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Research and Applications

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Development and evaluation of visualizations of smoking data for integration into the Sense2Quit app for tobacco cessation

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Abstract

Objectives: The purpose of this paper is to detail rigorous human-centered design methods to develop and refine visualizations of smoking data and the contents and user interface of the Sense2Quit app. The Sense2Quit app was created to support tobacco cessation and relapse prevention for people living with HIV.

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Materials and Methods: Twenty people living with HIV who are current or former smokers and 5 informaticians trained in human-computer interaction participated in 5 rounds of usability testing. Participants tested the Sense2Quit app with use cases and provided feedback and then completed a survey.

Results: Visualization of smoking behaviors was refined through each round of usability testing. Further, additional features such as daily tips, games, and a homescreen were added to improve the usability of the app. A total of 66 changes were made to the Sense2Quit app based on end-user and expert recommendations.

Discussion: While many themes overlapped between usability testing with end-users and heuristic evaluations, there were also discrepancies. End-users and experts approached the app evaluation from different perspectives which ultimately allowed us to fill knowledge gaps and make improvements to the app.

Conclusion: Findings from our study illustrate the best practices for usability testing for development and refinement of an mHealth-delivered consumer informatics tool for improving tobacco cessation yet further research is needed to fully evaluate how tools informed by target user needs improve health outcomes.

Key words: mHealth; smoking cessation; HIV; usability testing; heuristics.

Introduction

Smoking tobacco is the leading cause of preventable death in the United States with more than 16 million Americans living with a disease caused by smoking.[1] This is exacerbated in people living with HIV (PWH) who have smoking prevalence rates 2–3 times higher than the general population.[2] Furthermore, the untoward health effects of smoking are aggravated in PWH who face increasingly negative health effects, such as lung cancer, other non-AIDS-defining cancers, cardiovascular disease, pulmonary infections, chronic obstructive pulmonary disease (COPD), and bacterial pneumonia, as a result of the disease and effects of antiretroviral treatment.[3–5]

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Although PWH frequently engage with healthcare providers, tobacco cessation support is rarely provided during routine visits.[6,7] Thus, even if PWH receive HIV treatment and care, they are still likely to need additional resources to quit smoking, making self-management tools ideally suited to fill this need. More specifically, self-management interventions delivered via mobile platforms are well suited for personal health interventions with evidence to support their use for PWH.[8–10]

Past smoking cessation studies have utilized mHealth interventions with app features such as tracking, social support, mindfulness training and personalized text-messaging. Although some of these studies have found mHealth to be successful in the short-term,[11–18] few studies have included PWH and there is a need for more smartphone-based smoking cessation apps tailored to the intended end-users' needs.[13,19,20]

Due to insufficient smoking cessation apps for PWH, our study focused on designing and testing the Sense2Quit app for PWH who want to quit smoking. Designing a patient-facing mHealth tool requires the integration of visualizations of patient information, specifically smoking use, which is interpretable by patients so that they can act upon this data in an effective manner.[21]

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The Information System Research (ISR) Framework guided this study. ISR consists of 3 iterative cycles: (1) rigor cycle, to evaluate and update the knowledge base; (2) relevance cycle, to understand the environment of the end-user by determining requirements through a series of focus groups with stakeholders (PWH, current and former smokers); and (3) design cycle in which artifacts are produced and evaluated, to inform and support the Sense2Quit app design.[22] Relevance and rigor cycles for the Sense2Quit project can be found elsewhere.[23]

Objective

The purpose of this paper is to detail rigorous human-centered design methods to develop and refine visualizations of smoking data and the contents and user interface of the Sense2Quit app. The Sense2Quit app was created to support tobacco cessation and relapse prevention for PWH. A secondary goal of this paper is to illustrate the process of understanding when to adhere to individuals' preferences while considering when their preferences may not match their cognitive support needs, as identified by experts in human-computer interaction.

