. These indicate that anxiety apps with the aforementioned permission requests have higher installs and ratings. In addition, the apps with permission requests for 'photo/media/files,' 'change audio settings,' 'full network access,' and 'modify system settings' have more installs. On the other hand, anxiety apps with camera permission requests have both lower installs and lower ratings. Apps with location and microphone permission requests show lower ratings. In general, the more permissions the apps request, the higher rate of installation the apps have ( $r = .200$ ,  $p = .001$ ).

**App Permission and App Installs.** The first hierarchical multiple regression with 24 predictors revealed that app permissions contributed significantly to the regression model  $F(24, 270) = 3.73$ ,  $p < .001$  and accounted for 26.8% of the variance in app

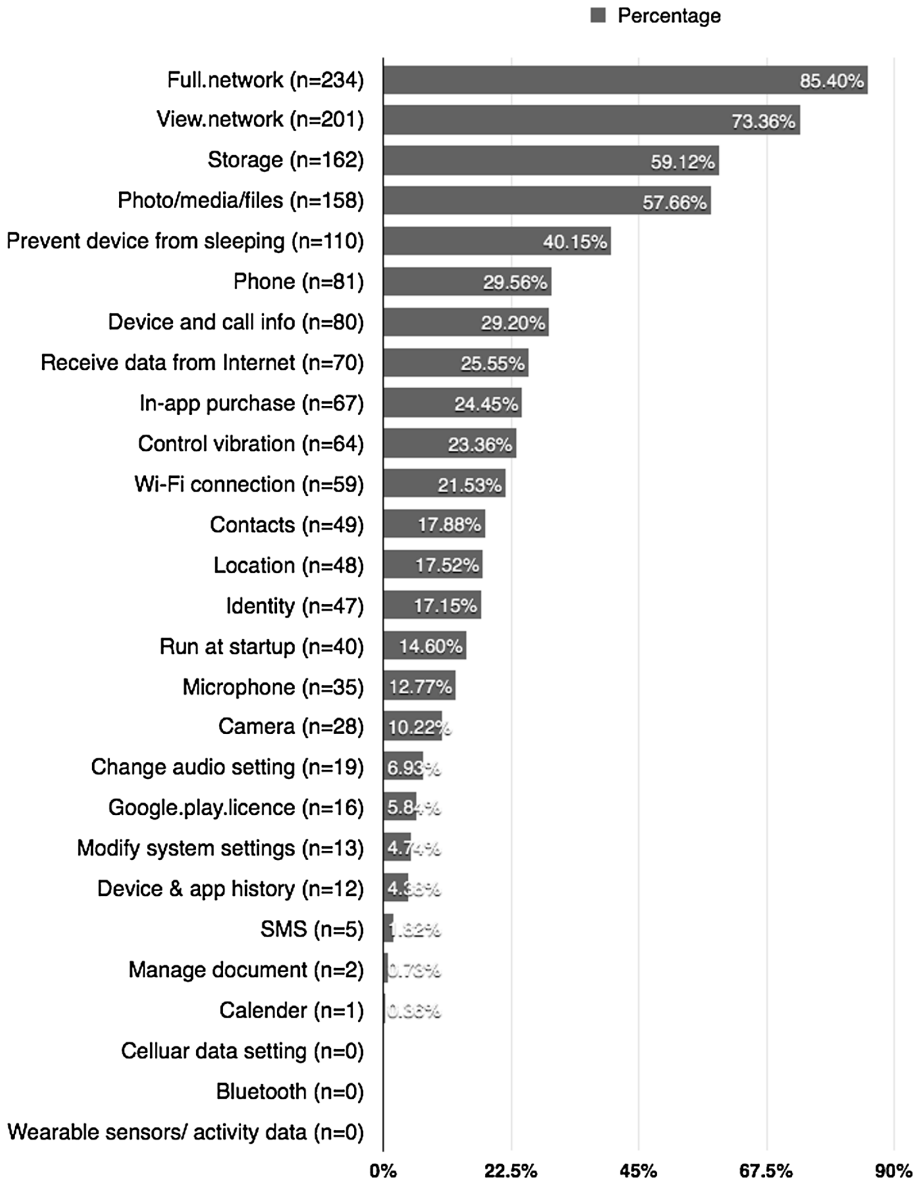


Fig. 1. App permission requested by anxiety apps

install. As displayed in Table 3, four permission requests have positive regression weights, including ‘in-app purchase,’ ‘storage,’ ‘view network connections,’ and ‘change audio settings.’ These results suggest that anxiety apps with these four permission requests will demonstrate higher installs. In the second model, we added three variables: price, review, and ranking, which explained an additional 37.6% of the

