



Can gamified behavioral change mental health mobile apps reduce students' anxiety and improve well-being? An efficacy study

Iolie Nicolaidou^{*} , Despo Nicolaidou 

Department of Communication and Internet Studies, Cyprus University of Technology, 3603 Limassol, Cyprus

***Correspondence:** Iolie Nicolaidou, Department of Communication and Internet Studies, Cyprus University of Technology, 3603 Limassol, Cyprus. iolie.nicolaidou@cut.ac.cy

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Abstract

Aim: Designed to support the mental well-being of university students, the gamified Student Stress Resilience (SSResilience) app guides users in setting and working toward goals related to studying, socializing, and exercising. The app monitors progress through a combination of data from a user's phone (via Internet of Things sensors) and information they enter themselves. This efficacy study documented students' goal-setting efforts (RQ1) and examined the app's effect on students' anxiety, resilience, and psychological well-being (RQ2).

Methods: A quasi-experimental pretest-posttest control group design was used. Experimental group students ($n_1 = 25$) used the app for two weeks. Control group students ($n_2 = 50$) used different means to set the same goals. All students were pre-tested and post-tested on anxiety, well-being, and resilience using standardized questionnaires.

Results: Nineteen out of 25 experimental group students used the app to set one or more goals (19/25), and 18 of them found it helpful (18/25). The experimental group experienced a significant ($t(22) = 2.72, P = 0.013$) decrease in anxiety from $M_{pre} = 8.96$ ($SD = 5.30$) to $M_{post} = 5.76$ ($SD = 4.59$), an increase in well-being from $M_{pre} = 54.6$ ($SD = 25.88$) to $M_{post} = 65.12$ ($SD = 23.90$), but no change in resilience. Control group students' ($n = 43$) measurements remained unchanged.

Conclusions: Preliminary findings indicate a potential value of the SSResilience app for significantly reducing students' anxiety and increasing their well-being. Integrating Internet of Things technology (built-in phone sensors) into gamified apps for health holds significant promise by offering valuable data to users, app developers, and researchers. Future research will use wearables to measure stress and physical activity more accurately than self-reports.

Keywords

gamification, behavioral change, mobile applications, resilience, anxiety, mental health



Introduction

Anxiety has increased in recent years. Considering the changes caused by the COVID-19 pandemic, stress levels in the post-pandemic era have risen considerably, mainly because of the rise of fear since 2019 [1]. Specifically, the pandemic resulted in an increase in severe depression and anxiety disorders (by 27.6% and 25.6% respectively) not only in the adult population but also in adolescents and children. Therefore, anxiety should be effectively addressed. According to the World Health Organization (WHO), some ways to reduce anxiety include, among others, increasing physical activity, maintaining routines (such as studying routines for students), supporting psychological resilience, defined as the ability to achieve goals despite adversity [2], and increasing social interaction [3].

Drawing examples from the COVID-19 situation, the Ericsson Mobility Report [4] revealed that using internet-connected devices, such as wearable devices and smartphones, has helped people cope with conditions such as home confinement, brought about by the pandemic. Interestingly, in 40% of the cases, the internet was used to improve physical activity, health, and well-being [4]. Hence, a very large number of health apps were downloaded, widening the market and allowing new health apps and users to enter [5]. Utilizing mobile devices in favor of people's health and well-being brings the internet into the users' hands and can help them track their progress on the spot at any given time and place [6]. In this new software industry, over four hundred thousand smartphone apps were developed with health monitoring and data storage functions, which accurately record and trend diet, fitness, and stress-related information, and their use has become increasingly popular [6]. Recent years have shown a pervasive interest in mobile health applications [7] and, more specifically, e-mental health post-pandemic [8]. This indicates that the market for health apps is broad and is exploited by a large percentage of the population interested in improving their health.

Targeting specific use and users, health apps promise solutions to various health and well-being issues to address users' and customers' needs [9–11]. Moreover, health, well-being, and fitness apps promise to provide personalized solutions based on users' data [12] to enable improvements in people's eating habits, proper monitoring of physical and other activity, helpful peer support, etc. [11, 13].

As health apps rely on users' data, it is essential to encourage individuals to use them and to keep them motivated to produce data. Despite the new users and the increase in health-related app use, only a few health apps are regularly used [14]. Regardless of the type of health app used, research has revealed that users expect the functionality of health apps to correspond to their needs and guide or motivate them toward achieving desired results and developing healthier habits or improved lifestyles [15]. For a health app to be preferred, it should allow users to record and self-monitor their activity daily, include training exercises and practicing lessons, or give health-oriented advice, and enable goal setting in a relatively quick and easy way, maybe by incorporating automatic functions allowing data transfers among connected devices, such as fitness bands [10, 15]. Furthermore, for a health app to be used for extended periods, the design should consider persuasive strategies and psychological factors that trigger continuous engagement [12, 15].