Methods

Following focus groups and design sessions,[23] our study team created an alpha version of the Sense2Quit app which connects via Bluetooth to a smartwatch to detect smoking behaviors. Briefly, the Sense2Quit app aims to help PWH quit smoking by tracking smoking habits and money spent on cigarettes, sending daily tips and reminders, and providing distractions, such as games and videos. Currently, the Sense2Quit app is compatible only with Android smartphones. To achieve the design cycle goals, a rigorous user-centered usability evaluation to refine the interface and ensure it aligned with the system's functionality was conducted using (1) end-user usability testing with PWH who were current or former smokers (compensated $40) and (2) a heuristic evaluation with informaticians trained in human-computer interaction (compensated $150).

An iterative process in which 4 end-users and 1 heuristic evaluator completed use cases for each usability round was used. Five usability rounds from September to December 2022 were conducted. The initial app mock-up was created by app developers with computer science backgrounds, who did not have graphic design or expertise. As a result, we hired a graphic designer to create designs for all app screens. Following each usability round, the study team met with the app developers to adjust the user interface based on recommendations from participants. In total, there were 6 mock-ups, each building on an earlier version. Prior to the fourth usability round, we again enlisted the graphic designer's help because the app was deviating from the original design and we required her expertise to strengthen usability.

Ethics

All study procedures were reviewed and approved by the Columbia University Institutional Review Board. The research team read through consent with participants and answered any questions. Study participants provided written informed consent prior to enrollment in any study activities.

Usability testing

Sample

Twenty PWH who were current (15 enrolled) or former (5 enrolled) smokers who did not participate in focus groups or design sessions[23] were recruited to evaluate the prototype user interface. Eligibility criteria included (1) PWH; (2) $\geq$ 18 years old; (3) current/former smoker; and (4) understand/read English. Recruitment was conducted by posting flyers, contacting participants scheduled for prior cycles who were no shows or cancellations but indicated interest in future participation, and snowball sampling.[24] Twenty participants were selected because research has shown that the minimum percentage of problems identified rose from 55% to 82% and the mean percentage of problems rose from 85% to 95% when number of users increased from 5 to 10.[25] Participants owned an Android (75%) or iPhone (25%) smartphone. Despite app compatibility with only Androids, we did not exclude iPhone users because the study team provided participants with the device for usability testing.

Technology comfort was assessed by how often they use their mobile device (95% reported daily; 5% weekly), when they started using it (90% reported more >2 years; 10% <6 months), what they use it for (90% use for more than texting), how many hours a day they use it (average=6.3), and how many texts they send a day (65% send 1–10 per day, 35% send >10). The age of participants ranged from 27 to 73 years with a mean of 53 years.

Procedures

Participants came to Columbia University School of Nursing for the visit and used the study team's Android with the Sense2Quit app installed to complete 16 use case scenarios (Table 1). Participants in later rounds of usability testing completed only 15, as task 10 (Table 1) was removed since it was deemed to be redundant with another item. The study team employed a think-aloud protocol and participants were asked to verbally express thoughts while using the app. The sessions were audio-recorded. After completing the use cases, participants wore the study smartwatch, connected to the Sense2Quit app, and were instructed to "turn on watch motion

Table 1. Usability testing use case scenarios.

	Task
1.	Open the Sense2Quit app
2.	Log in to the Sense2Quit app
3.	View the Cash Spent graph
4.	View the Daily Trend graph[a]
5.	Indicate on the app that you have started and stopped smoking
6.	Play Pac-Man
7.	Send a message to the study team
8.	Change the price of the pack of cigarettes
9.	Change the number of cigarettes per pack
10.	Change the amount of time for which you have quit smoking[b]
11.	Delete a reminder
12.	Add a 1-time reminder
13.	Add a reminder for every Monday and Tuesday at 9:00 AM
14.	Watch a video about quitting tips
15.	Turn on/off watch motion tracking
16.	Log out of the account

[a] After the first round of usability testing, the name of this graph was changed to the "Smoking graph."
[b] Question was not asked after the first round due to app edits.

tracking," hit "start smoking" on the Stats page, and make smoking gestures with their hand for 30 s. The purpose of this process was to collect data for the smartwatches to detect smoking gestures and distinguish them from everyday hand gestures (ie, eating, drinking, etc.).

