

Recent Smartphones Monitoring Apps Numeric Analysis Linger on Sleep Tracking: Review and Content Analysis

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Abstract

Background: in the era of smartphones and AI nowadays there are thousands of downloadable apps from different stores (Google play, and Apple store) that offer a viable and scalable options for sleep tracking at general population level. Lack of sleep is a health problem that needs to be closely and accurately monitored before it evolves to cause serious and sever health problems. One target of health and fitness app developers is sleep tracking apps, which have many functions, including smart alarms, sleep aids, sleep cycles, and sleep analysis.

Objective: This study aims to review and analyze most recent sleep tracking apps to explore their technical features and functions in order to find out about their effectiveness in tracking users' sleep activity.

Methods: In this study, we have searched the Apple Store and Google Play as the two major used stores for most popular sleep tracking apps. The following keywords were used in our search for applications: sleep app, sleep monitoring, sleep tracking, sleep analysis, sleep quality, sleep disturbance, and sleep cycle. Titles, descriptions, and keywords of the selected applications were checked. All publicly available apps in stores were included, then apps used for other than sleep tracking purposes were excluded, also apps that are not intended for self-management sleep tracking such as baby sleep tracking apps were excluded. Each app was rated for consistency with the well-known APA's app evaluation model, and each store was analyzed separately.

Results: a total of 245 apps related to sleep-tracking were firstly included in our study which took place during the period from December 2022 till end of April 2023 focusing on 21 major technical features of sleep-tracking apps, 60 apps (24.5%) were excluded from the study due to irrelevant main implementation purpose, while another 15 apps (6.12%) were excluded for not supporting self-management sleep tracking, then another 24 apps (9.8%) were excluded due to low usage and low rating during study period, after that 44 apps (17.95%) did not meet the designed requirement values of APA-based statistical model of the study, finally 102 apps (41.6%) met all the inclusion criteria, designed statistical model values, and technical features of the study.

Conclusions: Although there are many hundreds of approved sleep-tracking apps, this conducted analytical study evaluates and examines the 21 main technical features and content analysis in 102 of the more recent and highly rated apps in Google play and Apple store. which have several benefits, including intelligent alarms and sleep aids. But, sleep-wake detection is not reliable enough. A review of apps that met the inclusion requirements revealed that sleep-tracking applications have more room for improvements in features design and implementation, plus privacy for their users in sharing their data.

Keywords: Sleep app; Sleep monitoring; Sleep tracking; Sleep analysis; Sleep quality; Sleep disturbance; and Sleep cycle

Introduction

Sleep is a natural and biological need for humans that supports getting rest, mending, and it is extensively accepted as an influential factor leading to numerous health disorders. Sleep disorders include short sleep duration, wakefulness, snoring, sleep apnea, parasomnias, and restless leg patterns [1]. Besides; sleep disturbance is extremely prevalent and affects 33% - 45% of adults [2]. Furthermore, smartphones and apps tools have widely spread in popularity, with 87% ownership as of 2022 compared to only 35% in 2011 [3], many mobile apps have been developed as a self-management strategy for people with sleeping disorders. Apple Store and Google Play

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(Android) are the major mobile app stores in the world, they have over 3.59 million and 2.33 million apps, respectively [4]. According to PEW Center research, 35% of individuals in the U.S. owned a smartphone in 2011, and 77% reported ownership of a smartphone device in 2017. This study also found smartphone ownership worldwide was as high as 99% in some countries in South Korea, while only 50% among developing nations. Health-behavior tracking such as activity and sleep are two digital devices' most widely tracked behaviors since global estimates of sleep show that sleep difficulties are reported by 10-40% of adults sampled, highlighting that poor sleep health is an international and local issue [5].

A study in 2021 [8] mentioned that; sleep quality is an individual's self-satisfaction with all aspects of the sleep experience which differs from sleep quantity. Whereas; sleep quantity measures how much sleep an individual gets each night, while sleep quality measures how well to sleep; both measures are important. According to study in [5] most healthy adults from 20-to-45 years of age in both males and females; need between seven and nine hours a night to wake up feeling well-rested, but a lot depends on exactly what happens during those hours regardless of any mental dysfunctions. The quality of sleep ensures to get the essential physical, mental, and emotional benefits to need from slumber, such as feeling rested, normal reflexes, and positive relationships [9]. However; sleep quality as an important measure in this study, it should be stated that there are four items/characteristics generally assessed to measure sleep quality; sleep latency, sleep waking, Wakefulness after sleep onset (WASO), and Time in Bed (TiB) which are also crucial to calculate sleep efficiency [39]; all of which determine whether sleep quality is good or not, and therefore are taken to consideration of this study as supporting technical features and inclusion / exclusion criteria of sleep tracking apps under study.

According to new data from Sensor Tower, health and fitness app, consumer spending rose to \$66 million on the App Store and \$35 million on Google Play in Q2 2021 [6]. In addition, as smartphone users are different in app usage, health and fitness apps have become vital tools to make their lives healthier. Health and fitness app usage in the last three years increased by over 330% [7]. These health apps include medical apps for health providers and medical education, patient-centered apps for disease management or self-diagnosis, and general health and fitness apps for lifestyle management [8]. Sleep-tracking technologies, either in the form of a wearable sensor or smartphone-based software application (app), are powerful technologies that have become increasingly small and user-friendly [5]. These apps have a broad range of functions, such as smart-alarm clocks, sleep aids, sound recording during sleep, sleep duration, sleep cycle, and sleep analysis.

