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Improving Sleep-Wake Behaviors Using Mobile App Gamification

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ABSTRACT

Gamification can be used to encourage people to perform challenging tasks. Gamification can also be useful in altering unwanted habits and enhancing subjective well-being. Everyday health is affected by sleep-wake habits to a significant extent. Therefore, we can come across gamified products and mobile applications related to subjective well-being and sleep/wake activities. This paper presents a study investigating whether gamification can be used to affect sleep-wake behaviors in a positive way. The paper presents a quantified relationship between wake-up, go-to-sleep, work (start) hours and gamified features. For this purpose, a gamified mobile alarm clock application called the *Sleepy Bird* was designed, created and tested in a user study. The study included twenty-six participants in an A-B experimental set-up: thirteen participants using a gamified version and thirteen participants using a non-gamified version of the app for two weeks. The participants who used the non-gamified version had a poorer motivation to begin their day at the required times in comparison to those who used the gamified version. It was also observed that gamification made favorable modifications to participants' sleep-wake behaviors.

1. Introduction

Gamification can contribute to the management of sleep-wake behavior, which is among the most important aspects of subjective well-being. At least some people may find it difficult to wake up and go to bed when they have to. The main purpose of this study is to make users aware of sleep-related problems through a gamified app, so that they can begin to change their daily habits positively and improve their well-being in the long term. In this study, another goal was to determine if gamification could be used to change sleep-wake behavior. Tracking their sleep-wake habits with the help of an alarm clock app, users can become aware of the problems related to sleep. These problems can be caused by ignoring the correct times to wake up and to go to bed, length of sleep and snoozing actions. Therefore, the Sleepy Bird, a gamified alarm clock app, was created and tested in a user study in order to find out if the mentioned app could lead to positive emotions and higher perception of sleep-wake habits.

1.1. Gamification and well-being

Digital games have significantly contributed to the growth of gamification. Newzoo's 2019 Global Games Market Report states that worldwide, more than 2.5 billion people currently play games and mobile game revenues take the largest portion, with 80% belonging to smartphones and the other 20% to tablets. The report also indicates that mobile games will outpace PC and console games toward 2022 [1]. Playing has the potential to replace some behaviors by new ones [2].

Some people may be inclined to ignore certain activities or find them tedious, dull and even hard to achieve, wherein gamification can be an effective tool to influence people otherwise. Gamification is defined as "the usage of game elements in non-game contexts" [3]. It has the power to make unfavorable but necessary activities more interesting by creating extrinsic and intrinsic motivations, thereby convincing people to do something about such activities [4,5]. While needs with tangible outcomes such as reputation, titles, wealth and real rewards can be met by extrinsic motivation, intrinsic motivation represents the feeling of pleasure due to a riveting and pleasant activity [6]. A gamified tool can be successful when players can achieve intrinsic motivation and meet the goals they set for themselves [5].

Gamified tools may work only with a software to be downloaded to a mobile platform or a personal computer etc., or work with both software applications and hardware products that can be wearable or controlled

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physically. These can encourage people to be physically active, track their behaviors, compare them with others in a social platform and give them rewards in return for their success [7]. Personal wellness and healthcare take up a large proportion of gamification applications. The upcoming sections will explain the examples of such applications that are used on handheld devices in further detail and these applications will be called the 'apps' hereinafter. Gamified products and apps are useful in motivating people to be physically active. '*Fitbit*', '*Nike Plus*', '*Zamzee*' and '*Withings*' are wearable product examples aiming at motivating people to adopt a more active lifestyle. '*Goalpost*', which is a gamified app, targets smoking cessation among its users within 12 weeks. The developers of the app believe that social platforms are the only way to help people stop smoking. As shown in the 'Khan Academy' example, reward systems can be used in the integration of games into mobile systems for education, testing and learning. Moreover, gamified apps such as '*HabitRPG*', '*Epic Win*' and '*Mindbloom*' can help arrange daily routines as they determine the essential activities in daily life and rank these activities in the order of importance. These applications record, follow and shape daily activities of individuals in an efficient manner. Thus, it is possible to influence several behaviors with gamified tools.

Satisfaction with everyday activities affects our general wellness throughout life. Therefore, focusing on the aspects of well-being in daily life can be a good starting point in this respect. Accordingly, the initial requirement of the present study is to find a specific daily habit that requires extra motivation. The literature and observations indicate that day-to-day well-being is determined by sleep-wake behavior to a significant extent. Gamification can potentially contribute to the management of sleep-wake behavior. Therefore, this study investigated the effects of gamified tools on subjective well-being from the aspects of wellness and healthcare.

1.2. Sleep-wake habits

It is important to go to sleep at the appropriate time at night, get a good night's sleep and wake up at the appropriate time in order to have enough energy to keep going throughout the day. Sleep is defined as a repetitive and active behavior that is formed both in the brain and the body to enable physical development, healing, cognitive recruitment, and memory wellness [8]. The energy required for difficult tasks and regulation of a person's activities were ensured by the sleep [9]. Moreover, long-term well-being and happiness are influenced by sleep-wake behavior to a significant extent. It is stated that 60-–90% of the people who were depressed had issues associated with sleeping and waking up [10]. Emotional, psychological, and social well-being would be enhanced when problems related to sleeping are solved [11,12]. Therefore, many adults are eager to change their sleep behaviors since the systematic rhythm of sleep hours and length of sleep is important for the health [13,14]. Accordingly, the rhythm of sleep including fixed bedtime hours, wake-up hours and length of sleep form the sleep patterns.

Sleep patterns. Ideal sleep can be defined as a sleep ensuring that a person has sufficient energy throughout the day. Sleep quality can be understood from sleep efficiency and the time when a person goes to bed and wakes up. The NREM (non-rapid eye movement) stage of sleep starts right after a person falls asleep, wherein the sleep is longer and initially lighter and the NREM stage constitutes 50% of the total night's sleep. This stage is beneficial for daily physical relaxation and physiological healing of the body. The NREM stage is followed by the REM stage (20% of total night's sleep) which is a mental and psychological rest period [15,16].

Physical, psychological, and cognitive health are associated with the length of sleep. Despite the fact that required length of sleep decreases with age, adults are recommended to get 6–8.5 h of sleep [17]. It is known that the incidence of depression is lower among people who have optimal sleeping habits, since such people have higher self-confidence and stronger social bonds. On the other hand, people who do not get enough sleep may feel depressed, stressed out and experience physical and mental fatigue throughout the next day [18]. Sleep irregularities also impact the learning performance of adolescents [19]. Shorter length of sleep leads to depression and stress as well as physical and mental fatigue throughout the day [20]. On the contrary, people who get sufficient sleep have the necessary energy and psychological strength to fulfill their responsibilities and face difficult situations. People who experience optimal sleep would have the energy required to perform tasks, higher self-acceptance, more reasons to live and better relations with people [21]. It is stated that waking up in time and snooze-free is a determinant for high-quality sleep. Waking-up at early hours is significantly important as it induces melatonin secretion, thereby calming the body and maintaining well-being. The best time to go to bed is after sundown and the best time to get up is after sunrise. Therefore, the ideal time to go to sleep and wake up is 00:00 a.m. and 07:00 a.m., respectively in order to get a high-quality sleep [16]. It is also asserted that some time is required for people to be completely awake after waking up. Accordingly, people would be awake enough to start their daily routines at least 1–2 h after they wake up. When people are engaged in mind-related activities or sports after these hours, they often have more concentration. Moreover, alarm snoozing is a disruptive factor against the quality of sleep. By sleeping a few minutes or more after the wake-up time, the sleep quality is broken, and its overall efficiency reduced [16].

