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Abstract

Background: Despite the increased accessibility and availability of technology in recent years, equality and access to health-related technology remain limited to certain demographics . In particular, patients who are older or from rural communities represent a large segment of people who are currently underutilizing mHealth solutions and are considered medically underserved. Rural communities commonly have a higher rate of chronic disease and reduced access to providers; therefore, rural patients could benefit from adopting digital solutions such as mHealth apps. However, system usability continues to be a barrier to mHealth adoption among users with non-traditional digital literacy.

Objective: This study investigated if state-of-the-art mobile app interfaces from open-source libraries provide sufficient usability for rural cancer patients with minimal design changes and forgoing the co-design process.

Methods: We developed the Assuage app to serve as a research platform for any mHealth study. We conducted a pilot study using Assuage to assess the usability of four (4) mobile user interfaces (UIs) based on open-source libraries from Apple’s ResearchKit and CareKit that all had varying complexity in reporting distress symptoms with cancer patients. Cancer patients were recruited to complete the distress assessment using a randomly selected UI. Data was collected on participants’: ages, location, mobile app usage, and familiarity with mobile health apps. Participants rated usability with the System Usability Scale (SUS), and usability issues were documented and compared. A one-way ANOVA was used to compare the effect of the UIs on the SUS scores.

Results: Thirty (30) current and/or post-surgery cancer patients participated in this pilot study. Most participants were over 50 (24/30, 80%), from rural areas (25/30, 83%), had up to a high school education (19/30, 63%), and were unfamiliar with mobile apps for health (21/30, 70%). General mobile app use was split with (14/30, 43%) not regularly using mobile apps. The mean SUS score across the UIs was 75.8 (SD 22.2), with two of the UIs achieving an SUS score >=80, meeting the industry standard of 80. Critical usability issues were related to data input and navigation with touch devices, such as scale-format questions, vertical scrolling, and traversing multiple screens.

Conclusions: The findings from this study show that most cancer patients (20/30, 67%) who participated in this study rated the different interfaces of Assuage as above average (68). This suggests that with minimal interface alterations, Apple’s ResearchKit and CareKit libraries can provide usable UIs for older and rural users. When resources are limited, the design stage can be simplified by omitting the codesign process, while still preserving suitable usability for users with non-traditional technical proficiency. Usability comparable to industry standards can be achieved by considering heuristics for both interface and electronic survey design, specifically: how to segment and navigate surveys, present important interface elements, and signal

gestural interactions.

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and navigate surveys, present important interface elements, and signal gestural interactions.

Keywords: human-computer interaction; usability testing; mobile health; mHealth; cancer patients; distress; survey design

Introduction

Background

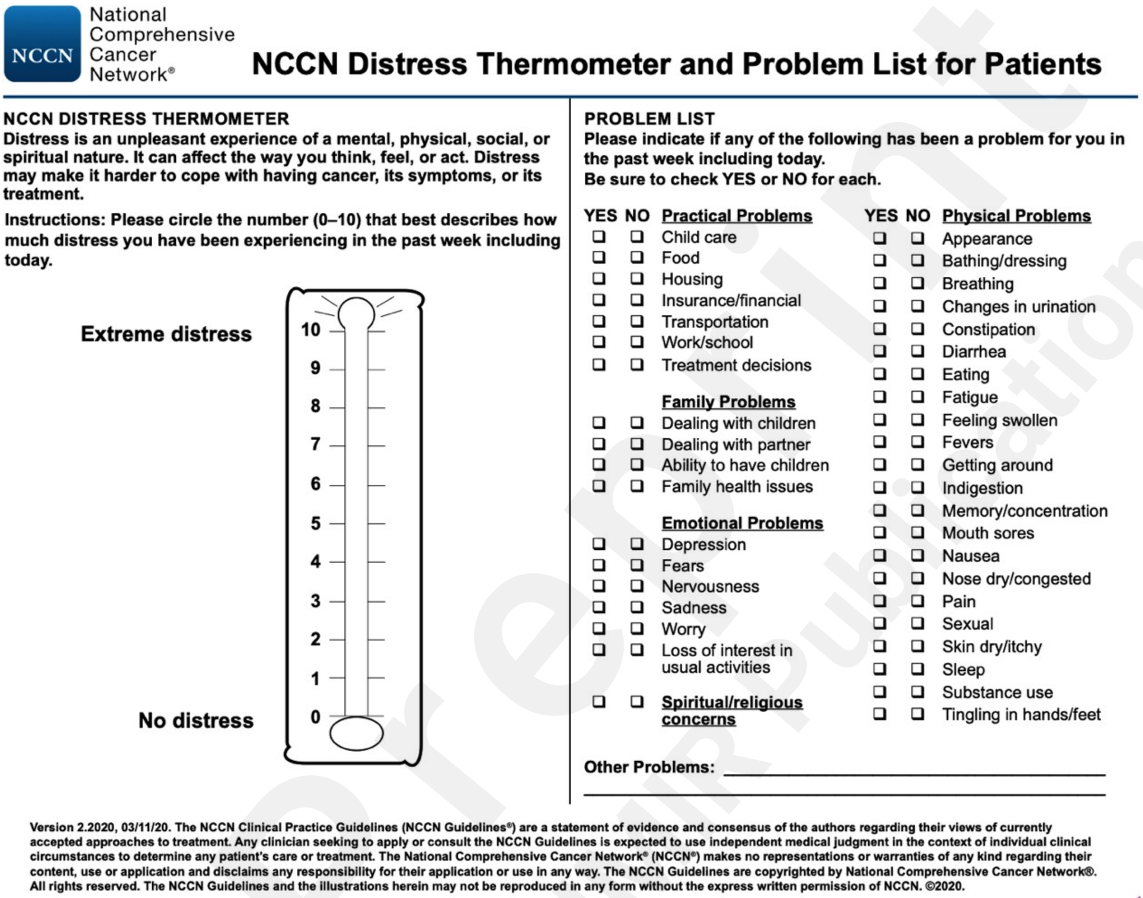
Mobile health (mHealth) technologies have been around for over a decade, yet the percentage of adult patients actively using these mHealth technologies is lower than desired [1,2]. The demographics of adults not utilizing mHealth solutions are consistent with patients from rural populations, racial and ethnic minority groups, and older individuals, which overlaps with persons categorized as medically underserved [3]. According to the Health Resources & Services Administration, medically underserved populations have been designated as having too few primary care providers, a high infant mortality rate, prevalent poverty, or a high elderly population. Specifically, rural communities, like those of the Southeastern United States or Appalachia, commonly have higher rates of chronic disease, reduced access to providers, and lack the same medical resources as their urban counterparts [4–8]. The ubiquity of mobile devices makes mHealth particularly attractive for reaching disadvantaged populations [9–12]. A promising use of mHealth is remote patient monitoring, which can include objective data, such as biometrics, via sensor devices or subjective data, such as quality of life surveys, via patient-reported outcomes; resulting in a better understanding of a patient's overall health and symptom tracking between visits [13].

As of 2023, 90% of people in the United States own a smartphone. In addition, it was reported that while 27% of people who lived in rural areas did not have broadband at home, 87% owned a smartphone. In particular, adopting new innovations in rural communities is important because the disparities between advantaged and disadvantaged communities continue to grow for digital literacy, also known as the digital divide [14,15]. Factors in the divide between advantaged and disadvantaged groups are health literacy, knowledge of technology, and comfort of use [16,17]. Designers should ensure system user interfaces (UIs) are universally acceptable, particularly with respect to users with limited technical proficiency. Ensuring the usability of a system is essential for accurate data collection and reducing attrition rates [18–20].

Simply digitizing a paper-based survey may present complexities that render the digitized counterpart unusable and discourage the required frequency and accuracy to encourage adherence. For example, patients may accidentally submit their responses prematurely or, alternatively, not at all. Not to mention the role that usability can play in the eventual penetration of an innovative technology, which has been explored through the Technology Acceptance Model [21–23] and research focused on mHealth adoption [20,24–26]. To address the aforementioned concerns; researchers and developers often co-design the UI to ensure digitization is tailored to the respective demographic [27,28]. A participants' age has been shown to significantly affect the ease of navigation and learnability, especially as cognition and motor control decline [29]. However, proper interface design can minimize user error and allow for a smooth user experience [30].

