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App Designs and Interactive Features to Increase mHealth Adoption: User Expectation Survey and Experiment

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Abstract

Background: Despite the ubiquity of smartphones, there is little guidance for how to design mobile health apps to increase use. Specifically, knowing what features users expect, grab their attention, encourage use (via predicted use or through positive app evaluations), and signal beneficial action possibilities can guide and focus app development efforts.

Objective: We investigated what features users expect and how the design (prototypicality) impacts app adoption.

Methods: In a web-based survey, we elicited expectations, including presence and placement, for 12 app features. Thereafter, participants (n=462) viewed 2 health apps (high prototypicality similar to top downloaded apps vs low prototypicality similar to research interventions) and reported willingness to download, attention, and predicted use of app features. Participants rated both apps (high and low) for aesthetics, ease of use, usefulness, perceived affordances, and intentions to use.

Results: Most participants (425/462, 92%) expected features for navigation or personal settings (eg, menu) in specific regions (eg, top corners). Features with summary graphs or statics were also expected by many (395-396 of 462, 86%), with a center placement expectation. A feature to “share with friends” was least expected among participants (203/462, 44%). Features fell into 4 unique categories based on attention and predicted use, including essential features with high (>50% or >231 of 462) predicted use and attention (eg, calorie trackers), flashy features with high attention but lower predicted use (eg, links to specific diets), functional features with modest attention and low use (eg, settings), and mundane features with low attention and use (eg, discover tabs). When given a choice, 347 of 462 (75%) participants would download the high-prototypicality app. High prototypicality apps (vs low) led to greater aesthetics, ease of use, usefulness, and intentions, (for all, \( P<.001 \)). Participants thought that high prototypicality apps had more perceived affordances.

Conclusions: Intervention designs that fail to meet a threshold of mHealth expectations will be dismissed as less usable or beneficial. Individuals who download health apps have shared expectations for features that should be there, as well as where these features should appear. Meeting these expectations can improve app evaluations and encourage use. Our typology should guide presence and placement of expected app features to signal value and increase use to impact preventive health behaviors. Features that will likely be used and are attention-worthy—essential, flashy, and functional—should be prioritized during app development.

(JMIR Mhealth Uhealth 2021;9(11):e29815) doi:10.2196/29815

KEYWORDS

smartphone; interactive design; mobile apps; preventive health; mental models; prototypicality; attention; affordances
**Introduction**

**Background**

With the rapid increase in the use of mobile technologies and smartphones for health information [1,2], mobile apps present one possible solution for communicating preventive health information to the public [3-5]. Over the past decade, hundreds of health mobile apps have been produced—many designed by public health interventionists and researchers for cancer and other chronic disease prevention by encouraging healthy eating and physical activity [6-8]. While it remains unclear how successful these apps have been in reducing the incidence of cancer or improving health outcomes for other chronic diseases, there is a call for an increase in the accountability, reliability, and standardizations of evidence-based health apps developed by the research community [8-10].

Despite the potential of mobile health (mHealth) apps for communicating up-to-date, evidence-based prevention information and helping users maintain or implement healthy habits, there is very little guidance on how these intervention apps should be designed to ensure adoption [11]. Designing apps so they are appealing and used is a critical first step for apps to have an impact [12]. Visual and interactive design influences initial user evaluations, which are made within milliseconds, and serve as gateways for subsequent user engagement (eg, use) of apps as mHealth interventions [13-15]. Ignoring design can detrimentally impact the communication of evidence-based science to health consumers and undercut the effectiveness of mHealth interventions; yet, few mHealth interventions mirror the look and function of popular, industry-developed apps. Thus, our study objective was to explore app features expectations and examine how meeting expectations with high- (vs low-) prototypicality apps may influence predictors of app adoption.

How apps are designed (visual display) and the features they include (interactivity) can influence users’ experience of and willingness to engage with apps. Individuals use salient cues that match their expectations, or mental models, to evaluate web-based information [16,17]. These expectations are met (or not) by the level of prototypicality or the degree to which an app resembles others in its comparative group [17,18]. Based on included design cues, in the form of interactive features, apps can range from having high prototypicality (looks like others and meets expectations well) to low prototypicality (does not resemble others nor meet expectations) [19]. Users are often quicker and more willing to attend to apps that have high prototypicality—when designs align with one’s mental models for how an app should look and function [19-21]. Indeed, users look for and pay attention to expected, salient features as guides to orient themselves to novel apps and platforms [21]. When these expected features are present, they increase familiarity and potential use of the app [19-21]; however, little is known on how attention for specific features translates into individual feature use versus overall app use.

The perceived affordances, or perceived action possibilities (eg, learn health tips), that users sense from app features also directly impact a user’s experience and likelihood to engage with a design [22-24]. Specifically for mediated communication, including apps, design communicates what the viewer can do or gain from the use of an app, through interface symbols. Thus, not only must mHealth interventions have evidence-based content to drive use, but also apps must incorporate an evidence-based design to appeal to and engage audiences.

Design features influence the appeal or perceived aesthetics of the app and the likelihood for use [25,26]. To be effective, health apps must surely be used. It is necessary to understand how objective design features (the visible objects or designs in an app) influence subjective evaluations for initial appeal on the basis of theories of aesthetics [27-29] and antecedents for technology adoption in the Technology Acceptance Model (TAM); that is, perceived ease of use, perceived usefulness, and intentions to use [30,31]. Aesthetics, including facets for how information is organized and displayed, function as a precursor to perceptions for technology acceptance [28,31]. Accounting for users’ expectations of features and placements within apps will shed light on how prototypicality impacts evaluations critical for future adoption.

Utility also drives evaluation of an app’s usefulness and potential adoption, according to Nielsen et al’s [32] well-established usability study. Utility refers to the inclusion of necessary features—whether an app provides the elements an individual needs or wants. When utility is paired with usability—when features are perceived as easy (perceived ease of use) and pleasant (aesthetics) to use—individuals are encouraged to engage or interact. In other words, interactivity is dependent on a user’s willingness to engage with specific design features, if present (utility) and function properly (usability). In our work, we focus on the former—how app features that are needed (utility) or expected (prototypical) are the gateway to potential adoption.

**Goal of This Study**

In sum, engagement with and use of an app is driven by initial impressions and perceptions of what the app can do for the user. Top-rated industry-developed apps often incorporate a user-focused sleekness and are feature loaded; in comparison, pared-down mHealth interventions—despite the inclusion of theory-based content—may not appeal to audiences who need them [33]. When resources are not abundant, health researchers and interventionists need evidence-based guidance for design investments. Thus, we explored app expectations for the presence and placement of potential features, how these features garner attention and predict use, and how high-prototypicality apps (vs low-prototypicality apps) may influence app adoption through app choice and predictors of use. We asked the following research questions: What features do people expect and where do they expect these features to be placed (RQ1)? What specific features are associated with attention and predicted use of the app features (RQ2)? Last, we also examined whether high prototypicality, resembling that of top downloaded apps (vs low-prototypicality apps, resembling research intervention apps) would increase app choice (H1), aesthetics (H2), perceived ease of use (H3), perceived usefulness (H4), intentions to use the app (H5), and perceived affordances or action possibilities with the app (H6).
Methods

Overview

To explore app features expectations and examine how meeting expectations with high-prototypicality apps (vs low-prototypicality apps) may influence predictors of app adoption, we conducted a web-based survey with an embedded within-subjects experiment. Participants first responded to survey items about expectations for specific app features to answer RQ1-2 and an app choice (preview of apps with high vs low prototypicality) to address H1. Participants were then asked to rate their perceptions of the app overall, with the exposure order of condition (high vs low) randomized, to address H2-6.

Participant Recruitment

Using G*Power, our a priori power analysis indicated a required sample of at least 450 participants to detect a small-to-medium effect (Cohen $f=0.14$) for within-subjects comparison of the high and low prototypicality apps. Participants (n=462) were recruited from Amazon’s Mechanical Turk (MTurk), a web-based crowdsourcing platform often used for social science research [34-36], through a link open to individuals over the age of 18 years. Participants were eligible if they were aged 18 years or older, resided in the United States, and had a task approval rate of 85% or higher on the MTurk platform, which indicates valid participation or completion of previous tasks. Participants received US $3 as compensation for their time (approximately 15 minutes). The institutional review board of University of North Carolina approved this study.

Procedure

Following consent, participants selected features (from a list) they would expect to find in a health app. For all expected features, participants were shown an outline of a smartphone and asked where that feature would be located in a typical health app. Participants were then randomly assigned to 1 of the 2 app types for the remainder of the study: fitness apps or nutrition apps. Participants selected the app they would most like to download from 2 previews (prototypical: high vs low). On subsequent pages, participants indicated what features grabbed their attention and what features they predicted they would use (predicted use) on their preferred app. Participants were shown the app previews again (one at a time, in a random order) and asked closed-ended items for perceived aesthetics, ease of use, usefulness, intentions to use the app in the future, and perceived affordances. Lastly, demographic, health, and health app information were collected from all participants. Closed-ended items and response options are described below (see Measures) and provided in Multimedia Appendix 1.

App Stimuli

To assess the impact of prototypicality on app perceptions, app previews were created for four fictitious brands: 2 fitness and 2 nutrition health apps (Figure 1). We designed previews for each app as they would appear if searched for in a mobile app store, including the app icon, brand name, and 2 preview screens of the app. High-prototypicality apps were developed on the basis of structure and content from top rated apps (Aaptiv, Lifesum) in the Health & Fitness section of the App Store. Low-prototypicality apps were designed to mirror the mobile interface of an interactive intervention (Carolina Health Assessment and Research Tool) for data collection and tailored feedback for preventive health behaviors [37].
Measures

Feature Selection and Placement
Participants selected features from a list they “would expect to find in a health app.” The list was generated from structured interviews about fitness tracker apps [38] and included 12 features: menu, search option, settings option, logo, log/input data option, share with friend option, summary statistics, summary graph/chart, calendar, page title, login, and user profile. For each expected (ie, selected) feature, respondents were shown a smartphone screen divided into a grid of 60 distinct clickable hot spot regions. Respondents selected as many regions of each screen as necessary for expected placement.

App Choice
Participants were instructed to “select the app you would most likely download.” The 2 response options were the low
prototypical app and the high prototypical app, for their randomly assigned app type (physical activity or nutrition).