Suggesting that any individual need may be “appified” [14] and developed into an engaging, well-designed tool addressing individual needs, health app software should go beyond its functions. Various research studies have revealed that gamifying health apps is vital for long-term engagement [12, 16, 17] and for self-management [13]. Gamification in the design of health apps may increase engagement with and adherence to mental health apps, as shown in systematic reviews and meta-analyses [18]. Specifically, a comparative systematic review on strategies used to persuade users to be actively engaged with their health apps showed that elements of gamification, such as challenges, leaderboards, and praises/rewards, engage users to keep working on achieving their goals, and influence their self-appreciation levels [12, 19]. Moreover, social comparison with friends or other groups may also be considered as a gamified element [12], which may evoke excitement and competition during the users' efforts to meet their goals and, subsequently, yield in feelings of accomplishment when a goal is achieved [5].

Gamified and theory-guided mobile apps have proliferated in recent years as a way to improve people's health and well-being [20]. These apps are often guided by established behavior-change theories, such as the transtheoretical model [21], social cognitive theory [22], and self-determination theory (SDT) [23], which based on research, can be particularly effective in promoting physical activity, reducing stress and anxiety, and improving social interaction [20, 24].

As mentioned above, the use of mobile apps for health promotion and resilience has been on the rise over the last few years, in various age groups, including older adults [25, 26], with many apps targeting physical activity, mental resilience, stress, and anxiety reduction, as well as improving social interaction. This trend is especially significant in students and young adults who often have high levels of stress, sedentary lifestyles, and limited social interaction [27]. For this reason, our literature review aims to explore the current state of research on mobile apps for health promotion in this population. This is relevant to the study's focus on designing a mobile app to positively affect students' anxiety, well-being, and resilience.

A literature review was conducted to present studies that demonstrate the potential of mobile apps in improving physical activity, resilience, stress, anxiety, and social interaction, focusing on young adults. Electronic scientific database searches were conducted for the literature review in the following databases: Google Scholar (<https://scholar.google.com/>) and PubMed (<https://pubmed.ncbi.nlm.nih.gov/>) during June 2023. An updated literature review using the same keywords was conducted in August 2025. The following keywords were used in different combinations using Boolean operators to search for relevant literature: "mobile apps", "physical activity", "resilience", "stress" or "anxiety", "social interaction", "young adults", "undergraduates". Considering that physical inactivity is a significant public health problem worldwide, mobile apps can be a useful tool to increase physical activity in young adults and students. A recurring theme in the literature is the effectiveness of mobile apps in promoting physical activity. Studies revealed that mobile apps connected with activity trackers effectively motivate people to start exercising [28], increase physical activity, and reduce sedentary behavior [29]. Moreover, many mobile apps incorporate features such as step tracking, workout routines, and challenges to encourage users to stay active [27]. Several studies have also demonstrated a robust correlation between gamification elements, such as points, rewards, and social competition, and increased physical activity levels and exercise adherence [30].

Beyond physical activity, this line of research also explores how mobile apps can enhance resilience and reduce stress in students and young adults. An overview of systematic reviews examining the effects of mobile apps on stress, anxiety, and depression found that the apps that used behavior change strategies reported significant effects on depression, anxiety, and stress, concluding that mental health apps are promising for reducing depressive symptoms [31]. Furthermore, a consensus has emerged around the effectiveness of apps that incorporate mindfulness and relaxation techniques in reducing stress and promoting emotional well-being [32]. Similarly, mobile apps that provide cognitive-behavioral therapy interventions have consistently been found to be effective in reducing symptoms of anxiety and depression [33].

While the literature offers compelling evidence for the efficacy of these apps, a clear disagreement exists regarding the magnitude of their effect. A systematic review and meta-analysis examining mobile apps that promote well-being in the general population showed a small effect on improving well-being [34], while another showed that mobile apps have a small but meaningful impact on reducing symptoms of anxiety and depression [35]. Based on the literature, a combination of different mechanisms for anxiety reduction, such as deep breathing exercises, regular exercise, and social support, can provide optimal results in managing stress and anxiety [36]. These mechanisms are typically built into mobile apps to support users in stress management.

The literature also highlights the importance of social support, as some mobile apps incorporate social support and peer-to-peer interactions to reduce stress and enhance resilience [37, 38]. While the effectiveness of these apps may vary depending on the specific app and the individual using it, research suggests that they can be an effective tool for improving mental health outcomes. For example, a meta-

analysis of 14 studies found that social support interventions delivered through mobile apps were associated with significantly reduced depression symptoms [39]. Additionally, a randomized controlled trial of a mindfulness-based stress reduction app with social support features showed significant improvements in stress and anxiety levels among college students [40]. Based on these studies, it can be concluded that social support has a vital role in the design of health apps targeting stress relief and well-being improvement.

To summarize, mobile apps have great potential for promoting healthy behaviors and improving health outcomes in students and young adults. A major theme in the literature is that gamification has positively impacted research outcomes in mobile apps designed for these purposes. Several studies have demonstrated that gamification techniques increased engagement and improved the effectiveness of mobile apps for enhancing social support and reducing depression and anxiety, respectively [30, 41, 42]. Gamified mobile apps have also been effective in promoting physical activity among sedentary young adults [27], which has also helped boost social interactions. These findings suggest that gamification is an effective tool for improving engagement and outcomes in mobile health apps to promote physical activity, reduce stress and anxiety, and enhance social interaction in young adults and students. The present study describes the design of a gamified mobile app to support resilience (Student Stress Resilience or SSResilience app in short) and evaluates its effect on undergraduate students' anxiety, resilience, and psychological well-being.