In a study conducted on 2022 [7] it has been stated that; sleep management applications on a smartphone have been supported to help people with sleep disturbance to achieve better situations of sleep control and better sleep quality issues. With increased smartphones spread and power on a global scale, rapid and large-scale development in mHealth technologies allows users to self-monitor and fantasize their sleep patterns, symptoms, and behavioral data and prop them in taking applicable conduct on a potentially daily basis [7]. Most of the available sleep-tracking apps are accelerometer-based in which the decision to use raw-

data accelerometers is motivated by the improved comparability of output across different sensor brands, and better control over all steps in data processing, which can employ built-in mobile detectors similar to microphones and light sensors to gain sleep data [40]. Sleep tracking apps use smartphones erected accelerometers to record and interpret sleep data each night [5]. These apps generally track movements during sleep, record sound, wake sleepers up during light stages of their sleep cycle and give perceptivity to help the user interpret the data [12]. Sleep apps are generally accessible, affordable, and salutary for the user overall sleep quality [7]. Former studies have analyzed the confirmation and effectiveness of sleep apps. For example, in [10] a scoping review is conducted of the use of consumer-targeted wearable such as Apple watch, FitBit, Nike+, Jawbone, Biostrap Active set, and mobile technology which set up that most of the articles (9 out of 12 studies - 75%) they reviewed concentrated on the confirmation of sleep operation, and there was a gap in interventions in further target populations similar to patient populations. Furthermore; in [11] a study stated that mobile phone intervention could devalue sleep diseases and ameliorate sleep quality. With a three-piece test set up by [11], the results show that 16 eligible studies were evaluated to examine the impact of mobile phone interventions on sleep disorders and sleep quality. These included one case study, three pre-post studies, and 12 randomized controlled trials. The studies were categorized as (1) conventional mobile phone support and (2) utilizing mobile phone apps. Based on the results of sleep outcome measurements, 88% (14/16) studies showed that mobile phone interventions have the capability to attenuate sleep disorders and to enhance sleep quality, regardless of intervention type. However, the utmost apps (almost 76%) cannot distinguish and record snoring noises from colorful disturbing noises in real-life situations.

Problem statement

This study aims to conduct a content analysis of app developers' written descriptions of sleep apps in the Apple and Google Play stores. Recognizing that an analysis of these written descriptions falls short of a study design that might entail purchasing, downloading, and using the sleep apps available, the scope of this study aimed to analyze the same information that is available to consumers when considering an app purchase utilizing a statistical model based on the American Psychiatric Association (APA) application evaluation model which is used for the goal of evaluation process is to employ a hierarchical rating system and embedded rubric to familiarize APA members, patients, and other providers with important information upon any application selection, and how this differs from choosing more traditional therapeutic interventions, such evaluations include important considerations and choosing the correct app for a particular situation will hopefully result in better clinical decision-making, and improved patient outcomes [19].

Objectives

This study aims to review and analyze Smartphones' (iOS and Android) sleep apps in to explore their features and functions in order to find out about their effectiveness in tracking users' sleep activity utilizing classification of the common technical features of most recent sleep-tracking apps, and using a statistical model based on the American Psychiatric Association (APA) Application

evaluation model as inclusion / exclusion criteria. Therefore; for achieving the study main objective it is been a necessity to subdivide it into five specific objectives:

1. To explore apps related to sleep more recently available on the Apple store and google play store.
2. To analyze the features and discover the more common sleep app features.
3. To build a classification of features.
4. To build a Statistical model based on American Psychiatric Association (APA) App evaluation model to determine and evaluate technical rating for using the sleep-tracking app.
5. To promote the developers to design better sleep apps.

Methods

Selection of Related Apps

In this study we focused on the Apple Store and Google Play for sleep apps searching, as these are the most popular and used apps on smartphones during the period December 2022 – to – April 2023. The following search strings were used to find the applications: sleep app, sleep monitoring, sleep tracking, sleep analysis, sleep quality, sleep disturbance, and sleep cycle. Apps that were publicly available in app stores were included. In this round, apps that weren't just for sleeping were excluded. Apps belonging to the Apple and Android stores were identified, shared across both stores, and each Apple Store was analyzed separately and the joint software we bundled with the Apple Store app.

Screening and Statistical Analysis

One of the study authors designed a statistical model utilizing the American Psychiatric Association (APA) application evaluation model which is used for the goal of APA App Advisor's evaluation process is to employ a hierarchical rating system and embedded rubric so that APA members, patients, and other providers, become familiar with important information that should be considered when picking an app, and how this differs from choosing more traditional therapeutic interventions. Evaluations include important considerations and choosing the correct app for a particular situation will hopefully result in better clinical decision-making, and improved patient outcomes. The APA application evaluation-based statistical model is designed in this study to add more technical feature extraction methodology for selecting sleep-tracking apps from the two major stores (Apple and Google Play stores) as clarified in Multimedia Appendix 3 of this study. Each app was rated separately for its consistency with the designed statistical APA app evaluation-based model which includes 37 objective questions based on major five classes of consideration of evaluating an application: (1) Access and Background, (2) Privacy and Security, (3) Clinical Foundation, (4) Usability, and (5) Data Integration towards Therapeutic Goal. These characteristics were evaluated to gain a broader understanding of the significant features of each app category in comparison against a control group [19,22].

Applications Screening and Eligibility

Apps Exclusion Criteria

Sleep-related apps publicly available on the Apple App

Store and Google Play were included. a total of 245 apps related to sleep-tracking were firstly included in our study which took place during the period from December 2022 till end of April 2023 focusing on 21 major technical features of sleep-tracking apps, 60 apps (24.5%) were excluded from the study due to irrelevant main implementation purpose, while another 15 apps (6.12%) were excluded for not supporting self-management sleep tracking, such as baby sleep tracking apps Baby Tracker: baby feeding & sleep tracker, Baby sleep diary tracker, Baby Tracker: Sleep & Feeding, Luna-Baby monitor with video, Huckleberry Sleep BabyTracker, Little Winks Sleep Tracker, Baby sleep tracker, Baby tracker - feeding, sleep. Then another 13 apps (5.3%) were excluded due to low usage and low rating during study period, after that 44 apps (17.95%) did not meet the designed requirement values of APA-based statistical model of the study. Finally; 11 apps (4.49%) game-based apps such as SleepTown, were excluded in addition to duplicated apps were identified and removed. In the event of a duplication, we included the Apple Store app, as it had all the required information about the app including its date of release.