**Feature Attention and Predicted Use**

To identify features that attracted participants’ attention and predicted use, participants were shown the app preview they selected during app choice. Participants were asked, “What elements in the app caught your attention?” and instructed to “select all elements that grabbed your attention within the app preview.” On the following page of the questionnaire the app preview was shown again; participants were asked, “What elements in the app do you think you would use?” and selected the elements in the preview. As performed in previous studies [39,40], a priori hot spots were constructed around each app feature (Multimedia Appendix 1). Hot spots were not visible until participants selected the feature and then the feature was highlighted.

**Perceived Aesthetics**

The validated Visual Aesthetics of Website Inventory (VisAWI) assessed 4 facets of aesthetics with 18 items for simplicity, “The layout appears well structured”; diversity, “The layout appears dynamic”; colorfulness, “The colors are appealing”; and craftsmanship, “The app is designed with care” [28]. Response options ranged from “strongly disagree” (coded as 1) to “strongly agree” (5). Responses were averaged for each facet (α=.76-.90).

**Perceived Ease of Use**

Participants’ perceived ease of use, or belief that using the technology would not be difficult, were assessed with 3 adapted Likert-type items [30]: “The app was clear and understandable,” “Getting the app to function does not require much mental effort,” and “I find the app to be easy to use.” Response options ranged from “strongly disagree” (coded as 1) to “strongly agree” (5). Responses were averaged (α=.84-.87).

**Perceived Usefulness**

The degree to which one believes that the technology will enhance their life was assessed with 3 adapted Likert-type items [30]: “Using the app would improve my health,” “Using the app would make me more likely to meet my health goals,” and “I would find the app useful for achieving my health goals.” Response options ranged from “strongly disagree” (coded as 1) to “strongly agree” (5). Responses were averaged (α=.85-.88).

**Intentions to Use**

Intentions or plans to use the app “if the app were available” were assessed with 2 Likert-type items [30]. Participants rated their agreement to statements that they “intend” and “predict” they would use the app next month with response options that ranged from “strongly disagree” (coded as 1) to “strongly agree” (5). Responses were averaged (r=0.88-0.93).

**Perceived Affordances**

Participants reported perceived action possibilities from the app with the item, “This app would allow me to…” Response options included a list of 13 dichotomous items generated from evidence-based behavior change techniques and reasons for eHealth adoption, such as “set health goals,” “track my progress,” “earn rewards,” and “share my health data with friends” [41,42].

**Participant Characteristics**

Demographic items assessed age, gender, race, ethnicity, and education. Additionally, we asked about one’s health and mental health status with the item: “in general, would you say your [mental] health is…” Response options ranged from “very poor” (coded as 1) to “very good” (5). We also asked whether participants “use a health app” with a “yes”/“no” response option.

**Data Analyses**

We used n (%) values to describe app feature expectations, placement, app choices, attention, predicted use, and perceived affordances. Frequencies for attention vs predicted use and for perceived affordances of the high- vs low-prototypicality apps were compared with McNemar chi-square tests. Prior to this analysis for direct effects of prototypicality, a multivariate analysis of variance (MANOVA) was used to determine if there are any significant differences in perceptions among the app types (fitness and nutrition) across aesthetics and TAM outcomes. No differences were observed for high prototypicality (aesthetics outcomes: Wilks λ=.98; F[1,452]=1.08; P=.10; TAM outcomes: Wilks λ=.99; F[1,452]=1.08; P=.36) or low prototypicality (aesthetics outcomes: Wilks λ=.99; F[1,452]=0.68; P=.61; TAM outcomes: Wilks λ=.99; F[1,452]=0.10; P=.96), so data within conditions (high vs low prototypicality) were combined for analyses. Two repeated measure (RM) MANOVAs and analyses of variance (ANOVAs) were then conducted with high vs low prototypicality as the predictor; 1 for aesthetic outcomes (simplicity, diversity, colorfulness, and craftsmanship) and 1 for technology acceptance outcomes (perceived ease of use, usefulness, and intentions to use).

**Results**

**Participants**

Participants (n=462) were aged 18 to 70 years (mean age 35.03 years, SD 10.02 years) and half of them were female (50%, 232/462). Participants identified as White (78%, 358/462), African American (13%, 58/462), Asian (8%, 35/462), or multiracial/other; additionally, 48 of 462 participants (10%) reported their ethnicity as Hispanic. Education levels included high school to some college (33%, 135/462), associate degree (13%, 57/462), bachelor’s degree (43%, 197/462), master’s degree (10%, 46/462), and doctoral or professional degree (2%, 7/462). Most participants reported their health as good (48%, 220/462) or very good (17%, 78/462), although some did report that their health was fair (30%, 129/462), poor (4%, 20/462), or very poor (1%, 4/462). Over half of the participants (53%, 248/462) reported currently using health apps.

**App Feature Selection and Placement**

Each of the 12 features was selected by at least 44% (203/462) of participants (RQ1). The majority of participants (92%, 425/462) selected a menu, settings options, and user profile; notably, these features (ie, menu, settings option, and user profile) were selected an equal number of times but not by the...
same respondents. Additional features were expected, including the following: login (88%, 406/462), summary graph/chart (86%, 396/462), summary statistics (86%, 395/462), input data feature (80%, 368/462), calendar (77%, 354/462), logo (77%, 357/462), search (69%, 321/462), page title (62%, 286/462), and an option to “share with friends” (44%, 203/462).

Most features were expected in similar locations (Figure 2) among participants who had expected features (n=425). Menus were consistently expected to be in the top-left, while search and login options are placed in the top-right corner. Other features—title, logo, profile, and settings—were expected along the top, in the center, or either side. Sharing capability was expected to appear in the bottom-right of the app, although expectations of where to log input data were more diffuse. Users expect summary statistics, graphs, and calendars to be shown across the center of the app.

Figure 2. Expected app feature location (n=425).
Attention and Predicted Use of App Features

Respondents selected features of their preferred app, which caught their attention and they would use (Table 1 and Multimedia Appendix 1). Attention and predicted use patterns of the high-prototypicality apps indicate 4 distinct categories of mHealth app features. Mundane features are those that have similar low attention and predicted use values. In the fitness app, the footer menu options “Discover” and “Saved” represent mundane features. Functional features have higher predicted use than attention, but predicted use remains low (<50%, <231/462) among participants, such as the settings icon in both apps. Flashy features are elements identified as attention-capturing by most participants (>50%, >231/462), and attention is significantly higher than the predicted use. In the nutrition app, large photo-based links for the “Ketogenic Easy” and “Ketogenic Medium” diets represent flashy features. Essential features are elements that most participants (>50%, >231/462) thought they would use, and where predicted use is higher than or similar to attention, as with the “Calorie Tracker” in the nutrition app. Not included in these 4 categories are elements that have higher attention than predicted use, but the attention remains low (<50%, <231/462); the only features with these characteristics were logos and app titles, as well as 2 features partially obscured in the design.

Table 1. Reported attention and predicted use of app features (n=462).

<table>
<thead>
<tr>
<th>App</th>
<th>Feature</th>
<th>Attention, n (%)</th>
<th>Predicted use, n (%)</th>
<th>Chi-square (df)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mundane</td>
<td>Fitness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Footer menu option “Discover”</td>
<td>48 (29)</td>
<td>52 (32)</td>
<td>0.20 (1)</td>
<td>.66</td>
</tr>
<tr>
<td></td>
<td>Footer menu option “Saved”</td>
<td>41 (25)</td>
<td>42 (26)</td>
<td>0.00 (1)</td>
<td>&gt; .99</td>
</tr>
<tr>
<td></td>
<td>Footer menu option “Plus”</td>
<td>23 (13)</td>
<td>28 (15)</td>
<td>0.46 (1)</td>
<td>.50</td>
</tr>
<tr>
<td>Functional</td>
<td>Fitness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Footer menu option “Settings”</td>
<td>49 (30)</td>
<td>69 (42)</td>
<td>7.22 (1)</td>
<td>.007</td>
</tr>
<tr>
<td></td>
<td>Nutrition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Search Icon</td>
<td>21 (12)</td>
<td>38 (21)</td>
<td>5.95 (1)</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>Footer menu option “Profile”</td>
<td>25 (14)</td>
<td>58 (32)</td>
<td>19.32 (1)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Flashy</td>
<td>Fitness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Activity 1 “Outdoor Running”</td>
<td>109 (66)</td>
<td>63 (38)</td>
<td>32.66 (1)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td></td>
<td>Activity 2 “Treadmill”</td>
<td>104 (63)</td>
<td>53 (32)</td>
<td>38.46 (1)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td></td>
<td>Nutrition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ketogenic Easy feature</td>
<td>109 (60)</td>
<td>71 (39)</td>
<td>20.74 (1)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Essential</td>
<td>Fitness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Performance Tracker feature</td>
<td>142 (86)</td>
<td>157 (95)</td>
<td>N/A a</td>
<td>.003</td>
</tr>
<tr>
<td></td>
<td>Nutrition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Calorie Tracker feature</td>
<td>156 (86)</td>
<td>160 (88)</td>
<td>N/A</td>
<td>.54</td>
</tr>
<tr>
<td></td>
<td>Calendar feature</td>
<td>88 (48)</td>
<td>114 (63)</td>
<td>11.57 (1)</td>
<td>.001</td>
</tr>
</tbody>
</table>

aN/A: chi-square values are not applicable if fewer than 25 discordant pairs; binominal distributions are used for exact 2-tailed significance in these comparisons.

Effects of Prototypicality on App Choice, Aesthetics, and Technology Acceptance

When asked to choose between the high-prototypicality app and one designed to look more like a typical health intervention (low prototypicality), 347 of 462 (75%) participants indicated they would download the high-prototypicality app (H1). Prototypicality had a significant main effect on all facets of aesthetics and technology acceptance outcomes (Table 2). High-prototypicality apps (vs low-prototypicality apps) had significantly higher ratings of aesthetics for simplicity ($F_{1,455}=291$; $P<.001$), diversity ($F_{1,455}=578$; $P<.001$), colorfulness ($F_{1,455}=295$; $P<.001$), and craftsmanship ($F_{1,455}=462$; $P<.001$). Similarly, the high-prototypicality app was rated higher than the low prototypicality app for perceived ease of use ($F_{1,455}=84$; $P<.001$), usefulness ($F_{1,455}=116$; $P<.001$), and intentions to use the app ($F_{1,455}=170$; $P<.001$). H2-5 were supported.
Table 2. Main effects of prototypicality on aesthetics and technology acceptance (n=456).