The following heuristics should be followed to provide an optimal user experience for respondents in digital surveys. Surveys should be aesthetically pleasing and easy to navigate [31,32] with an explicit visual flow [33]. Although some researchers [34] have found that scrolling layouts can sometimes have faster completion times, designers should still be strategic in deciding between paging versus scrolling along with the grouping and sequencing of questions. Furthermore, when considering answer choices, potential options should include some variation of, "do not know" [35,36]. In addition, surveys should be succinct [31,33,37] and maintain a standardized format, as variations in format can lead to decreased usability [32]. Surveys should always be easy to understand with clear directions for answering questions [32,33,37]. Moreover, survey language should mimic verbal dialogue whenever possible [32]. Additional features to consider implementing are showing participants their progress towards completion, a "thank you" page, and an overview of results at the end [32]. Lastly, incorporating Nielsen's 10 general principles for interaction design (Figure 2) will make UIs more accessible, user-friendly, and intuitive. [38,39].

Figure 1. National Comprehensive Cancer Network's Distress Thermometer and Problem list. The version shown here was the version used for this study. The newest version can be found here [40].



Distress Screening

According to the National Cancer Institute, distress is an "emotional, social, spiritual, or physical pain or suffering that may cause a person to feel sad, afraid, depressed, anxious, or lonely" [41]. Distress is prevalent in cancer patients regardless of disease stage or modality [6,42–45], and untreated distress has been shown to lead to greater pain, reduced physical function, increased medical costs, and longer stays in the hospital [6,42,46]. The National Comprehensive Cancer Network (NCCN) created the Distress Thermometer (DT) and Problem List for use as a screening tool for recognizing distress in cancer patients (Figure 1) [40,47], and has since been shown to accurately indicate distress [42,48]. The NCCN DT was designed to improve patient care and increase patient quality of life. Furthermore, studies have shown that distress screening can improve health outcomes, including reduced morbidity and mortality [6,42].

Unfortunately, due to factors like staff burnout or emotional fatigue, signs of distress in patients may go unnoticed [42,43]. In addition, there can also be variations across different cancer centers regarding when patients should be screened. This raises the need for a more effective and efficient process related to distress screening [43]. The implementation of digitizing the NCCN DT as a mobile app poses many advantages, such as real-time identification of distress factors and triage to the proper provider, generating insightful data around common issues during the cancer experience, and providing insight into potential resource allocation [12,13,49].

Conversely, there are barriers to the implementation of new tools in healthcare. For example, modifying any clinical practice can be challenging, and providers hesitate to make drastic changes without enough evidence of substantial benefit and patient-driven motivation [50–52]. Additionally, digital implementations of distress screening that are considered complex or not user-friendly by target users can lead to reduced effectiveness. Effective distress screening requires patient adherence and accurate information input to enable providers to devise proper interventions and follow-ups [14]. Despite the challenges, technology poses a great solution to address the needs of patient distress monitoring when resources and access to care are limited [53,54]. In particular, the prevalence and ubiquity of mobile devices presents opportunities for patients in remote and rural areas to utilize mHealth apps to enhance their care. By reducing the time between distress screenings, providers and researchers can better understand a patient's overall distress and causes of distress and track symptoms between visits.

This Study

Ensuring the interface usability of an mHealth system is essential to its effectiveness, which often requires patient adherence and accurate information input to enable providers to devise proper interventions and follow-ups and prevent attrition [20,55]. Previous research suggests that co-designing for users with limited digital literacy, such as older or rural users, may be required to build suitable usable interfaces, but it often requires considerable time and resources [56–58]. Designers often co-design the UI to address the concerns and ensure digitization is tailored to the respective demographic [28]. This pilot study assesses the usability of multiple UI implementations of the NCCN DT (Figure 1). In particular, for understudied populations, such as Appalachian and rural cancer patients who are underserved and vulnerable [59,60].

The different UIs were designed without co-design to assess whether or not usable UIs could be achieved for this demographic when resources for the design stage are limited.

Figure 2. Nielsen's 10 usability heuristics and the different heuristics covered in Assuage's 4 UIs.

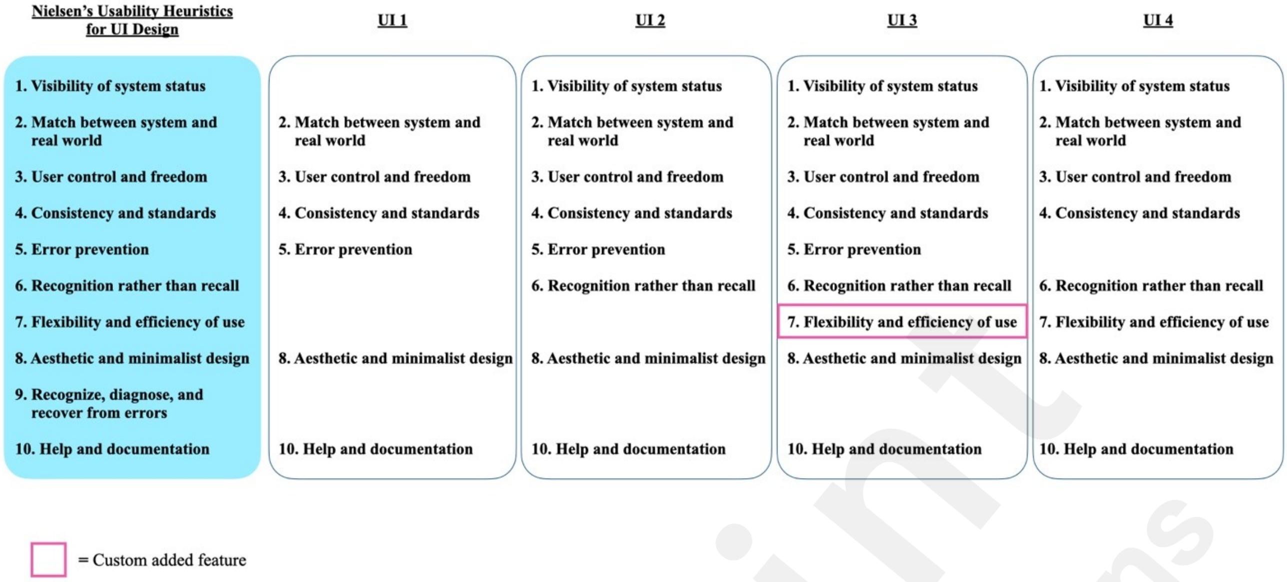


Figure 2 shows an overview of usability heuristics in each interface variation, out-of-the-box implementations of UIs from Apple's open-source libraries that have not been co-designed for the target demographic. As will be discussed later in the *Interface Design* section of the Methods, we created UI 3, which is a modification of UI 2 to include navigational features based on Nielson's 10 general principles [38,39], specifically, (#7) flexibility and efficiency of use, which also correlates with navigation suggestions [31,32] of survey design recommendations. It should be noted that the heuristic; (#9) recognize, diagnose, and recover from errors, was not reflected in any of the interfaces. Omitting (#9) was intentional as the DT (Figure 1) paper survey questions and answers were created by the NCCN and user-input errors such as out-of-range values are not possible [40,47].

Methods

Cancer patients were recruited from the Markey Cancer Center to participate in this study between July and August 2021. We recruited 30 patients to assess a random UI in the Assuage app (discussed in the App Design and Development section). The University of Kentucky's Institutional Review Board approved all research activities (#64149). The pilot study used A/B testing between 4 different UI designs for completing a distress survey. A/B testing protocols are commonly used in industry and randomly assign different system versions to users for comparative analysis [61,62]. Scores from the System Usability Scale (SUS) [63] were compared between the UI design variations within Assuage. The SUS is a validated tool with a positive reputation for providing swift and reliable results [64,65]. The SUS consists of 10 statements, or items, with a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). A negative response is considered a score less than 3 for positively worded statements and greater than 3 for negatively worded statements. While the SUS is not a diagnostic tool, it can effectively determine whether the tested system would be generally usable even when used to evaluate small sample sizes with as few as five (5) users [63–69]. The SUS has been used in industry and academic research and is sufficient for pilot studies of mHealth applications [18,20,28,66,70–72]. Individual SUS Items can be seen in Multimedia Appendix 1.