Post the COVID-19 pandemic, students need help to cope with elevated levels of anxiety [43] and to be resilient when setting their goals. The SSResilience app was developed in response to the increasing demand for digital tools aimed at promoting mental well-being, particularly in the form of apps and online platforms tailored to support students during the pandemic. Its main objective is to enhance the resilience of undergraduate students and assist them in managing stress and anxiety by setting and achieving personal goals (such as studying, social interaction, and physical exercise). Students' goals are tracked using built-in phone sensors (Internet of Things, IoT) and self-reports within the app [44]. In this study, the term IoT refers specifically to the use of built-in smartphone sensors (accelerometer and noise sensor) that automatically track users' physical activity and social interaction. There is a notable absence of mobile applications in the literature designed specifically to enhance the resilience of nonclinical students within the general population. While there have been efforts to develop resilience interventions for certain professional groups heavily impacted by the COVID-19 pandemic, such as healthcare workers [45] and student veterans with posttraumatic stress disorder [46], few apps in the existing literature incorporate gamification [47] or clearly outline their theoretical frameworks. Furthermore, none have leveraged IoT in their design. This study aims to address these gaps in the current body of research.

Existing apps for mental health show limited evidence of efficacy and are not responsive to user needs. To address this shortcoming and to respond to calls for an informed participation approach [48], a participatory design method was used for developing the health mobile app called SSResilience. The SSResilience app focuses on three goals: increasing physical activity, focusing on studying, and increasing social interaction (Figure 1). It incorporates IoT in addition to measuring users' psychological state using self-evaluations.

The app is theory-driven; its design was based on SDT as it attempts to cover the users' three innate psychological needs for autonomy, competence, and relatedness, which yield enhanced self-motivation and mental health [23]. The app implements the following persuasive features, derived from a taxonomy of app features based on SDT to motivate users towards their desired goals [49]: Goal setting, motivational messages, and reminders, which fall under autonomy; activity feedback, self-monitoring through reflection and rewards with the use of badges, which fall under competence; and performance sharing through social media, which falls under relatedness.

Different gamification design principles, or mechanics, are used in developing mobile health applications [13]. The SSResilience app incorporates badges, points and levels, challenges in the form of goals, and social engagement [13]. The app was designed to respond to calls for research on applying gamification to mental health and well-being [50]. It furthermore incorporates IoT functionality using

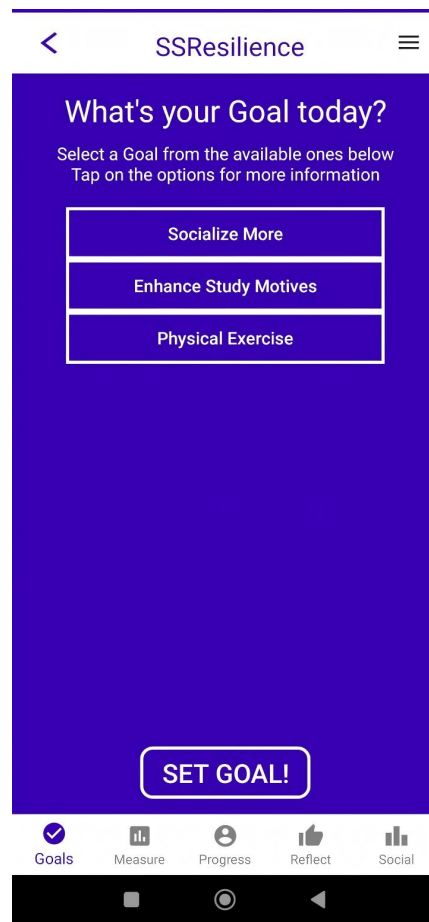


Figure 1. SSResilience prototype app user interface showing three goals (socialization, studying, and physical activity). Reproduced with permission from the developer of SSResilience. © 2025 Loizos Aristeidis.

phone sensors (accelerometer and noise sensor) to measure students' progress on physical activity and socialization goals. A detailed description of the design of the SSResilience app is provided in Nicolaidou et al. [44].

This study aimed to examine the efficacy of the SSResilience app using the same research design and data collection methods as those used in a pilot study with 11 users who participated in the experimental group and 13 students in the control group. The pilot study showed a potential value of the SSResilience app for increasing students' resilience and well-being and reducing anxiety [51]. Specifically, the pilot study showed a decrease in anxiety from a mean (M) in the pre-test (M_{pre}) of 7.30 and standard deviation (SD) of 6.57 to a M in the post-test (M_{post}) of 5.20 ($SD = 4.78$) (percentage change = -30%), an increase of well-being from $M_{pre} = 64/100$ ($SD = 30.98$) to $M_{post} = 73.6/100$ ($SD = 20.84$) and an increase of resilience from $M_{pre} = 66.5$ ($SD = 19.8$) to $M_{post} = 74.75$ ($SD = 14.02$) (percentage change = 22%) after using the app. The present study expands the pilot study in two ways. Firstly, it uses a larger sample of students. Secondly, while in the pilot study, control group participants were passive and only completed pretest and post-tests, in the present study, control group participants were asked to set the same goals as experimental group students and monitor their progress with respect to reaching those goals using any means, either with or without technological support. In this way, a comparison between the experimental group that used the app and a control group that used alternative means of reaching the same goals was achieved.