Apps Inclusion Criteria

Each app's webpage was visited in both the Apple Store and Google Play. Data for each app was extracted and collected: app name, price, rating, number of reviews, author or developer name, technical features, and source (link to app webpage). Appendix 1 provides full details of our sample applications. After Five phases of app filtering and exclusion process; begins with irrelevant main implementation purpose other than sleep-tracking (1st exclusion phase), then not supporting self-management sleep tracking (2nd exclusion phase), after that low usage and low rating during study period (3rd exclusion phase), then not achieving the designed requirement values of APA-based statistical model of the study (4th exclusion phase), finally the game-based apps and duplicated apps (5th exclusion phase); consequently remaining 102 sleep-tracking app to be thoroughly examined and analyzed. Figure 1 shows the flowchart of the app selection process emphasizing the inclusion and exclusion phases and criteria.

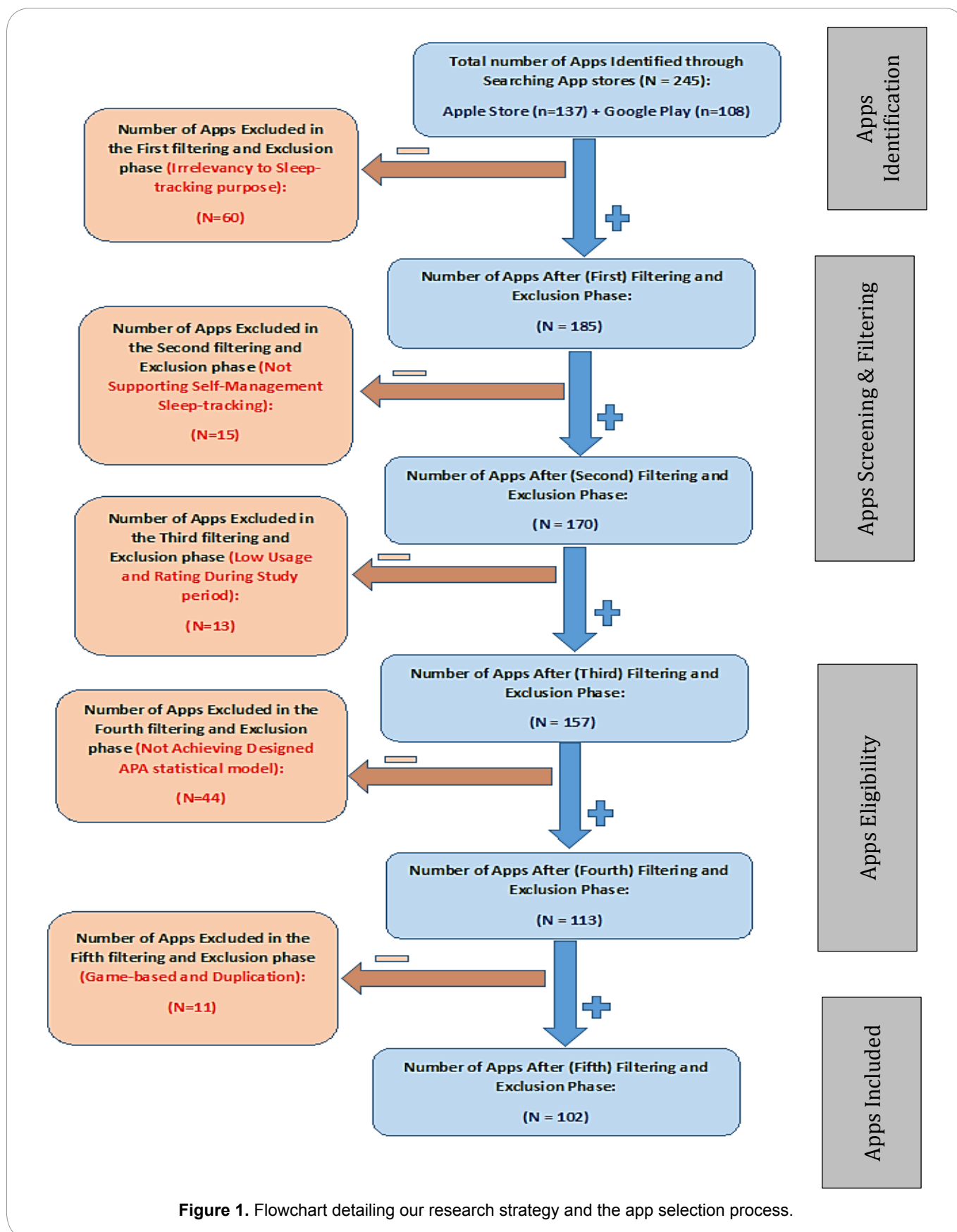
Data Analysis

After both authors researched all apps; technical features were determined based on the most popular Apple and Google Play apps. Then all the components were put in ascending order in one table. Similar technical features are linked and categorized in a graph, and the technical elements are highlighted and given a title. For example, the attribute "User can set the alarm for bedtime and wake up time" is under the heading (Notifications feature). All features have been grouped into categories, each representing a different purpose served by the app. Parts were checked repeatedly by two other co-authors.

Results

User Statistics and Reviews

The ratings were obtained from the mobile app store on a scale of 1 to 5. Whereas; 11 (4.48%) Apple store apps and 2 (0.9%) Google Play apps are not included in the rating. For apps with available ratings, the average rating for Apple store apps was 4.3, and the average rating for Google Play apps was 4.1.



Technical Characteristics and Features of the Included Sleep-tracking Apps

After conducting open coding of the descriptions of lasting included 102 applications, 21 technical features were aggregated and extracted. Table 1 presents the main technical features, with the associated number and percentage of examined apps, and examples of applications that support these technical features, the table is arranged in a descending order. Furthermore, each technical feature is described in detail in the following sections:

The first and most popular technical feature in our review is the Smart Alarm, developed in more than n= 83 (81.37%) applications. This feature allows waking up at a specific time and is sensitive to any sound and noise during sleep. The primary function of this feature is to wake people up from their deep sleep or nap, and it is sometimes used as a reminder. Allows the user to choose alarm ringtones and in some cases, can download music and set it as the alarm tone for waking up [12].