Snooze habits. Alarm snoozing habit is a disruptive factor for the quality of sleep. Sleeping a few minutes or more after the wake-up time would lead to poorer sleep quality and reduced overall efficiency of sleep. Therefore, having no benefit for people, snoozing should be avoided [16]. It is also evidenced in the literature that sleeping and waking up have a considerable influence on our daily life, and gamification in this respect can potentially have a role to positively affect subjective well-being. Using an application to monitor sleep may assist people to be more conscious about their sleep-wake behavior and enhance their health in the long run [22].

1.3. Sleep-wake habit-related products

Gamified products are partly based on the association between sleep and welfare. There are various examples of physical products and mobile apps that integrate gamification to track and shape people's sleep patterns.

Physical products. Waking up at the appropriate time and prevention of snoozing can be achieved using various alarm clocks dedicated to this purpose. For example, '*Clocky*' (by Gauri Nanda) is one of the first smart gamified alarm clocks. At the due time, it starts to move away from the user, who needs to catch it to stop the alarm. Similarly, the '*Helicopter Alarm Clock*' (by BoysStuff) would only stop ringing after the user catches the flying helicopter and places it in its nest [23]. '*Ruggie*' (by Winson Tam) is another innovative product designed to make users wake up on time and without snoozing. If users step on this floor mat within 30 s after it goes off, the app shows motivational quotes to start the day [24]. Therefore, such entertaining and practical products can be used to make users wake up without snoozing.

Mobile apps. Some alarm clock apps with gamified features are intended to wake people up by playing games. For example, '*Early Bird*' (by Berghs School of Communication), which was created for Starbucks, provides feedback messages and has a reward system on a social platform in order to make its users wake up at the appropriate time. The application rewards users when they do not hit snooze while using the alarm clock app [25]. The '*AlarmMon*' (by Malang) app wakes users up with its loud sounds, enjoyable characters, and fun mini games [23]. '*Mimicker Alarm*' (by Microsoft) is another alarm clock app that gives three game alternatives to be played in 30 s just after the alarm starts to ring. Only after the user plays one of the games successfully does the alarm stop ringing [26]. '*Wake-up Club*' (by Sony PlayStation Vita) motivates users with enjoyable social interactions and achievements

[27]. These apps use gamification in order to prevent snoozing.

Mobile apps with physical products. Some apps work in communication (or together) with physical products to achieve effective sleep. For example, '*Zeo Sleep Manager*' (by Zeo) measures the length of each sleep stage with headbands, and enables its users to manage the stages of their sleep and organize their time. It tracks sleep cycles using wearable devices and sends the information to the mobile platform [28]. After sleep tracking studies with Zeo Sleep Manager, Zeo score and reward system showed that monitoring sleep activity with light and deep sleep stages improved sleep quality [29]. It was also reported that better sleep and wake scores were achieved with better total sleep time, total wake up time and sleep efficiency [30]. '*Sleep Well*' (by Intersog) and '*Sleep Cycle*' (by Sleep Cycle AB) also track sleep patterns and give detailed information about sleep cycles of users. They can distinguish between NREM that exhibits light and deep sleep patterns and REM. Using game mechanics, they try to wake people up at the most suitable hours.

The significant number of downloads and applications of the existing gamified alarm clocks show that they have a potential to positively impact the sleep-wake behavior. Moreover, the money spent for these apps besides their high number of reviews and ratings shows the interest and the need related to monitor the sleep quality upon gamified alarm clock apps [31]. These apps generally use gamification related to waking up at specific hours and not snoozing. In the present study, however, we employ a specifically designed gamified app using the 'fun factor' in a persuasive and motivative way to focus on wake-up and go-to-sleep times, length of sleep, the time from getting up and beginning to work, and number of snoozes.

2. Methodology

This section presents the purpose to design a gamified app for the study. It explains the improvement of the app and decisions behind its running while describing the methods employed in the study, such as determining the user groups, stages of the study, and data collection tools.

2.1. Sleepy Bird – Gamified app for sleep-wake habits

The present study largely focuses on the association between gamification and sleep-wake behavior. In the study, a mobile alarm clock app called the '*Sleepy Bird*', which was designed and developed to monitor and acquire data associated with sleep, was used to test the effect of gamification by identifying the persuasive and motivative impacts thereof. The goal was to understand if gamification had a long-lasting positive impact on the subjective well-being of the participants by providing motivation and creating awareness to enhance sleep-wake behavior. The information gathered from the literature related to ideal sleep-wake hours and gamification helped to form our decisions for the intended app. In addition, the application collected information about the sleep-wake times, length of sleep, the time from getting up and beginning work and the number of snoozes, allowing remote data collection to understand and track the existing sleep-wake habits of the participants.

Also the gamified and non-gamified versions of the mentioned application were compared in order to do further analysis on sleep-wake habits. Thus, it was planned to use both versions of the app to decide whether the modifications in the sleep patterns were caused by gamification or not.

Development of the app. *Sleepy Bird* is intended to provide fun while being easy to learn and play. The app should not make its users to give all the attention to the game and ensure that the users also utilize the alarm clock. The game genres were reduced to a platform that could be implemented with an alarm clock and played on the smart phone easily. Since the time duration of the study was limited, the decision of modifying an existing successful game instead of designing a totally new game was made in that step. The criteria used for game selection were as follows: game popularity, uncomplex gameplay and rapid level-up. It was thought that the progress users make could be readily assessed in platform games. The selected genre was a platform game based on '*Flappy Bird*' (Fig. 1), which was a successful app worldwide, hence, established a basis for our model. In this game, a bird, which is a side scroller, would fly horizontally on the screen. The players guided the bird's flight by tapping on the screen and they had to avoid the green pipes, wherein they earned one point whenever the bird flew through the opening between the pipes. It was a popular game as stated before and nearly 3 million users downloaded the game each day [32]. For the purpose of this study, the whole game was designed once more for use with the Android operating system including the alarm function, calculations and feedback. Java programming and a game development framework called *LibGDX* graphics library were used for the technical development of the *Sleepy Bird* app.

For this study, both gamified (G) and non-gamified (N-G) versions of *Sleepy Bird* were designed. Table 1 shows the differences between the two versions. Due to the fact that comprehensive feedback messages are required to ensure intrinsic motivation for the participants, the both versions provided feedback messages tailored to the user and insights with respect to wake-up times, snoozes and length of the sleep.

The goal of *Sleepy Bird* was to help users feel good in the morning when they begin their day. Therefore, the colors were selected and the graphic design was made with the purpose of preparing the participants to start the day positively. The game used soft colors and light to create an environment, implying that it was past sunrise. The 'Sleepy Bird character' was designed to fly from the left side of the screen to the right, showing a big red eye representing the degree of sleepiness of the bird.

The app could also be used in Turkish to be applicable in the intended country, Turkey, and to suit target users who would be asked to participate in user trials. In the G version, users could see their score and how many lives they had at the uppermost part of the game screen (Fig. 2a). *Sleepy Bird* had four buttons on the main screen, wherein there were two different groups of buttons with two different colors. The orange PLAY and LEADERBOARD buttons were related to gaming; brown SET ALARM and SLEEP buttons were associated with sleep (Fig. 2b). For example, when a participant set the alarm at 9.00 a.m. (Fig. 2c), the red-colored notification indicated that the player would play the game three times when s/he set the alarm at that time. For the N-G version, PLAY and LEADERBOARD buttons were removed and game notifications did not exist.

