Gamification to improve medication adherence: a mixed-method usability study for MedScrab

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Abstract

MedScrab, a gamification-based mHealth app, is a first attempt to deliver crucial life-saving medication information to patients and increase their medication adherence. The paper presents the development of MedScrab and a two-phase mixed-method usability evaluation of MedScrab. Phase I qualitatively evaluated MedScrab using a think-aloud protocol for its usability. With 51 participants, qualitative data analysis of Phase I revealed two themes: positive functionality of the app and four areas of improvement. The improvement recommendations were incorporated into MedScrab's design. Phase I also validated a widely used mHealth App Usability Questionnaire (MAUQ). Quantitative data analysis of Phase I reduced the original 18-item MAUQ scale to a 15-item scale with two factors: ease of use (4 items) and usefulness and satisfaction (11 items). Phase II surveyed 83 participants from mTurk using a modified MAUQ. The modified MAUQ scale showed strong internal consistency and high loadings. Data analysis results showed that MedScrab was perceived as ease of use (6.24 out of 7) with high usefulness and satisfaction (5.72 out of 7). The results support the use of the modified MAUQ as a valid instrument for mHealth usability evaluation. However, the instrument should be used with adaptation based on the app's characteristics. This study can serve as a methodological guide for designing, evaluating, and improving mHealth apps.

1. Introduction

Medication non-adherence refers to the failure to take medications reasonably and as closely as prescribed by health care providers [1]. In the United States (US), 50% of patients who use prescription medication to manage their chronic diseases are not adherent to their medication efforts [2, 3]. It is a prevalent healthcare problem with poor health outcomes and added healthcare costs. It is also well documented that medication non-adherence is associated with increased healthcare costs [2, 4].

Patient education is the most frequent medication adherence intervention type [5], where the focus is on educating patients on why and how to take the medication. For patient education, Patient Package Inserts (PPIs) play a key role in alerting patients on important drug information, including warnings, side effects, and drug interactions [6]. While patients claim to read PPIs, research shows that they are only taking a cursory glance at the information [7]. One likely explanation is that the format of PPIs places a lot more cognitive demands on the mental faculties of an average patient and lacks patient engagement [8]. Thus, patients are often unable to identify crucial warnings in PPI, a partial reason for the growing number of ADR (Adverse Drug Reactions)-related hospitalizations [9].

Mobile health (mHealth) apps may improve patient engagement with the medication information presented in PPIs. There is a growing body of evidence to support the use of mHealth apps in addressing behavioral interventions to significantly reduce medication non-adherence [10]. The literature suggests that interactive information presentation can improve a person's ability to remember and recall information [11, 12]. In a recent study, Roosan et al. developed a mHealth prototype app to deliver medication information through interactive visualization [8]. The users from their study suggested a gamification-based approach to enhance their learning engagement.

Gamification is a relatively new trend in mHealth, although it has been widely adopted in domains such as education, industry training, and business [13]. In health care, gamification has mostly been studied in areas of chronic disease management, physical activities, nutrition, and mental health [13]. A recent study attempted to design a gamification app to improve medication adherence for people with epilepsy [14]. However, their study focused on motivating people with a specific disease to adhere to medication regimens. To the best of our knowledge, no study has applied gamification towards medication information education for a general population.

MedScrab[i], a gamified mHealth app, was designed to address this literature gap. It provides a fun and iterative process for users to learn about crucial medication information, shifting them from passive information recipients to active information seekers. The benefits of MedScrab can only be realized by its effective use, which requires the assessment of MedScrab quality as perceived by the users [15].

The goal of this study is to evaluate the usability of MedScrab. More specifically, the paper presents (1) the development of MedScrab, (2) a mixed-method approach for evaluating and improving the usability of MedScrab, and (3) the assessment of MedScrab usability using a modified mHealth App Usability Questionnaire (MAUQ). The contributions of our study are twofold. First, we adapt and validate the widely used MAUQ [16] for evaluating gamification-based mHealth apps. We demonstrate that MAUQ should be used with adaptation based on the app characteristics. Second, we present a mixed-method approach for studying usability. It can serve as a methodological guide for designing, evaluating, and improving mHealth apps.