The study aimed to examine students' goal setting and progress monitoring efforts and to evaluate the effect of the Student Stress Resilience (SSResilience) app on undergraduate students' anxiety, resilience, and psychological well-being.

The research questions are the following:

RQ1: How do students evaluate their goal-setting and progress monitoring efforts with and without using the SSResilience app?

RQ2: How does the SSResilience app influence undergraduate students' mental health outcomes, including anxiety, resilience, and well-being?

Materials and methods

Research design

The study employed a quasi-experimental design using a pre-test and post-test with a control group. However, it did not involve random sampling or random assignment of participants to groups. Rather, students chose whether to participate in the intervention (experimental group) or not (control group), resulting in self-selection into the respective groups. Students who were Android users constituted the experimental group ($n_1 = 25$), downloaded the SSResilience app (which is currently only available for Android), and were asked to voluntarily use it for two weeks. The rest of the students, who were iPhone users, constituted the control group ($n_2 = 50$).

A power analysis, conducted using the G*Power software, for a one-tailed paired-samples *t*-test indicated that the minimum sample size to yield a statistical power of at least 0.8 with an alpha of 0.05 and a medium effect size ($d = 0.5$) is 45.

Ethics approval, participants, and context of the study

A total of 75 first- and second-year undergraduate students from two departments of the same school of a European public university were invited to participate in the study. The SSResilience app was demonstrated to all students. Informed consent was obtained from all participants included in the study. Students were informed in writing about the study's objective. The research protocol for this study was developed and executed in accordance with established ethical guidelines, including those of the Declaration of Helsinki (2013), those of the American Psychological Association (APA) and General Data Protection Regulation (EU) 2016/679 (GDPR). Approval for the study was granted by the Cyprus University of Technology Ethics Committee and the Cyprus National Bioethics Committee, with approval number EEBK EII 2021.01.218. As part of the consent process, all participants confirmed electronically that they were adults (18 years or older) and understood the terms of their participation. They voluntarily provided anonymous data, and they could withdraw from the study without any consequences at any time. Students used a self-selected 8-digit number for pairing purposes of their pre- and post-test data; therefore, their personal data, i.e., their name, was not used.

Students were pre-tested and post-tested concerning their anxiety, well-being and resilience. A subset of these students (Android users) downloaded the SSResilience app and were asked to voluntarily use it for two weeks. These students constituted the experimental group ($n_1 = 25$). The rest of the students (iPhone users, who constituted most of them) were asked to use either another app or non-technologically supported means to set and track their progress on the same three goals (studying, social interaction, and physical exercise). These students constituted the control group ($n_2 = 50$). All students were post-tested concerning their anxiety, well-being, and resilience. A few students from both groups, who failed to complete either the pre-test or the post-test, were not included in the data analysis for the study's second research question.

The duration of the study was intentionally limited to two weeks because if it were longer, post-measurements would coincide with midterm exams, which is a period when students have heightened anxiety levels. Moreover, we followed the methodological rationale of previous studies in the literature, which focused on the use of mobile apps for mental health and well-being, such as the study of Patel et al. [20] and Zhao et al. [9], who used mobile apps for two and one weeks, respectively.

Data sources

Three data sources were used in the study to evaluate the efficacy of the SSResilience app (RQ2):

- a) The Connor-Davidson Resilience Scale (CD-RISC): a standardized Likert-type scale evaluating personal resilience, with participants responding on a 5-point Likert scale ranging from 0 (not true at all) to 4 (true nearly all the time) [2]. A sample item includes: "I can deal with anything."
- b) Generalized Anxiety Disorder Screener (GAD-7): a widely used 7-item instrument assessing symptoms of generalized anxiety [52]. Participants rate how often they experienced each symptom over the past two weeks using a 4-point Likert scale from 0 (not at all) to 3 (nearly every day). An example item is: "I was not able to stop or control worrying."
- c) World Health Organization Well-Being Index (WHO-5): A 5-item measure assessing subjective well-being, which is among the most frequently used tools in this domain [53]. Participants reflect on the previous two weeks and respond on a 6-point Likert scale from 0 (at no time) to 5 (all the time). An illustrative item is: "I have felt calm and relaxed."

For RQ1, post-intervention, all students were asked to answer closed-ended questions related to whether they set goals (yes/no) and what types of goals they set. Experimental group students were asked to rate the app's usefulness in their progress monitoring and completed an additional open-ended question to identify desired features of the app. Control group students were asked to indicate their chosen ways of tracking their progress towards achieving goals and rate their effort in meeting them.