**Table 2.** Correlational analysis of anxiety app permission and adoption

	App install correlation r (sig.)		App rating correlation r (sig.)
In-app purchase	.341 ( $p < .001$ )	In-app purchase	.242 ( $p < .001$ )
Photo/Media/Files	.120 ( $p = .048$ )	Location	-.187 ( $p = .002$ )
Camera	-.138 ( $p = .023$ )	Camera	-.192 ( $p = .001$ )
Storage	.164 ( $p = .007$ )	Microphone	-.136 ( $p = .024$ )
Control vibration	.161 ( $p = .008$ )	Control vibration	.169 ( $p = .005$ )
Prevent device from sleeping	.281 ( $p < .001$ )	Prevent device from sleeping	.225 ( $p < .001$ )
View network access	.242 ( $p < .001$ )	View network access	.120 ( $p = .047$ )
Change audio settings	.141 ( $p = .020$ )	Run at startup	.154 ( $p = .011$ )
Full network access	.209 ( $p = .001$ )		
Modify system settings	.125 ( $p = .039$ )		
Run at startup	.158 ( $p = .009$ )		

variance in app install. This change in  $R^2$  is significant  $F(27, 270) = 7.03, p < .001$ . However, the result shows that the predictive effects of certain app permissions were changed. The permission ‘storage’ and ‘change audio settings’ are insignificant predictors; on the other hand, the ‘Wi-Fi connection’ and ‘prevent device from sleeping’ are significant predictors. These indicate that the variables (price, review, and ranking) have mediator effects between app permission and app install. The most significant predictor of app install is the number of app reviews, followed by the price.

**App Permission and App Ratings.** The third model of hierarchical multiple regression shows that app permission contributed significantly to the regression model  $F(24, 271) = 2.65, p < .001$  and accounted for 26.8% of the variance in app rating. As displayed in Table 4, three permission requests have positive regression weights, including ‘in-app purchase,’ ‘view network connections,’ and ‘preventing device from sleeping.’ These indicate that anxiety apps with these three permission requests could have higher ratings. One app permission with a significantly negative regression weight is ‘Wi-Fi connection,’ indicating that anxiety apps with this permission could have lower user ratings. For the fourth model, we added three variables, which explained an additional 17.3% of the variance in app ratings and this change in  $R^2$  is significant  $F(27, 271) = 3.10, p < .001$ . Two permissions ‘Wi-Fi connection’ and ‘prevent device from sleeping’ remain significant positive predictors. However, the permission ‘in-app purchase’ and ‘view network connection’ are no longer significant predictors. Instead, location permission request becomes a significant negative predictor of ratings. This means that anxiety apps with location permission requests will have lower ratings. Furthermore, app price is the most significant predictor of ratings, followed by ranking.