App Design and Development

Assuage is a HIPAA-compliant mobile iOS, iPadOS, and watchOS platform developed using Apple's

HealthKit [73], CareKit [74], and ResearchKit [75]. Assuage is a research testbed for assessing and improving patient care through health-related studies. Remote patient monitoring can be accomplished through Assuage by adding various quality-of-life surveys, such as the NCCN DT survey in Figure 1. Additional frameworks like ParseCareKit [76] synchronize ResearchKit and CareKit data with a HIPAA-compliant server [77]. Assuage allows researchers to select from multiple UIs for patient input of subjective information such as their distress symptoms. The decision to offer multiple UIs is based on the knowledge that some demographics, like rural cancer patients, have not heavily adopted mHealth, but are also not completely removed from modern everyday technologies, like mobile devices or smartphones. Conversely, the number of rural-dwelling adults who own a smartphone continues to rise, creating avenues for mHealth to have a larger impact on this population. Therefore, we wanted to gauge if standard UI elements common in mobile interfaces provide acceptable usability for an mHealth use case, such as symptom reporting, without expending extra resources on co-design.

Figure 1. User interface 1.

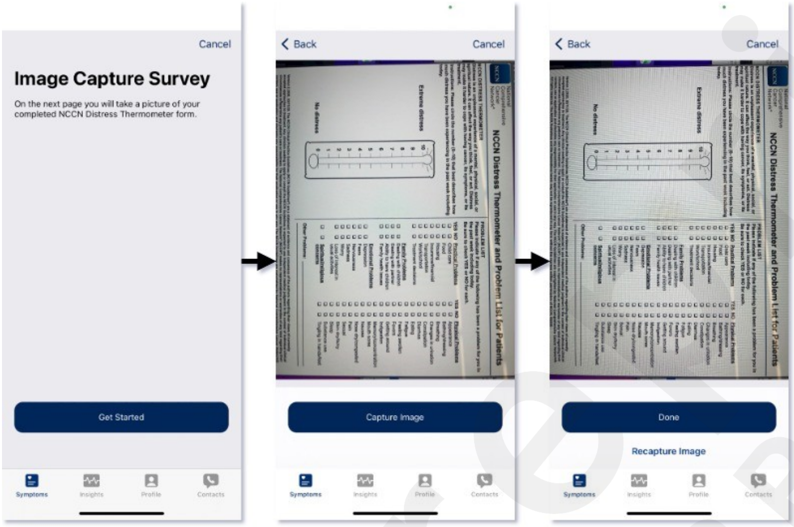


Figure 2. User interface 2.

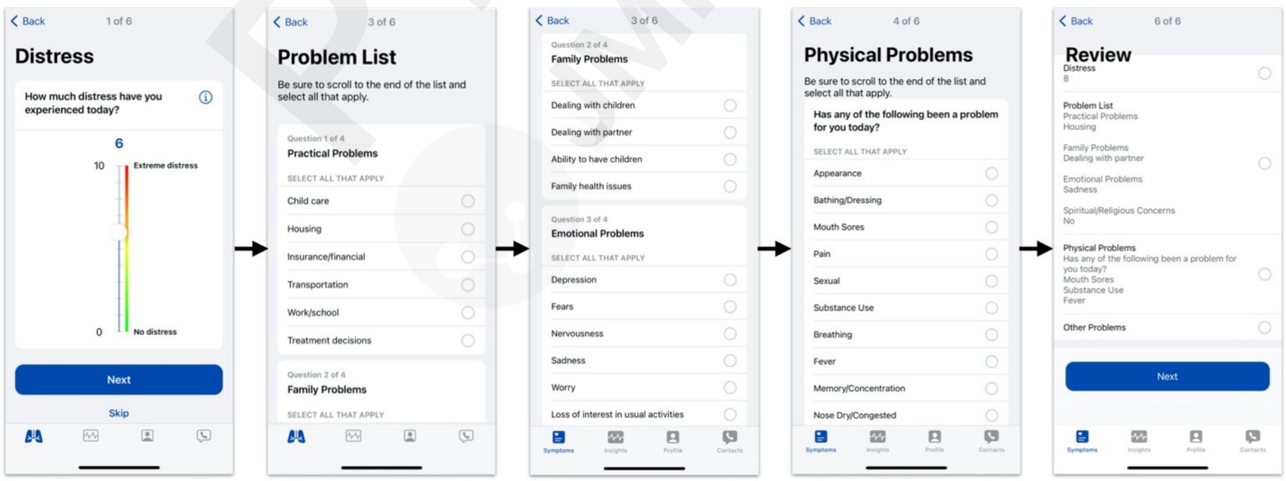


Figure 3. User interface 3.

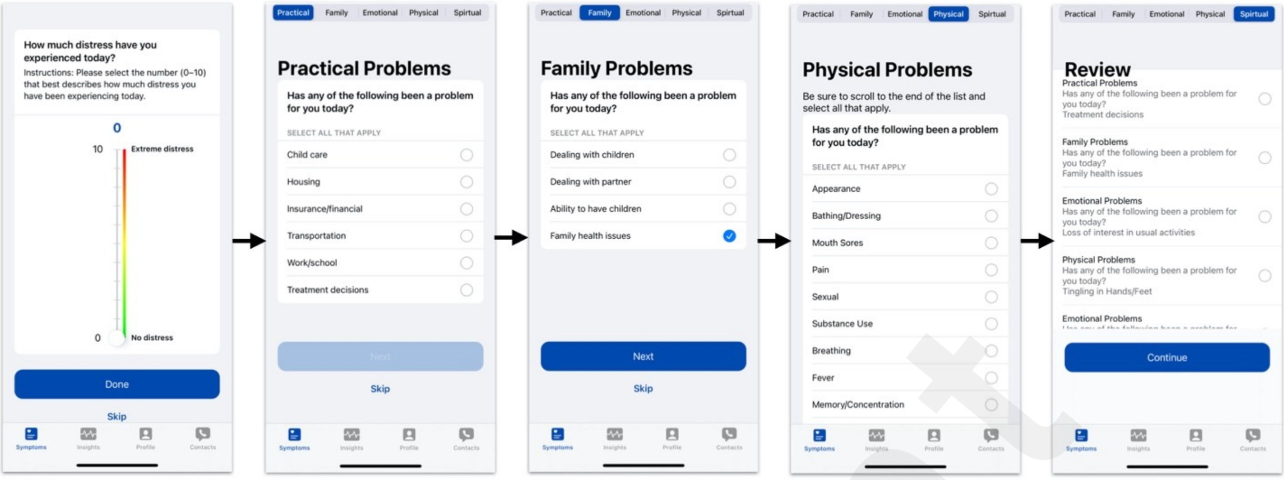
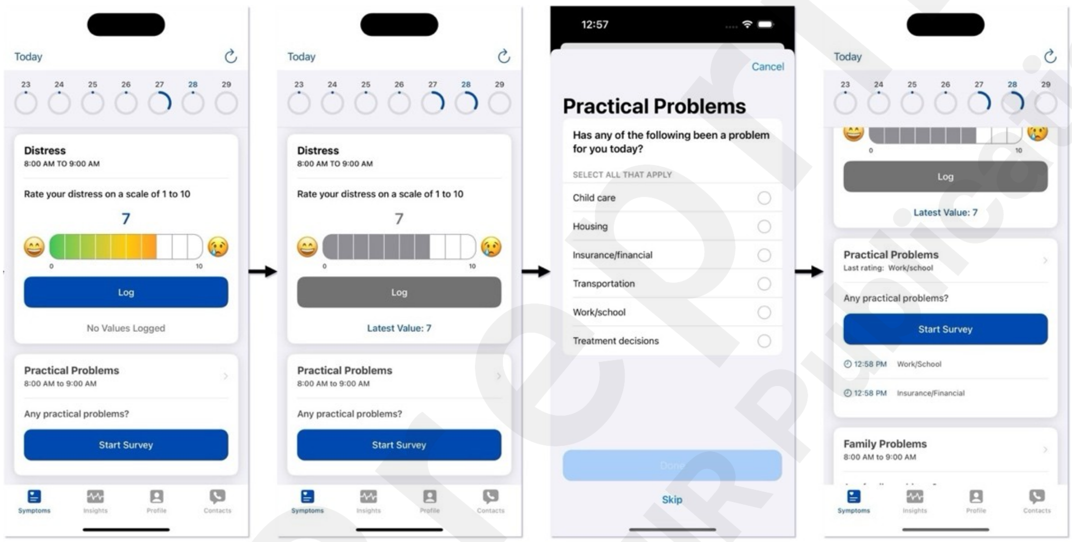


Figure 4. User interface 4.