By using personal feedback messages, the app provided information concerning wake-up times, snoozes and length of sleep. To ensure the participants attention, the messages were displayed in red color. If the messages were long, the Sleepy Bird provided feedback messages in a pop-up screen to interact with the users about their action. Some examples from the feedback messages of G version are as follow:

- (If a user wakes up at the optimal time) "Good morning and congratulations! You woke up at the best hour for you, x o'clock, 1.5 hours before your work. You have won the maximum-30 lives today."
- (If a user wakes up earlier/later than they should) "Good morning! How do you like waking up later/earlier tomorrow morning? You got only x lives today."
- (If a user hits the snooze) "Good morning! For better sleep, try not to snooze again tomorrow. For every snooze action, you lose 25 meters in the game."
- (If a user surpasses other participants in the game) "Congratulations! You have just passed your rivals in the game. Don't fall behind them again."
- (If a user goes to bed earlier/later than they should) "Good night! You will sleep too long/short tonight. How about sleeping less/more? Your bird will fly faster tomorrow."

Depending on whether the participants woke up early or late, the app

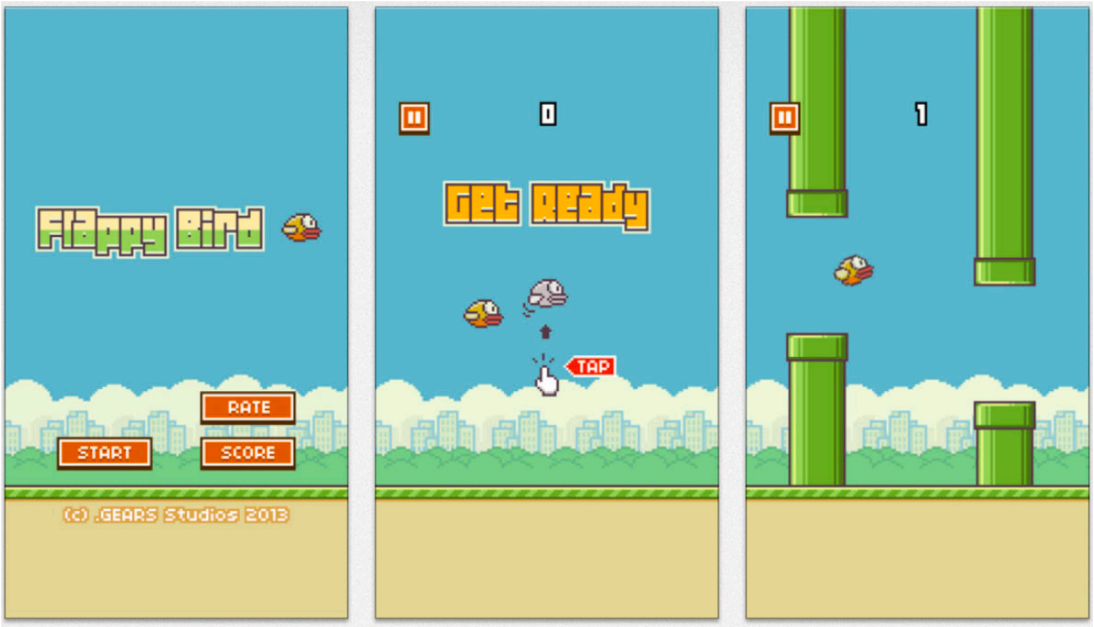


Fig. 1. Images of Flappy Bird © (Retrieved from https://techcrunch.com/2014/02/01/developer-behind-flappy-bird-the-impossible-game-blowing-up-the-app-store-says-he-just-got-lucky/, 2021).

Table 1
Differences between gamified and non-gamified versions of *Sleepy Bird* app [33].

G: Gamified Version (Experiment Group)	N-G: Non-Gamified Version (Control Group)
Alarm time and sound	Alarm time and sound
Going to bed hour and length of sleep	Going to bed hour and length of sleep
Feedback about wake/sleep actions	Feedback about wake/sleep actions
Revised *Flappy Bird* game	N/A
Game elements (e.g. scores, lives, visual elements, notifications)	N/A
Four buttons (play, leaderboard, set alarm, sleep)	Two buttons (set alarm, sleep)

showed their gained or lost lives for the following day, respectively. The participants had to hit the SLEEP button before going to sleep so that the app could record the length of their sleep. The participants were free to play the game at any time during the day, once the alarm rang and woke them up in the morning. While waking the participants up, the bird would continue to fly horizontally on the screen, adding to the distance travelled and the scores of the players. The leaderboard displayed the scores gained by all players. Since, this app was built for Android, it used the Google leaderboard Application Programming Interface (API) to track user scores. The scores were sent to the Google servers at certain time intervals and notified to all players online. The interface also enabled the users to check the daily/weekly and monthly leaderboard so that the users could see their ranking among the others who played the game.

Decisions Behind the Features of '*Sleepy Bird*'. The following items were considered while developing the versions of the app:

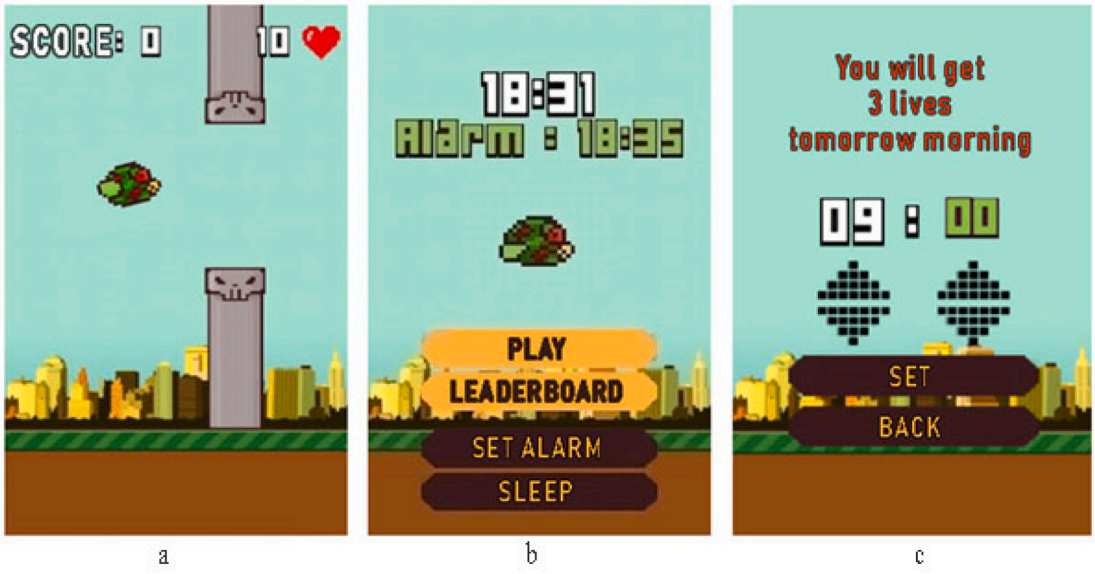


Fig. 2. Example screenshots from the gamified (G) version of 'Sleepy Bird' [30].

- The ideal wake-up time was set to be between 6.00 and 8.00 a.m. and at least 1.5–2 h before the work time [16].
- The adequate length of sleep was set as 7 h for the target group [9].
- Game elements such as scores, lives and leaderboards were added to motivate the participants [34].
- Feedback messages were displayed continuously in order to communicate the required sleep-wake hours specific for each user [6].
- While waking up, the app did not require the users to play the game to stop or snooze the alarm.