Data analysis

Statistical analysis on students' data from the three pre- and post-questionnaires was performed using IBM SPSS Statistics 25. The total score for the seven-item GAD-7 scale was calculated, yielding a possible score range of 0 to 21. Scores were interpreted as follows: A low score between 0 and 4 indicates minimal anxiety, whereas a score of 15 to 21 suggests severe anxiety.

For the WHO-5, participants' raw scores were calculated by summing their responses to the five items. This total was then multiplied by 4, resulting in a percentage score ranging from 0 to 100. A score of 0 indicates the poorest possible well-being, while a score of 100 reflects the highest possible well-being.

In the Connor-Davidson Resilience Scale-10 item version (CD-RISC-10), participants rated each of 10 items on a 5-point scale from 0 (not true at all) to 4 (true nearly all the time). Total scores could range from 0 to 40 and were converted to percentage scores (0–100) by multiplying the raw score by 2.5. Higher percentages reflect greater resilience, while lower scores suggest reduced resilience.

Descriptive statistics (M and SD) were used to answer RQ1, while inferential statistics (paired and independent samples *t*-tests) were used to answer RQ2. Basic assumptions for conducting parametric tests were met. An alpha level of 0.05 was set a priori for statistical analyses.

Results

Participants' demographic data

Experimental group students ($n = 25$) included 9 male and 14 female students (2 students did not specify their gender). They had an average age of 19.25 years ($SD = 1.44$).

Control group students ($n = 50$) included 12 male and 31 female students (7 students did not specify their gender). They had an average age of 18.98 ($SD = 0.86$).

RQ1: students' efforts in goal setting and progress monitoring

The first research question of the study (RQ1) attempted to document the type of goals students set in the two conditions, with and without the use of the SSResilience app. RQ1 furthermore examined students' evaluation of the usefulness of the SSResilience app for their goal setting for the experimental group and the evaluation of students' personal effort in their goal setting and progress monitoring in the control group, in which students did not use the SSResilience app.

Out of the 25 students who downloaded the SSResilience app, the majority (19/25) reported that they set goals within the app. Experimental group students attempted to either set a specific goal or a combination of goals (socialization, studying, and physical exercise) (Table 1). Specifically, six students (6/25) focused on physical exercise, five (5/25) focused on socialization, and three (3/25) focused on studying. Other students focused on a combination of two goals, e.g., studying and socialization (3/25), studying and physical exercise (1/25), or all three goals (1/25).

Table 1. Frequency and percentage of experimental group students who set goals using the SSResilience app.

Goals set	Frequency	Percentage (%)
No goal	6	24
Physical exercise goal	6	24
Socialization goal	5	20
Study goal	3	12
Studying and socialization goals	3	12
Studying and physical exercise goals	1	4
All three goals (physical exercise, socialization, studying)	1	4
Total	25	100

The experimental group students, who used the app, evaluated its usefulness. Nine experimental group students (9/25) found the SSResilience app to be very useful or extremely useful, and nine (9/25) found the app to be somewhat useful. Seven students (7/25) did not find the app useful at all or found the app only a little useful.

In an open-ended question asking students to indicate features of the app that they liked, the following features were identified: “easy functionality”, “an easy-to-use app with simple steps”, “simple design”, “helpful app for self-improvement”, “user-friendly”, and “original app”.

Out of the 50 students of the control group who did not have access to the SSResilience app, 33 students (33/50) reported that they attempted to set goals on their own. As shown in Table 2, control group students focused on individual goals, such as studying (9/33), physical exercise (7/33), or socialization (3/33), or a combination of goals, e.g., socializing and physical exercise (4/33) (Table 2).

Table 2. Frequency and percentage of control group students who set goals without the use of the SSResilience app.

Types of goals set	Frequency	Percentage (%)
Physical exercise goal	7	21.2
Socialization goal	3	9
Study goal	9	27.3
Studying and socializing	2	6.1
Socializing and physical exercise	4	12.1
Studying and physical exercise	2	6.1
Other goals	6	18.2
Total	33	100

Most students did not specify how they tracked their progress (13/33) or did not track their progress (7/33). Some ways control group students used for progress monitoring included: “note taking” (7/33), “measuring calories using smartphone during workout and while running” (1/33), “using another app” (1/33), “measuring time of studying” (1/33), “by observing myself” (1/33), “in my own way” (1/33), and “by noting how I felt on a daily basis” (1/33).

Control group students who set goals without the use of the app evaluated their effort as follows: The majority of the students were somewhat satisfied with their effort (18/33), nine students (9/33) were very satisfied, and four (4/33) were extremely satisfied. Two students were a little bit satisfied (2/33).

RQ2: students' anxiety, well-being, and resilience pre- and post-intervention

The second research question of the study (RQ2) attempted to document students' anxiety, well-being, and resilience in the two conditions before the intervention, establish group equivalence, and then calculate the difference between students' anxiety, well-being and resilience levels from pre- to post-intervention to examine whether the SSResilience app had an impact on the experimental group's anxiety, well-being and resilience and whether this impact was significant.