Interface Design

Four user interfaces were implemented in Assuage for the pilot. All the UIs were designed with Apple's ResearchKit and CareKit, which leverage Apple's Human Interface Guidelines [78]. ResearchKit and CareKit provide out-of-the-box UI views and elements for developers to build health and medical mobile apps, which have been used in various research studies [24,79–83]. Screenshots of the different UIs are shown (Figure 2-5). In particular, the UIs differ in how the NCCN DT components are displayed and navigated. When gauging a patient's distress using the NCCN DT questionnaire, the value of the distress thermometer component is the most important factor and directly correlates to immediate actions taken by the care team regarding the patient. With this in mind, the fully digitized interfaces (UIs 2-4) present the distress thermometer first, but patients can still choose to skip any question in all UI versions. Descriptions of the different UIs are as follows.

(1) UI 1: (Figure 2) Enables patients to sequentially step through three (3) screens to capture a picture of the paper-based NCCN DT. UI 1 depends solely on ResearchKit's standard survey design with no alterations. Navigation is limited to *next* and *back* buttons. Patients familiar with the NCCN DT survey may benefit from UI 1 since it requires completing the paper-

based survey as normal. Conversely, if a patient is unfamiliar with mobile devices or has ailments that prevent them from holding the camera steady, UI 1 could be less usable.

(2) UI 2: (Figure 3) Patients navigate sequentially through the NCCN DT survey components. UI 2 depends solely on ResearchKit's standard survey design, also with no alterations. Navigation is limited to the *next* and *back* buttons. Patients unfamiliar with the NCCN survey may benefit from UI 2 since it requires all the NCCN survey questions to be viewed before completing the survey. Conversely, the sequential requirement of UI 2's design does not allow the user to quickly navigate different survey sections when compared to the paper NCCN DT or UI 3 and UI 4. This may require more time to be spent on the survey and could burden patients already familiar with the NCCN survey question set, who prefer to skip sections that do not apply to their current distress. When a patient reaches the end of UI 2, they can review their answers before submission and are allowed to change previously entered questions.

(3) UI 3: (Figure 4) Patients can navigate the NCCN DT surveys sequentially and non-sequentially with a horizontal navigation segment allowing patients to skip around to different sections. UI 3 is designed by retrofitting ResearchKit's survey design with a horizontal navigation segment that allows patients to skip around to different sections of the NCCN DT, providing improved navigation. In addition, UI 3 requires minimal vertical scrolling by the patient compared to UI 2. Like the paper-based NCCN DT, UI 3 allows patients to quickly see all relevant distress categories. However, unlike the paper-based survey, patients are not overwhelmed by having to step through all questions and are only presented with questions associated with the respective section of interest. Patients familiar with the NCCN DT may benefit from UI 3's design as it can allow for quicker survey completion times since they can navigate to sections and questions of interest. On the contrary, if a patient is unfamiliar with the NCCN DT or a familiar patient forgets a relevant question to their distress belonging to a particular segment label, skipping around may cause important questions to be missed, reducing the ability of the care team to provide the best care. When patients reach the end of UI 3, they can review answers before submission and change previously entered questions.

(4) UI 4: (Figure 5) Implements a modern and modularized view of the NCCN DT questions highly dependent on vertical scrolling. Patients can select *cards* corresponding to surveys, allowing for the most fluid navigation between sections. The navigation and card layout in UI 4 leverages both ResearchKit and CareKit and takes advantage of the latest iOS design principles. The distress thermometer in UI 4 keeps the thermometer aesthetic of the paper-based NCCN DT but deviates by being horizontally placed instead of vertically. In addition to the temperature and number values that UIs 1-3 have on the distress thermometer, UI 4 also has emojis representing extreme distress points. UI 4 allows patients to scroll through survey sections vertically, while answers provided on previous days can be viewed by swiping the screen horizontally. Individual survey cards display the answers entered for the respective survey section. An adherence circle is also shown at the top of UI 4 to represent survey completion. Limitations to UI 4 are like UI 3 concerning patients unfamiliar with the NCCN DT may miss recording relevant answers. In addition, if a patient is not comfortable with the latest UI design principles of iOS, patients could be deterred from UI 4.

To reiterate, the most significant change in design between the different UIs is the navigation style and how a user will traverse through the application/survey. Regarding mHealth tracking apps for users with chronic illness, the design should be simple, self-explanatory, visually appealing, and intuitive to navigate [16].

Recruitment

Study participants were recruited at the Markey Cancer Center. Two medical oncologists at the cancer center gave permission for researchers to interact with willing patients at their respective clinics. The doctors asked if patients would be willing to speak to a researcher about the study during their visits. If patients agreed, the researcher went to the respective waiting room, informed the patients about the study, gauged interest, and, if applicable, proceeded with the study tasks. If patients were not interested in the study, the researcher thanked them for their time, and they were not entered into the pilot study.

Procedure

The Assuage app was pre-installed onto an iPad for participants to use. Following the completion of the informed consent, the procedure went as follows; the researcher asked patients the following demographic questions: age range, gender identity, ethnicity and race, education, residence, familiarity with the NCCN DT paper form, mobile application use frequency, and mobile applications for health and medical use frequency. The researcher then introduced the application to the patient, which re-iterated consent via an in-app onboarding process and study information and re-verified that the patient was still interested in participating.

Participants were presented with a randomly selected UI and instructed to follow the app prompts to complete the distress assessment. Assuage was programmed to display one of the UIs randomly at the beginning of each session for this pilot study. Therefore, researchers did not have direct control over the number of participants assessing each UI. If a participant went through the assessment with a companion, the participant did all the physical interaction with the interface. It was appropriate for some patients (2/30) to enlist the help of their accompanying caregiver, as this mimics assistance needed naturally in the clinical or at-home setting.

While participants were completing the assessment in the app, the researcher observed and collected notes on any usability issues, software bugs, and other noteworthy information. After participants completed the NCCN DT in Assuage, a researcher went through the SUS. Once the SUS questionnaire was completed, participants were asked to submit additional comments regarding the study and their use of Assuage. The researcher also inquired about each participant’s specific set of mobile devices. No identifiable participant information was collected through the Assuage app. No video or audio recordings took place. Notes about the participants' actions, usability issues, and responses were also collected, and usability issues were organized into related themes.

Data Analysis

The SUS scores from participants (N=30) were grouped by the respective user interfaces tested by the participants, and results were analyzed using the SciPy Python3 package in iPython Notebooks [84]. A one-way ANOVA was performed to compare the effect of the different UIs on usability, represented by the SUS score. Lewis and Sauro assessed data from 241 usability studies to create a curved grading scale where the SUS score of 68 is a “C” grade and considered acceptable usability [64]. However, industry targets an SUS score of 80 to represent an above-average user experience [17, 62, 94]. We used a content analysis approach to analyze qualitative data such as observed usability issues and participant comments. Content analysis is a method used to systematically classify data, usually written, into segments with codes (labels) to make inferences about the content and underlying themes [85]. Data was coded using Taguette [86].

Results

This section presents the findings of this pilot study regarding the 4 UIs. Descriptive statistics are reported (Table 1). Thirty (N=30) usability surveys were completed across Assuage's 4 UIs. This study was not designed or powered to detect the differences between the UIs; therefore, the comparative results reported should be considered preliminary evidence [28].