<table>
<thead>
<tr>
<th>Attributes</th>
<th>High prototypicality, mean (SD)</th>
<th>Low prototypicality, mean (SD)</th>
<th>F test (df)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplicity</td>
<td>4.26 (0.74)</td>
<td>3.19 (1.00)</td>
<td>291 (1,455)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Diversity</td>
<td>4.10 (0.74)</td>
<td>2.48 (1.09)</td>
<td>578 (1,455)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Colorfulness</td>
<td>4.38 (0.74)</td>
<td>3.41 (0.94)</td>
<td>295 (1,455)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Craftsmanship</td>
<td>4.25 (0.75)</td>
<td>2.83 (1.07)</td>
<td>462 (1,455)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Perceived ease of use</td>
<td>4.26 (0.75)</td>
<td>3.74 (0.97)</td>
<td>84 (1,455)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Perceived usefulness</td>
<td>4.08 (0.74)</td>
<td>3.58 (0.91)</td>
<td>116 (1,455)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Intentions to use</td>
<td>3.83 (1.00)</td>
<td>2.95 (1.28)</td>
<td>170 (1,455)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Impact of Prototypicality on Perceived Affordances

Participants reported that the app would allow them to carry out various actions in both the high- and low-prototypicality design (Table 3). Almost all perceived affordances had significantly higher endorsement for the high-prototypicality (vs low-prototypicality) apps (P<.01), partially supporting H6; to “learn health tips” was the only affordance endorsed similarly in both conditions. The most highly endorsed affordances (>60% across conditions or >277/462) were the following: “track my progress” (high: 93%, 430/462; low: 70%, 325/462), “set health goals” (high: 88%, 405/462; low: 73%, 339/462), “improve my health” (high: 74%, 342/462; low: 63%, 293/462), “learn health tips” (high: 73%, 336/462; low: 76%, 353/462), and “give me more information about my health” (high: 70%, 325/462; low: 63%, 292/462).

Table 3. Frequencies and McNemar chi-square differences for perceived affordances (n=462).

<table>
<thead>
<tr>
<th>Affordances</th>
<th>High prototypicality, n (%)</th>
<th>Low prototypicality, n (%)</th>
<th>Chi-square (df)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track my progress</td>
<td>430 (93.1)</td>
<td>325 (70.3)</td>
<td>79.70 (1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Set health goals</td>
<td>405 (87.7)</td>
<td>339 (73.4)</td>
<td>30.75 (1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Improve my health</td>
<td>342 (74.0)</td>
<td>293 (63.4)</td>
<td>20.15 (1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Learn health tips</td>
<td>336 (72.7)</td>
<td>353 (76.4)</td>
<td>2.59 (1)</td>
<td>.11</td>
</tr>
<tr>
<td>Give me more information about my health</td>
<td>325 (70.3)</td>
<td>292 (63.2)</td>
<td>6.86 (1)</td>
<td>.009</td>
</tr>
<tr>
<td>Create new health habits</td>
<td>310 (67.1)</td>
<td>265 (57.4)</td>
<td>11.06 (1)</td>
<td>.001</td>
</tr>
<tr>
<td>Increase my control over my health</td>
<td>323 (69.9)</td>
<td>239 (51.7)</td>
<td>46.86 (1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Make meeting my health goals easier</td>
<td>292 (63.2)</td>
<td>195 (42.2)</td>
<td>51.28 (1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Have fun with technology</td>
<td>256 (55.4)</td>
<td>135 (29.2)</td>
<td>79.57 (1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Interact with others</td>
<td>120 (26.0)</td>
<td>47 (10.2)</td>
<td>56.63 (1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Share my health data with friends</td>
<td>100 (21.6)</td>
<td>47 (10.2)</td>
<td>35.12 (1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Share my health data with a healthcare provider</td>
<td>74 (16.0)</td>
<td>50 (10.8)</td>
<td>11.50 (1)</td>
<td>.001</td>
</tr>
<tr>
<td>Earn rewards</td>
<td>57 (12.3)</td>
<td>34 (7.4)</td>
<td>10.30 (1)</td>
<td>.001</td>
</tr>
</tbody>
</table>

Discussion

Principal Findings

For mHealth to have an impact on reducing risk for chronic disease, intervention apps must be designed to effectively reach wide audiences to promote preventive health behaviors. Identifying the impact of prototypicality—the extent to which apps meet expectations—on app reception and adoption is a critical step in mHealth intervention research. Designs that match users’ perceptions of organization and content evoke prototypicality and can influence intentions to use web-based tools, including health resources [21,31,43]. Our study on prototypicality serves as an antecedent to positive app reception and technology acceptance in preventive health apps. We also found designs that contradict what users typically expect from apps (eg, low prototypicality), leading to a suboptimal first impression and diminishing users’ expectations [19].

It is likely that the actual use of multiple apps influences preventive behavior [44]; thus, identifying key features, or classes of features, to increase orientation and facilitate ease of use and usefulness are needed to guide intervention development. Our findings for user attention and predicted use of features point to 4 distinct types of mHealth features that should be considered when developing mHealth. Of these, 3 categories serve as useful features of mHealth: driving attention, perceived use, or both.

Functional features have higher predicted use than attention, and a majority “would expect to find” these sorts of features in a health app. To meet expectations, salient functional features such as search options, settings, and menus should be included,
in their expected corner placement. Even if these features do not draw attention as much as others, users still expect to see them in mobile apps, and meeting baseline expectations can reduce time and cognitive demand for initial orientation and web-based information processing [21]. Arguably, these functional features constitute a sort of prototypical milieu or background environment for mHealth apps to likely help users orient themselves within new and unfamiliar apps.

Flashy features garner significantly more attention from users; these attention-capturing features may be most influential for positive initial impressions. Flashy features often incorporated photographs or novel design elements, which have been shown to increase attention and appeal [43,45]. Beyond meeting expectations, flashy features represent the unique category that should be treated differently in designs: using visuals to highlight salient benefits and perceived affordances.

Essential features—including those selected by most users as features that they predict to use and garner their attention—are also important components of mHealth designs. It is important to note, however, that the essential features seen in this study are all familiar: calendar, calorie counter, and performance tracker. Even though some designers may assume that features as basic as a calendar are not worth the time and effort to include, respondents strongly indicated that these features remain important components of mHealth apps.

Our findings also highlight a distinct category that can be skipped or given little attention in development: mundane features. Mundane features, such as app title and tabs for discovering or saving, elicited little attention and predicted use and are a good indication not to waste precious resources on these elements.

Potential mHealth users had consistent expectations for some features by region (eg, middle or top corner), but not necessarily a specific location. Essential features, such as a calendar, were expected to be shown across the center of the app. Other features, such as function features including search and settings, had more narrow placement expectations. Understanding these location expectations is critical to ensure that feature placement matches individual models [21].

Higher prototypicality led to higher ratings for aesthetics, perceived ease of use, usefulness, and intentions to use apps. Individuals also expect greater function, possibilities, and valuable outcomes from apps with higher prototypicality. Low prototypicality led to lower rankings for aesthetics, perceived ease of use, and perceived usefulness. Additionally, low prototypicality runs the risk of users initially dismissing the app. Negative product evaluations—where expectations are not met—can also lower satisfaction with product interaction [46].

Limitations
This study is limited to the specific health apps manipulated herein; these apps do not represent all available mHealth strategies. Although we evaluated placement, attention, and predicted use, we could have reviewed more features within apps. Our findings are also limited to a convenience sample of participants of a web-based panel. It is possible that our participants have more digital literacy or skills than the general population or diverse subgroups.

Future Work
Future studies should consider assessing actual use after download, instead of solely predicted use. Replication with more diverse audiences, varied app designs, and expanded methodological approaches are needed to generalize our findings. Notably, future research should account for additional personal characteristics, such as health literacy or the ability to obtain, process, and understand health information [47], to examine how these skills affect both first impressions for app adoption and actual use to determine the effectiveness of health apps.

Conclusions
Mobile apps can communicate critical health information for preventive health behaviors through readily available and consumer-friendly tools. Apps that are thoughtfully designed to match potential users’ expectations, with increased prototypicality, will support app use. Conversely, designs that do not include a threshold of expected features will be dismissed, thus undermining the potential of app-based interventions. Designing mHealth apps to account for user expectations will increase the likelihood of adoption and impact from actual use. Prototypicality is positively related to favorable reception and expectations for future use of health apps. These findings provide guidance for user expectations of feature presence and location.

Acknowledgments
This work was supported by an award from the University of North Carolina Lineberger Comprehensive Cancer Center. The funders had no role in the study design, data collection, and analysis, decision to publish, or preparation of the manuscript.

Conflicts of Interest
None declared.

Multimedia Appendix 1
App hot spots and survey items.

[PDF File (Adobe PDF File), 680 KB - mhealth_v9i11e29815_app1.pdf]

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Abbreviations

ANOVA: analysis of variance
MANOVA: multivariate analysis of variance
mHealth: mobile health
MTurk: Mechanical Turk
RM: repeated measures
TAM: technology acceptance model
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Analysis of Apps With a Medication List Functionality for Older Adults With Heart Failure Using the Mobile App Rating Scale and the IMS Institute for Healthcare Informatics Functionality Score: Evaluation Study

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Abstract

Background: Managing the care of older adults with heart failure (HF) largely centers on medication management. Because of frequent medication or dosing changes, an app that supports these older adults in keeping an up-to-date list of medications could be advantageous. During the COVID-19 pandemic, HF outpatient consultations are taking place virtually or by telephone. An app with the capability to share a patient’s medication list with health care professionals before consultation could support clinical efficiency, for example, by reducing consultation time. However, the influence of apps on maintaining an up-to-date medication history for older adults with HF in Ireland remains largely unexplored.

Objective: The aims of this review are twofold: to review apps with a medication list functionality and to assess the quality of the apps included in the review using the Mobile App Rating Scale (MARS) and the IMS Institute for Healthcare Informatics functionality scale.

Methods: A systematic search of apps was conducted in June 2019 using the Google Play Store and iTunes App Store. The MARS was used independently by 4 researchers to assess the quality of the apps using an Android phone and an iPad. Apps were also evaluated using the IMS Institute for Healthcare Informatics functionality score.