[i] https://www.medscrab.com/

2. Methods

2.1. Application Details

MedScrab (shown in Fig. 1) was deployed (iOS and Andriod versions are available to download in app stores). A patient can learn about medication information by selecting their medication upon login (see Screenshot b in Fig. 1) drug(s) to play.

Conceptualized around a popular board game (i.e., Scrabble), MedScrab is guided by the design principles of Hierarchical Task Analysis (HTA) that align the tasks in the app to human cognitive processes to optimize the users' learning [17]. The medication information is organized into 6 information types (i.e., indications, adverse effects, warning and precaution, contradiction, interaction, and counseling point) based on how pharmacists would provide consultation to patients. Each information type is assigned as a game level and each medication will have multiple associate keywords associated with each information type. Logical clues are provided to help the user decode the words while points are awarded for each correct response. Critical PPI information is gamified through scrabble words with a reward system motivating the user to internalize presented information. All these features may be positively associated with medication adherence [18].

Additionally, MedScrab's backend collects user activity logs tracking how many times and where users clicked, how long they were on the game, and if they completed a section. A dashboard was built to summarize the user interaction within the app by sections, including the accuracy of the quiz responses (see Fig. 2). Higher accuracy scores indicate better medication information retention.

2.2. Usability Study Design and Participants

The study included two phases. Phase I had two purposes: (1) using qualitative data to improve the app design; and (2) validating and modifying the MAUQ for Phase II of the usability evaluation. The modified MAUQ questionnaire includes 15 items and two subscales.

Phase I of the study was carried out in a laboratory environment. Participants were recruited using the following inclusion criteria: aged 18 years and older, ability to access the app through the smartphone, and ability to read and understand English. The qualitative study used a think-aloud protocol [19] to analyze the thought process of users. It is an important tool for user-centered design (UCD) [20] and an effective method to guide system modification [21]. The use of the think-aloud protocol for usability evaluation helped the MedScrab development with fewer design iterations. The participants were asked to complete the following 4 tasks: download the MedScrab app on their mobile phones, navigate through the app for 3 minutes, watch a demonstration for one round of the game, and think aloud while playing 3 rounds of the game, one round for each of the given drug (i.e., lisinopril, simvastatin, and sertraline). Once they finished playing the game, participants were asked to complete the MAUQ survey plus additional demographic information. A total of 51 participants completed the usability survey and their demographic information is shown in Table 1.

Table 1
Demographic Information of the pilot study participants (n = 51)

Characteristics	Value
Gender, n (%)	34 (66.67%)
Female	17 (33.33%)
Male	
Age, n (%)	12 (23.52%)
18–25 years	39 (76.47%)
26–35 years	
Race, n (%)	4 (7.84%)
White	11 (21.56%)
Hispanic or Latino	3 (10.98%)
Black or African American	33 (64.87%)
Asian	0 (0%)
Other	
Highest degree earned, n (%)	37 (72.54%)
Undergraduate degree	14 (27.45%)
Doctorate degree	1 (1.96%)
Associate's degree	1 (1.96%)
Master's degree	
Background education, n (%)	51 (100%)
Health	
Previously worked in healthcare domain, n (%)	43 (84.31%)
Yes	8 (15.68%)
No	

Phase II of the study used Amazon's Mechanical Turk (MTurk) to evaluate the usability using a modified MAUQ scale. MTurk is a crowdsourcing marketplace allowing individuals (Turkers) to complete human intelligence tasks (HITs). We chose MTurk to reach a more diverse population, especially when in-person usability studies were not possible during the pandemic. The MTurk survey needs to be carefully designed to ensure data quality [22]. We included multiple validation points to ensure the data quality based on literature to ensure more reliable and valid research data [23]. Appendix describes the details of the MTurk study design. There were a total of 115 Turkers accepted the job, and 83 were approved after the data quality check discussed above. Their demographic information is shown in Table 2.