Participant Demographics

The demographics of participants are summarized in Table 1. The majority of participants were older than 50 years old (24/30, 80%), had up to a high school education (19/30, 63%), lived in a rural area (25/30, 83%), and were unfamiliar with mHealth apps (21/30, 70%). Participant gender and general mobile app use were split with slightly more females (16/30, 53%) and users of mobile apps with a frequency of at least sometimes or more (17/30, 57%). About half the participants (16/30, 53%) used Assuage in light mode, and the rest (14/30, 47%) used Assuage in dark mode.

*Table 1. Participant demographics. *Percentages may not total 100 due to rounding.*

Variable		UI 1 n=6	UI 2 n=8	UI 3 n=7	UI 4 n=9	Total N=30
Gender, n (%)						
	Female	3 (50)	4 (50)	3 (43)	6 (67)	16 (53)
	Male	3 (50)	4 (50)	4 (57)	3 (33)	14 (47)
Age, n (%)						
	> 50	5 (83)	6 (75)	7 (100)	9 (100)	24 (80)
	< 50	1 (17)	2 (25)	-	3 (33)	6 (20)
Race & Ethnicity, n (%)						
	Non-Hispanic White	5 (83)	6 (75)	7 (100)	9 (100)	27 (90)
	Non-Hispanic Black	1 (17)	2 (25)	-	-	3 (10)
Education, n (%)						
	Did not complete high school	-	-	3 (43)	1 (11)	4 (13)
	High school	3 (50)	5 (63)	2 (29)	5 (56)	15 (50)
	Some College	1 (17)	2 (25)	1 (14)	2 (22)	6 (20)
	College Degree	2 (33)	1 (13)	1 (14)	1 (11)	5 (17)
Mobile Apps, n (%)						
	Never/Rarely	3 (50)	3 (38)	4 (57)	3 (33)	13 (43)
	Sometimes or more	3 (50)	5 (63)	3 (43)	6 (67)	17 (57)
Health Apps, n (%)						
	Familiar	2 (33)	3 (38)	1 (14)	3 (33)	9 (30)
	Unfamiliar	4 (67)	5 (63)	6 (86)	6 (67)	21 (70)

Residence, n (%)						
	Rural	4 (67)	6 (75)	7 (100)	8 (89)	25 (83)
	Urban	2 (33)	2 (25)	-	1 (11)	5 (17)
NCCN DT, n (%)						
	Yes	2 (33)	2 (25)	2 (29)	3 (33)	9 (30)
	No/Unsure	3 (50)	3 (38)	5 (71)	6 (67)	17 (57)
	N/A	1 (17)	3 (38)	-	-	4 (13)
Display mode, n (%)						
	Light	2 (33)	3 (38)	4 (57)	7 (78)	16 (53)
	Dark	4 (67)	5 (63)	3 (43)	2 (22)	14 (47)
Mobile, n (%)						
	No mobile device	3 (50)	4 (50)	5 (71)	6 (67)	18 (60)
	Basic Phone	-	-	-	1 (11)	1 (3)
	Android	2 (33)	2 (25)	-	-	4 (13)
	Apple	1 (17)	2 (25)	2 (29)	2 (22)	7 (23)

System Usability Scores

The mean SUS score across the UIs was 75.8 (SD 22.2). Participants were randomly distributed across the 4 UIs. Among them, 20% (6/30) assessed UI 1 with a mean SUS score of 70.4 (SD 25.3), 27% (8/30) assessed UI 2 with a mean SUS score of 67.2 (SD 31.2), 23% (7/30) assessed UI 3 with a mean SUS score of 80.0 (SD 14.1), and 30% (9/30) assessed UI 4 with a mean SUS score of 80.3 (SD 16.1). The SUS scores for each UI are reported in Table 2. Figure 7 shows the distribution of SUS scores for the different UI groups in relation to different target SUS scores. The dashed-line represents an acceptable usability rating of 68 or above [87]. The dash-dotted line represents the industry target score 80 to determine good usability [87]. Of the 4 UIs, 3 (UI 1, UI 3, UI 4) had an average SUS score above the acceptable threshold of at least 68, and 2 (UI 3, UI 4) met the industry threshold of at least 80. The average SUS score of UI 2 was just below what can be considered acceptable usability by 0.8 points. A one-way ANOVA was done to compare the effect of the UIs on the SUS scores. However, the results were not statistically significant ($F_{3,26}$ = 0.68, P=0.57). Figures 8-10 depict the SUS scores across the UIs grouped by participant age, mobile use, and light-mode versus dark-mode. The averages of these groupings are shown in Table 3. The average score for each item on the SUS (Multimedia Appendix 1) is also reported in Table 4. Of the participants who rated the UIs in Assuage as having less-than-acceptable usability, all were over 50 and unfamiliar with health applications (10/30); and (2/30) did not regularly use mobile apps.

Figure 7. Boxplots depicting the distribution of SUS scores grouped by user interface.

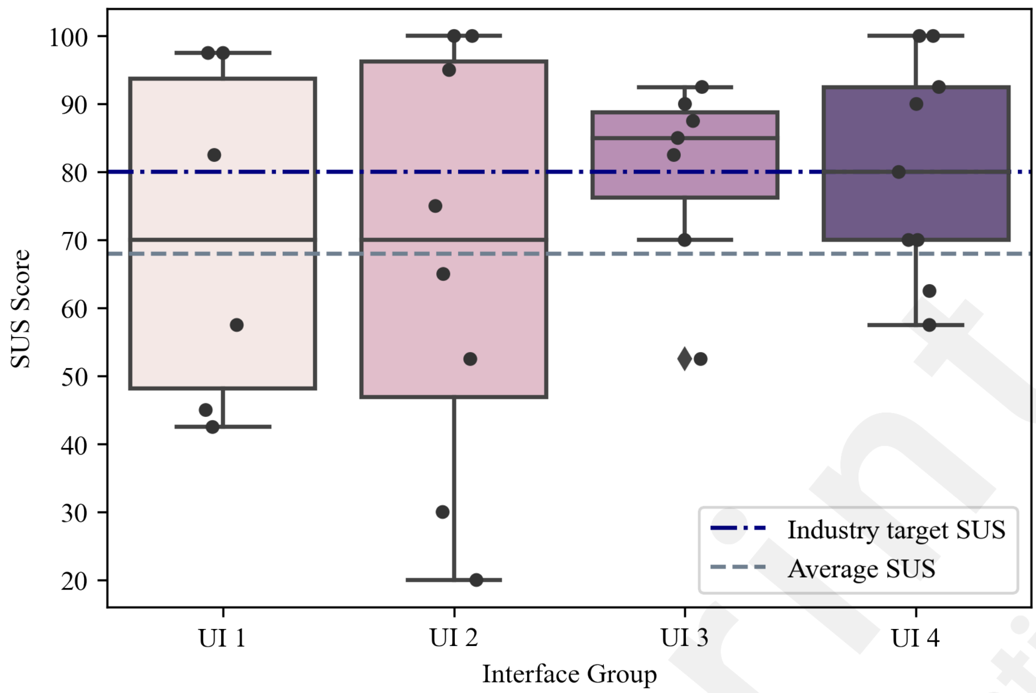


Table 2. An overview of the usability for each UI group is presented. Number of participants per group, the mean and median SUS scores per group, how many participants rated a UI with a less than acceptable usability score, and how many usability issues occurred with each UI group.

Interface	**Users**, n	**SUS score**, mean (SD)	**SUS score**, median (IQR)	**Unacceptable usability**, n (%)	**Usability issues**, n
UI 1	6	70.4 (25.3)	70.0 (48.1-93.8)	3 (50)	1
UI 2	8	67.2 (31.2)	70.0 (46.9-96.3)	4 (50)	11
UI 3	7	80.0 (14.1)	85.0 (76.3-88.8)	1 (14)	14
UI 4	9	80.3 (16.1)	80.0 (70.0-92.5)	2 (22)	10
Total	30	74.8 (22.2)	81.3 (58.8-92.5)	10 (33)	36

Figure 8. Boxplots depicting the distribution of SUS scores grouped by interface and mobile app use.