The game rules were set as follows:

- Initially, the game gave 10 lives by default.
- The app provided personal settings to calculate the ideal wake-up hours for each user. The starting time of work/school by the participants was important for app calculations because the application granted the maximum number of lives when users woke up 1–2 h prior to the time they began working. The users lost 1 life for each 5 min of sleeping past the ideal wake up time.
- The game granted the highest number of lives (30) when users woke up at the ideal time, which was found to be a suitable solution to preserve the balance between promoting fun and maintaining its significance as a regulator of sleeping habits. In the worst-case scenario, that is waking up either too early or late, the participants would still have 3 lives.
- The game could only be played at normal speed when the length of sleep was between 6 and 8 h in a day. However, when participants slept too early or too late, the bird moved faster the next day, making the game more difficult.
- Snoozing the alarm would draw the participants behind in the competition by 25 m for each 5 min of snoozing.

2.2. Selection and distribution of the participants

E-mail, social media and personal relations were used to find participants for enrollment. The participants had to fulfill the following criteria to be eligible.

- Waking up with an alarm
- Aged 18–35 and sharing similar sleep-wake behavior
- Finding it moderately difficult to wake up
- Possessing a mobile phone with the Android operating system
- Lack of a specific dislike for the Flappy Bird game

Eligible individuals who volunteered to participate were sent a pre-use questionnaire. Those who did not have issues associated with sleep or had health problems were not included in the study. The participants were assigned to two groups, i.e. one using the G version and the other using the N-G version of the application. The game provided by the application was an altered version of the Flappy Bird. Therefore, grouping was mainly based on the participants' view of the game; if positive, they were assigned to the G version. While developing the game, the application was used by different user groups during independent time periods (beta and pilot studies) for piloting purposes before the main study was finalized. Consequently, this was useful in detecting and correcting potential functional faults, enhancing the app's performance, determining the appropriate statistical analysis methods, as well as establishing the number of users to be included the study.

For the final study, each group included same number of users. Overall, 30 participants were secured. After a few days, four participants left the study due to either technical issues with their mobile phones or unwillingness to use the alarm. In all, the 325 sleep-wake data of 26 participants (13 G; and 13 N-G users) were used. These individuals had to set the alarm each night for the next day before going to sleep. When this task was not fulfilled, the data could not be created and used for the assessment of that day. In both G and N-G versions, the Sleepy Bird symbol was shown on the main display at 10.00 p.m. to alert the participants to set their clock and not to stay up late so that they can get up without difficulty the next day. The analysis and discussions were performed with both positive and negative variations from the optimal wake-up time, sleep time, and length of sleep compared to the normal behaviors of the users in these three situations.

Firstly, the Beta Study group used the app to detect probable bugs and shortcomings. Three participants utilized the *Sleepy Bird* for two weeks, providing remarks later used to solve the app's technical problems and to further assess them throughout the pilot study. Secondly, four participants used the G version, while the other four used the N-G version in the Pilot Study. In total, 102 wake-up data belonging to eight participants were obtained for more than 24 days. It was understood that the participants generally did not use their alarms on their days off and weekends. This observation was taken into account for timing in the final study. It was decided that the app should be used for four weeks every day without interruption and regardless of holidays-weekends. To attain a more accurate conclusion, the results of the pilot study were analyzed mainly during the improvement process and were not coupled with the final study analysis.

2.3. Data collection tools

Data related to awareness levels, subjective motivations and habits concerning the sleep-wake habits were obtained through a pre-use questionnaire distributed among the participants before using the app, a post-use questionnaire distributed upon finalization of the predetermined usage period, and computer logs as usage data. The purpose of the pre-use questionnaire was to group the participants based on their answers and scores concerning their attitude towards games and basic sleep-wake behaviors. The purpose of the post-use questionnaire was to gather usage-related data. The flow and objective of the data collection can be seen in Fig. 3.

In both questionnaires, Epworth Sleepiness Scale (ESS), Pittsburgh Sleep Quality Index (PSQI), Morningness-Eveningness Questionnaire (MEQ), and Delighted-Terrible Scale were used to gather individual assessments. The ESS is a 4-point Likert scale with eight questions in Turkish. It is one of the most useful subjective assessment approaches for determining the sleeping habits of individuals while performing various activities [35,36]. The PSQI, developed by Dr. Daniel J. Buysse and coworkers, is applied to reveal sleep-wake patterns in addition to quality [37]. The MEQ, developed by Horne and Ostberg, can help analyze sleep patterns correctly [38]. With 19 questions, the MEQ groups people based on sleep-wake patterns taking into account their biological rhythm [39]. The last scale, Delighted-Terrible Scale, was used by Andrews and Withey in 1976 to measure short-term subjective well-being [40].

Pre-use Questionnaire. In Part 1 of the pre-use questionnaire, the candidate's subjective assessment of sleep habits was collected using the ESS. Part 2 adapted some of the questions from the PSQI. In this part, snooze habits, the time to sleep and wake up (for weekdays and weekends), and the starting time of work/school were asked to the participants. Part 3 used MEQ questions related to sleep-wake behaviors. The 26 participants were asked to score the following six questions ranging from 1 (strongly disagree) to 5 (strongly agree). Q1 asked whether it was easy to wake-up in the morning; Q2 asked whether a gamified app made waking up easier; Q3 and Q4 focused respectively on the level of being alert or fatigued in the first hour after waking up; Q5 asked about the positive feelings of the participants when they wake up at the right time, and Q6 inquired about the motivation to use a gamified app to wake up on time.

Computer Logs. During the usage of the app, computer logs (usage data) were recorded. After the installation of the game, i.e. Sleepy Bird, on the participants' phones, the usage data was automatically collected in a database, and activities in the application were remotely logged in