After usability testing, participants were asked to rate the prototype app using the Health Information Technology Usability Evaluation (Health-ITUES) and the Post Study System Usability Questionnaire (PSSUQ). Health-ITUES is a 20-item customizable instrument with 4 subscales: Quality of life (items 1–3); Perceived Usefulness (items 4-12); Perceived Ease of Use (items 13-17); and User Control (items 18–20) scored from 1 (strongly disagree) to 5 (strongly agree).[26] PSSUQ is a 16-item instrument divided into 3 subscales: System Usefulness (items 1-6); Information Quality (items 7-12); and Interface Quality (items 13-15) scored from 1 (strongly agree) to 7 (strongly disagree).[27] Both scales assess user satisfaction and perceptions of the system's usability and have strong evidence of reliability, and content and construct validity.[26,27]

Table 2. Heuristic evaluation use case scenarios.

	Task
1.	Please make smoking data appear on the smoking graph.
2.	View a tips video.
3.	Set a reminder for 3:30 PM on Tuesdays and Fridays that says "Take a nap!"
4.	Change the price per pack of cigarettes to $12.50.
5.	Send a chat to the study team asking for assistance.
6.	Start playing Pac-Man.
7.	Exit the Pac-Man game.
8.	Delete the alarm you previously set.
9.	Log out of the app.

Data analysis

Analysis was based on the audio recordings of user sessions, transcriptions, notes, and surveys. The team searched for critical incidents characterized by comments, silence, and repetitive actions. Recurring critical incidents among participants in each usability round were noted by research staff who then discussed with the app developers how to make changes accordingly to improve usability. The incidents identified and the users' written comments were summarized. Descriptive statistics were used to calculate Health-ITUES and PSSUQ results (Tables 3 and 4).

Heuristic evaluation

Sample

Five informaticians participated as usability experts. Nielsen recommends using 3 to 5 evaluators since additional information is not generally gained by using larger numbers.[28] Each expert had training in human-computer interaction, was PhD-prepared, and had published in the field of informatics.

Procedures

Heuristic evaluations took place over Zoom and were audio- and video-recorded. Recording the users' app interactions and vocalizations provided feedback to highlight problems that would not be identified with static screenshots.[29] The usability experts were provided with a description of the app's functionality and a study overview. Each expert remotely tested the prototype user interface independently with 9 use case scenarios (Table 2) using a think-aloud protocol for 45–90 min. Because these sessions were remote, the

Table 3. Mean (SD) scores of usability measures and submeasures at each round of usability testing.

Measure	Round 1	Round 2	Round 3	Round 4	Round 5
PSSUQ overall	1.5 (0.71)	2.03 (1.02)	1.84 (1.01)	2.12 (1.01)	1.69 (0.66)
System quality	1.42 (0.65)	1.83 (0.82)	1.71 (1.04)	2.17 (1.2)	1.42 (0.5)
Information quality	1.63 (0.77)	2.21 (1.21)	1.79 (0.93)	2.25 (1.03)	1.96 (0.81)
Interface quality	1.44 (0.73)	2.06 (.99)	2.12 (1.09)	1.88 (0.62)	1.69 (0.48)
Health ITUES overall	4.59 (0.77)	4.46 (0.76)	4.4 (0.87)	3.96 (0.79)	4.2 (0.93)
Quality of work life	5 (0)	4.5 (0.9)	4.58 (0.79)	4.58 (0.51)	4.92 (0.29)
Perceived usefulness	4.72 (0.45)	4.33 (0.79)	4.39 (0.77)	3.67 (0.68)	3.81 (0.95)
Perceived ease of use	4.5 (0.51)	4.75 (0.55)	4.5 (0.83)	4.15 (0.81)	4.6 (0.82)
User control	4.25 (0.96)	4.33 (0.78)	4.08 (1.24)	3.92 (0.9)	4 (0.85)

Abbreviations: Health-ITUES: Health Information Technology Usability Evaluation; PSSUQ: Post Study System Usability Questionnaire.