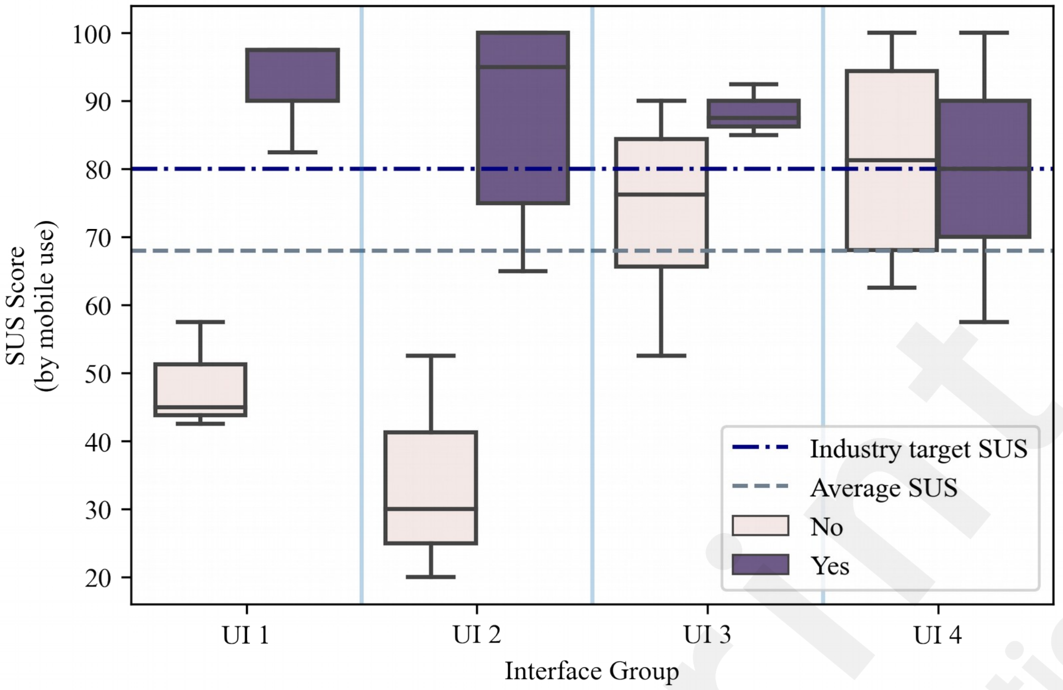


Figure 9. Boxplots depicting the distribution of SUS scores grouped by interface and age.

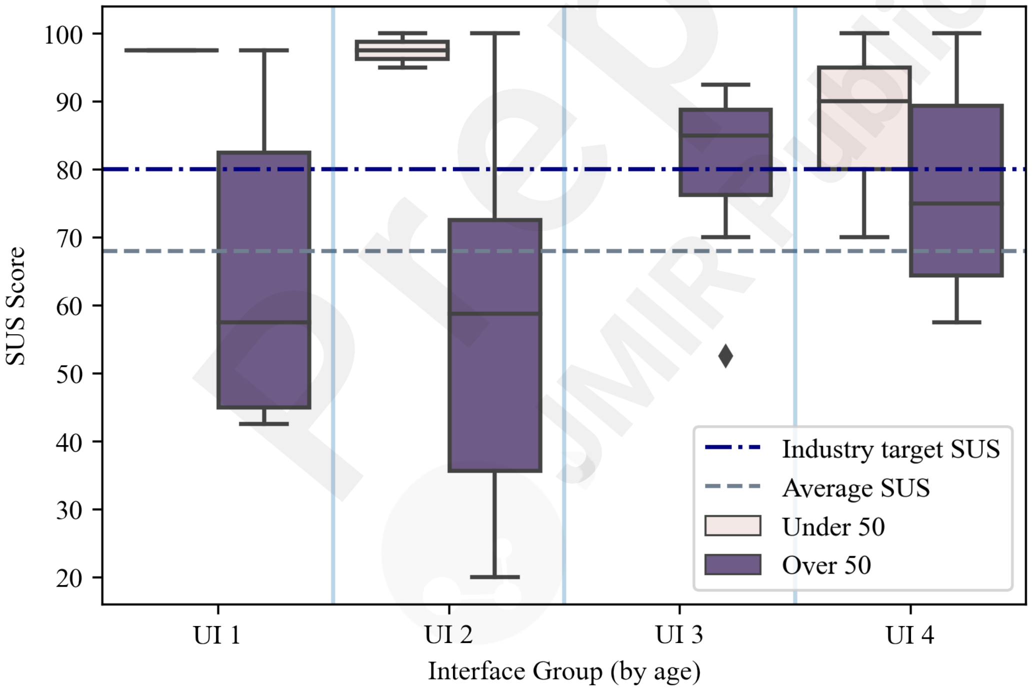


Figure 10. Boxplots depicting the distribution of SUS scores grouped by interface and display mode.

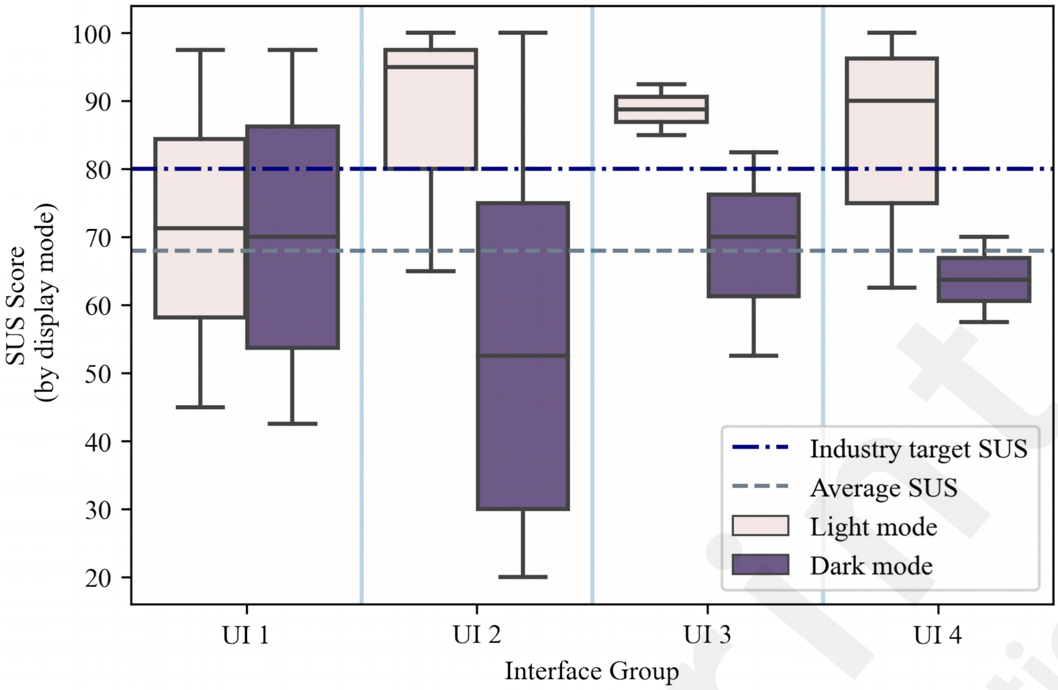


Table 3. Average SUS scores for each UI grouped by age, mobile app use, and display mode.

Variable		**User Interface**									
		UI 1	n	UI 2	n	UI 3	n	UI 4	n	Total	n
Age, mean (SD)											
	< 50	98	1	98 (4)	2	-	0	87 (15)	3	92 (11)	6
	> 50	65 (24)	5	57 (30)	6	80 (14)	7	77 (17)	6	70 (22)	24
Mobile App Use, mean (SD)											
	No	48 (8)	3	34 (17)	3	74 (16)	4	81 (18)	4	62 (24)	14
	Yes	93 (9)	3	87 (16)	5	88 (4)	3	80 (17)	5	86 (13)	16
Display Mode, mean (SD)											
	Light	71 (37)	2	87 (19)	3	89 (3)	4	85 (15)	7	85 (16)	16
	Dark	70 (25)	4	56 (33)	5	68 (15)	3	64 (9)	2	64 (24)	14

Table 4. Average scores for each item on the System Usability Scale for the different UIs.