The experimental group students' average anxiety score was $M = 8.96$ ($SD = 5.30$) before the intervention. Specifically, descriptive statistics of experimental group students' scores before the use of the app indicate that 12 students (12/23) experienced moderate to severe anxiety (Table 3). The control group students' average anxiety score was $M = 8.14$ ($SD = 5.25$) before the intervention. Specifically, descriptive statistics of experimental control group students' scores before the use of the app indicate that 17 students (17/43) experienced moderate (13/43) to severe (4/43) anxiety (Table 3). Cumulative results do not include missing data, specifically 2 students from the experimental group (2/25) and 7 students from the control group (7/50) who failed to complete the pretest on anxiety and were therefore not included in this analysis.

Table 3. Experimental group and control group students' anxiety levels based on the pre-test.

Anxiety level based on GAD-7	Experimental group		Control group	
	Frequency	Percentage (%)	Frequency	Percentage (%)
No anxiety (score 0–4)	4	17.4%	13	30.2%
Mild anxiety (score 5–9)	7	30.4%	13	30.2%
Moderate anxiety (score 10–14)	10	43.5%	13	30.2%
Severe anxiety (score 15–21)	2	8.7%	4	9.3%
Total	23	100%	43	100%

GAD-7: Generalized Anxiety Disorder-7.

An independent samples *t*-test was run to examine whether groups were equivalent before the intervention. This showed that the difference between the experimental ($M = 8.96$, $SD = 5.30$) and control group students' ($M = 8.14$, $SD = 5.25$) average anxiety scores was not statistically significant ($t(64) = 0.60$, $P = 0.551$), indicating equivalence of the two groups.

Table 4 shows experimental ($n = 23$) and control group ($n = 43$) students' anxiety, well-being, and resilience before and after using the SSResilience app. A paired samples *t*-test analysis ($t(22) = 2.72$, $P = 0.013$) of students' scores before and after the use of the app showed a decrease in anxiety for the experimental group which consisted of 23 students who used the app from pre-test average anxiety scores ($M = 8.96$, $SD = 5.30$) to post-test average anxiety scores ($M = 5.76$, $SD = 4.59$) (Table 4). Cohen's *d* was calculated at 0.57, indicating a moderate effect size. As can be seen in Table 4, the control group's anxiety levels had a very slight increase from $M = 8.14$ ($SD = 5.25$) to $M = 8.36$ ($SD = 5.88$); therefore, we can claim that they remained unchanged.

Table 4. Experimental and control group students' anxiety, well-being, and resilience before and after using the SSResilience app.

Variables	Range of scores	Experimental group				Control group			
		Pre-test		Post-test		Pre-test		Post-test	
		M	SD	M	SD	M	SD	M	SD
Anxiety (GAD-7)	0–21	8.96	5.30	5.76*	4.59	8.14	5.25	8.36	5.88
Well-being (WHO-5)	0–100	54.6	25.88	65.12	23.90	53.02	21.93	48.08	25.42
Resilience (CD-RISC)	0–100	74.24	17.15	70.10	19.00	62.27	15.81	60.90	19.17

*: $P < 0.05$ in Paired samples *t*-test comparing pre-test and post-test scores. GAD-7: Generalized Anxiety Disorder-7; WHO-5: World Health Organization Well-Being Index; CD-RISC: Connor-Davidson Resilience Scale.

An independent samples t -test ($t(60) = -2.099$, $P = 0.040$) showed that, post-intervention, experimental group students' anxiety level was significantly lower ($M = 5.76$, $SD = 4.59$) than control group students' anxiety level ($M = 8.36$, $SD = 5.88$). Cohen's $d = 0.51$ indicates a moderate effect size. These findings indicate that the use of the SSResilience app, which is what differentiated the experimental group from the control group, potentially contributed to the experimental group students' decreased anxiety level.

With respect to students' well-being pre- and post-intervention, as can be seen in Table 4, the experimental group students' well-being level had an increase from $M = 54.6$ ($SD = 25.88$) to $M = 65.12$ ($SD = 23.90$), which was not statistically significant. Control group students experienced a slight decrease in their well-being levels (Table 4) from $M = 53.02$ ($SD = 21.93$) to $M = 48.08$ ($SD = 25.42$), which was not statistically significant.

With respect to students' resilience pre- and post-intervention, as can be seen in Table 4, both the experimental and control groups' resilience levels remained relatively unchanged, as a slight decrease that was observed for both groups was not statistically significant.

Discussion

Undergraduate students can be supported in learning ways to manage their stress and form healthy habits for a stronger mental health using mental health apps. Based on the literature, a multi-faceted approach that combines physical, mental, and social strategies is most effective in dealing with stress and anxiety [36]. This efficacy study attempted to evaluate the effect of a gamified, theory-based mental health app, the SSResilience app, which focused on the aforementioned three strategies, on undergraduate students' stress, well-being, and resilience.