The second most common technical feature is Sleep Recording & Info representation. It was developed in more than n= 57 (55.88%) applications. This feature allows the app to record sleep habits, sounds, and analytics and then represent them in a clear understandable tables and graphs [12].

The third most popular technical feature is Sleep sounds feature, with n = 55 (53.9%) of applications. It carries several sounds, including nature, rain, and calm music. This feature works on good sleep and has been developed by several developers [12].

The fourth most common technical feature is the Timer feature, with n = 47 (46%) of the included applications. It measures the time of sleep start and time of waking-up and hence it helps measuring sleep duration [12].

The fifth most common technical feature is Sleep duration, with n = 46 (45%) of the included apps. This intelligent feature determines the time you need to go to bed and the time you need to wake up, along with information on a regular and healthy sleep pattern [15].

The Sleep statistics feature is supported, with n = 41 (40.2%) applications, it provides graphs for each night separately. It detects sleep stages and analyzes them comprehensively daily. This feature is based on the principle that sleep is not a one-track process but is instead a multiple wave consisting of peaks - which is a stage closer to awakening - and bottoms, which is the stage of deep sleep, and this process is repeated throughout the sleep period. It works by calculating these waves to find out the quality of sleep you got during the last night [12].

The seventh common feature is Meditation, with n = 39 (38.23%) of apps. In practice, meditation before bed stimulates deep sleep and high-quality sleep. It helps in discovering new techniques and mechanisms aimed at relaxing and emptying the brain of all thoughts. Meditation before bed calms the body. Meditation helps generate the same physiological effects that occur in the early stages of sleep [15].

Accessibility and Exporting Data is also a common feature included in our study with n = 38 (37.25%) of the included apps.

Table1. Main Technical Features of the Included Apps with Examples.

Selected app example	Number of Apps: (n=102), n (%)	Technical features (number of Technical features: m=21)
Alarm Sleep	83 (81.37%)	1. Smart alarm
SleepScore	57 (55.88%)	2. Sleep Recording & Info representation
Sleep sounds	55 (53.9%)	3. Sleep sounds
Cycle alarm timer	47 (46%)	4. Timer
PrimeNap	46 (45%)	5. Sleep duration
Sleep Analyser	41 (40.2%)	6. Sleep statistics
Meditation & Relaxation	39 (38.23%)	7. Meditation
Sleep++	38 (37.25%)	8. Accessibility & Exporting Data
Relaxing music sleep	36 (35.3%)	9. Music
Natural sounds	31 (30.4%)	10. Natural sounds
Sleepiest	28 (27.45%)	11. Sleep stories
SleepScore	27 (26.47%)	12. Light sleep
Tracker sleep	26 (25.5%)	13. Heart rate
Better sleep	25 (24.5%)	14. Deep sleep
Sleep theory-sleep better	24 (23.5%)	15. Sleep Note
Bedtime sleep	22 (21.56%)	16. Bedtime reminder
Sleep recording	20 (19.6%)	17. Sleep talking record
Snore Lab	20 (19.6%)	18. Snoring
REM: auto sleep tracker	19 (18.6%)	19. REM
Pillow	19 (18.6%)	20. Breathing
Sleep Bot	18 (17.6%)	21. Movement

whereas sleep app ownership is increasing exponentially, due to their accessibility and ease-of-use. Moreover, sleep apps may increase engagement with healthcare professionals, which may place additional strain on under-pressure sleep services [15].

Music, with $n = 36$ (35.3%), which are the attributes of a piece of music that can be used to describe and analyze it. Some familiar music features include melody, harmony, rhythm, timbre, and shape. Music features also have more specific characteristics, such as certain chord progressions, instruments, and rhythmic patterns, and these features can be used to classify and understand the different musical styles, genres, and emotions conveyed by the music. Music is a common self-strategy that many people use as an aid when they are having trouble sleeping [12].

The Natural sounds feature is supported by the $n = 31$ (30.4%) of the applications, which are quiet or refined and monotonous sounds. The sounds of nature, such as sea waves or autumn leaves, simulate familiar sounds that give an atmosphere of relaxation. Inconvenience and distant sounds are confusing, so many sounds of nature rely on tinnitus masks to cover up tinnitus and any disturbing sounds, which was evident in a report by the American Tinnitus Association (ATA), which explained the importance of using white noise applications to get a reasonable premium. From sleeping [12].

The Sleep stories feature is supported by the $n = 28$ (27.45%) applications. It stimulates creativity and develops imagination, and promotes psychological and emotional maturity to be able to sleep well. Improving communication skills and increasing focus and discipline are beneficial and healthy habits [12].

The Light sleep, and Deep sleep features are supported by $n = 27$ (26.47%) and $n = 25$ (24.5%) respectively of the included apps. Light sleep is a tool that will help you adjust the brightness level on your smartphone screen to avoid damaging your eyes in situations where the lighting is not appropriate (e.g., when you are browsing your phone at night before going to sleep), which may help you sleep better [12].

The Heart rate futures is supported by $n = 26$ (25.5%) apps. It analyzes heart and respiratory rate variance based on sleep movements to better understand your sleep behavior. You'll also get data based on your sleep patterns, the ratio of light sleep to the comforter [15].

The Sleep Note feature is supported by $n = 24$ (23.5%) apps. It enables users to take notes and gives tips to overcome sleep disturbances. There are some examples of those tips that you can keep track of in Sleep Diary. The time you go to sleep, the time you sleep, it helps you review your daily habits [15].