Results: Google Play and iTunes App store searches identified 483 potential apps (292 from Google Play and 191 from iTunes App stores). A total of 6 apps (3 across both stores) met the inclusion criteria. Of the 6 apps, 4 achieved an acceptable MARS score (3/5). The Medisafe app had the highest overall MARS score (4/5), and the Medication List & Medical Records app had the lowest overall score (2.5/5). On average, the apps had 8 functions based on the IMS functionality criteria (range 5-11). A total of 2 apps achieved the maximum score for number of features (11 features) according to the IMS Institute for Healthcare Informatics functionality score, and 2 scored the lowest (5 features). Peer-reviewed publications were identified for 3 of the apps.

Conclusions: The quality of current apps with medication list functionality varies according to their technical aspects. Most of the apps reviewed have an acceptable MARS objective quality (ie, the overall quality of an app). However, subjective quality (ie, satisfaction with the apps) was poor. Only 3 apps are based on scientific evidence and have been tested previously. A total of 2 apps featured all the IMS Institute for Healthcare Informatics functionalities, and half did not provide clear instructions on
how to enter medication data, did not display vital parameter data in an easy-to-understand format, and did not guide users on how or when to take their medication.

*(JMIR Mhealth Uhealth 2021;9(11):e30674) doi:10.2196/30674*

**KEYWORDS**

mobile app; mHealth; medication app; heart failure; Mobile App Rating Scale

**Introduction**

**Background**

Managing the care of older adults with heart failure (HF) largely centers on symptom and medication management [1]. Medication management in patients with HF is challenging due to frequent medication or dosing changes [2,3] and polypharmacy, as some patients with HF typically take on average 10-25 tablets daily [4]. Polypharmacy is associated with poor adherence to pharmacological therapies, drug interactions, inappropriate drug prescriptions, and other adverse effects [5]. A recent report by the World Health Organization [6] argues that technology can improve patient experiences and medication adherence and enable patients to become active participants in medication reviews. Mobile apps offer the potential to augment care for patients with HF. Apps can potentially support older adults to find information on the medications (ie, drug interactions), track their medication, communicate with health care providers, keep a daily record of their blood pressure and weight measurements, and facilitate an accurate medication history. However, there is a dearth of literature on apps specifically to support medication management. An accurate medication list prevents adverse drug events [7], increases patients’ care outcomes, decreases hospitalization and mortality rates [8,9], and supports medication adherence for patients self-managing at home.

Given the complexity of HF self-care, assisting older adults in managing their own care at home is critical to the success of HF management. Emerging evidence suggests that mobile health (mHealth), particularly mobile technologies, can serve as a form of support for patients with HF and may enhance patient-provider collaboration for self-management [1,10]. By their nature, mobile devices, such as phones, are carried by people and, therefore, are always with them, offering opportunities beyond simple remote monitoring to assist with the management of care. In the current context of the COVID-19 pandemic, when the community (and especially older adults) is requested to maintain social distancing, the public health landscape is changing and mHealth has never been so important for treatment [10,11].

For older adults, social isolation and loneliness increase the risk of anxiety, depression symptoms, heart disease, reduction of activities of daily living, morbidity, and mortality [12,13]. Government recommendations to self-isolate during this pandemic have undoubtedly had a detrimental effect on older adults, including those that previously had wide social connections with the community and relatives [14]. Older adults who were previously attending outpatient appointments have seen their access restricted. In Ireland, the Health Service Executive website notes that all outpatient appointments are postponed until further notice [15]. Health care professionals (HCPs) working in outpatient clinics are seeing a reduced number of patients, with most consultations now taking place over the phone, bar medical emergencies. In Ireland, McGlynn [16] drew attention to the sharp decline in cardiac outpatient appointments during March to April 2020 (300,000 appointments) compared with the same period in 2019. Therefore, the need for new models of care in this changed environment to support older adults at home to alleviate their mental and physical burden, as well as provide medical care, is especially timely [10,11].

Across many countries, emerging evidence confirms the important role that mHealth can play in community care, especially during COVID-19. In the United States, there have been 10-fold web-based consultations in a few weeks [17], “...as big a transformation as any ever before in the history of US health care.” Similarly, Canada, South Africa, India, and the United Kingdom are conducting health care web-based consultations at an exponential rate [17]. In Ireland, the platform *Attend Anywhere*, endorsed by the Health Service Executive, is now widely available for HCPs to conduct web-based consultations [18]. However, the use of this platform is not even across Irish clinical settings (some HCPs are actively using it and others are not). Many outpatient services are consulting patients over the phone during the COVID-19 pandemic [19,20], except for patients with exacerbated symptoms.

The process of medication review over the phone is difficult and time-consuming [21]. HCPs have to listen attentively to the information the patient is conveying while lacking visual cues (ie, printed medication list or medication blisters provided by pharmacists). Instead, each patient has to spell each medication list over the phone, raising confusion over similarities of the medication name or dose, thus increasing the length of the consultation. An app sharing an up-to-date medication list with HCPs preconsultation could reduce medication and dosing errors, making the consultation process more efficient. A usability study of an app developed for HF self-management was conducted in Australia [22]. A total of 8 participants tested the app over a 14-day period and 6 of them assessed the app using the Mobile App Rating Scale (MARS; widely used to assess the quality of mobile apps). The app was found to be of acceptable quality and beneficial for HF self-management. Interestingly, the medication list feature on the app was considered by the patients to be beneficial; however, none of the patients used it during the 14 days. The authors suggested that participants found it difficult to incorporate the app into their self-care routine [22].

Emerging evidence suggests that apps can support patients by checking drug interactions, tracking medication intake, and facilitating an up-to-date list of medications. However, although
some app interventions have explored HF self-management [23,24], app interventions focusing on older adults with HF maintaining an accurate medication list have been limited and largely unexplored. This paper aims to explore the benefits of apps with a medication list functionality, explore their role in the COVID-19 pandemic context, and assess their quality using the MARS and the IMS Institute for Healthcare Informatics functionality score.

**Objectives**

The objectives of this review are two-fold: to review apps with a medication list functionality and to evaluate the quality of the apps included in the review with a validated scale. To assess the quality and functionality of the apps, 2 tools were used: the MARS tool and the IMS Institute for Healthcare Informatics functionality score. For the purpose of this paper, an app with a medication list functionality is an app that generates a comprehensive medication history, allowing the patient to email or share the list in real time with HCPs.

**Methods**

**Overview**

A systematic search of apps accessible in Ireland was conducted in June 2019 using the Google Play and iTunes App stores. The purpose of this search was to identify apps with a medication list functionality. The search term medication list was used to identify apps with a medication list functionality. The term medication app was excluded from the search as it identified apps with a different primary purpose (eg, medication alarm, medication tracker, medication reminder, apps providing educational information only, medical decision support systems for clinicians, medication adverse effect, pharmacy locator, and prescription refills). After the initial identification of apps containing a medical list function, the apps were tabulated. If the same app was available on different platforms (iOS or Android), both versions were retained for analysis as apps behave differently depending on the platform, as seen in previous work by Nicholas et al [25]. Inclusion and exclusion criteria (discussed next) were applied to each app to determine whether they should be retained for further analysis.

Apps that met the inclusion criteria were downloaded and evaluated by a team of 4 researchers. The MARS was used to assess the quality of the apps using an Android phone and an iPad. Apps were also evaluated using the IMS Institute for Healthcare Informatics functionality scores.

A Google Scholar search of the apps was conducted to identify apps included in this review that have been evaluated and published in peer-reviewed journals.

**Inclusion and Exclusion Criteria**

Apps were included if they had a medication list function; if they were updated in the last 2 years; were free of charge, reflecting popular trends in app downloads [26]; were available in English; and had a strict privacy policy written on their website or app store. Although a strict privacy policy is not an ultimate standard, given the sensitive nature of health information, the presence of a transparent privacy policy on medication apps was deemed highly important [27].

Apps were excluded from evaluation if they were a game app, were not available in Ireland, focused solely on a particular medical condition (eg, asthma), were a mobile clinical decision support system, were designed primarily for self-care management of a condition (eg, chronic obstructive pulmonary disease or diabetes), were not available for patients to use at home, and had a barcode scanner that did not recognize medication used in Ireland.

**Data Extraction**

The following information for each app with a medication list function was downloaded: developer, number of downloads of the app, last update, and description of the app in the app store. The apps were downloaded from the app store, and scientific support was evaluated by investigating their content. Scientific support provides information on the app’s evidence of validity, as apps that are not supported by evidence are associated with decrements in quality and safety [28]. For example, issues relating to patient confidentiality, inadequate content present in the app, and malfunctioning clinical decision-making apps could result in negative health outcomes for patients [29]. Apps that fulfilled the inclusion criteria were assessed using the MARS and IMS Institute for Healthcare Informatics functionality scoring criteria [30].

**Rating Tools**

**MARS Description**

All apps were subjected to in-depth analysis and evaluation using the MARS. To the best of our knowledge, there are no published studies using the MARS to assess the quality of apps with a medication list functionality. The MARS was developed by a team of researchers at the University of Queensland, Australia, to provide a systematic means of assessing, classifying, and rating the quality of mHealth apps [31].

Within this framework, apps are rated according to 4 objective measures (engagement, functionality, aesthetics, and information quality) and one subjective measure (Table 1). More specifically, engagement involves determining whether the app is fun, interesting, customizable, interactive, and well-targeted to its audience. Functionality assesses whether the app is easy to learn, navigate, and flow logically. The esthetics category evaluates the graphic design, overall visual appeal, color scheme, and stylistic consistency of the app. Information quality involves evaluating whether the app contains high-quality information from a credible source. Subjective quality reflects user satisfaction, app endorsement, and continuity of use (ibid). A complete description of the MARS items and subscales can be found in Multimedia Appendix 1 [31].
The apps were independently reviewed by 4 reviewers using a five-point scale (1=inadequate, 2=poor, 3=acceptable, 4=good, and 5=excellent), as shown in Multimedia Appendix 2. Scores for each category were obtained by calculating the mean of the ratings for each subscale according to the 5 measures described above. The total score for each app was determined using the average of the 4 objective measures. The overall mean app quality total score and the total score for the subjective measure (subjective quality, worth recommending, repeat use of the app, and overall satisfaction) were also calculated.

The reviewers carefully read the MARS instructions, independently reviewed the apps, and provided a rationale for their ratings. Subsequently, they compared the results and reached a consensus on each of the ratings for each of the MARS subscales [31]. Before rating the included apps, each reviewer rated 2 randomly selected apps for training purposes (from those apps that were excluded from the review). The results were discussed to ensure that all reviewers had an understanding of the MARS items and the rating process.