Table 4. Nielsen's heuristic ratings by round.

Nielsen's heuristic	Round 1	Round 2	Round 3	Round 4	Round 5	Mean (SD)
(1) Visibility of system status	3	1	2	3	2	2.2 (0.84)
(2) Match between system and real world	3	2	3	2	1	2.2 (0.84)
(3) User control and freedom	2	0	2	3	3	2 (1.22)
(4) Consistency and standards	2	0	2	2	1	1.4 (0.89)
(5) Help users recognize, diagnose, and recover from errors	1	0	3	0	N/A	1 (1.41)
(6) Error prevention	2	0	2	0	2	1.2 (1.09)
(7) Recognition rather than recall	3	0	1	3	2	1.8 (1.3)
(8) Flexibility and efficiency of use	1	0	2	3	0	1.2 (1.3)
(9) Aesthetic and minimalist designs	3	0	1	3	1	1.6 (1.34)
(10) Help and documentation	3	0	3	4	3	2.6 (1.52)

study team screen-shared the app through Zoom. To complete use cases, experts indicated where study staff should click or scroll while sharing their thoughts. Remote testing was a limitation because participants were not able to physically test the app on their own, which may have led to different outcomes than if the visit had been in-person.

After completing the use cases, experts were asked 3 open-ended interview questions, with questions omitted if previously answered during usability testing. Open-ended interview questions were: (1) thinking back to the Sense2Quit app, how do you think PWH who want to quit smoking would apply the information, lessons, or activities in their daily lives; (2) how do you think this app would be relevant to PWH who want to quit smoking; and (3) how easy or intuitive is it to navigate through the app to perform particular tasks? Finally, experts completed the Heuristic Evaluation Checklist[30] to evaluate the extent to which the user interface violates usability heuristics: visibility of system status; match between system and the real world; user control and freedom; consistency and standards; help users recognize, diagnose, and recover from errors; error prevention; recognition rather than recall; flexibility and efficiency of use; aesthetic and minimalist design; and help and documentation.[31,32] Each heuristic was evaluated by 1 or more items to which the participants responded "yes" or "no" and the overall severity of the identified heuristic violations was rated from 0 (not a usability problem) to 4 (usability catastrophe).[33]

Instrument

Data analysis

Evaluators' comments on the evaluation form and Zoom audio and video recordings were reviewed.[28] Comments that aligned with study goals and feasible changes for our app developers to make were prioritized. Findings are organized based on each usability round and recommendations for app changes are coded based on Nielsen's Heuristics (Table 4).

Results

Usability testing resulted in 6 app versions. A total of 66 changes between all screens were made based on end-user and expert recommendations for design, content and features. Table 3 illustrates mean scores of usability measures from end-users by round. Table 4 illustrates expert scores of each heuristic factor by round.

Figure 1 illustrates changes to the Home Screen, Stats/My Smoking Trends, Reminders, and Settings organized by round. Further, findings from each round which informed these changes are detailed below. Changes to the app were related to design, content, and features.

Findings from usability testing and heuristic evaluations

Round 1

The Sense2Quit demo app in round 1 consisted of the following tabs on the bottom navigation bar: Stats, to view graphs and information about cigarettes smoked, cash spent from smoking and time since last smoke; Games, to play Pac-Man; Chat, to communicate with the researchers; and lastly, User. User contained the following pages: Reminders, to set/delete reminders; Tips, to view a video and daily tip; Settings, to turn on/off watch motion tracking; and Account, to personalize cigarette prices. Upon logging in, users viewed Stats.