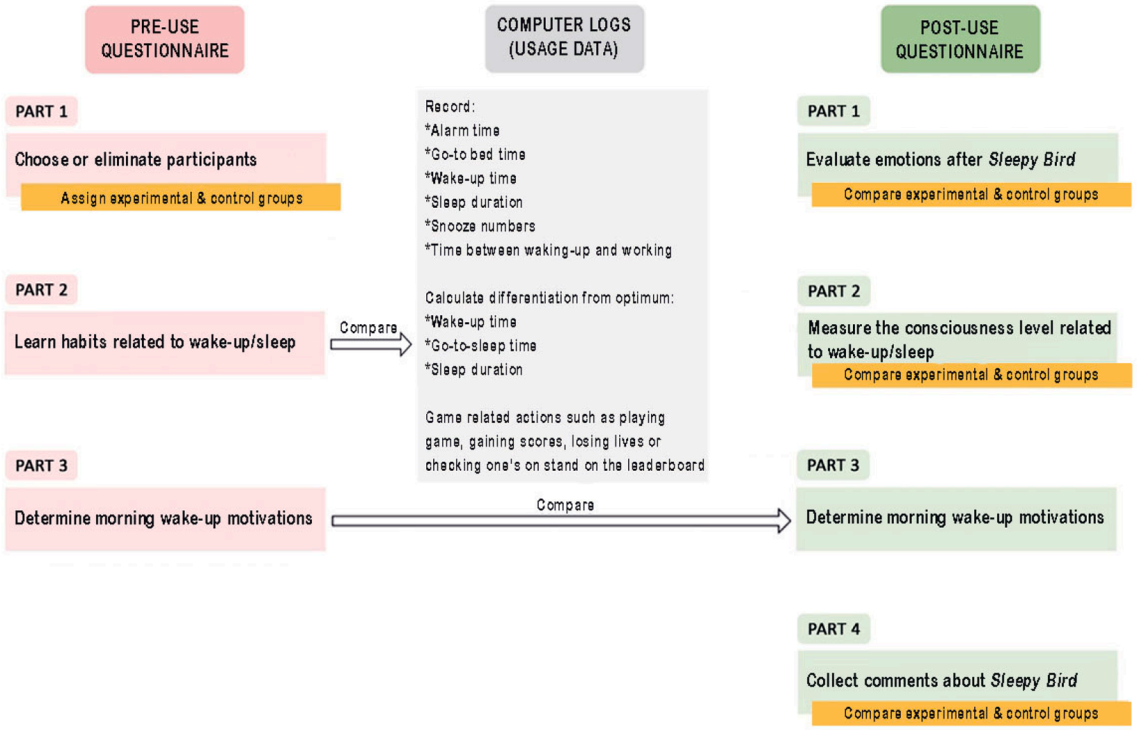


Fig. 3. Flow and related objectives of data collection.

the system. These actions included all interventions by the participants known as 'logs'. Concerning sleep and game actions such as opening the app, logging in the sleep time and setting the alarm to wake up, playing a game, losing lives, checking the leaderboard, etc. These actions were logged and stored for each user in the queries to provide comprehensive results related to their actions.

Post-use Questionnaire. The Delighted-Terrible Scale (one question requiring the choice of one facial expression) was used in Part 1 of the post-usage questionnaire to measure short-term subjective well-being following the use of *Sleepy Bird*. Part 2 was designed to assess improvements in the users' understanding of sleep-wake patterns following the use of the application. The questions were as follows: wake-up time (Q1), length of sleep (Q2), the time between getting up and beginning study/work (Q3), and the number of snoozes (Q4). In Part 3, the same questions (Part 3 of pre-usage questionnaire) were asked regarding the usage period of the app and the post-use questionnaire results were compared to those of the pre-use regarding MEQ. Part 4 included open-ended questions in order to compile participants' opinions on the favorable and undesirable aspects of Sleepy Bird. This section was also used to illustrate their tendency to modify their sleep-wake behaviors, as well as their suggestions for novel app features.

3. Results and analysis

This section describes the findings from both questionnaires, i.e. pre-use and post-use, and the computer logs.

3.1. Pre-use questionnaire

The pre-use questionnaire is divided into three sections to determine the eligibility of the participants for the study and afterwards to compile the relevant data (Fig. 3).

i) Part 1. The total Epworth Sleepiness Scale scores showed if the participants had 'average sleep problems' (rating from 4 to 9), 'sleep problems' (10–14) or 'sleep problems requiring professional medical assistance' (15 +). A moderate score (4–14) suggested that the participants were eligible to be included in the study. In the ESS results, the lowest total score was 4, and the highest score was 14, with a mean score of 8.6 with a standard deviation of 3.6 within the selected group of participants.

ii) Part 2. This part assessed the users' sleep patterns including sleep, wake-up and snooze behaviors before using the *Sleepy Bird* app. The mean value of all participants for sleep time is 0.22 a.m. on weekdays, 01.24 a.m. at the weekends; wake-up hours is 7.42 a.m. on weekdays, 09.53 a.m. at the weekends; and length of sleep is 7.23 h. Pertaining to snooze behavior, 92% of the participants stated that they usually used this feature at least once a day. In order to accurately determine the acceptable wake-up hours of the individuals, the participants were asked to enter the time they had to be at work or school. Based on the results, 92% of the participants had to be at work or school by 8.00–10.00 a.m.

iii) Part 3. This part concentrated on personal evaluations of the users regarding their wake-up behaviors and motivations before using the alarm app. The scores are out of 130 (the sum of G and N-G = 26 participants × 5 highest points). Accordingly, the answers to Q1 received the lowest total score, showing that waking up in the morning is difficult (54/130); Q2 asked whether a gamified alarm application would help users get up more effortlessly (81/130). Q3 received 63 points, implying wakefulness in an hour after waking up in the morning; Q4 scored 74 points, that is feeling fatigued after getting up; Q5 obtained the highest total score (99/130), showing that the users had positive thoughts and a tendency to wake up at the right time; lastly, Q6 also received a high score (87/130), suggesting that a gamified application would motivate users to begin the day. The scores of the questions related to the sleep-wake behaviours were compared with *t*-test in order to understand first attitudes of the participants (Table 2).

According to the one sample *t*-test results, the scores were compared to the midpoint of the scale (test value = 3 for each question) in order to calculate the statistical tests of significance. Before using the app, the scores of the users remarked three questions (Q1, Q3, and Q5) at the significant level; Q1 [($M = 2.07$, $SD = 1.01$), $t(25) = -4.62$, $p < 0.001$], Q3 [($M = 2.42$, $SD = 1.13$), $t(25) = -2.58$, $p = 0.016$]; and Q5 [($M = 3.8$, $SD = 1.05$), $t(25) = 3.88$, $p = 0.001$]. These results formed the basis for

Table 2
One sample *t*-test results for the pre-use questionnaire, Part 3.

No.	N	M	SD	df	t	p
Q1	26	2.0769	1.01678	25	−4.629	**0.000**
Q2	26	3.1154	1.03255	25	0.570	0.574
Q3	26	2.4231	1.13747	25	−2.586	**0.016**
Q4	26	2.8462	0.83390	25	−0.941	0.356
Q5	26	3.8077	1.05903	25	3.889	**0.001**
Q6	26	3.3462	1.09334	25	1.614	0.119

subsequent comparisons, which is given in Part 3.3. Post-use questionnaire analysis.

3.2. Computer logs (Usage data)

Usage data of all 26 participants were used to compile the sleep-wake behaviors of the users. Ultimately, a total of 325 data samples (i.e., the total number of behaviors linked to wake-up times, length of sleep, and the number of snoozes) were obtained. Data were compared according to the app version used (G or N-G), the users' behavior in relation to the first half and second half of the application period and the time of usage (weekday or weekend). The data related to days 8–22 of the app usage were found to be useful for analysis. The average values of the first half of the application period were compared to those of the second half to check for changes in the awareness level of the participants regarding sleep-wake habits. The dissimilarities between the following behaviors were determined:

- Number of snoozes (Snooze number): Each 5 min delay in the participants' wake-up times,
- Difference from ideal wake-up time (Difference from ideal wake): ± deviation from *personalized* ideal time in minutes,
- Difference from ideal going-to-sleep time (Difference from ideal go-to-sleep): ± deviation from *personalized* ideal time in minutes,
- Difference from ideal length of sleep (Difference from ideal length): ± deviation from *personalized* ideal sleep length in minutes,

There was a small difference in terms of the frequency of use between the G and N-G versions. The G alarm provided a total running data of 170 (52.3 %) samples, while the result for the N-G alarm was a total of 155 (47.7 %). Considering the deviation from 0.50, a binomial test indicated that the of use ratio of G version 0.52 was not at the significant level ($p = 0.437$) between groups, which indicated that there was no statistically significant difference in terms of the choice of version.