**IMS Institute for Healthcare Informatics Functionality Score Description**

To complement the MARS quality assessment, another tool was used to independently evaluate app functionalities [30]. This evaluation focused on the scope of functions and the potential role that each functionality plays in supporting self-management for patients with HF.

Unlike MARS, this tool only assesses objective quality and has been used previously to evaluate app capabilities [32,33]. The functionality score consists of 7 functionality criteria and 4 functional subcategories. The complete structure of the IMS Institute for Healthcare Informatics functionality scoring criteria can be found in Multimedia Appendix 3 [30]. If a function was present, it was coded as 1; otherwise, it was coded as 0. Functionality scores ranging from 0 to 11 were generated for each app.

### Results

#### Overview

Google Play and iTunes App stores searches identified 483 potential apps (292 Google Play stores and 191 iTunes App stores), the app selection process for both app stores can be seen in Multimedia Appendices 4 and 5. A total of 6 apps (3 across both stores) met the inclusion criteria. Out of the 6 apps reviewed, 4 achieved an acceptable quality score (MARS score 3/5), one achieved a good quality score (4/5), and one had a poor quality score (2.5/5). The median overall MARS score was 3.5/5, ranging from 2.5/5 to 4/5 (mean 3.4, SD 0.49). As stated earlier, the apps are rated according to 4 objective measures: engagement, functionality, aesthetics, and information. The functionality dimension mean score achieved the highest score (3.7), whereas the mean score for the information and engagement dimensions was the lowest (3.2). The total mean subjective MARS score (2.8/5) was lower than the total mean objective MARS score (3.4/5).

On average, the apps had 8 functions based on the IMS criteria (range 5-11). Two apps achieved the highest IMS functionality criteria score (11 functions), whereas 2 apps achieved the lowest score (5 functions). All functions (n=11) are listed in Table 2.
All apps had collecting, sharing, and recording functionality. However, half of the apps did not provide clear instructions on how to enter medication data, did not display vital parameter data in an easy-to-understand format, and did not guide or provide users with advice on how or when to take their medication. Only 2 apps allowed users to communicate with HCPs, family, and friends in real time.

Table 2. IMS Institute for Healthcare Informatics functionality score results.

<table>
<thead>
<tr>
<th>IMS functionality scoring criteria</th>
<th>Doscast (Google Play and iTunes)</th>
<th>My Therapy (Google Play and iTunes)</th>
<th>Medication List &amp; Medical Records (Google Play)</th>
<th>Medisafe (Google Play and iTunes)</th>
<th>Pill Reminder (iTunes)</th>
<th>MedList Pro (Google Play)</th>
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</thead>
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<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
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<td>Remind or alert</td>
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<td><img src="#" alt="a" /></td>
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<td><img src="#" alt="a" /></td>
<td><img src="#" alt="a" /></td>
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<tr>
<td>Total functions present</td>
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<td>11</td>
<td>5</td>
<td>11</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

[a✓]: Function present in the app.

Quality Assessment Using the MARS

Four out of the six apps achieved acceptable quality, suggesting that most apps are of acceptable quality. None of the apps presented any major technical issues during the review, and all were updated in the last 2 years. Features included in most apps reviewed were medication reminders, medication history logs with the ability to share a medication report with others, vital parameter tracking, and syncing the account to other devices.

Only one app (Medisafe) achieved the highest objective and subjective overall MARS scores. One of the distinctive features of this app was the ability to educate users on how and when to take their medication, drug-drug interaction information, and medication side effects. This information was presented in videos using a clear and concise language and text format. In addition, there is evidence of effectiveness, as the Medisafe app has been previously tested in 2 randomized controlled trials [34,35], as a medication adherence tool using scheduled reminders [36] and as a medication reminder related to patients’ intention to use the app [37].

The overall subjective quality dimension was significantly lower (2.8/5) than the overall objective mean of all apps (3.4/5). Only one app (Medication List & Medical Records) achieved a lower objective overall score (2.5/5) than the subjective overall score. The subjective quality represented the opinion of the user on the level of satisfaction with the app, willingness to pay for it, and the extent to which the user will recommend it to others. It appears that the apps reviewed, to a certain extent, are well designed, as most apps achieved an acceptable objective quality. However, the subjective quality was poor, as the reviewers provided lower scores on continuity of use and willingness to recommend the apps to others.

The functionality dimension mean score achieved the highest score (3.7), indicating a trend toward higher responses in a timely manner, intuitiveness and ease of use, and navigation across all apps. However, the mean score for the information and engagement dimensions was the lowest (3.2). The information dimension represents the quality and quantity of information present in the app and the way this information is provided, for example, through the use of different formats, such as videos, text, or graphs. The quality of the information on the apps reviewed varied, as some provided good quality medication information; in others, there was a very poor level of information or none present at all.

None of the apps included in the review performed very well in the engagement dimension (if the app was fun or interesting to the user). Medication apps as a rule are not fun and entertaining; however, most apps allow interactivity (ability to input information and prompting) and customization (sending notifications and setting up medication reminders). Another category in engagement, the target group, evaluated if the app content (ie, visual information, language, and design) was appropriate for the user. Most patients diagnosed with HF are older adults. The apps reviewed were not specifically designed for use by older adults and did not have an age-friendly interface. An example of an age-friendly interface is when an app facilitates older adults to enlarge the font size of the screen if required. Avoiding information overload and providing detailed instructions on how to use the app are also age-friendly interface examples [38]. Three of the apps reviewed (Doscast, Medication List & Medical Records, and MedList Pro) did not
provide clear instructions on how to use the app or how to input medication. App developers should consult with and take older adults’ views, needs, and preferences into consideration to make apps more age-friendly and increase usability [38].

IMS Institute for Healthcare Informatics Functionality Score Evaluation and Implications for Patients With HF

Inform

Only 2 apps (Medisafe and MyTherapy) communicated effectively to users, offering an educational component about medication and the medical condition associated with each medication. In addition, both apps informed users about the medication they are taking and possible drug-to-drug interactions. Due to frequent medication or dosing changes in patients with HF, this is a critical function. Medication adherence and continuous education on the condition and symptom management are vital to reduce rehospitalization, illness progression, and exacerbation of symptoms in patients with HF [39].

Instruct

Some of the apps reviewed (Dosecast, Medication List & Medical Records, and MedList Pro) were not intuitive and did not provide clear instructions on how to enter medication strength, time of the day, route, and setting up medication reminders. In other studies, the level of detailed instructions varied. Providing clear instructions on the use of an app is vital for older adults with HF. Patients with HF are predominantly patients aged ≥ 65 years [40], and old age has been cited as a barrier to app use and uptake [41]. Therefore, app designers should consider the needs of older adults using apps and include basic usability advice and easy-to-understand content [38,42].

Record

All apps allowed users to record their medication and a history of use. Most apps also had the capability to record vital parameters. For patients with HF, blood pressure and weight measurements are useful for monitoring the progress of their illness and identifying when symptoms exacerbate. One of the main goals of HF care is to avoid rehospitalization and major adverse cardiac events [32]. In particular, one app offered the possibility of tracking mental well-being, another key area that needs particular attention. For individuals diagnosed with HF, depression and anxiety are common, leading to rehospitalization, poorer quality of life, and increased morbidity and mortality [43].

Evaluate Data

Four apps (MyTherapy, Medication List & Medical Records, Medisafe, and Pill Reminder) allowed data entered into the app to be analyzed and evaluated by the user, a relative, or an HCP. This functionality allows for information to be shared easily and in a timely manner for HCPs to evaluate it and act accordingly. For example, relatives and clinicians can evaluate whether a person is adhering to medication.

Intervene

Five out of the six apps (except Medication List & Medical Records) had the capability to recommend the user, a relative, or a medical practitioner to intervene based on the data collected. Building from the example provided in “evaluate data,” once the health information is evaluated, an intervention can be put in place. Examples of interventions for patients with HF could be to reduce or increase the medication dose, reduce fluid intake, and attend the clinic or emergency department on the day. Other examples are the ability of the app to communicate effectively to provide a positive intervention, that is, reminders to refill their medication or a suggestion to engage in physical activity to achieve their daily activity goal.

Display

Apps with a cluttered or bland display do not engage users and are less likely to offer a positive user experience. In 3 of the apps reviewed (MyTherapy, Medication List & Medical Records, and Medisafe), the data were displayed in a clear and colorful graphical representation format. This function could potentially be useful for patients with HF as they can easily understand health reports, that is, medication, weight, and blood pressure [22]. Consequently, health reports will highlight behavioral changes, for example, to adhere to the medication prescribed, reduce fluid intake, or ring the clinic regarding weight gain.

Guide

Half of the apps (Dosecast, Medication List & Medical Records, and Pill Reminder) did not provide comprehensive guidance or training about the correct administration of medication or advice on the time of day that the medication should be administered, for example, before or after a meal. HF medication management is complex, and continuous education and advice on regular medication use is vital for HF self-management [32].

Reminder or Alert

All apps issued an alert to remind users to take their medication and most allowed the users to tick off their medication once they take it or record it as a missed dose. Most apps also had the capability of reminding users of upcoming medical appointments. Apps with a reminder function improved medication adherence and enhanced complex medication management in patients with HF [32]. One of the apps, Medisafe, alerted users and their relatives of drug-drug interactions and of missed medication doses.

Communicate

This function offers the option to communicate with HCPs or with an online support group in real time. The Medisafe app offers users the possibility to communicate with unlimited Medfriends supporters (relatives, friends, or caregivers). Another app, MyTherapy, provides HCPs with an overview of patients’ data to plan for their treatment between visits through the web dashboard function.

Google Scholar Search

A search was conducted to identify the apps included in this review that have been evaluated and published in peer-reviewed

https://mhealth.jmir.org/2021/11/e30674
journals. Out of all the apps reviewed, 3 apps were identified in the search: (1) Dosecast, (2) MyTherapy, and (3) Medisafe app.

Discussion

Principal Findings

To our knowledge, this is the first study to assess the quality of apps with a medication list functionality using the MARS and the IMS Institute for Healthcare Informatics functionality scale available to Irish consumers. The most common functionalities found in the apps reviewed were medication reminders, medication history logs, and the ability to share medication reports with others, vital parameter tracking, and syncing the account to other devices. However, half did not provide clear instructions on how to enter medication data, did not display vital parameter data in an easy-to-understand format, and did not guide users on how or when to take their medication.