SUS Item Number	**UI 1**, mean (SD)	**UI 2,** mean (SD)	**UI 3,** mean (SD)	**UI 4,** mean (SD)
1	2.7 (1.2)	3.0 (1.6)	3.1 (1.1)	3.1 (1.5)
2	1.7 (1.2)	2.0 (1.5)	1.7 (1.5)	1.6 (0.7)
3	4.2 (1.0)	3.9 (1.5)	4.4 (1.5)	4.4 (0.9)
4	2.3 (2.1)	3.0 (1.8)	1.7 (1.5)	2.0 (1.6)
5	4.3 (0.8)	4.1 (1.1)	4.7 (0.5)	3.8 (1.4)
6	1.7 (1.0)	2.1 (1.6)	1.4 (0.8)	1.6 (0.9)
7	4.2 (1.2)	4.4 (1.4)	4.9 (0.4)	4.0 (1.4)
8	2.0 (1.3)	2.3 (1.8)	2.1 (1.7)	1.3 (0.7)

9	3.3 (2.0)	3.8 (1.6)	4.0 (1.5)	4.6 (0.9)
10	2.8 (1.8)	2.9 (2.0)	2.1 (1.6)	1.4 (0.7)

Usability Issues

Although all UIs were considered usable for patients, there were quite a few usability issues that could correlate with users' lack of digital literacy. About half of the participants (16/30, 53%) encountered usability issues when using Assuage. Most participants who experienced issues were over 50 years old (13/16) and did not regularly use mobile apps (12/16). A total of 16 usability problems were identified during the study. The usability issues experienced were divided into the following themes: data input and collection (15 issues), navigation (12 issues), instructions (3 issues), NCCN (4 issues), and color and interaction (2 issues). Table 5 presents the usability issues and the frequency of occurrence. Data input and collection are issues that could affect the user's accuracy and input of distress data. Navigation issues related to how the user navigates the assessments within the app. Instructions are issues where clearer instruction is needed. NCCN are issues related to the NCCN questionnaire. Color and interaction are usability issues that did not fit well in the previous themes.

Table 5. Usability issues experienced by users and frequency of occurrence.

Theme (n)	Usability Issues (n)
Data input and collection (15)	
	Unclear how to answer distress scale (7)
	Unclear how to indicate no to a specific symptom (3)
	Unclear what to do when no symptoms (2)
	Unsure if assessment was done and submitted (3)
Navigation (12)	
	Confusion when needing to vertical scroll (4)
	Uncertainty on how to start assessment (1)
	Unclear how to skip sections (3)
	Unsure how to continue to next part of assessment (2)
	Accidental navigation to other parts of app (1)
	Tapping on wrong button to complete surveys (1)
Instructions (3)	
	In-app instructions not clear (2)
	Review page unclear (1)
NCCN (4)	
	Question wording confusing (3)
	Too many questions (1)
Color and Interaction (2)	
	Confusion when log button changed colors (1)
	Hard to take a pic of paper form (1)

Participant Feedback

Patients had mixed perceptions of the different UIs learnability and usefulness. Positive responses from the participants described the UIs as: easy, simple, intuitive, helpful, and good. Negative responses can be summarized as: difficult, non-intuitive, inconsistent, and not for everyone. Regarding overall willingness to use an app for self-reporting symptoms, (2/30) explicitly said they would want to use a symptom-reporting app more frequently (separate from the SUS item 1 which states "*I think that I would be willing to use this system frequently*"). Participants also expressed that if a doctor told them to use the app, they would. Table 6 presents selected participants' comments after using Assuage.

Desired features and improvements for reporting distress symptoms in a mHealth platform included distress data being sent directly to the doctor, flagging the medical team if a patient reports high distress, prompts following completion of the distress assessment that can direct patients on who to contact depending on symptoms reported, proper feedback letting the patient know that their answers have been recorded, and an option to answer "none" if the patient has no symptoms instead of choosing to skip the question set.

Table 6. Selected participant comments following usability testing. Demographic data of the participants and the UI they used is included.

Sentiment	Comments (Demographics)	UI
Positive	"Someone like me, if they know just a little stuff, then they'd be able to use it." (Over 50, High school education, Does not use mobile apps)	UI 4
Mixed	It was not easy for this participant, but they did not feel it would be hard for others to learn. (Over 50, High school education, Does not use mobile apps)	UI 2
Negative	"Just doesn't pertain to everybody." (Over 50, High school education, Does not use mobile apps)	UI 2
	"Not a lot of people computer savvy." (Over 50, High school education, Uses mobile apps)	UI 4
	"Would be difficult to older people." (Over 50, Some college, Uses mobile apps)	UI 2

Discussion

Principal Findings

This study assessed if state-of-the-art mobile app interface designs from Apple's open-source ResearchKit and CareKit libraries would be usable for cancer patients from rural areas. We leveraged the UI elements from Apple's ResearchKit and CareKit frameworks to implement four (4) different UI designs for patients to complete a distress assessment with the Assuage platform. The UIs varied by how the assessment questions were presented and navigated. This pilot study found that a survey-based app developed with Apple's open-source libraries have a usable interface for cancer patients within our target demographic.

Additionally, we evaluated if co-designing the interfaces with intended users was necessary to achieve acceptable usability. Predictably, participants who were older than 50 and did not use mobile devices regularly experienced the most usability issues. The most prominent usability issues were related to data input and navigation, with 15 and 12 occurrences, respectively. The most critical usability issues were participants needing to learn how to answer the distress scale and the UI assuming a participant knows when to vertically scroll. Not only did these two issues have the highest count of participants who experienced them, 23% (7/30) and 13% (4/30), respectively, but not addressing them can hinder participant completion of the survey, accurate reporting of symptoms and distress, and motivation to use the system.

Finally, we wanted to understand what features caused a specific UI to have a higher usability rating than the others as a base to move forward for future research studies with our target demographic. Our findings show that most participants (20/30, 67%) rated the UIs as having acceptable and above-average usability across the different interfaces, with UI 3 and UI 4 averaging around 10 points higher than UI 1 and UI 2 using the SUS. UI 3 and UI 4 also met the industry threshold for good usability with average SUS scores of at least 80. Despite navigation and input challenges, participants could still complete the in-app survey and expressed the willingness to use an mHealth system for self-reporting symptoms. Unsurprisingly, participants were more concerned about what happened after reporting symptoms, such as: whether the doctor would be notified, or if the participant would receive feedback on how to continue based on the reported symptoms.

When considering a user's comfort of use regarding the technology, many researchers may assume that users who do not extensively use mobile apps will rate the usability of the UIs significantly lower than someone with a higher frequency of mobile app usage. Though our findings depict differences in scores between participant groups, they are not as significant. For example, UI 3 had a difference of ~19% and UI 4 had a difference of ~1.3% when comparing mobile app users to non-users (Table 3). Similarly, when looking at participants over the age of 50, UI 3 and UI 4 have a smaller variance in usability score, and UI 3 had the tightest distribution with only one (1) user rating below acceptable usability. Another interesting finding was the difference in usability scores between interfaces in dark mode and light mode. Aside from UI 1, the UIs in dark mode received significantly lower average usability scores, about 20-30 points, when compared to light mode.

Comparison with Prior Work

Prior work suggests that mHealth systems require co-design with target users for optimal outcomes and usability [5,6,28]. Authors in [28] used participatory design to recreate an alternative design to the NCCN DT. Digital and paper prototypes of the redesigned survey were compared to the original using the SUS, resulting in patients finding the digital prototypes more usable than their paper counterparts. The usability of Assuage's UIs were comparable to the co-designed prototypes without undergoing the resource-intensive process. Similarly, our usability results were comparable to other mHealth studies using the SUS to assess iterative designs [18,88–90].