Round 1 comments highlighted an issue with the app's layout. A total of 22 design and 4 feature-related changes between all app pages were made based on feedback. The most significant comment from end-users and expert 1 was that there should be a home page. End-users assumed there would be a home page and had trouble navigating the app. Some were inclined to hit the Android's home button to move to other pages, leading them to exit the app. One end-user suggested, "in the top [there] should be like an X, so you could X out and go back to the home screen. Or a little house that you can hit and go back to the home screen." Expert 1 also "advocated" for adding a home page, because they believed there needed to be a neutral page to include important features such as the "start smoking" button to manually record a smoke.

Another layout concern was the User tab (Figure 2). It was not intuitive for participants to click on User to access Reminders, Tips, Account, and Settings. When completing tasks, participants found these 4 tabs by process of elimination (ie, they knew they weren't within the other 3 tabs). One participant explained they "wouldn't know how to get there" to change account information. Expert 1 urged that there was no "logical choice" in the current app for where to update cigarette prices (Table 1, Task 8). In response, a new layout which consisted of a home page with the following tabs: Stats, Games, Chat, Reminders, Tips, and Settings was developed. The home page replaced the bottom navigation bar because many users expressed difficulty reading small fonts and spacially it looked better.

Aside from layout concerns, issues such as thinking static information about smoking trends within Stats was clickable, and struggling to interpret military time were identified by end-users. These items were addressed by placing static information on the Stats page in a table; and replacing the 24-h with a 12-h clock.

Round 2

Re-working the layout of the app improved usability so that end-users had little to no difficulty using the home icon at the top right of the page to return to home. However, similar to round 1, participants identified minor usability issues throughout the app; a total of 8 design and 2 feature changes were made to Stats, Chat, Settings, and Reminders (Figure 1). The Y axis values in Stats had decimal points and confused end-users who thought that 1.0 was a 10, meaning they smoked 10 cigarettes rather than 1. Other issues, identified by Expert 2, were that the Chats page header moved upward when scrolling, and that the save function did not work in Settings. Moreover, a challenge that participants repeatedly encountered within Reminders was that the Android's keyboard popped up and blocked the "repeat" function when setting a recurring reminder. Users had to minimize the keyboard to select days of the week. This caused confusion and frustration among some end-users when attempting to complete the task of setting a recurring reminder. One participant stated that we were "hiding" this function. Another assumed they had to type in which days of the week they wanted the reminder to repeat on. Expert 2 assumed the developers had forgotten to include the week days.

Consequently, the following changes were made: removed decimal places from the graph's y axis; adjusted formatting so