App users prefer apps that are effective, useful, and easy to use [44]. From the apps reviewed, the Medisafe app achieved the highest objective and subjective overall MARS score and the highest IMS Institute for Healthcare Informatics functionality score. One of the distinctive features of this app is the ability to educate users on how and when to take their medication, drug-drug interaction information, and medication side effects. This information was presented in videos using a clear and concise language and text format. The app was found to be very intuitive and had an age-friendly interface.

The quality and efficacy of health apps is another important factor to be considered by users, as they provide positive user experiences and a higher uptake [45]. Most of the apps included in this review had acceptable quality. However, for users, it is not easy to determine the quality, performance, and trustworthiness of apps. The number of apps available in app stores has been growing exponentially in the last decade [30,46] impacting the user’s ability to distinguish app quality and performance. Therefore, a reliable and easy-to-use tool to facilitate this process is warranted [47].

The use of mHealth apps is growing at an exponential rate, but there are questions about their efficacy. One of the methods to check the evidence of efficacy is to conduct a search for peer-reviewed academic evidence. For the purpose of this study, a search was conducted for each app in Google Scholar to identify any published peer-reviewed articles. Three of the reviewed apps were identified in the search. The Medisafe app has been previously tested in 2 randomized controlled trials: (1) a medication adherence study [34] and (2) a medication adherence and blood pressure control study [35]. The MyTherapy app was tested in a study [48] as a medication tracker and reminder, whereas the Dosecast app was included in the IMS Institute for Healthcare Informatics review [30], a MARS review [49], and on a feasibility and acceptability medication adherence experimental trial [50]. However, many widely used apps have not yet been scientifically tested. Therefore, there is a need for more apps to be tested scientifically and the outcomes to be disseminated to inform the mHealth research community [22,51].

The mHealth research community has been actively searching for self-management solutions to support older adults shielding at home during the COVID-19 pandemic. One of their focus areas is to support self-management and medication adherence [52]. Apps with a medication reminder functionality may play a potentially important role in promoting greater self-management of vulnerable older adults living at home. In Ireland, as per March 2021, older adults are shielded, and movement is restricted to a 5 km radius. The monotonous routine makes each day very similar to the previous one, and daily routines, such as taking medication at scheduled times might become easy to forget. All apps reviewed, with the exception of one, have the capability of reminding users to take their medication. Medication reminder apps have been found to be effective and to increase medication adherence [48,49,53-55], even for patients with HF [56]. Another app feature that might be of benefit during the COVID-19 pandemic is the ability of older adults with HF to communicate with their medical team or relatives via the app. As mentioned earlier, in Ireland, the number of in-person HF outpatient consultations has considerably decreased by 2020 [15,16]. As of March 2021, the probability of contracting the virus for health care personnel remains high [57], and patients with HF are considered to be one of the most vulnerable groups [58].

Finally, this paper identified a small number of apps that could be suitable for patients with HF sharing their medication list with HCPs before consultation. Owing to the sensitive nature of health care data and in an era where General Data Protection Regulation (GDPR) legislation considerations are increasingly important, a strict data policy was a criterion for selection. For example, one of the most frequent concerns app users have is how their health data are processed. Under GDPR legislation, app users are encouraged to ask and obtain information in relation to data security and data processing [59]. However, after the introduction of the GDPR in 2018, no specific guidance on privacy has been developed for apps widely available to consumers [60]. Therefore, the need for transparent and easy-to-understand strict privacy policies in health apps should be mandatory if consumers are expected to download and use mHealth apps [60,61] and if clinicians are expected to recommend apps to their patients [62].

Conclusions

The quality of current apps with a medication list functionality varies according to their technical aspects. Most of the reviewed apps have acceptable MARS objective quality. However, the subjective quality or satisfaction with the apps was poor. The objective quality assesses whether an app is interesting, easy to navigate, and overall visual appeal, among other characteristics. Subjective quality reflects user satisfaction, app endorsement, and continuity of use. Only 3 apps are based on scientific evidence and have been tested previously. Two apps featured all the IMS Institute for Healthcare Informatics functionalities and half did not provide clear instructions on how to enter medication data, did not display vital parameter data in an easy-to-understand format, and did not guide users on how or when to take their medication.
To our knowledge, this is the first study to use the MARS to assess the quality of apps with a medication list functionality available in the Irish app stores. The need for an app to support older adults with HF to maintain an accurate medication list is warranted. We recommend that app developers display either in the app or on the website, a transparent and easy-to-understand privacy policy to increase patients’ and HCPs’ trust and use.

Limitations
One of the limitations of this review is the limited number of apps, as only those with a strict privacy policy written on their website or app store were included. Furthermore, due to the fast pace of app development, it is possible that by the time this paper is published, there may be new apps with a medication list functionality available to Irish consumers.

Acknowledgments
This study was supported by the Eastern Corridor Medical Engineering Centre, a collaborative research project focusing on improving cardiovascular health. The Eastern Corridor Medical Engineering Centre is funded by the European Union’s Interreg VA Programme, which is managed by the Special European Union Programmes body.

Conflicts of Interest
None declared.

Multimedia Appendix 1
Mobile App Rating Scale items and subscales.

Multimedia Appendix 2
Mobile App Rating Scale ratings of included apps.

Multimedia Appendix 3
IMS Institute for Healthcare Informatics functionality scoring.

Multimedia Appendix 4
App selection process (Google Play app store).

Multimedia Appendix 5
App selection process (Apple app store).

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Abbreviations

GDPR: General Data Protection Regulation
HCP: health care professional
HF: heart failure
MARS: Mobile App Rating Scale
mHealth: mobile health

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GPS Mobile Health Intervention Among People Experiencing Homelessness: Pre-Post Study

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Abstract

Background: People experiencing homelessness are at risk for gaps in care after an emergency department (ED) or hospital visit, which leads to increased use, poor health outcomes, and high health care costs. Most people experiencing homelessness have a mobile phone of some type, which makes mobile health (mHealth) interventions a feasible way to connect a person experiencing homelessness with providers.

Objective: This study aims to investigate the accuracy, acceptability, and preliminary outcomes of a GPS-enabled mHealth (GPS-mHealth) intervention designed to alert community health paramedics when people experiencing homelessness are in the ED or hospital.

Methods: This study was a pre-post design with baseline and 4-month postenrollment assessments. People experiencing homelessness, taking at least 2 medications for chronic conditions, scoring at least 10 on the Patient Health Questionnaire-9, and having at least 2 ED or hospital visits in the previous 6 months were eligible. Participants were issued a study smartphone with a GPS app programmed to alert a community health paramedic when a participant entered an ED or hospital. For each alert, community health paramedics followed up via telephone to assess care coordination needs. Participants also received a daily email to assess medication adherence. GPS alerts were compared with ED and hospital data from the local health information exchange (HIE) to assess accuracy. Paired t tests compared scores on the Patient Health Questionnaire-9, Medical Outcomes Study Social Support Survey, and Adherence Starts with Knowledge-12 adherence survey at baseline and exit. Semistructured exit interviews examined the perceptions and benefits of the intervention.

Results: In total, 30 participants were enrolled; the mean age was 44.1 (SD 9.7) years. Most participants were male (20/30, 67%), White (17/30, 57%), and not working (19/30, 63%). Only 19% (3/16) of the ED or hospital visit alerts aligned with HIE data, mainly because of patients not having the smartphone with them during the visit, the smartphone being off, and gaps in GPS technology. There was a significant difference in depressive symptoms between baseline (mean 16.9, SD 5.8) and exit (mean 12.7, SD 8.2; t₁₉=2.9; P=.009) and a significant difference in adherence barriers between baseline (mean 2.4, SD 1.4) and exit (mean 1.5, SD 1.5; t₁₉=2.47; P=.03). Participants agreed that the app was easy to use (mean 4.4/5, SD 1.0, with 5=strongly agree), and the email helped them remember to take their medications (mean 4.6/5, SD 0.6). Qualitative data indicated that unlimited smartphone access allowed participants to meet social needs and maintain contact with case managers, health care providers, family, and friends.

Conclusions: mHealth interventions are acceptable to people experiencing homelessness. HIE data provided more accurate ED and hospital visit information; however, unlimited access to reliable communication provided benefits to participants beyond the study purpose of improving care coordination.
Introduction

Background

Mobile phone ownership is nearly ubiquitous among American adults, with 96% owning a mobile phone of some type, and most (81%) mobile phones are smartphones [1]. Accordingly, mobile technology is increasingly common in the health care sector. Mobile devices are being used for medical diagnostics [2], disease monitoring [3], smoking cessation [4], and dietary tracking [5]. Smartphone capabilities, including texting and apps, have contributed to improved medication adherence [6], higher attendance at medical appointments [7], and increased vaccination rates [8]. Mobile technology has also been explored as a useful tool to bolster the transmission of information and care coordination during transitions of care [9,10], and studies have demonstrated the potential of mobile technology to improve communication among health care providers and populations at risk for poor outcomes, including people of lower socioeconomic status [11,12]. Recent estimates of mobile phone use among the homeless population indicate that 89% of the people report having and using a mobile phone [13], and researchers have begun to explore the possibility of using mobile technology to improve the health of people experiencing homelessness. For example, Burda et al [14] concluded that mobile phones are a feasible way to monitor and manage medication regimens for people experiencing homelessness with co-occurring disorders. Furthermore, in a survey of people experiencing homelessness, 77% of the respondents were interested in appointment reminders, and most were interested in medication refill reminders (66%) and medication taking reminders (60%) [13]. Despite the accumulating evidence that mobile health (mHealth) interventions among homeless populations are feasible, GPS-enabled mHealth (GPS-mHealth) interventions in this population have remained underexplored. The purpose of this study, therefore, is to investigate the acceptability and preliminary outcomes of a GPS-mHealth intervention designed to improve care coordination in a sample of people experiencing homelessness.

Evidence suggests that the health service experiences of people experiencing homelessness are often interrupted and involve extensive barriers, including unmet physical needs, lack of affordable and available services, and lack of compassion that prevents people experiencing homelessness from accessing appropriate community-based services [15-17]. These barriers lead to disruptions in continuity of care, which is problematic because of evidence that continuity of care—that is, timely, accessible, person-centered, and coordinated care—improves outcomes [18]. Interventions such as case management, respite care, and housing services that target critical transition points have led to decreased acute care use [19] in people experiencing homelessness. Community paramedics have also been used to coordinate care and link high-risk patients to needed health and social services [20], which has led to reduced health care use among diverse populations and improvements in patient outcomes [21]. Despite these multifaceted programs, interventions, and service delivery models intended to improve care coordination among people experiencing homelessness, gaps in services along the continuum of care persist.