Table 2
Demographic Information of the mTurk Usability study participants (n = 83)

Characteristics	Value
Gender, n (%)	37 (45.12%)
Female	46 (56.10%)
Male	
Age, n (%)	3 (3.66%)
18–25 years	36 (43.90%)
26–35 years	21 (25.61%)
36–45 years	18 (21.95%)
46–55 years	3 (3.66%)
56–65 years	2 (2.44%)
65 above	
Race, n (%)	64 (78.05%)
White	2 (2.44%)
Hispanic or Latino	9 (10.98%)
Black or African American	8 (9.76%)
Asian	0 (0%)
Other	
Highest degree earned, n (%)	11 (13.41%)
High school	13 (15.85%)
Associate's degree	43 (52.44%)
Undergraduate degree	12 (14.63%)
Master's degree	4 (4.88%)
Doctorate degree	

Characteristics	Value
Background education, n (%)	16 (19.51%)
Business Administration	8 (9.76%)
Economics and Finance	14 (17.07%)
Education	9 (10.98%)
Health	19 (23.17%)
Information Technology	1 (1.22%)
Politics	2 (2.44%)
Public Health	14 (17.07%)
Others	
Previously worked in healthcare domain, n (%)	7 (8.54%)
Yes	76 (92.68%)
No	

2.3. Data Collection and Analysis

For Phase I qualitative study, all verbal responses of the participants were recorded and transcribedTwo researchers performed a thematic analysis of the qualitative responses in a four-step process involving an initial review of the data set, data coding, synthesis, and grouping of codes and representation by themes [24]. They collaboratively coded each transcript of the interview responses, merged the similar codes into a refined category, and then merged the categories with content similarity into the subthemes that were parts of the organized themes. If there was any disagreement, the team reached a consensus through group discussions.

The quantitative data collection and analysis were carried out in both pahses. In Phase I, the MAUQ was validated and refined. It is a newly developed questionnaire specific for the evaluation of mHealth apps, and has been validated in many published studies with high reliability and validity [25, 26]. Exploratory factor analysis (EFA) was used for quatitative data analysis [27]. Based on the factor loading, the mean and standard deviations of the subscales were calculated for the evaluation of each subscale. The reliability of the questionnaire was examined using Cronbach alpha. The originally MAUQ has 18 items on a 7-point Likert scale of agreement (from 1 – strongly disagree to 7 – strongly agree) with three subscales (i.e., *ease of use*, *interface and satisfaction*, *usefulness*). The questionnaire was reduced to 15 items with two subscales (i.e., *ease of use*, *usefulness, and satisfaction*) after dropping two cross-loading items and one item with low factor loading.

3. Results

3.1. Phase I Qualitative Study Results

Two themes emerged from the qualitative data analysis (see detailed description below). They serve as a guide for future usability improvements for the MedScrab app.

Theme 1: Positive functionalities of the app

Participants complimented the simple navigation of the app, the quick loading time, the clean aesthetic appeal of the interface, and the user-friendly layout that does not strain the eyes.

The overall satisfaction expressed by the participants suggests the likelihood of its continual use. The participants also remarked that the content of the app is informative (e.g., “Easy to navigate through. Good at giving general information about medications.”)

Theme 2: Recommendations for improvement

The specific recommendations for app improvement coded by researchers were grouped into four areas (see Table 3). Among these areas, interface, ease of use, and usefulness are consistent with existing research on the factors related to the use of mHealth technologies [28], while information representation is more specific to digital learning [29].

Table 3
Recommendations for improvement

Area of improvement	Recommendations
Interface	• Add graphic and sound effects. • Make the app more user-friendly (e.g., “Font size can be bigger.”)
Information presentation	• Reduce heavy medical jargon and explain medical vocabulary in laymen terms (e.g., “Some medical terms like ‘SJS’ might be too hard, but it is still important to know; can have more details near the lightbulb.”) • Clarify hint (e.g., “Hints should be clarified to correlate with the keywords.”)
Ease of use	• Delay timing between the answer and the next question • Registration should accept phone numbers, not just email addresses.
Usefulness	• Add review and summary sections provided to reinforce learning. • Add different difficulty levels to the questions to increase the depth of comprehension. • Add over-the-counter (OTC) medications

Based on recommendations from the participants, we made the following improvements. The interface design was enhanced by adjusting font type and sizes (e.g., Arial 12 for regular text and Arial 23 for headings) to improve readability for populations with poorer vision. Other interface design improvements included additional visual aids added to questions and hints for visual engagement and added sound effects for auditory engagement. The information presentation of MedScrab was improved by replacing medical jargon with adaptive text without compromising the vital information that patients need to retrain and by clarifying all hints. To improve ease of use, the MedScrab game now allows the user to quickly advance through the prompts from task to task to minimize any technical delay. To improve usefulness, the questions and scrabble words are now graded by complexity levels, and the level is automatically adjusted with increasing or decreasing difficulty, depending on the number of correct answers by the user. Additionally, at the end of each game, the user is presented with a screen that shows a summary of the main points for reinforcing learning.