**Table 3.** Hierarchical regression model of app permission and app install

Independent variables: app permission	Model 1: install		Model 2: install	
	Standardized beta	t-value (sig.)	Standardized beta	t-value (sig.)
In-app purchase	.231	3.78 ( <i>p</i> < .001)	.111	1.99 ( <i>p</i> = .048)
Device & app history	-.098	-1.56 ( <i>p</i> = .121)	-.054	-.96 ( <i>p</i> = .339)
Identity	-.109	-.70 ( <i>p</i> = .483)	-.070	-.51 ( <i>p</i> = .608)
Contacts	.047	.30 ( <i>p</i> = .763)	.054	.39 ( <i>p</i> = .697)
Calendar	-.044	-.78 ( <i>p</i> = .437)	-.027	-.55 ( <i>p</i> = .583)
Location	-.094	-1.22 ( <i>p</i> = .223)	-.129	-1.89 ( <i>p</i> = .060)
SMS	.085	1.46 ( <i>p</i> = .147)	.077	1.48 ( <i>p</i> = .139)
Phone	-.056	-.32 ( <i>p</i> = .753)	-.099	-.63 ( <i>p</i> = .527)
Photo/Media/Files	-.369	-1.96 ( <i>p</i> = .052)	-.267	-1.60 ( <i>p</i> = .111)
Camera	-.081	-.96 ( <i>p</i> = .339)	-.067	-.89 ( <i>p</i> = .372)
Microphone	-.107	-1.38 ( <i>p</i> = .169)	-.040	-.58 ( <i>p</i> = .566)
Wi-Fi connection	-.104	-1.62 ( <i>p</i> = .107)	-.139	-2.39 ( <i>p</i> = .018)
Device ID & call information	.125	.71 ( <i>p</i> = .481)	.193	1.23 ( <i>p</i> = .219)
Storage	.435	2.29 ( <i>p</i> = .023)	.287	1.70 ( <i>p</i> = .090)
Receive data from Internet	-.018	-.21 ( <i>p</i> = .831)	-.040	-.54 ( <i>p</i> = .589)
Control vibration	.043	.59 ( <i>p</i> = .558)	.039	.60 ( <i>p</i> = .552)
Prevent device sleeping	.142	1.90 ( <i>p</i> = .058)	.145	2.19 ( <i>p</i> = .030)
View network connections	.167	2.12 ( <i>p</i> = .035)	.144	2.07 ( <i>p</i> = .039)
Change audio settings	.143	2.31 ( <i>p</i> = .022)	.073	1.31 ( <i>p</i> = .192)
Full network access	.032	.43 ( <i>p</i> = .666)	-.029	-.44 ( <i>p</i> = .662)
Modify system settings	.062	.99 ( <i>p</i> = .322)	.007	.12 ( <i>p</i> = .903)
Run at startup	.030	.47 ( <i>p</i> = .643)	.026	.45 ( <i>p</i> = .651)
Google play license	-.010	-.17 ( <i>p</i> = .869)	.094	1.64 ( <i>p</i> = .103)
Manage access to documents	.030	.53 ( <i>p</i> = .595)	.030	.59 ( <i>p</i> = .557)
Price			-.264	-5.01 ( <i>p</i> < .001)
Review			.285	5.43 ( <i>p</i> < .001)
Ranking			-.157	-3.03 ( <i>p</i> = .003)
(Constant)		10.64 ( <i>p</i> < .001)		12.81 ( <i>p</i> < .001)
R <sup>2</sup>	.268		.439	

## 5 Discussion

This study investigated the relationship between app permission and the adoption of anxiety apps by analyzing observational data collected from the Google Play store. We found that the most requested permissions by anxiety apps are mainly for Internet access, data storage, or device operation. Interestingly, our results show that anxiety



**Table 4.** Hierarchical regression model of app permission and app rating

Independent variables: app permission	Model 3: rating		Model 4: rating	
	Standardized beta	t-value (sig.)	Standardized beta	t-value (sig.)
In-app purchase	.162	2.53 (p = .012)	.101	1.57 (p = .118)
Device & app history	-.030	-.45 (p = .653)	-.016	-.25 (p = .801)
Identity	-.136	-.84 (p = .400)	-.114	-.72 (p = .470)
Contacts	.051	.31 (p = .758)	.046	.29 (p = .775)
Calendar	-.030	-.51 (p = .613)	-.016	-.29 (p = .775)
Location	-.155	-1.92 (p = .056)	-.163	-2.07 (p = .040)
SMS	.058	.94 (p = .346)	.054	.91 (p = .366)
Phone	.112	.66 (p = .513)	.065	.39 (p = .699)
Photo/Media/Files	-.096	-.49 (p = .627)	-.037	-.19 (p = .846)
Camera	-.108	-1.22 (p = .223)	-.098	-1.13 (p = .261)
Microphone	-.065	-.80 (p = .424)	-.034	-.42 (p = .673)
Wi-Fi connection	-.196	-2.90 (p = .004)	-.186	-2.78 (p = .006)
Device ID & call information	-.068	-.40 (p = .690)	-.013	-.08 (p = .936)
Storage	.134	.68 (p = .500)	.055	.28 (p = .779)
Receive data from Internet	-.036	-.42 (p = .677)	-.059	-.70 (p = .486)
Control vibration	.124	1.61 (p = .108)	.112	1.49 (p = .138)
Prevent device sleeping	.164	2.10 (p = .037)	.177	2.33 (p = .021)
View network connections	.164	1.99 (p = .047)	.154	1.92 (p = .056)
Change audio settings	.092	1.41 (p = .159)	.071	1.09 (p = .275)
Full network access	-.055	-.71 (p = .479)	-.093	-1.21 (p = .228)
Modify system settings	-.014	-.22 (p = .825)	-.024	-.37 (p = .714)
Run at startup	.013	.20 (p = .840)	.010	.15 (p = .883)
Google play license	.006	.08 (p = .933)	.043	.65 (p = .517)
Manage access to documents	.031	.51 (p = .610)	.020	.35 (p = .729)
Price			-.173	-2.87 (p = .005)
Review			.051	.84 (p = .402)
Ranking			-.139	-2.33 (p = .021)
(Constant)		12.25 (p < .001)		12.00 (p < .001)
R <sup>2</sup>	.205		.256	