The Bedtime reminder feature is supported by $n = 22$ (21.56%) apps. This feature does not track your sleep quality in the main form. Still, it offers useful features, such as giving reminders before bedtime and automatically setting the alarm for you, and the ability to customize your sleep schedule on certain days of the week [14].

The Sleep talking record feature is supported by $n = 20$ (19.6%) of the applications. It records annoying sounds only, puts them in different audio tracks and sorts them in a timetable for easy browsing, and saves them on the smartphone without needing continuous recording throughout your sleep. It automatically records when a

sound occurs, thanks to intelligent technology that records exactly what you say while you are asleep and dreaming [12].

The Snoring tracking feature is also supported by $n = 20$ (19.6%) of the applications. It enables you to analyze your sleep quality and detect if any problems impede your proper sleep. It only records snoring moments or disturbing sounds [12,15].

The Rapid-Eye-Movement (REM) feature is supported by $n = 19$ (18.6%) applications. Sleep tracking technology that is now generally available cannot accurately measure REM sleep, as researchers in sleep tracking laboratories measure sleep stages with more sophisticated scientific equipment that usually includes devices sensors attached to a person's face and neck; to measure eye and brain activity, and other scientific variables used in the measurement [12,14].

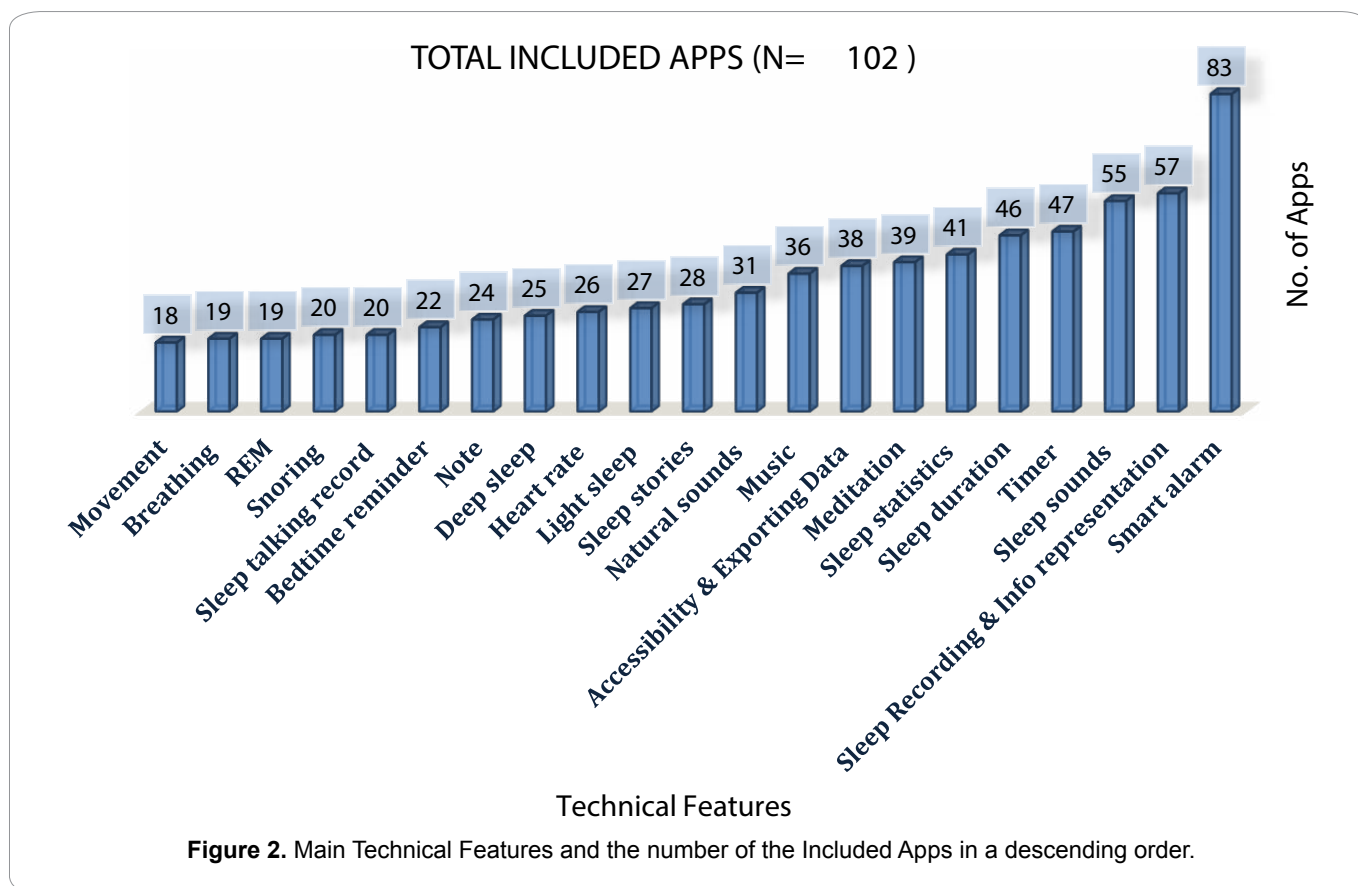
The Breathing feature is also supported by $n = 19$ (18.6%) of the applications. It helps to advise users and remind them of correct breathing methods. It also allows deep breathing exercises to get rid of sleep problems, in addition to straightforward lessons that teach the user about the benefits and importance of deep breathing [14,15].

The Movement feature is supported by $n = 18$ (17.6%) apps. It monitors sleep cycles in addition to monitoring your movement during the day [12].

Figure 2 presents a graph showing the main technical features, with the associated number of examined and included apps arranged in a descending order.