3.2. Phase I Original MAUQ Results

The original 18-item MAUQ scale was used in Phase I to quantitatively measure the usability of the MedScrab app. An exploratory factor analysis (EFA) resulted in two factors (see Table 4). The values of Cronbach alpha in the overall questionnaire and the two subscales showed strong internal consistency. There were two cross-loading items (Q5 - recovery from mistake and Q10 – time). We assume that Q5 is not relevant within the MedScrab app context due to its gamification feature where the user will start the game again instead of recovering from mistakes. Since Q10 was also a cross-loading item in the originally MAUQ development study [16], we decided to drop this item. Additionally, Q17 – no internet access, had a low factor loading. This was understandable because our gamification app is an Internet-based game (e.g., the game needs to connect to our backend server for randomized words and quizzes based on the response) and will not play without the Internet. Thus, this item was removed.

Table 4
Exploratory factor analysis results for the 18 items of the original MAUQ (n = 51, overall Cronbach alpha = 0.915). Values > 0.50 for each factor are italicized.

Item	Factor 1	Factor 2
Ease of use (Cronbach alpha = 0.798), 5 items		
Q1. The app was easy to use.	-0.116	*0.678*
Q2. It was easy for me to learn to use the app.	-0.178	*0.751*
Q3. The navigation was consistent when moving between screens.	0.171	*0.62*
Q4. The interface of the app allowed me to use all the functions offered by the app.	0.210	*0.623*
Q5. Whenever I made a mistake using the app, I could recover easily and quickly.	.424	.460
Usefulness (Cronbach alpha = 0.919), 13 items		
Q6. I like the interface of the app.	*0.667*	-0.185
Q7. The information in the app was well organized, so I could easily find the information I needed.	*0.563*	0.235
Q8. The app adequately acknowledged and provided information to let me know the progress of my action.	*0.676*	-0.192
Q9. I feel comfortable using this app in social settings.	*0.597*	0.220
Q10. The amount of time involved in using this app has been fitting for me.	0.411	0.425
Q11. I would use this app again.	*0.755*	0.131
Q12. Overall, I am satisfied with this app.	*0.735*	0.239
Q13. The app would be useful to learn medication information	*0.910*	-0.083
Q14. This app could improve my understanding of important medication information.	*0.873*	-0.104
Q15. This app can help me understand medication information more effectively.	*0.852*	0.013
Q16. This app has all the functions and capabilities I expected it to have.	*0.651*	0.339
Q17. I could use the app even when the Internet connection was poor or not available.	0.349	-0.022
Q18. This mHealth app provides an acceptable way to access important information about medication.	*0.566*	.280

3.3. Phase II Modified MAUQ Results

Table 4 shows the factor loadings for the 15-item modified MAUQ questionnaire for measuring MedScrab usability. Similar to the phase I study (see Table 5), there are two factors: *ease of use* (4 items) and *usefulness and satisfaction* (11 items). The factor loadings range from 0.623 and 0.987. The Cronbach alpha also showed strong internal consistency.

The first subscale measures the *ease of use* of the MedScrab. The mean of this subscale is 6.24 out of 7 with a standard deviation of 0.86. This demonstrates that MedScrab is perceived to be easy to use. The second subscale measures the *usefulness and satisfaction* of MedsScrab. The mean of this subscale is an average of 5.72 out of 7 with a standard deviation of 1.31. This shows that the users are satisfied with the MedScrab and consider it useful in learning medication information. The result could translate into more people using the MedScrab and thereby increasing their knowledge of crucial medication information.

Table 5
Exploratory factor analysis results (N = 83, overall Cronbach alpha = 0.959, 15 items).