While the usability issues encountered by participants could be attributed to digital literacy, developers can take extra steps to ensure universal design when using development frameworks. Formatting a survey for web and mobile delivery has been evaluated, but has had conflicting results [34,37,91,92]. For example, usability heuristics say that vertical and horizontal scrolling should be avoided when possible. Apple's Human Interface Guidelines offer suggestions regarding best practices for scroll views, such as scroll indicators, which double as a way to show how much of the screen to progress [78]. Designing using paging instead of scrolling formats surveys in a clean and easy-to-read manner. Minimizing scrolling prevents users from possibly missing questions or important interface elements, such as navigation buttons. Alternatively, studies have also found that scrolling layouts resulted in higher perceived usability and faster survey completion times [34,91]. Our usability results were slightly better with a paging design (UI 2 versus UI 3, with an average usability score of 67.2 (SD 31.2) and 80.0 (14.1), respectively). UI 4 used Apple's CareKit UI (a modular design combined with vertical scrolling) and received good usability scores (80.3 (SD16.1)), contradicting some of the aforementioned best practices found in the literature. Notably, the modularized surveys display similar to paging designs. In addition, is interesting to note that the two UIs that provided more freedom in navigating the survey were the most highly rated. Reflecting on Nielsen's usability heuristics from Figure 1, the navigation schemes implemented in UI 3 and UI

4 were the only interfaces that satisfied Nielsen’s heuristic, (#7) flexibility and efficiency of use. Considering the visual similarities between UI 2 and UI 3, we can infer that the flexible navigation, coupled with grouping questions on different pages, significantly improved usability scores.

Prior work suggests respondents should be offered a “none” option or similar when presented with a list of other choices [36]. However, the placement of that option influences whether participants choose it. Placing an option, like “none,” when other choices do not apply at the top of the page results in more respondents choosing it compared to when placed at the bottom of the survey [92], which can be important to consider for the thoroughness of data. In our case, we did not require participants to input an answer in every section and included a "skip" option at the bottom of the page, separate from the possible symptom choices. Even so, some participants would have preferred an actual answer choice instead of skipping the page, as it made them feel like they were not fully completing the assessment. At times, the “skip” button did not stand out to participants as a tappable button compared to the “next” button, which had a visible background (ex. Figure 5, steps 2-3).

Participants encountered the most problems with the distress scale. The use of rating scales in surveys is fairly common [31,93]; however, for some participants, it was not intuitive to slide or tap to interact with the distress scale. All but one of the participants who experienced this problem (6/7) did not regularly use mobile apps. We attempted to keep the question format as similar to the original NCCN DT as possible; however, an alternative format to a rating scale could be a number picker or text entry with specific number values. Similar to the symptoms, a list view could also be considered, although potentially less efficient if all numbers do not fit on the device screen. Alternatively, gestural signifiers can be used to demonstrate how to complete tasks. The findings of this usability study support prior research on electronic survey design, particularly with aging users, such as those older than 50, which should be considered when using frameworks that provide pre-determined UI features. It should be noted that although important, prior work suggests that question-wording does not affect usability as much as the layout [92].

Regarding the use of dark-mode versus light-mode in UI designs, studies have investigated how the trend of dark-mode, or negative polarity, interfaces impact users [94–97]. A recent study found that light-mode interfaces are more advantageous to young and older users concerning cognitive load [95]. Considering most of our participants were over 50, this could give insight into the drastic difference in usability scores between those who used Assuage in light-mode and those in dark-mode. Similarly, many cancer patients and survivors experience cognitive effects due to cancer and its treatment [27]. Therefore, while developers of mHealth systems can implement a dark-mode interface, attention must be given to ensuring the different UI elements are not adding unnecessary mental effort for users [96]. However, based on these preliminary results, not implementing dark-mode should not have an adverse effect on our demographic of cancer patients who are older than 50 and rural.

Limitations and Future Work

A sample size of thirty (30) is typically considered small; however, previous research on system usability studies implies that small sample sizes, ∼5, can capture most usability issues [68,69]. This study was also interrupted due to a spike in COVID-19 cases, which resulted in the hospital halting all non-essential and non-medical activities, limiting our sample size. We attempted to use additional techniques during usability testing, such as a think-aloud approach; however, as patient participants were being seen between appointments, brain fog from chemo treatments resulted in frustration from participants with this approach. Excluding cognitive impairment due to cancer-related treatments, the normal aging process can also cause a decline in cognitive function for older people in similar studies. Likewise, with respect to participant time, the study survey was kept as short as possible. This further supported our choice to use the SUS versus a more in-depth questionnaire, such as the Mobile Application Rating Scale (MARS) [98], the Health Information Technology Usability Evaluation Scale (Health-ITUE) [99], or the mHealth App Usability Questionnaire (MAUQ) [100]. Finally, we invited healthcare professionals to assess Assuage; however, only 1 responded, and we did not include their SUS score in this paper.

Despite limitations, we identified areas of improvement for the interface design of survey-based mobile apps. We also determined which UIs in Assuage would be suitable for future deployment studies with our target demographic of cancer patients who are rural, older than 50, and may not regularly use mobile apps. Not all participants owned mobile devices, posing a potential wide-scale implementation problem. While reports show smartphone use to be consistently rising among members of the rural United States, this may not be consistent across all rural areas. Conversely, participants without mobile devices usually had other family members with mobile devices and smartphones. Most participants expressed a willingness to use an application to monitor their symptoms. However, deploying the app among rural patients in the Southeastern and Appalachian regions is necessary to determine if apps are a viable solution for this demographic. In the future, we plan to conduct follow-up studies to assess adherence and reasons for engagement with Assuage to report distress symptoms of patients over time.

Conclusions

Digital implementations of validated paper-based surveys can have unexpected outcomes on the usability of the survey and an application. If a digital survey has low usability, patients could be deterred from entering information, or data could be unreliable, limiting the tool's effectiveness. This could also affect research findings from this method or how the clinic responds. The findings from this pilot study show that most cancer patients (20/30, 67%) who participated in this pilot usability study rated the different interfaces of Assuage as above average (68) [64]. This suggests that Apple's health and research frameworks provide usable UIs with minimal alterations to the default interface for users older than 50 and with limited digital literacy. The usability issues observed align with common usability problems for designing surveys. ResearchKit and CareKit can be used to reliably design a mobile app for collecting survey-based data. However, heuristics for both usability and electronic survey design should be considered when deciding how to best segment and navigate surveys and how to present important interface elements.

The main difference between the UIs was how users could navigate between the different survey sections. The interfaces that satisfied Nielsen's heuristic, (#7) flexibility and efficiency of use, allowed users to freely jump between survey sections non-sequentially and achieved the highest usability scores. Therefore, it can be inferred that flexible question navigation is a feature that should not be overlooked when digitizing surveys. Other ways to increase the usability of interface designs for self-reporting outcomes by patients who do not frequently use mobile apps include gestural signifiers, visual cues when scrolling is available, such as scroll indicators, minimizing scrolling per page, and dedicated answer choice when none apply.

Findings from this paper do not aim to undermine the importance or benefits of co-design or participatory design for underserved and understudied populations but to demonstrate the possibility for successful digital implementations when resources cannot be heavily allocated to the design process. Although the UIs in the Assuage app had overall good usability, if resources and time permit, involving end-users in the design process can improve the overall usability of the final product. However, for survey-based mHealth iOS apps, ResearchKit and CareKit are legitimate options for developers and researchers seeking open-source libraries with suitable interface designs to use with similar populations to this study. Participatory design is still suggested to understand key features to support users unfamiliar with smart devices and touch interfaces when assistance is not readily available. A follow-up longitudinal study deploying Assuage with end users is currently underway.

Conflicts of Interest

None declared.

Abbreviations

DT: distress thermometer
mHealth: mobile health
NetRecon: Network Reconnaissance lab
NCCN: National Comprehensive Cancer Network
SUS: System Usability Scale
UI: user interface

Multimedia Appendix 1

SUS questions

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Supplementary Files

Multimedia Appendixes

The System Usability Scale (SUS).
URL: http://asset.jmir.pub/assets/045bbaecc3f7749448881fb2e1df240a.png