Statistical Analysis based on APA Application Evaluation model of the Included Sleep-tracking Apps

a statistical model utilizing the American Psychiatric Association's (APA) application evaluation model has been designed by one of the authors to add more technical feature extraction methodology for selecting sleep-tracking apps from the two major stores (Apple and Google Play stores). Each app was rated separately for its consistency with the designed statistical APA app evaluation-based model which includes 37 objective questions based on major five classes of consideration of evaluating an application: (1) Access and Background, (2) Privacy and Security, (3) Clinical Foundation, (4) Usability, and (5) Data Integration towards Therapeutic Goal. These characteristics were evaluated to gain a broader understanding of the significant features of each app category in comparison against a control group by sub-dividing each of the five major classes into sub-categories (objective questions) to furtherly evaluate each app functionality and consistency as an exclusion / inclusion criterion. Moreover, thorough clarification is shown in the Excel sheet designed by one of the authors in Multimedia Appendix 3 of this study. Table 2 below shows the five major classes of consideration and the related evaluation questions associated with each class based on the APA Application Evaluation model, along with the average (between 0 and 1) of each APA related question as an evaluation result, and the percentage of impact of each of the five classes of APA application evaluation model. The numeric data (answers for the sub-divided related questions of each major class) have been acquainted or retrieved either from the app developers' website or the Apple store and Google Play stores, and/or been statistically calculated from the data-sheets of the applications under study.



As shown in Table 2 above; a percentage of 66.18% of the total 102 included apps achieve accessibility and trusted background sources due to the Accessibility and Background class of consideration in the APA application evaluation model, while 79.78% of the included apps achieve Privacy and Security section of the APA application evaluation model. Moreover, a percentage of 97.20% is achieved by the study included apps in the class of Clinical Foundation of the APA application evaluation model, and a percentage of 100% is achieved by the study included apps in the class of Usability in the APA application evaluation model. Finally, a percentage of 94.40% is achieved by the study included apps in the last Data Integration towards Therapeutic Goal class of APA application evaluation model. All the statistical model results based on the APA application evaluation model are shown graphically in Figure 3. Below.

Discussion

Principal Results and Findings

This app review and content analysis study shows that sleep-tracking apps differ in terms of the type of developer and background, core 21 common technical features, purposes of use, privacy and security, accessibility, clinical foundation, and data integration towards therapeutic goal. This study reveals various apps developed by multiple developers and authors, and analyzes the most common technical features as sleep data, calculating vital signs such as heart rate and breathing, detecting sleep disorders, and working to improve sleep quality. With the pervasive nature

of smartphones, the use of health-related apps, including sleep analysis apps, will increase [12]. Several studies have found that sleep is linked to several health outcomes, including mood and blood pressure [4].

In our study we have focused on apps because they are accessible and inexpensive, making them more attractive to most people. Sleep apps have many features, but after analyzing them in the apple and google stores, we found that the most popular features are smart alarms, sleep sounds, and Timers. One major attraction for users when downloading sleep apps is the smart alarm, which reportedly wakes the user at the optimal time [12]. Smart alarm feature in 83 apps helps users wake up, refresh and invigorate in the morning at the perfect sleep cycle (light stage). Several “smart alarms” assume that sleep cycles are 90 minutes long.

Sleep quality and quantity are important factors for measuring sleep. Sleep tracking apps can collect data to measure the quality and quantity of users' sleep. Detection of sleep disorders is one of the crucial functions offered by mobile applications; conditions in the early stage are much easier to treat than those later [2]. As the result of this study show in Table 1. the sleep Duration feature in 46 apps, which tracks the sleep cycle by listening to sounds and analyses those sounds with the help of ever-evolving machine learning algorithms, presents the results and helps users to understand sleep with unique data analysis and graphs. Progressing multiple times through the sleep cycle, composed of

Table2. Five major classes of consideration and the related evaluation questions associated with each class based on the APA Application Evaluation model along with evaluation results.

APA Class of consideration	Related Objective Questions of a major class of consideration	Average Evaluation of Each APA related objective Question (out of 1)	Averaged Percentage of each major Class of APA Consideration related to the objective questions
1. Access and Background	1. Does the app identify ownership?	1	66.18%
	2. Does the app identify funding sources and conflicts of interest?	0.509	
	3. Does the app come from a trusted source?	0.705	
	4. Does it claim to be medical?	0.627	
	5. Are there additional or hidden costs?	0.0290	
	6. Does the app work offline?	0.421	
	7. On which platforms/operating systems does it work?	1 (at least one of the two platforms under study: iOS or Android)	
	8. Does the app work with accessibility features of the iPhone/ android?	1	
	9. Has the app been updated in the last 180 days?	1	
2. Privacy and Security	10. Is there a transparent privacy policy that is clear and accessible before use?	1	79.78%
	11. Does the app declare data use and purpose?	1	
	12. Does the app describe use of Protected Health Information (PHI)?	0.705	
	13. Can you opt out of data collection or delete data?	0.784	
	14. Are data maintained in the device or on the web?	0.612	
	15. Does the app explain security systems used?	0.892	
	16. Does the app collect, use, and/or transmit sensitive data? If yes, does it claim to do so securely?	1	
	17. What third parties does the app share data with?	0	
18. If appropriate, is the app equipped to respond to potential harms or safety concerns?	1 (all the apps under study according to the security policy conditions from app developers' websites)		
3. Clinical Foundation	19. Does the app appear to do what it claims to do?	1	97.20%
	20. Is the app content correct, well-written, and relevant?	1	
	21. What are the relevant sources or references supporting the app use cases?	1	
	22. Is there evidence of specific benefit from academic institutions, publications, end user feedback, or research studies?	1	
	23. Is there evidence of effectiveness/efficacy?	1	
	24. Was there an attempt to validate app usability and feasibility?	0.803	
	25. Does the app have a clinical/recovery foundation relevant to your intended use?	1	
4. Usability	26. What are the main engagement styles of the app?	N/A (non-numeric data)	100%
	27. Do the app and its features align with your needs and priorities?	1	
	28. Is it customizable?	1	
	29. Does the app clearly define functional scope?	1	
	30. Does the app seem easy to use?	1	
5. Data Integration towards Therapeutic Goal	31. Do you own your data?	0.951	94.40%
	32. Can data be easily shared and interpreted in a way that's consistent with the stated purpose of the app?	1	
	33. Can the app share data with EMR (Electronic Medical Record System) and other data tools (apple Healthkit, FitBit)?	0.696	
	34. Is the app for individual use or to be used in collaboration with a provider?	0.980	
	35. If intended to be used with a provider, does the app have the ability to export or transfer data?	0.980	
	36. Does the app lead to any positive behavior change or skill acquisition?	1	
	37. Does the app improve therapeutic alliance between patient and provider?	1	