Analysis strategy for the logs. The data were analyzed using the SPSS software to determine the mean, range, minimum and maximum wake-up and sleep time, snooze action, length of sleep values, and their deviation from ideal situations. Multivariate of general linear model included three independent and four dependent variables and a covariate. A unified One-Way MANCOVA model was run to determine the statistically significant results, and *t*-test was used for further comparisons of multiple predictors. The model incorporated multiple predictors (fixed factors) as the following: i) app version, ii) first half and second half of the usage period, and iii) weekday vs. weekend usage; dependent variables were i) number of snoozes, ii) difference from ideal wake-up time, iii) difference from ideal going-to-sleep time, and iv) difference from ideal length of sleep; and number of the week days was determined as a covariate. According to 2-tailed Pearson correlation analysis, number of week days was correlated weakly with snooze number ($r = -0.11$, $p = 0.041$), difference from ideal wake-up time ($r = 0.16$, $p < 0.001$), difference from ideal going-to-sleep time ($r = -0.10$, $p = 0.050$), and difference from ideal length of sleep ($r = 0.15$, $p < 0.001$) variables. All variables were analyzed together in a unified model (Table 3). The study employed 95% confidence interval to reach a high level of reliability.

One-Way MANCOVA results revealed some statistically significant difference between sleep-wake-related dependent variables after controlling the effect of number of week days. App version [$F(4, 306) = 5.46$, $p < 0.001$, Wilks' $\Lambda = 0.93$, partial $\eta 2 = 0.06$] and weekday vs weekend usage [$F(4, 306) = 27.38$, $p < 0.001$, Wilks' $\Lambda = 0.73$, partial $\eta 2 = 0.26$] showed statistically significant difference. There was no statistically significant difference [$F(4, 306) = 0.83$, $p = 0.506$, Wilks' $\Lambda = 0.98$, partial $\eta 2 = 0.01$] for the first half and second half of the usage period after controlling number of week days variable.

According to tests of between-subjects effects, snooze number ($p = 0.102$), difference from ideal wake-up time ($p = 0.707$), difference from ideal go-to-sleep time ($p = 0.436$) and difference from ideal length of sleep ($p = 0.553$) stayed at the insignificant level at the 95% confidence interval when analyzed by three fixed factors' simultaneously. Although the triple correlation of app version*first half and second half of usage period*weekday vs. weekend usage changed sleep-wake behaviors to some extent, there were no any statistically significant differences. Thus, post-hoc analysis focused on separated three fixed factors of the model in order to compare dependent variables between groups.

i) App version (G and N-G). The main goal of the study was to investigate the possible effects of gamification on sleep-wake patterns. The app calculated the differences from ideal sleep patterns for each participant. The ideal time to wake up should be 1.5 h before the work begins, that is 6–8.00 a.m.; and the length of sleep should be 7 h, accordingly. The difference from these ideal hours indicates the participants' deviations from their personal ideal times in minutes, while using the app. Hence, the ideal cases could be obtained when these differences were tending to zero. As shown in Table 4, the mean of snooze numbers (which should be 0) of the G version was (*0.7;* between 0 and 1 times), which is lower than that of the N-G version (*1.2* between 1 and 2 times). The variance from ideal length of sleep (7 h) of the G version was 24.3 min less than the mean values for the N-G version (46.3 min). Furthermore, going-to-sleep time was nearly at the optimal value (0.00 a.m. approximately) for the G version, with a mean deviation of −11.7 min, while the same was −36.8 min for the N-G version.

Table 3
Multivariate Tests[a] of the usage data.

Effect	Value	F	Hypothesis df	Error df	p	Partial Eta Squared
Intercept	0.830	15.714[b]	4.000	306.000	**0.000**	0.170
Number of weekdays	0.890	9.463[b]	4.000	306.000	**0.000**	0.110
App version	0.933	5.463[b]	4.000	306.000	**0.000**	0.067
First half and Second half of usage period	0.989	0.832[b]	4.000	306.000	0.506	0.011
Weekday vs. Weekend usage	0.736	27.382[b]	4.000	306.000	**0.000**	0.264
App version * First half and Second half of usage period * Weekday vs. Weekend usage	0.987	1.025[b]	4.000	306.000	0.395	0.013

Table 4
Independent-samples *t*-test by app version [30].

	App version*	N	M	SD	df	t	p
Snooze number	G	170	0.74	1.373	302.781	−2.682	**0.008**
	N-G	154	1.19	1.604			
Difference from ideal wake	G	170	13.18	56.324	322	0.528	0.598
	N-G	154	9.77	59.607			
Difference from ideal go-to-sleep	G	169	−11.75	84.303	317	2.776	**0.006**
	N-G	150	−36.85	76.252			
Difference from ideal length	G	169	24.33	88.391	316	−2.256	**0.025**
	N-G	149	46.33	84.928			

*G: gamified; N-G: non-gamified.

As displayed in bold in the Table provided above, *Sleepy Bird* (G version) had a positive impact on sleep patterns of the participants. Independent sample *t*-test was employed to assess if there was a statistically significant difference in sleep-wake behaviors between the participants included in the G (experiment) and N-G (control) groups. There were statistically significant differences in three actions. These were as follows; snooze number [$t(302.78) = -2.68$, $p = 0.008$], difference from ideal go-to-sleep times [$t(317) = 2.77$, $p = 0.006$], and difference from ideal length of sleep [$t(316) = -2.25$, $p = 0.025$], at the $p < 0.05$ level. There was no statistically significant difference in terms of the difference from ideal wake-up time; $t(322) = 0.52$, $p = 0.598$. As a result, the G version was found to affect these three actions by making them closer to ideal cases (which is 0) during usage.

In addition, the results of pre-use subjective questionnaire assessments and usage data revealed that the wake-up hours had improved for participants using the G version. The N-G users modified their wake-up time with inputs from the app too. The users of the G version (with the mean average of 7.24 h) moved close to ideal length of sleep (7 h) compared to those using the N-G version (7.46) by the end of the study. Going-to-sleep time also improved for each user of both the G (changed from 01.13 a.m. to 00.19 a.m.) and N-G versions (changed from 00.32 a.m. to 23.53 p.m.).

ii) First half and second half of usage period. As participants used the applications during varying time periods, the median value for each user was different. Duration of application use varied from 8 to 22 days among the users. The average values belonging to the wake-up and sleep time, length of sleep, number of snoozes for the first half of the usage period were compared with the same for the second half. In the second half, the mean figures for the tested dependent variables approached zero. Therefore, all of the actions showed improvement over the course of the study. Independent-samples *t*-test for the first and second half of the usage period for all users of G and N-G app versions is shown in Table 5.

The Table revealed a significant impact on the use of snooze number [$t(322) = 2.11$, $p = 0.035$], implying an improvement in snooze behaviors due to the use of the application. Independent-samples *t*-test also shows that there were no statistically significant change in the difference from ideal wake-up time [$t(322) = 0.41$, $p = 0.677$], difference from ideal going-to-sleep time [$t(317) = -0.07$, $p = 0.938$], and difference from ideal length of sleep [$t(316) = 0.68$, $p = 0.494$].

For the users of the G version, all mean values approached zero in the second half, suggesting ideal situations. In the beginning, the users more frequently used the snooze option (once on average), got up later (17 min later than their personalized ideal time), went to bed earlier (15.5 min earlier than their personalized ideal time) and slept longer (32.9 min longer than their personalized ideal length of sleep). Considering the independent-samples *t*-test results, gamification led participants to snooze the alarm significantly less in the second half of the application period. In detail:

- The snooze activity between the first half of usage by G ($M = 0.99$; between 0 and 1 times, $SD = 1.498$) and the second half of usage by G ($M = 0.43$; between 0 and 1 times, $SD = 1.129$); $t(168) = 2.703$, $p = 0.008$ versions.