Item	Factor 1	Factor 2
Ease of use (Cronbach alpha = 0.881), 4 items		
Q1. The app was easy to use.	.718	
Q2. It was easy for me to learn to use the app.	.847	
Q3. The navigation was consistent when moving between screens.	.954	
Q4. The interface of the app allowed me to use all the functions offered by the app.	.754	
Usefulness and Satisfaction (Cronbach alpha = 0.965), 11 items		
Q5. I like the interface of the app.		.740
Q6. The information in the app was well organized, so I could easily find the information I needed.		.623
Q7. The app adequately acknowledged and provided information to let me know the progress of my action.		.782
Q8. I feel comfortable using this app in social settings.		.637
Q9. I would use this app again.		.883
Q10. Overall, I am satisfied with this app.		.902
Q11. The app would be useful to learn medication information		.955
Q12. This app could improve my understanding of important medication information.		.927
Q13. This app can help me understand medication information more effectively		.987
Q14. This app has all the functions and capabilities I expected it to have		.898
Q15. This mHealth app provides an acceptable way to access important information about medication.		.887

4. Discussion

Previous studies on interventions for medication adherence focus mainly on traditional medication counseling such as medication guides and health provider-patient consultation. These approaches are proven to be ineffective for patients to retain crucial medication information due to information overload [9, 30]. Studies of mHealth apps for medication adherence intervention are limited to general health information, medication scheduling, tracking and, reminders [12]. Most published apps do not include interactive features to engage users. To the best of our knowledge, MedScrab is the first attempt to deliver crucial life-saving medication information to patients through gamification. It bridges the gap between patients' knowledge of medications and the vital medication information in the PPI. The usability study findings suggest that MedScrab is considered as easy to use and useful, and has the potential to engage users in medication education through gamification.

The mixed-method approach used in this study highlights the benefits of the UCD method in mHealth app usability testing. The think-aloud protocol retrieves actively processed information from a participant's working memory, and thus, censoring and distortion of the participant's thought process are minimized. Qualitative data analysis of the participants' verbal responses can provide detailed insights not only into the usability problems but also reveal the causes underlying these problems. Subsequently, we improved the functionalities of the MedScrab app based on the qualitative data analysis results. These improvements made the app more adaptive and engaging for a broader audience. These recommendations may also guide the design of user-friendly gamification-based mHealth applications.

Worth mentioning here is that the originally MAUQ has three subscales (i.e., *ease of use*, *interface and satisfaction*, *usefulness*). In our study, *interface* subscale items (Q5-Q10) *and satisfaction* subscale items (Q11-Q15) were loaded as the same factor as *usefulness and satisfaction*. A likely explanation is that, for the gamification-based mHealth app, the user's *satisfaction* with the interface design is an integral part of their perception of its *usefulness*. Future research should explore scale items that are better distinguish the differences among satisfaction, usefulness, and information organization in gamification-based mHealth apps. Additionally, three items from the original questionnaire were dropped for either cross-loading or low factor loading. Our finding is similar to a recent study [26] in adapting the MAUQ to evaluate a mobile app for promoting eye donations, where items were dropped or modified based on the app characteristics. This demonstrates that although MAUQ is considered a valid instrument to measure the usability of mHealth apps, it should be used with adaptation for different types of mobile apps.

4.1. Limitations and Future Work

Several limitations exist within the Phase I study participants. First, all participants were from various subgroups within the healthcare system (e.g., pharmacy, nursing, physician). The lack of a diverse professional group could affect each participant's perceptions of the overall design and structure of the MedScrab app. Another limitation was that the participants were relatively young (ranged from 18 to 35). A younger population is more adept at using mobile technology. Nevertheless, the purpose of the pilot usability study was to improve the app design through qualitative data analysis and the MAUQ scale for later evaluation on a larger population. Additionally, some commonly used over-the-counter products such as acetaminophen, ibuprofen, guaifenesin, loratadine, and pseudoephedrine would be added to the app database using evidence-based practice. Future research will focus on the full deployment of the app with a large number of medications to the general public. Finally, an experimental study is planned to understand the improved medication information recall using MedScrab.