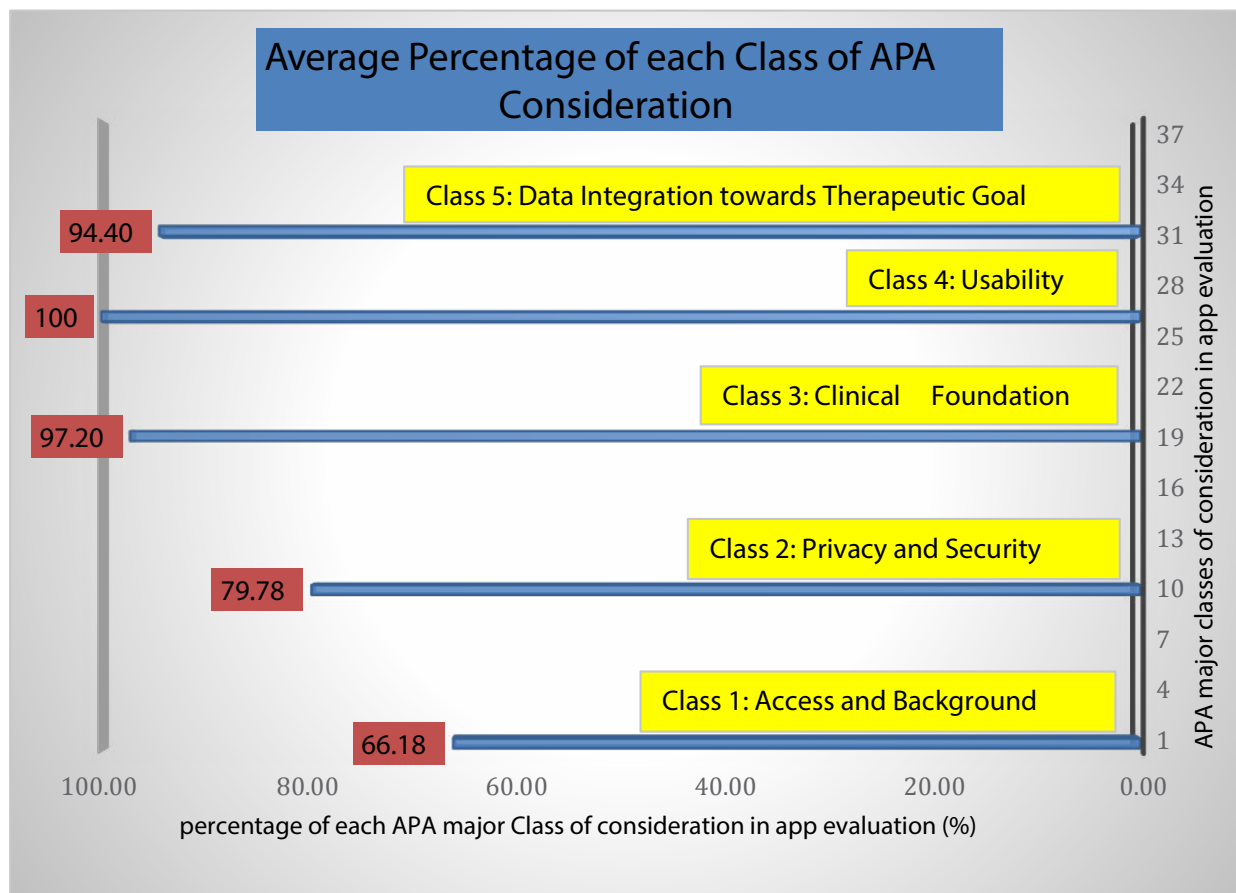


Figure 3. Percentage Achieved Results by the Included Apps in each Class of APA Classes of application evaluation model.

four separate sleep stages, is vital to getting high-quality sleep. Understanding the sleep cycle helps to explain certain sleep disorders which can impact a person's sleep and health [14]. In stage 1 (Light Sleep): the brain slows down, the body has some muscle tone, and breathing is regular. Stage 2 (Light Sleep): heart rate and body temperature both decrease. Stage 3 (Deep Sleep): brain waves at this stage, called delta waves, are at their slowest of the night. REM sleep feature in 19 apps; during REM sleep, brain activity is similar to awake, with loss of muscle tone except for the eyes, which move rapidly, breathing irregularly, and heart rate speed up [15]. This study found no correlation between the polysomnogram findings and the sleep apps under study such as Sleep Cycle, Sleep Score, Pillow concerning sleep efficiency, light sleep percentage, deep sleep percentage, or sleep latency. Some smartphone meditation apps can help users measure sleep quality [2], [3]. The meditation feature in 39 apps in study results enables users to relieve stress, and meditation before bed stimulates deep sleep and high-quality sleep since it helps discover new techniques and mechanisms to relax and empty the brain of all thoughts [19].

Twenty of the included apps in this study record snoring during users' sleep. These apps use the smartphone's built-in microphone to register during the night. Recording snoring during sleep may benefit clinicians examining patients who don't

know about chronic snoring. Habitual snoring is an increased risk factor for CVD and may indicate obstructive sleep apnea. Although the apps are not intended for screening, their use in identifying snoring in specific populations could be helpful [12]. Nevertheless, twenty-four apps in this study can record sleep notes about sleep quality, any reasons for difficulty falling asleep, habits that may affect sleep, such as drinking coffee, eating late or exercising at night, and mood upon waking. Take brief notes about sleep, then discover how these factors affect sleep quality. Sleep doctors recommend using a sleep diary to collect information about a patient's sleep patterns. This is particularly critical for patients with hypersomnia due to poor sleep hygiene, insomnia, circadian disturbances, or phase shift [12].