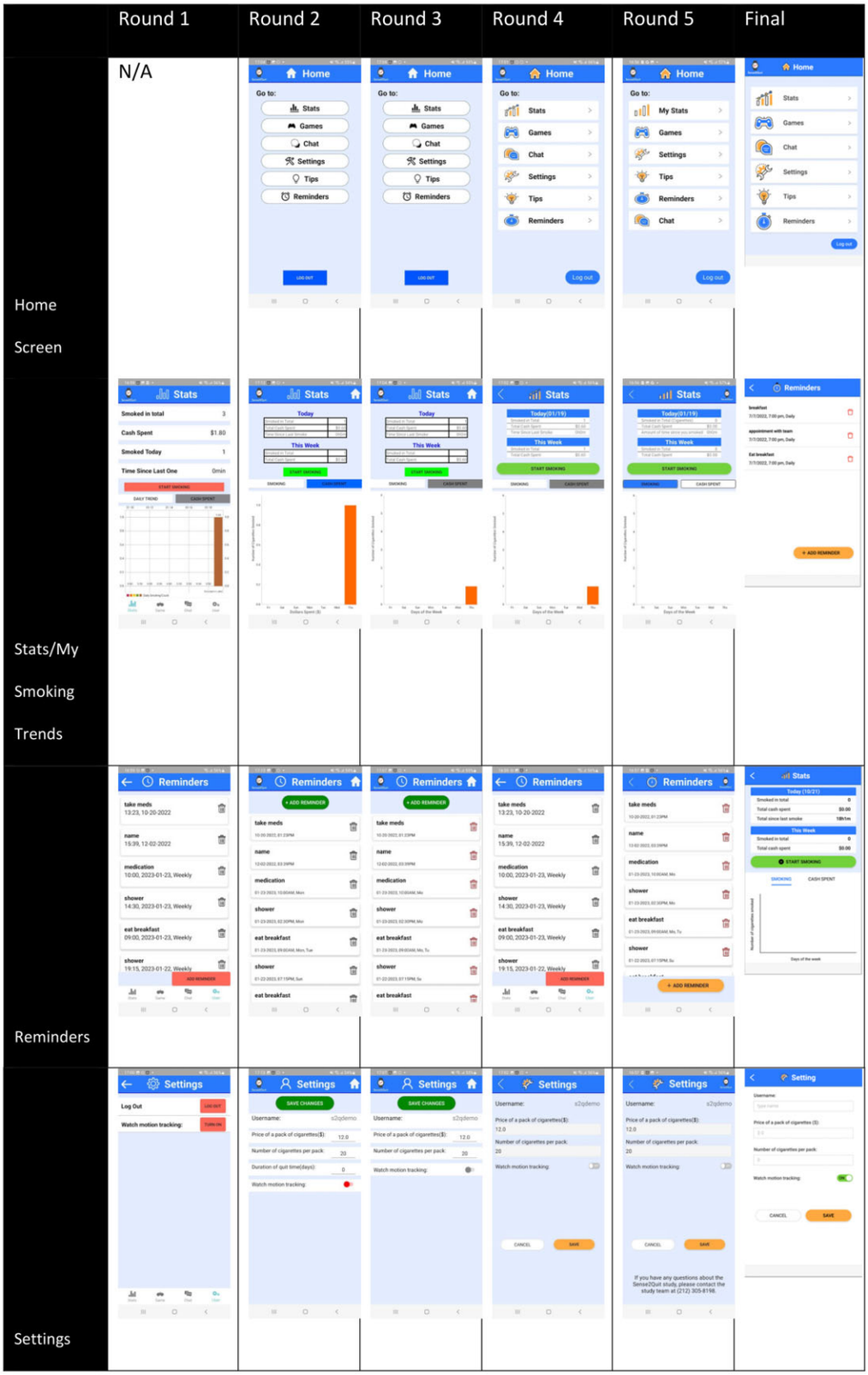

Figure 1. Changes to app screens organized by usability round.

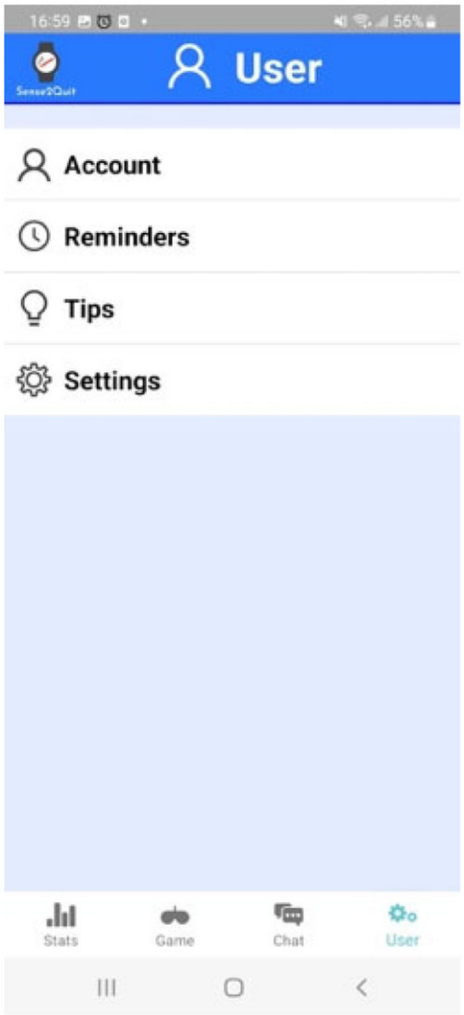

Figure 2. User tab.

that the Chat header remained static; corrected the "save" function; and altered the "repeat" function in the "Add Reminders" page so that users did not have to minimize the keyboard to see options for setting a repeating reminder.