Study Premise and Objectives

This study focuses on the significant gap along the continuum of care that begins at the point of an emergency department (ED) visit or hospitalization for people experiencing homelessness. The study intervention was created on the basis of feedback from health care providers and case managers who deliver care to homeless individuals, and the fact that fragmented communication among various health care organizations limits the ability to provide real-time information about ED or hospital visits. When a person experiencing homelessness enters the ED or hospital, they are at high risk of losing contact with community-based health care providers and case managers [22]. This is exacerbated in the people experiencing homelessness living with depression as it is more difficult to manage their chronic conditions, including attending appointments and taking medications as prescribed [23]. The loss of contact between homeless individuals and their community-based care team creates a time of high risk for the individual and represents missed opportunities to provide services and potentially decrease acute health care use. For preventing or minimizing this loss of contact, this study used geofencing to create virtual boundaries that triggered automatic notification of community paramedics if and when a person experiencing homelessness visited an ED or hospital. The use of such geofencing technology in health care has been previously studied in smoking cessation, dietary recommendations, anxiety, and hospitalizations in patients with cardiovascular disease [5,10,24,25]. However, the utility of a GPS-mHealth intervention specifically in transitions of care for people experiencing homelessness has not been previously reported. Therefore, the following research questions guided this study:

1. What is the accuracy of GPS technology in terms of tracking participant visits to the ED or hospital?
2. How do depression symptoms, medication adherence, social support, and experience with and perceptions of GPS and mobile phone technology compare at baseline and exit?
3. What is the number and type of community health paramedic encounters?
4. What concerns do participants express regarding technology or privacy?
Methods

Design and Participants

This study used a pre-post design with assessments at baseline, 1 month, 2 months, 3 months, and 4 months after enrollment to evaluate the acceptability and preliminary outcomes of a GPS-enabled mHealth intervention. Participants were recruited from 2 churches that provided services to people experiencing homelessness. The first serves breakfast at 5:45 AM two mornings each week and is open to anyone in the community. The research staff attended this breakfast once per week for the study duration. Potential participants were referred to study staff for eligibility screening by either the meal program coordinator or the police officer assigned to the downtown Homeless Outreach Service team, whose job function includes attending these twice weekly breakfasts. The second church site doubles as a navigation center for people experiencing homelessness during weekdays. Services at the navigation center include coordinated assessments for housing, assistance with obtaining IDs, and case management. The research staff were on site at the navigation center 2 to 3 days per week for the study duration. Similar to the first site, potential participants were referred by the director of the navigation center or by navigation center volunteers to study staff for study eligibility screening.

Recruitment occurred between October 2018 and April 2019. Community partners assisted with recruitment by distributing flyers to clients and by referring potential participants to research staff. Participants also referred peers who were potentially eligible to the study staff. Potential participants were screened for study eligibility on site at the churches by a member of the research team. The eligibility criteria included (1) being at least 18 years old, (2) currently experiencing homelessness as defined where the person had slept most nights in the past 30 days, (3) score of at least 10 on the Patient Health Questionnaire-9 (PHQ-9), (4) currently prescribed at least 2 medications for chronic medical conditions, (5) diagnosed with at least 1 chronic medical condition, and (6) experienced at least 2 hospitalizations or ED visits in the past 6 months. Exclusion criteria included (1) onset in the past 3 months of depressive symptoms and (2) suicide attempts or suicidal ideation in the past 6 months.

This study was approved by the institutional review board of the university. Individuals interested in participating were screened by research staff, and, if eligible to continue, study details, including the purpose, procedures, risks, and benefits of study participation, were explained. If participants remained interested, informed consent was obtained. None of the participants who were eligible for the study declined to participate after being informed of the study details. After obtaining informed consent, a researcher administered a series of baseline assessments to collect information about demographics, health history, medication adherence, social support, and recent ED visit and hospitalizations. After completion of the surveys, participants were provided with a smartphone activated with a plan for unlimited texting, calling, and data; a hard-plastic smartphone case; and an armband to use for securing the smartphone. Participants were also given US $25 cash for the time spent enrolling in the study and a 31-day unlimited use bus pass to ensure their ability to attend the monthly follow-up assessment. They then received training on the intervention. The training described the expectations of participants, including keeping track of the smartphone, keeping it turned on and charged, attending monthly check-in visits, answering the daily email regarding medication adherence, and responding to community health paramedics or research staff as applicable. The training also included how to use the smartphone, set up voicemail, access email and SMS text messages, and access and use the bus pass. Participants were also informed that one replacement smartphone would be issued if their study smartphone was lost, stolen, or broken during the 4-month study.

GPS-mHealth Intervention

For this study, a mobile app was used to establish and monitor geofences around the 10 EDs located within the city limits where this study took place. The geofences were established using the mobile app so that when a participant entered a local ED or hospital, the research staff and the commander of the community paramedic team would receive an email notification. The email notification sent a secure link to view the participant’s name, geofence location, date, and time of entry and exit. On receipt, the commander tasked a community health paramedic member of his team to contact the participant via their smartphone within 2 business days of the geofence entry to follow-up on the visit and any identified health or social needs. The community health paramedic completed an event form documenting the participant-reported reason for the hospital or ED visit, admission, and discharge dates; if the ED or hospital visit was potentially preventable; what intervention may have prevented the ED and hospital visit; and the duration of the community health paramedic visit with the participant.

In addition to the geofencing and care provided by community health paramedics as needed, the intervention had two additional components: (1) monthly in-person meetings and (2) daily adherence reminder emails. In-person meetings occurred between each participant and research staff at enrollment; 1-, 2-, and 3-month follow-up appointments; and at the exit.Monthly follow-up visits (at 1, 2, and 3 months) were scheduled to maintain contact with participants and to identify any issues with the technology. Participants were also asked at these monthly meetings if they had visited the ED or been hospitalized in the past 30 days. At months 1, 2, and 3, participants received US $10 cash and an additional 31-day bus pass. Next, participants received an email every evening at 8 PM asking if they had taken their medications that day. Response options were “yes” or “no,” with a follow-up question requesting a short reason why they had not taken their medication if applicable. During the exit interviews, participants responded to a series of questionnaires before engaging in a semistructured interview to assess the overall acceptance of the intervention. Textbox 1 summarizes the interview guidelines. Finally, the local health information exchange (HIE) provided research staff with dates of hospital admissions and ED visits, as applicable, for participants during the 4-month study period.
Textbox 1. Semistructured interview guide.

Questions about the study

1. Please describe your experience with this research study (probe 1: Did you experience benefits from participating in this study? probe 2: Was participating in this study helpful to you? probe 3: Were there any difficulties that you experienced with this study?)
2. Can you share any barriers to study participation that you experienced? (Examples may include keeping the smartphone secure or charged)
3. What strategies did you use to successfully complete the study requirements? (This includes things such as keeping the smartphone charged and operational as well as attendance at monthly check-in visits)
4. What concerns did you have about your visits to the emergency room and hospital being monitored with GPS technology?
5. Can you describe any experiences or interactions you had with community health paramedics?
6. What suggestions do you have for us to improve this intervention for people in the future?

Measurements

Sociodemographic and Health-Related Variables

At baseline, sociodemographic characteristics, including sex, race, highest education obtained, veteran status, and income, were collected. Participants were also asked a series of six questions from the American Community Survey designed to identify individuals who may experience functional limitations [26]. Response options were 1=yes or 0=no. The items were summed for a total score, with higher scores indicating a higher burden of functional limitations. The Cut down, Annoyed, Guilty, and Eye-opener questionnaire, a 4-item screening tool, was used to screen for alcohol use [27]. Response options were 1=yes or 0=no. The items were summed for a total score, and a total score of >2 was considered clinically significant [27]. The single-item screen in which the participant is asked, “how many times in the past year have you used an illicit drug or used a prescription medication for nonmedical reasons?” was used to screen for substance use [28]. Responses ≥1 were considered to be positive.

Health Literacy

Health literacy was measured using the Brief Health Literacy Screening Tool [29], which comprises 4 questions that assess respondents’ ability to complete tasks such as filling out medical forms, reading hospital paperwork, and learning about one’s medical condition. Each item is worth 1 to 5 points, depending on the response. Scores were summed for a composite score ranging from 4 to 20. Scores of 4-12 indicate limited health literacy, scores of 13-16 indicate marginal health literacy, and scores of 17-20 indicate adequate health literacy [30].

Accuracy of the GPS Technology

The accuracy of the GPS technology was measured in 2 ways. First, when community health paramedics received an alert indicating that a participant had entered a geofence at an area hospital, a community health paramedic attempted to make contact with the participant within 2 business days. If contact was established, the community health paramedic confirmed the visit to the ED and hospital, as indicated by the geofence alert. Second, at the end of the study, the research staff obtained use records from the HIE. These records provided the dates of participants’ ED and hospital visits during the study period. Use records for the 25 participants for whom HIE data were collected were triangulated with geofence entry notifications to measure the accuracy of the GPS technology.

Depression

The 9-item PHQ-9 was used to establish participant eligibility and as a baseline measure for depression symptoms. The PHQ-9 is a reliable and valid tool for diagnosing and grading depressive symptom severity [31]. Each item is scored from 0-3 and then summed. Scores of 5, 10, 15, and 20 represent cutoff points for mild, moderate, moderately severe, and severe depression, respectively [31]. To be eligible to participate in this study, individuals were required to score at least 10, indicating moderate depression.

Medication Adherence

Medication adherence was measured using a modified version of the Adherence Starts with Knowledge-12 (ASK-12). The ASK-12 is a brief, 12-item scale with 3 subscales that measure medication behavior, health beliefs, and inconvenience/forgetfulness [32]. For this study, we modified the subset of 5 questions assessing medication behavior into dichotomous yes/no response options to assess medication adherence during the preceding month. The number of yes responses was counted and summed for a medication behavior subscale score. Scores on the full ASK-12, with the modified medication behavior subscale, ranged from 12-40, with higher scores indicating greater barriers to adherence. At baseline, the full scale with the modified behavior subscale was used. At monthly visits and exit, only the modified medication behavior subscale was used as it was unlikely that medication beliefs would change within the short time frame of this study.