Moreover, this study has revealed that a percentage of 66.18% of the total 102 included apps achieve accessibility and trusted background sources regarding the Accessibility and Background class of consideration in the APA application evaluation model, while 79.78% of the included apps achieve Privacy and Security section of the APA application evaluation model. Moreover, a percentage of 97.20% is achieved by the study included apps in the class of Clinical Foundation of the APA application evaluation model, and a percentage of 100% is achieved by the study included apps in the class of Usability in the APA application evaluation model. Finally, a percentage of 94.40% is achieved by the study

included apps in the last Data Integration towards Therapeutic Goal class of APA application evaluation model.

Limitations

While 102 apps were included and analyzed in this study, it is possible that some apps that met the inclusion criteria were missed. Our research study for health apps related to sleep tracking was limited to the major app stores Apple Store and Google Play. However, these stores are the largest global platforms for app distribution. Furthermore, the quality of these apps was not examined and rated. Mobile apps also collect and manage users' sleep data, so data privacy becomes a common concern.

Additionally, this study did not explore the specific written reviews of users; only the star ratings were provided. Without taking the written user comments into account it is unclear what factored into users' ratings. For instance, a user may have enjoyed the content of an app but experienced a technical fault and therefore decided to give the app a lower rating. Last, we did not directly explore the aesthetics or marketing of sleep apps in the Google Play store and Apple App Store, and future research should explore how these factors influence use of particular apps over others. The apps were not downloaded, thus more potential information regarding the app may be missing. Finally, short battery life is also a limitation of sleep apps, especially those that fit small sensors.

Comparison with Prior Work

This study has collected and analyzed recent smartphones apps in the two major app stores (Apple store and Google Play) in the period from December 2022 – to- April 2023. During the study period the authors have focused on the most common technical features regarding sleep tracking apps which have been found to be 21 technical features, then a thorough statistical analysis is conducted by the authors to determine the importance, impact, and frequency of these technical features in sleep-tracking apps during the recent time of the study. Exclusion and inclusion criteria of included apps have been designed by the authors concerning the technical features been analyzed, the irrelevancy of app main implementation purpose (other than sleep-tracking), low star-rating or usage of apps in the developer's website, and duplication of apps from the same developer with similar features. Moreover, this study designed and conducted a specific and accurate content and review statistical analysis of the included apps based on the American Psychiatric Association (APA) application's evaluation model classes of consideration and related questions, all information has been collected and reviewed from the apps developers' websites.

Conclusions

In conclusion, smartphones are an integral part of today's society; sleep-tracking technologies have become very small and easy to use, which has led to an increase in smartphone ownership. This analytical study only searched the two major app stores, the Apple Store and Google Play, for sleep apps. These stores are the world's largest platforms for app distribution. Technology has increased awareness of sleep and its effects on health and functional outcomes, and mobile apps have become a popular tool for delivering sleep therapies. However, there is little evidence that the information provided by these apps is correct

to support their usefulness. Multiple developers have developed sleep apps to measure and analyze sleep data, calculate vital signs, and detect sleep disorders. This study evaluated 102 apps and found that sleep-wake detection is unreliable enough to evaluate sleep efficiency and sleep quality since only 17 apps of 102 apps under study (16.6%) used sleep-wake detection technical feature, compared to sleep mapping feature which is used in most of the apps under study (88 apps – 86.3%). The most popular aspects of sleep apps are intelligent alarms, sleep sounds, and timers.

Apps that monitor sleep can collect information about users' sleep patterns, including their duration and quality, and provide services such as detecting sleep disorders. Although 102 apps were examined for this study, some of them likely met the requirements for inclusion. Users' sleep data is collected and managed by mobile apps as well, so data privacy becomes a common issue. In addition, only star ratings were provided in this search; No specific written user reviews have been screened. It is unclear what influenced user ratings without considering written user comments. For example, a user may have liked the app's content but had a technical problem, so he gave the app a lower rating.

Finally, this study designed and conducted a specific and accurate content and review statistical analysis of the included apps based on the American Psychiatric Association (APA) application's evaluation model classes of consideration and related questions. Future studies should investigate how these factors influence the use of certain apps over others. We did not specifically examine the aesthetics or marketing of sleep apps in the Google Play Store or the Apple App Store. As the apps are not downloaded, more details may not be available. Sleeping apps should undergo a rigorous validation study and give more autonomy to their users over how their data is shared.

Based on our study we found that Most apps include intelligent alarm clock function and sleep recording function, but sleep-related physiological signal recording function accounts for a small proportion; that is the reason this study strongly recommends the app developers to focus and improve sleep-related physiological signal recording function in most of their apps through utilizing sensors, AI, and machine learning new and advancing technologies.

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MA contributed in conceptualizing the study and participated in data collection from the app stores and also participated in designing the statistical analysis of the common technical features and manuscript revision. NA contributed in drafting the manuscript, and participated in conducting data acquisition, and analysis, designed the APA application evaluation-based statistical model and revised the obtained statistical results.

Conflicts of Interest

none declared.

Abbreviations

App: Application

REM: Rapid Eye Movement

APA: American Psychiatric Association

AI: Artificial Intelligence

ATA: American Tinnitus Association

PEW: The Pew Research Center is a nonpartisan American think tank based in Washington, D.C. It provides information on social issues, public opinion, and demographic trends shaping the United States and the world.

Multimedia Appendix 1

Multimedia Appendix - Summary of the studied Sleep Tracking Apps [PDF File]

Multimedia Appendix 2

Multimedia Appendix - Common Technical Features of Sleep Tracking Apps Statistical Analysis [Excel File]

Multimedia Appendix 3

Multimedia Appendix - Statistical Model for Sleep-tracking Apps based on APA Application Evaluation Model [Excel File]

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