Round 3

Round 3 findings yielded a total of 6 slight changes to design and feature, and 2 larger content changes. Specifically, comments and suggestions about video and tip refinements from all 3 prior rounds were incorporated. Participants had stated that the existing 15-s video, which was intended to encourage participants to quit smoking, was "dead," "giving you one theory," "quick," "boring," and "unhelpful." Eleven out of 12 end-users and all experts thus far had not liked the video. Participants believed the Tips page had potential for educating users on smoking harms, quitting benefits, and distractions.

End-users and experts proposed including a selection of videos with encouraging messages, distractions such as meditation, tips on overcoming triggers, advice on how to quit without gaining weight, education on adverse health effects and financial burden of smoking, testimonials, and resources. One end-user, a former smoker, shared that it would be helpful to explain misconceptions about smoking, stating "Because people think when you smoke cigarettes it relieves the stress. But when you smoke a cigarette, when the cigarette's done, the stress is still there." Participants also advocated for additional tips. Round 3 edits were focused on adding videos and tips.

Slight changes were made to the design and features, based on feedback from expert 3 that standard icons should be used for certain buttons, such as "play." Additionally, expert 3 urged that an app user would expect a "Cancel" button under "Add Reminders." Our study team re-hired the graphic designer as a consultant to provide requisite expertise on necessary design edits.

Round 4

Round 4 edits consisted of 8 design, 1 content, and 1 feature-related minor changes. Re-organization of Tips and correction of usability issues, as suggested by expert 4, such as rounding button edges, changing the Stats icon to a bar graph, and adding the unit "cigarettes" to smoking data were prioritized. Further, evaluation of the newly refined "Tips" tab was enlightening for app development as participants explored and commented on the new content. While some participants favored the Center for Disease Control (CDC) informational videos, others preferred testimonials. One participant related to a testimonial video of someone who quit for her family.

Although expert 4 appreciated the videos and tips selection, she urged that a daily push notification to view a video or tip was necessary to ensure participant engagement with these features. She stated, "For me, it's about reinforcing the message. What I've learned in my work is that users prefer different ways of consuming information. Some people will come to this page on their app and not even watch the video, but only read the text. Some will just watch the video. Some will do both." As a result, setting a daily notification to view Tips was incorporated. Due to time constraints, however, this update was not implemented until the last round.

Round 5

Three content, 2 design and 7 feature edits were incorporated based on feedback from all 5 rounds. One of the final changes to the app was in Stats. Although participants are expected to wear their smartwatch continuously to detect smoking data, expert 5 explained, "I would definitely expect the ability to have a manual logging, you forgot to charge your watch, you ended up, you know leaving it somewhere." Therefore, we collaborated with our graphic designer and app developers to add a feature to manually log smoking data.

Common feedback in all usability rounds also indicated that the Games page needed improvement. Participants identified 3 main issues: (1) a need for another game; (2) the Pac-Man screen was too small; and (3) the Pac-Man game needed to be changed to the original version. End-users shared their favorite games that they would like to see in the app. Many participants indicated they would like to see a word or puzzle game. We were limited to open-source games; thus, a "Tetris"-like game was selected. The sizing of the Pac-Man game was an issue because many participants had poor eyesight and it did not fill the screen. To address this, the app developers used a different version which could be re-sized to fill a smartphone screen.

Another concern was the Pac-Man game's smoking theme. Rather than using the usual Pac-Man ghosts and game icons, our game replaced the ghosts with cigarettes and included medical and smoking background images. Because the game was small, end-users had difficulty deciphering the images and experts advocated for the original Pac-Man theme. Expert 2 explained, "I studied meditation and I was brought up in the tradition of influence of image, and one of the things is what you think about affects you. And so, if you're trying to get people away from smoking, making them think about it, it's going to be a distraction that might not be the best thing." Similarly, expert 5 stated, "So, the point is pure escapism. And to achieve a state of flow. So, I kind of get the thing about trying to dodge the cigarettes, but I don't see anything wrong with like the original ghosts." Therefore, the game theme was changed.