For the N-G group, despite general improvements, there were no statistically significant differences in these four actions from the first half of usage to the second half in line with the *t*-test results.

iii) Weekday vs. weekend usage. The users utilized *Sleepy Bird* mostly on Tuesdays and Wednesdays (18%), and the least frequent use was observed on Saturdays (9.5%). Table 6 indicates the independent-samples *t*-test statistics by weekday vs. weekend usage for all users of G and N-G app versions.

According to the Table, the snooze number [$t(152.52) = 2.21$, $p = 0.028$] and the difference from the ideal go-to-sleep time [$t(317) = 2.80$, $p = 0.005$] were statistically significant at $p < 0.05$ for the weekday vs. weekend usage of 26 participants. There were no statistically significant change in the difference from ideal wake-up time [$t(89.45) = -1.92$, $p = 0.057$] and difference from ideal sleep length [$t(100.81) = -1.55$, $p = 0.123$]. Usually, the participants woke up later and stayed up late, with longer length of sleep over the weekends. They woke up with a deviation of 25.77 min later at the weekend compared to their ideal length of sleep. Moreover, they slept 16.85 min earlier compared to the ideal time, with 50.01 min more sleep during the weekends.

For the group using the G version, 133 action data events for Monday through Friday and 37 action data for Saturday and Sunday were obtained. The users got out of bed later, went to sleep later, slept more and snoozed less on Saturdays and Sundays in comparison to weekdays. In line with the *t*-test results, the differences in the snooze action while using the G version of *Sleepy Bird* remained less than the N-G version and statistically significant between weekdays and weekend usage:

Table 5
Independent-samples *t*-test for the first half and second half of the usage period.

	First/Second half of usage period	N	M	SD	df	t	p
Snooze number	1st	179	1.11	1.525	322	2.116	**0.035**
	2nd	145	0.76	1.454			
Difference from ideal wake	1st	179	12.77	56.698	322	0.417	0.677
	2nd	145	10.07	59.389			
Difference from ideal go-to-sleep	1st	176	−23.88	84.729	317	−0.078	0.938
	2nd	143	−23.16	77.551			
Difference from ideal length	1st	175	37.67	91.242	316	0.685	0.494
	2nd	143	30.92	82.489			

Table 6
Independent-samples *t*-test by weekday vs. weekend usage.

	Weekday/Weekend usage	N	M	SD	df	t	p
Snooze number	Weekday	253	1.04	1.579	152.528	2.219	**0.028**
	Weekend	71	0.66	1.146			
Difference from ideal wake	Weekday	253	7.57	51.570	89.453	−1.925	0.057
	Weekend	71	25.77	74.846			
Difference from ideal go-to-sleep	Weekday	249	−16.85	80.198	317	2.803	**0.005**
	Weekend	70	−47.41	82.028			
Difference from ideal length	Weekday	248	30.29	84.352	100.810	−1.554	0.123
	Weekend	70	50.01	96.286			

- The snooze behavior between weekdays of usage by G (M = *0.86;* between 0 and 1 times, SD = 1.478) and weekend of usage by G (M = *0.32;* between 0 and 1 times, SD = 0.784); t (168) = 2.109, p = 0.036 versions.

For the group using the N-G version, 117 data events for Monday through Friday and 33 data events for Saturday and Sunday were collected. Most importantly, in comparison to the G version, all the mean values of four actions were greater and away from zero in the N-G version; this implied that the differences from ideal cases were higher. The participants slept earlier from their ideal hours in the weekdays (approximately 1 h earlier) than weekends (approximately 0.5 h earlier). As per the *t*-test, the N-G version of *Sleepy Bird* provided statistically significant results in terms of difference from ideal go-to-sleep time:

- The difference from ideal sleep time concerning the weekdays of usage by N-G (M = -61.55, SD = 87.730) and the weekend of usage by N-G (M = -29.89, SD = 71.574); t (148) = 2.131, p = 0.035 versions.

3.3. Post-use questionnaire

In answering if a gamified alarm app generated positive feelings and understanding of sleep-wake behaviors, the post-use questionnaire was used to make data comparisons between the users of the G and N-G versions of the application.

i) Part 1. This section sheds light on the feelings experienced due to the use of the app. The results of the Delighted-Terrible Scale of 26 participants showed that a single user (4%) felt 'very delighted' due to using *Sleepy Bird*. Six participants (23%) felt 'delighted' and 15 others (58%) stated that that they felt 'happy'. Also, four participants (15%) felt 'neutral' while starting the day with this app. The average emotion for the G version was within the 'delighted' and 'happy' range, while the average emotion for the N-G was between 'happy' and 'neutral'. The design of the app seems to have helped to increase the fun and motivate the participants in the G group. Since this version supports sleep-wake habits with its game features like the gameplay, score, lives, feedback messages, visual elements, and the leaderboard, it motivated the participants more to wake-up on time and start the day compared to the N-G version.

ii) Part 2. The answers to the questions in this part (see section 2.2) showed that individuals using the G version received a total of 177 points, whereas the group using the N-G version scored only 124 points, demonstrating that the awareness levels of sleep-wake habits reached a higher level for the former group. For Q2, concerning the users' awareness of the length of sleep, both G and N-G users scored a total of 80 points, which was the highest score earned in this section of the questionnaire. The total scores for both Q3 and Q4 were the same for G and N-G users (75), suggesting that the *Sleepy Bird* application helped boost their understanding of the time period from wake-up time until start-work time, as well as snooze behavior. The total score for Q1 was the lowest (71) among all questions, and it was about the awareness level of the right time to start the day. When the results were analyzed in SPSS using a *t*-test, the awareness levels of the sleep-wake habits between G and N-G showed statistically significant differences for all the questions (Q1: p = 0.010; Q2: p = 0.042; Q3: p = 0.004; Q4: p = 0.011). As a result, the G group participants increased their awareness more significantly.

iii) Part 3. Contrary to the same part (Part 3) of the results for the pre-use questionnaire, the total scores were greater as shown in Table 7 (text in bold), suggesting that the morning wake-up motivations were improved following the use of the app. For all participants (including both G and N-G groups), Q1 received the highest score (103 points) from these participants and also there was a statistically significant difference for this question according to the paired-samples *t*-test between pre-use (M = 2.07, SD = 1.01) and post-use (M = 3.96, SD = 0.91) questionnaires [t(25) = -7.93, p < 0.001], which provided information about how much these users believed they were getting up when they had to in the morning. The scores of other questions were not calculated at the statistically significant level between pre and post usage of the app.

The group using the G version assessed themselves as fairly more successful, more motivated, and full of positive emotions in terms of getting up early. The users of the G version scored higher than N-G users for Q1(54), Q5 (52) and Q6 (50) in the post-use questionnaire. This suggested that the application made them feel mentally better and more driven to wake up at the appropriate time. While the total scores of the G and N-G participants were higher on an individual question basis in the post-use questionnaire, a single question was identified to be statistically significant. As per paired-samples *t*-test analysis, Q1 exhibited a significant difference in the G [pre-use (M = 2.07, SD = 1.03); post-use (M = 4.15, SD = 0.55), t(12) = −6.71, p < 0.001] and N-G [pre-use (M = 2.07, SD = 1.03); post-use (M = 3.76, SD = 1.16), t(12) = −4.63, p < 0.001] users. Q2 (40) has shown that the G group has not been able to wake up so quickly while using the application. Although G version scored higher than N-G for the Q3 (36) and Q4 (36), low points indicated that the users did not feel that alert, well-rested and energetic after waking up in the morning.