The study's first research question aimed to document students' interest in setting goals within the SSResilience app, examine the type of goals they showed a preference for, and document their evaluation of the usefulness of the app. The majority of the experimental group students who voluntarily downloaded the app on their mobile phones used the app to set one or more goals (19/25). Eighteen experimental group users (18/25) found the app from "somewhat useful" to "extremely useful" for their goal setting and progress monitoring. More students in the experimental group engaged in goal setting compared to the control group, indicating that potentially the app encouraged this activity. These results seem to agree with reports documenting an increasing interest among users in the use of mobile health apps [4, 6, 10], which are becoming increasingly more popular. The majority of the experimental group students who used the app to set a goal showed a preference towards the goal of increasing physical activity, a preference also shared by the control group students, who also chose to work towards increasing their physical activity. Experimental group students' preference for setting a goal to increase physical activity agrees with studies that showed user acceptance of gamified behavior change mobile apps for increasing physical activity [29]. However, continued use of gamified e-health apps is not necessarily predicted by or affected by perceived usefulness, at least in older adults, as Hurmuz et al. [25] showed. Moreover, an analysis of real-world usage of mental health apps showed that user engagement over time is low, with a median 15-day retention of only 3.9% of the users [54]. Therefore, we cannot be certain that the percentage of students who reported that they found the app useful in our study will continue to use it in the future, and this is an area that warrants further study.

The study's second research question focused on evaluating the effect of the SSResilience app on undergraduate students' stress, well-being, and resilience. A statistically significant decrease in anxiety from $M_{pre} = 8.96$ ($SD = 5.30$) to $M_{post} = 5.76$ ($SD = 4.59$) was observed only for the experimental group, which consisted of students who used the app over a period of two weeks. This is the most promising finding of the study, with a moderate effect size (Cohen's $d = 0.57$). This finding is consistent with the results of recent studies, which represented similar interventions for students and attempted to improve aspects associated with mental health with the use of mobile apps. More specifically, this finding is in line with systematic reviews [35, 55] and other studies that demonstrated the effectiveness of health apps for reducing stress and anxiety [32, 33, 37–39]. Gamified mobile apps for health leverage several mechanisms

to reduce anxiety, including increased engagement and adherence. Gamification elements, such as goal setting tracked with points, badges, and levels, which were personalized for each user, allowed for self-monitoring and acted as persuasive strategies [12]. As such, we hypothesize that they may make the SSResilience app engaging, increase user motivation, and potentially distract users from anxious thoughts and worries. However, as there was no non-gamified version of the app for comparison purposes, we could not test this hypothesis. Immediate, motivational feedback that users receive on their progress, using points, may also reinforce positive behaviors and evoke positive emotions, which counteract anxiety and promote well-being. Visualizing progress in the app may provide a sense of accomplishment, while sharing their completed goals with other users through social media may foster a sense of community and support, which is also associated with anxiety reduction. However, quantitative data analysis alone cannot provide a thorough explanation as to how or why this decrease in anxiety happened.

An increase, even though not significant, in experimental group students' well-being is also considered a positive finding, again in line with similar interventions and previous studies' findings, which reported improvements in variables such as life satisfaction through the use of mobile apps for one month [56, 57], and improvement of well-being through the use of mobile apps for two weeks [20] and even one week [9]. This finding is also in line with the results of systematic reviews that showed that the use of mobile apps that promote well-being in the general population has a small effect on improving well-being [34]. On the contrary, the control group students' well-being decreased over time, a finding that potentially indicates the need for behavioral interventions to support students in finding ways to improve their mental health.

Our study furthermore shows that variables such as anxiety or stress can be influenced within a rather short period of time through interventions delivered via mobile apps, while other variables, such as resilience, might represent more stable traits. Resilience was a variable that remained relatively unchanged in both groups and seemed to be unaffected by either students' use of the app or by their efforts to set goals and monitor progress using their own means. It is more difficult for a change to be noticeable in stable traits, such as resilience, especially over a short period of time, even though there have been studies that had positive findings on resilience over 10 weeks, on employees, and not students, using an app-based intervention [58] and there have been studies with positive outcomes indirectly related to resilience, such as emotion regulation and depression through the use of an app, which was used for four weeks [59]. The lack of statistically significant findings for resilience might be attributed either to the short duration of the intervention, which was insufficient for positive findings to be detected, or to the delivery method. Based on a systematic review, meta-analysis, and meta-regression study that examined digital training for building resilience, with regard to the digital platform used, resilience training that was delivered over the Internet had a greater effect when compared to mobile applications [60].

Limitations

There was no clinical collaborator in the study, and no support was provided if a student experienced heightened anxiety, either self-identified or identified in the app. Moreover, we had no data comparing a gamified version to a non-gamified version of the app. Therefore, it is not possible to identify which gamification elements might explain the results of the study. These are important limitations of the study. Real-world usage of apps is typically not sustained over time [55]. Therefore, the uptake of apps is a challenge for app designers and researchers. The potential of mobile applications (apps) as a resource to support the well-being of young people is hampered by low usage [61], as users typically abandon apps within a few weeks. Another limitation of our study was that participants' engagement with the app was not tracked, and no data was analyzed to indicate the extent to which users made actual use of the app besides their self-reports. Another limitation was the use of only quantitative data in the study. Quantitative data analysis provided preliminary evidence that experimental group students' anxiety levels decreased, potentially as an effect of their use of the app, and therefore confirmed the hypothesis of the study. However, quantitative data analysis and interpretation cannot provide an explanation as to how or why this decrease in anxiety happened. Moreover, the existence of an app in a short-term evaluation period that makes students pay attention to their anxiety is likely to provide an effect that may be a temporary one.