apps with higher installs request more permissions. A possible explanation is that the apps with higher installs may provide users with more functionality, and these request more permissions. Furthermore, we found that certain app permission requests correlated significantly with app adoption (see Table 5). For instance, apps with permission requests for ‘in-app purchase’ have higher installs and ratings. We infer that apps requesting permission for an in-app purchase would have lower prices, which could

**Table 5.** Overview of app permission and app adoption

	Install	Rating
In-app purchase	Higher	Higher
Control vibration	Higher	Higher
Prevent device from sleeping	Higher	Higher
View network access	Higher	Higher
Run at startup	Higher	Higher
Photo/Media/Files	Higher	X
Storage	Higher	X
Change audio settings	Higher	X
Full network access	Higher	X
Modify system settings	Higher	X
Camera	Lower	Lower
Location	X	Lower
Microphone	X	Lower

lead more users to install them. Also, apps with an in-app purchase request may provide users more autonomy to decide if they want to purchase certain functions in the app, rather than automatically including them at the time of installation. This may result in higher ratings. Our findings also indicate that anxiety apps with permission of ‘control vibration,’ ‘prevent device from sleeping,’ ‘view network connections,’ and ‘run at startup’ have higher installs and ratings. These four permissions are involved with the operating functions of mobile devices, suggesting that these anxiety apps may either provide functions that users need or they have better functionality. On the other hand, apps with permission requests for the device’s camera have significantly fewer installs and lower ratings than apps without camera permission. Also, anxiety apps with location and microphone permissions have lower ratings. Although it is difficult to infer whether these apps have lower installs or ratings because they evoke users’ privacy concerns, these findings may suggest that these three permission types could reduce users’ adoption of anxiety apps. We encourage future studies to investigate whether or not the camera, location, and microphone permission requests elicit more concern in users about their privacy and if this further affects their adoptions.

We conducted hierarchical multiple regression analysis to examine the predictive effect of app permission and other influential factors (price, review, and ranking) on app adoption. Our findings show that the price, review, and ranking of anxiety apps remain the dominant predictors of app installation and rating. In another words, app permission does not appear to be an impactful factor on anxiety app adoption, but certain app permissions still have impacts. For instance, two types of permissions: ‘in-app purchase’ and ‘prevent device from sleeping’ are positive predictors for both app installs and ratings. Interestingly, our results reveal the mediator effects of price, review, ranking on app permission and app adoption. A salient example is the Wi-Fi connection permission that only showed effects on the installation and rating of apps after adding price, review, and ranking. The location exhibited a similar effect on app

rating. Since users' app adoption is an intricate process involving various factors, how informational factors such as price, review, and ranking, mediate the effect of app permissions on app adoption needs further investigation.

## 6 Limitations

We want to note several limitations in this study. First, we acknowledge that the correlational coefficient between app permission and app adoption is rather weak, although we have enough of a sample size to show the significance. Second, we only examined anxiety apps on Google Play, which may limit our findings to a specific mental health context and app market. Since we did not compare the results of anxiety apps to other kinds of apps (e.g., game, health and fitness), we have no conclusion about whether anxiety apps request more or different app permissions than other kinds of apps request. We recommend that future studies adopt a similar approach and compare the permission requests among mental health apps and other kinds of apps. Furthermore, due to the observational nature of our data, we cannot identify the cause and effect of app permission on users' app adoption. We suggest that future studies conduct empirical work for further investigation on the effect of app permission on mental health app adoption.

## 7 Conclusion

In this study, we revealed the relationship between app permission and users' anxiety app adoption by analyzing the observational data of apps collected from Google Play. Interestingly, our findings show that anxiety apps with more app permissions have higher installs. Also, app permissions associated with the operating functionality are significantly related to the install and rating of apps, such as the permission to access users' 'in-app purchase', 'camera', and 'location'. We found the mediator effect of app price, review, and ranking on app permission and adoption that still needs further investigation. Overall, this study contributes a general picture of how app permission is connected with mental health app adoption, which is an important step before we can identify which apps may have higher risks of compromising users' information privacy and security.

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