Additional content and design changes included the addition of Frequently Asked Questions (FAQ) and changes to theme colors. Some end-users were frustrated when unable to perform tasks, supporting the addition of this FAQ page. As for design colors, feedback was generally positive, however, some end-users did not care for the "brick red" colors. These comments, in addition to expert 5's suggestion that we test colors in colorblindness filters[34] required color adjustments, which were accomplished with the help of our graphic designer. Following the final round, these outstanding issues were addressed and changes were implemented.

Discussion

Robust feedback and suggestions on app features, content and designs were elicited in all usability rounds. While many themes overlapped between usability testing with end-users and heuristic evaluations, there were also discrepancies.

Through conversations with end-users, we gained insight on what would promote maximum app usage and help PWH quit smoking. Inclusion of the target population, which has been demonstrated in other studies,[32,35,36] was critical for the development of Tips since end-users shared what would be helpful for their own quitting journeys.

On the other hand, heuristic evaluators provided a more technical viewpoint, highlighting where standard app formatting should be adhered to. For example, experts were more likely to find usability errors from a general user's perspective such as that a header should remain static, or that corresponding icons should be added to buttons (for "Add," "Play," etc.). Experts also made suggestions on how to encourage participants to engage with the app.

The difference in findings from end-users and experts ultimately allowed us to fill knowledge gaps and make improvements to the app. Both of these perspectives, with the added graphic design expertise, were essential in creating a usable and visually appealing mHealth app.

Across all testing, some end-users and experts thought that certain features of the app were not necessary. Feedback indicated that reminders and games may not be helpful since users had similar apps on their phone; financial burden may not be an incentive to quit; and videos may go unwatched. Despite some negative feedback, most participants liked or did not mind these features, thus, we retained them.

There were several gaps between desired app changes and those that we were ultimately able to make. Time was a limitation as we were often unable to make all edits between each round. Another limitation was that many end-users found some words and buttons to be too small. In response, darker, larger fonts were used when possible. Despite this, several participants found the Android's screen to be too small, so we were limited when addressing this visibility issue.

Limited mHealth interventions are available for PWH who smoke.[13,19,20] Given this gap, usability testing is even more critical to ensure that the tools that are developed meet the needs of end-users. Aside from the lack of apps tailored to PWH, many tobacco cessation apps currently on the market do not include targeted end-users in the development process or are single-function apps and consequently not desirable for smokers interested in quitting.[37] The quitSTART app, which is CDC recommended, combines different strategies to help users through their quitting process; however, it requires the user to manually record slips, and does not have sensors to track smoking behaviors.[38] The Sense2Quit app overcomes these limitations. Importantly, it overcomes the time burden that smokers encounter if they need to track their smoking behaviors.

Past studies have tested smartwatch sensors to track smoking, but many are still under evaluation and few are available on the app marketplace.[39–43] To our knowledge, the Sense2Quit app is the only app that combines these cessation strategies, tracks smoking habits through smartwatch use, and is targeted specifically toward PWH. Thus, the Sense2Quit app is needed since it overcomes many limitations of the extant tools.

Conclusion

In summary, findings from this study describe best practices for usability testing for development and refinement of a mHealth-delivered consumer informatics tool for improving tobacco cessation. The participatory human-centered design methods and evaluation tactics demonstrate the integration of feedback from experts and end-users to develop a product which is perceived as highly usable from a human-computer interaction perspective and concurrently perceived as highly useful from end-users. Although there are data to support the efficacy of this approach,[10,44] further research is needed to fully evaluate how tools informed by target audiences' needs improve health outcomes.

Author contributions

All authors made substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; R.S. and M.B. drafted the work; P.T., M.-C.H., P.C., H.C., and W.X. reviewed it critically for important intellectual content; all authors provided final approval of the version to be published; and all authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Conflict of interest

The authors have no competing interests to declare.

Data availability

De-identified data can be made available upon request from the corresponding author.

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