Qualitative data in the form of student interviews and additional follow-up data collection can shed light on how participants appropriated and conceptualized the app and can document whether the app was used according to its designers' intentions.

Additional limitations include the small sample size of the study and the lack of random assignment to groups. Since participants were not randomly assigned and instead self-selected their group based on device compatibility (Android for the experimental group and iPhone for the control group), this introduces a self-selection bias. Self-selection bias occurs when participants choose their group, potentially leading to differences in characteristics between the groups that are unrelated to the intervention itself. This bias limits the study's ability to generalize findings, as the sample may not fully represent the wider student population. To reduce the potential impact of self-selection bias, future studies could consider using random assignment if feasible or employing matched groups to control for potential confounding variables, to enhance the generalizability of the findings.

Lastly, the small duration of the study, which was only two weeks, is a limitation, as improvements in resilience and well-being typically require longer-term interventions to produce measurable effects.

Implications for research, practice, and/or society

Some implications for the design of gamified apps for health can be drawn from this study. Integrating IoT technology into gamified apps for health holds significant promise by offering valuable data to multiple stakeholders. This information can benefit users, who may receive personalized recommendations and insights into their own behavioral trends, serving as an effective persuasive strategy [12]. The data is also useful for app developers, who can leverage it to improve the application, and researchers, who can analyze it to better understand which behavioral change techniques have the most effective and efficient impact on users.

This study addresses the growing need for research on digital mental health interventions and offers initial evidence supporting the potential of gamified mobile applications as preventive tools for promoting mental well-being among nonclinical undergraduate students in the post-pandemic context.

Recommendations for future research

Many mobile mental health apps are available, but current knowledge about the requirements of designing such solutions is scarce, especially from sociotechnical and user-centered points of view, according to Aryana et al. [61]. Moreover, according to Cheng et al. [50], "there is little research on the application of gamification to mental health and well-being". Future research will aim to identify which behavior change gamification features of the app are associated with a positive effect, namely a reduction of students' anxiety. What gamification techniques do students find most useful? Do students value the challenge of setting a goal and reflecting on progress at the end of each day? Is the gamification technique of providing an external reward of accumulating points and receiving badges that demonstrate students' effort an effective technique? Do students make use of and appreciate the social component of being able to share their progress with contacts on social networks for motivation purposes? These are questions that remain unanswered.

As Wu et al. [55] pointed out, no studies systematically examine which features increase sustained engagement with apps or examine the relationship between engagement features and efficacy. Future studies may provide incentives to increase user uptake or use a qualitative research methodology to understand the reasons behind the low or high use of an app and user acceptance. Future studies can also examine not only intention for future use but also barriers towards continued use of the app.

Self-reported instruments, such as the GAD-7 questionnaire employed in this study, have limitations, including susceptibility to recall bias and providing only a momentary measure of an individual's perceived stress. A more robust alternative involves using smartwatches equipped with Heart Rate Variability (HRV) sensors. These devices can unobtrusively and accurately estimate a person's physiological stress levels with greater detail over time. A recent methodological study [62] indicated that the use of sensor-based stress

data provided by a commercial activity tracker (Garmin Vivosmart 5) can be used for triangulation purposes to better evaluate the efficacy and effectiveness of mobile applications targeting students to help them manage their stress. Given the results of this methodological study, which showed a satisfactory level of agreement between the two data collection methods (GAD-7 and smartwatches), future research can also integrate the use of smartwatches to strengthen the research design with an additional data source and to measure students' stress more accurately compared to self-reported measures during the intervention period.

Abbreviations

CD-RISC: Connor-Davidson Resilience Scale

GAD-7: General Anxiety Disorder-7

IoT: Internet of Things

SDT: self-determination theory

WHO: World Health Organization

WHO-5: World Health Organization Well-Being Index

Declarations

Author contributions

IN: Conceptualization, Investigation, Methodology, Data curation, Formal analysis, Funding acquisition, Project administration, Validation, Writing—original draft, Writing—review & editing, Supervision. DN: Writing—original draft, Writing—review & editing. Both authors read and approved the submitted version.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethical approval

The study was conducted in accordance with the Declaration of Helsinki (2013), the American Psychological Association (APA) and General Data Protection Regulation (EU) 2016/679 (GDPR). Approval for the study was granted by the Cyprus University of Technology Ethics Committee and the Cyprus National Bioethics Committee, with approval number EEBK EΠ 2021.01.218.

Consent to participate

Informed consent to participate in the study was obtained from all participants.

Consent to publication

Informed consent to publication was obtained from relevant participants.

Availability of data and materials

The dataset analyzed for this study is available at DOI: [10.5281/zenodo.10894020](https://doi.org/10.5281/zenodo.10894020) (<https://zenodo.org/records/10894021>).

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