5. Conclusion

In this study, we present the successful development of a gamification-based mHealth app called MedScrab and a mixed-method approach for studying its usability. The user-centered qualitative method provided recommendations that were incorporated into MedScrab's design, and these improvements were subsequently validated based on the quantitative usability evaluation. The usability study showed that the participants were satisfied with MedScrab, considering it easy to use and useful. The quantitative data analysis results support the use of the modified MAUQ as a valid instrument to measure the usability of the MedScrab. However, the instrument should be used with adaptation based on the app's characteristics. Additionally, researchers and mobile application developers may use the study as a methodological guide for designing, evaluating, and improving mHealth apps.

Declarations

The authors did not receive support from any organization for the submitted work. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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Figures

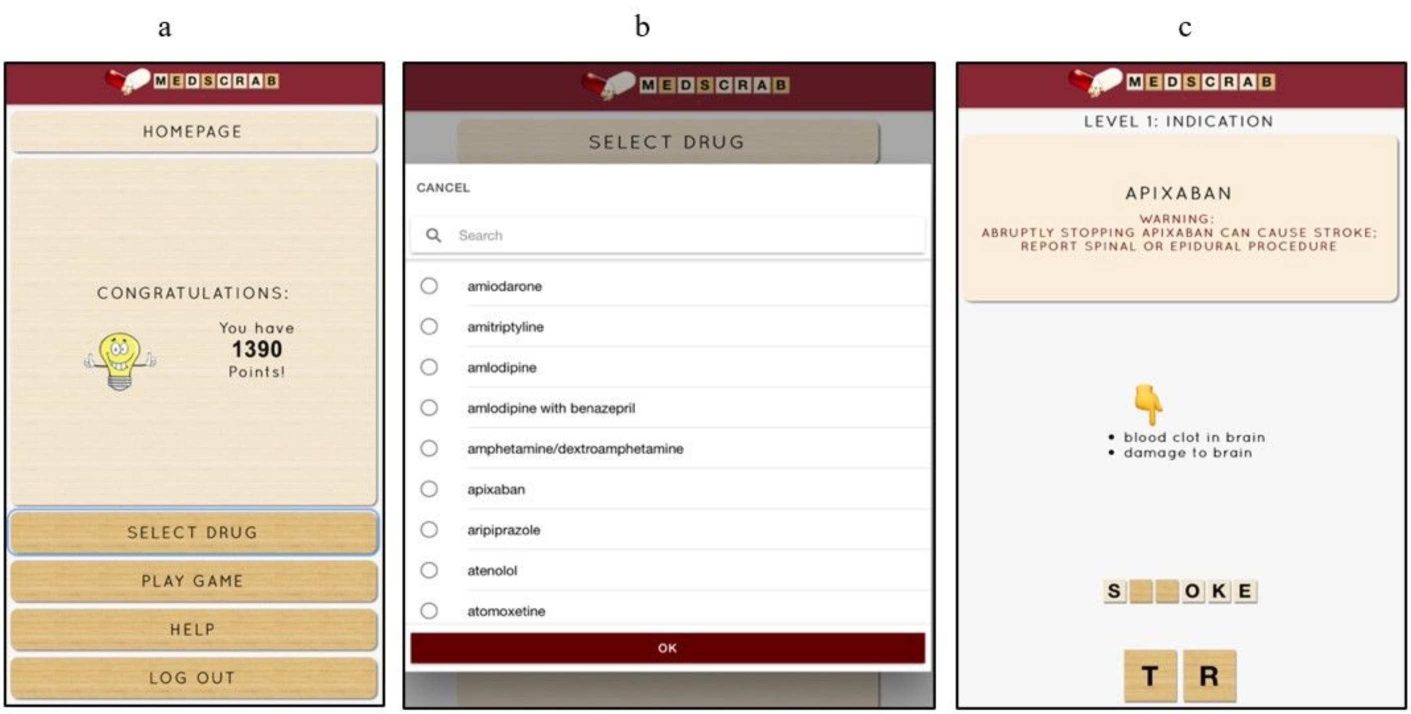

Figure 1

Screenshots of the MedScrab mHealth app: image a is the home screen, b is the screen where the user can search or select a specific drug to play, and c is a specific word game.