Since separate tests were run for multiple comparisons related to G and N-G groups and pre-use and post-use questionnaire scores, Benjamini-Hochberg correction was used to interpret false discovery rate (Table 8).

According to B-H correction, comparing the p value for the individual p-value's rank 3, which was 0.001, is equal to the new cut-off p-value of 0.008 and therefore, the *t*-test originally showed that there was a significant difference in Q1 (e.g. p < 0.05) for every case. Since p-value

Table 7
Total results obtained for six questions in pre- and post- questionnaires [30].

	Pre-Questionnaire		Post-Questionnaire	
No.	G	N-G	G	N-G
Q1	27	27	54	49
Q2	45	36	40	41
Q3	31	32	36	34
Q4	37	37	36	33
Q5	53	46	52	43
Q6	49	38	50	44
Total Score	242	216	268	244

Table 8
Benjamini-Hochberg correction for the post-use questionnaire (Part 3).

Variable	K	i	alpha = 0.05
Q1 (for G&N-G)	0.0002	1	0.003
Q1 (for G)	0.0002	2	0.006
Q1 (for N-G)	0.001	3	0.008
Q6 (for N-G)	0.111	4	0.011

(e.g. 0.111) calculated for Q6 (for N-G) was higher than the critical false discovery rate (e.g. 0.011), all values above it were considered significant and shown in the table. This result still indicated that the application provided motivation and positive behavior in terms of sleep-wake patterns, particularly for getting up at the appropriate time.

iv) Part 4. According to the open-ended questions, 17 participants (65%) from both groups confirmed that a gamified application would affect their sleep-wake habits in the long run. Example comments from the users of the G version included:

- 'I got up 5–10 min earlier to have more lives in the game.' (Participant 10)
- 'Although I did not get a very long sleep, it was sufficient for me because I went to bed and woke up at an appropriate time. Eventually, I noticed that 6–7 h of sleep made me feel well-rested and satisfied.' (P14)

Contrarily, N-G users mostly reported that they were not certain if they learned something new from the application. When setting the alarm, the feedback notifications reminded the users of how long they were going to sleep. Examples of the comments are:

- 'I've discovered that there is a connection between the time when I wake up and begin work.' (P23)
- 'I felt like the Sleepy Bird was my mother, prompting and motivating me to go to sleep and get up at the appropriate time.' (P26)

The participants mostly had an optimistic attitude for the overall design of the app and the features such as graphics, interface, and sounds. Once the degree of difficulty (lives, distance, and speed) was changed as a result of the participants' sleep-wake behaviors, this made the game more interesting, playable and enjoyable for most. The 'leaderboard' of the G version was reported by the users to be the most interesting feature. These comments were also useful for the enhancement of *Sleepy Bird;* among them, the participants asked for additional features in the app as summarized in Table 9. Mostly they preferred to see their improvement in the game, thus asked for the addition of a 'level' feature to represent the degree of difficulty. The participants also proposed adding time charts for when they go to bed and get up on a weekly and daily basis, in order to track physiological and psychological improvement in the long run.

Table 9
Suggestions to develop the app according to post-use questionnaire.

Suggestions	Number of Participants	Percentage of Participants
inclusion of additional games	11	13%
creation a social platform for the players	8	9%
addition difficulty levels	16	19%
addition to background landscape	10	12%
inclusion of new characters	12	14%
addition of alarm sound alternatives	14	17%
inclusion of more tangible non virtual rewards	13	16%

4. Discussion and conclusions

The present study focused on whether gamification can motivate and enable users to control their sleeping-waking-up routines, using a specifically designed app, with an aim to increase their subjective well-being in the long run. In detail, it utilized a gamified app, *Sleepy Bird*, with a change from an extrinsic rewarding system to an intrinsic feedback system. The G version of the *Sleepy Bird* application was intended to concentrate on 'intrinsic motivation' due to the feedback system that satisfied the participants. Through the feedback messages and alerts, the application presented details and brought attention to the optimal sleep-wake schedule, the time between waking up and starting to work, the length of sleep, and the snooze activity. Given the challenge of changing sleep-wake patterns, the participants clearly demonstrated a positive inclination to modify these patterns, supporting the belief that such behaviors can be formed by gamification tools in the long run. With motivation from the application, the users could begin the day at the optimal time due to the notifications regarding the required sleep-wake time as well as length of sleep. The results showed that gamification can be effective in generating positive emotions and improved understanding of sleep-wake behaviors. In addition, certain benefits were obtained in the N-G version thanks to feedbacks from the app. When both versions were analyzed, wake-up time, length of sleep, go-to-sleep time and snooze number showed improvement in a four-week application period, specifically in case of the G version.

Sleepy Bird also helped to inform the participants about the time interval between getting up and beginning to work. The participants' comments showed that the app pointed out the need for this gap period to start the day with the added motivation of game lives in G version and notifications in both G and N-G versions. Nearly all participants felt happy during the usage of both versions, feeling "special" and "cool" according to their statements. The app helped to raise awareness of waking up at ideal times on weekdays.

The key contribution of this study is to show that turning an activity or task into a game can be successfully used to generate positive emotions and increase the understanding of one of the daily personal activities, which is sleep-wake habits. It can be concluded that waking up is a very personal habit and, perhaps, fairly difficult to modify in a limited period of time. However, the results of the study showed that gamification helped the participants to be aware of starting the day at the required times and show a tendency to change their habits. The app in the study informed them about necessary sleep-wake times and length of sleep, while motivating them not to snooze their alarms. This study also provided information related to the game design process. The game could be further improved by conducting various tests and rapid iterations to identify the bugs and shortcomings. The various stages of the implementation process provided an indication on the quality of the sound and visual elements of the game. Data pertaining to the game allowed for a balance between challenge and fun so that it can be possible to publish the app on Google Play following the study.

The results of the study revealed certain unexpected findings that were not anticipated at the start. There were some limitations related to the content of the app, game genre, game features, participant selection and numbers, technical deficiencies due to the need of Android platform, physical constraints possessing sleep-related problems, attitudes towards games, study duration, proper application duration to observe daily habits of individuals, and sleep-wake habits, observing the changes by a very specific and personal activity. Moreover, the participants of non-gamified version were determined relevant to their tendency or interest in playing a game. Since the assignment of participants were done at the beginning of the study, gamified version was used by the participants that had interests in playing games. Thus, this early choice of the version of the app caused the participants of non-gamified version benefit less from the gamified alarm clock, which may partially affect the success of this alarm app on behalf of gamified one. All of these were considered as the limitations of this study.

The study also helped to identify some useful findings to guide further studies that will be conducted in the future. The satisfaction of the users of a game is directly associated with the fun they get from it. If the gamified alarm app was created in a more motivative and enjoyable manner, it will not only meet inner urges to boost well-being but will also form a long-term behavior. Yet, in the coming studies, sleep-wake behaviors would be gamified as an entire process rather than utilizing a game like Flappy Bird inside an app. In addition, so as to achieve the most suitable utilization scenarios for future studies, the experiments can be conducted with higher number of participants and various of user groups. More data can be obtained by longer monitoring of the users in order to see certain crucial modifications in behaviors pertaining to going to bed and waking up. By gathering the user data related to sleep, the study showed the potential for the future to log all data for the requested user behavior. Many interpretations and predictions can be made with these recordings.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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