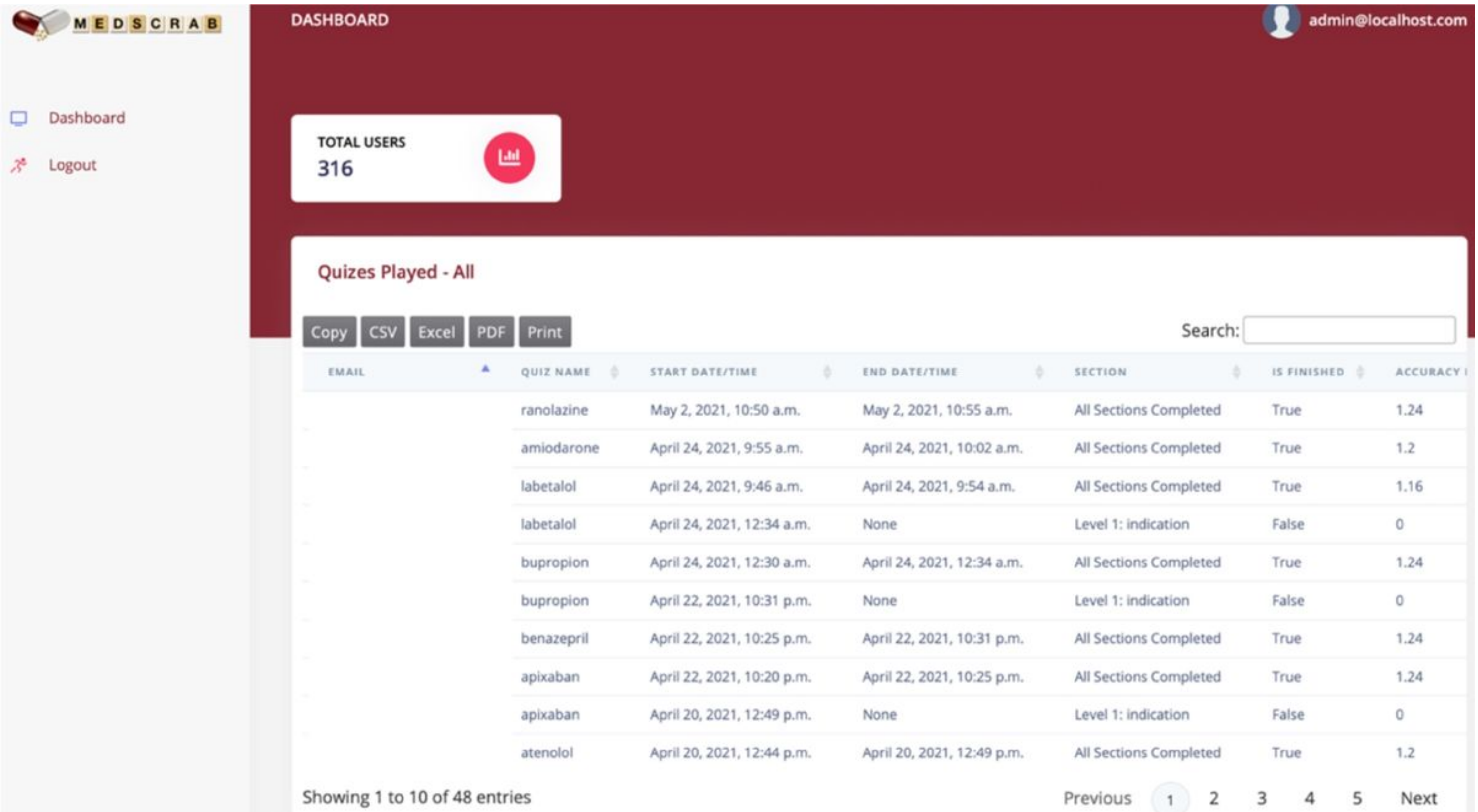

Figure 2

A screenshot of the backend analytic dashboard. It includes the total number of users, the email address of the user (unique identifier, hidden for personal health information protection), start and end date/time and which section of the game that the user played, whether the user finished the section, and accuracy score if a quiz was taken.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- AppendixtoUsabilityStudySubmission.docx