Social Support

Social support was measured using the Medical Outcomes Study Social Support Survey, a valid and reliable tool that has been used in multiple groups across various conditions [33]. It includes 19 questions yielding four subscales—emotional/informational support, tangible support, affectionate support, and positive social interaction. Each item is rated using a Likert scale ranging from 1 (none of the time) to 5 (all of the time). The total score was calculated by summing all 19 questions and averaging them. Higher scores represent greater levels of social support.
Experience With and Acceptance of Technology

At baseline, experience with mobile phone technology was measured using a series of questions asking about current mobile phone ownership, mobile phone service, length of time owning a mobile phone, ability to charge the mobile phone, and if the participant had had a mobile phone stolen before. Acceptance of technology was measured at baseline and exit. At baseline, acceptance of technology was measured using a modification of the Technology Acceptance Questionnaire [34]. At baseline, 17 items were used, and at exit, a subset of these items, as well as an additional 8 items, were used. Each item is rated using a Likert scale ranging from 1 (strongly disagree) to 5 = strongly agree. Higher scores indicate greater acceptance of technology. In addition, at exit, participants were asked how often they were able to charge their smartphone with options ranging from “None of the time” to “Always.”

Quality of Care Transitions

Self-reported ED and hospital use were assessed at baseline, monthly visits, and exit. If participants indicated that they had visited the ED or hospital within the past month, their experience and perception of patient-centeredness of their care were assessed using the care transitions measure (CTM), a 15-item measure reflecting 4 content domains [35]. The domains include critical understanding, important preferences, management preparation, and care plans [35]. Participants used a 5-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree to rate the quality of various components of a care transition within each domain. Lower scores indicate a poorer quality transition, and higher scores indicate a better transition. The CTM was administered at each monthly visit, during which a participant reported an ED or hospital visit. If someone reported more than 1 visit in the previous month, the CTM was completed only for the most recent visit.

Data Analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows (version 25.0, IBM Corp). Descriptive statistics were used to describe the sociodemographic and health characteristics of the sample and all study measures. Accuracy of the geofence entry notifications was determined by calculating the percentage of notifications that aligned with HIE use data. Paired sample t tests were used to compare scores at baseline and exit on the PHQ-9, ASK-12, Medical Outcomes Study, and technology acceptance scales.

Qualitative content analysis was used to identify participants’ acceptance of the intervention. All interviews were audio recorded and transcribed verbatim to facilitate coding and analysis. After a thorough reading and deductive coding of 5 representative transcripts by 2 members of the study team (LRM and WT), a consensus meeting was held to discuss and agree upon the codes. Discrepancies were resolved by discussing the context for each phrase being analyzed. After the meeting, a codebook was developed. The remaining interviews were divided between the 2 authors and coded separately. After coding was complete, the study team organized the codes into categories.

Results

Overview

Between October 2018 and April 2019, research staff screened 39 individuals for participation; of the 39 individuals, 32 (82%) met the eligibility criteria, and 30 (77%) were enrolled in the study. The 2 individuals who were eligible to participate but did not enroll did not return for the subsequent enrollment visit in the study after screening. The reasons for ineligibility for the study were not scoring at least 10 on the PHQ-9 (2/39, 5%), not having been to the ED or hospital at least twice in the past 2 months (2/39, 5%), not being prescribed a medication (2/39, 5%), and endorsing suicidal ideation (1/39, 3%). The participant who endorsed suicidal ideation was referred to the public safety officer on site at the community entity for appropriate follow-up and mental health services. Of the 30 participants, 10 (33%) were screened and enrolled at the first church with 2 weekly breakfasts, and the remaining 20 (67%) were screened and enrolled at the navigation center housed in a church.

Of the 30 participants enrolled, 19 (63%) completed the 4-month intervention, with a completion rate of 63%. Of the 11 participants who did not complete the intervention, 6 (55%) were withdrawn from the study after they reported their second smartphone lost or stolen, 2 (18%) notified the research staff that they were moving to a different town, 2 (18%) were lost to follow-up, and 1 (9%) voluntarily withdrew from the study after losing his first smartphone. Of these 11 participants, 4 (36%) completed all but the exit data collection.

Quantitative Results

Participant Demographics and Health-Related Characteristics

Participants comprised 30 people experiencing homelessness. On average, participants were male (20/30, 67%), aged 44.1 years (SD 9.7 years), White (17/30, 57%), never married (17/30, 57%), and not working because of disability or other medical reasons (19/30, 63%). At baseline, participants reported a mean of 2.8 (SD 1.4) chronic conditions, and most (26/30, 87%) experienced multiple chronic conditions. All participants were prescribed at least 2 medications at baseline; 53% (16/30) were prescribed 4 or more medications. Tables 1 and 2 provide a summary of demographic and health-related characteristics.
Table 1. Summary of demographic information (N=30).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>44.1 (9.7)</td>
</tr>
<tr>
<td>Median</td>
<td>46</td>
</tr>
<tr>
<td><strong>Gender, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>20 (67)</td>
</tr>
<tr>
<td>Female</td>
<td>8 (27)</td>
</tr>
<tr>
<td>Transgender female</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (3)</td>
</tr>
<tr>
<td><strong>Self-reported race or ethnicity, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>17 (57)</td>
</tr>
<tr>
<td>Black or African American</td>
<td>7 (23)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Native American</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Other</td>
<td>3 (10)</td>
</tr>
<tr>
<td><strong>Marital status, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Married or domestic partnership</td>
<td>4 (13)</td>
</tr>
<tr>
<td>Divorced</td>
<td>9 (30)</td>
</tr>
<tr>
<td>Single or never married</td>
<td>17 (57)</td>
</tr>
<tr>
<td><strong>Children, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>18 (60)</td>
</tr>
<tr>
<td><strong>Number of children for those with ≥ 1 child</strong></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>2.9 (1.6)</td>
</tr>
<tr>
<td>Median</td>
<td>2</td>
</tr>
<tr>
<td><strong>Highest level of education, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Less than high school</td>
<td>8 (27)</td>
</tr>
<tr>
<td>High school graduate or GED&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12 (40)</td>
</tr>
<tr>
<td>Trade, technical, or vocational training</td>
<td>4 (13)</td>
</tr>
<tr>
<td>Some college</td>
<td>5 (17)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (3)</td>
</tr>
<tr>
<td><strong>Military veteran, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2 (7)</td>
</tr>
<tr>
<td><strong>Employment status&lt;sup&gt;b&lt;/sup&gt;, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Not employed</td>
<td>24 (83)</td>
</tr>
<tr>
<td>Employed</td>
<td>5 (17)</td>
</tr>
<tr>
<td><strong>Reason if unemployed&lt;sup&gt;b,c&lt;/sup&gt;, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Looking for work</td>
<td>6 (23)</td>
</tr>
<tr>
<td>Laid off</td>
<td>2 (8)</td>
</tr>
<tr>
<td>Disabled or medical reason</td>
<td>19 (73)</td>
</tr>
<tr>
<td>Other</td>
<td>3 (12)</td>
</tr>
<tr>
<td><strong>Annual income (US $), n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>0–10,000</td>
<td>27 (90)</td>
</tr>
<tr>
<td>Variables</td>
<td>Values</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>10,001-20,000</td>
<td>3 (10)</td>
</tr>
</tbody>
</table>

**Slept most nights**, n (%)

<table>
<thead>
<tr>
<th>Location</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>On the street</td>
<td>20 (67)</td>
</tr>
<tr>
<td>In a shelter</td>
<td>2 (7)</td>
</tr>
<tr>
<td>Other</td>
<td>9 (30)</td>
</tr>
</tbody>
</table>

**Length of homelessness (years)**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>8.1 (7.7)</td>
</tr>
<tr>
<td>Median</td>
<td>5</td>
</tr>
</tbody>
</table>

aGED: general educational development.
bData were missing for some participants.
cRespondents may have chosen more than one response.
Table 2. Summary of baseline health information (N=30)\(^a\).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of chronic conditions</strong></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>2.8 (1.4)</td>
</tr>
<tr>
<td>Hypertension, n (%))</td>
<td>19 (63)</td>
</tr>
<tr>
<td>Diabetes mellitus, n (%)</td>
<td>5 (17)</td>
</tr>
<tr>
<td>High cholesterol, n (%)</td>
<td>9 (30)</td>
</tr>
<tr>
<td>Asthma, n (%)</td>
<td>12 (40)</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease, n (%)</td>
<td>11 (37)</td>
</tr>
<tr>
<td>Congestive heart failure, n (%)</td>
<td>2 (7)</td>
</tr>
<tr>
<td><strong>Number of prescribed medications, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>2-3</td>
<td>14 (47)</td>
</tr>
<tr>
<td>4-5</td>
<td>12 (40)</td>
</tr>
<tr>
<td>≥6</td>
<td>4 (13)</td>
</tr>
<tr>
<td><strong>Self-reported number of ED(^b) visits or hospitalizations in past 6 months, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>18 (60)</td>
</tr>
<tr>
<td>3</td>
<td>6 (20)</td>
</tr>
<tr>
<td>4</td>
<td>3 (10)</td>
</tr>
<tr>
<td>≥5</td>
<td>3 (10)</td>
</tr>
<tr>
<td><strong>Visited ED in past 30 days (self-report), n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>17 (57)</td>
</tr>
<tr>
<td><strong>Visited hospital in past 30 days (self-report), n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>7 (23)</td>
</tr>
<tr>
<td><strong>Functional limitations, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Deaf or difficulty hearing (yes)</td>
<td>8 (27)</td>
</tr>
<tr>
<td>Blind or difficulty seeing when wearing glasses (yes)</td>
<td>11 (37)</td>
</tr>
<tr>
<td>Difficulty walking or climbing stairs (yes)</td>
<td>15 (50)</td>
</tr>
<tr>
<td>Difficulty dressing or bathing (yes)</td>
<td>5 (17)</td>
</tr>
<tr>
<td><strong>Number of functional limitations, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>8 (27)</td>
</tr>
<tr>
<td>2</td>
<td>6 (20)</td>
</tr>
<tr>
<td>≥3</td>
<td>6 (20)</td>
</tr>
<tr>
<td><strong>CAGE(^c) substance abuse screening score, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>≥2</td>
<td>10 (33)</td>
</tr>
<tr>
<td><strong>Drug use in past year, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>16 (53)</td>
</tr>
<tr>
<td><strong>Health literacy level</strong></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>13.7 (5.2)</td>
</tr>
<tr>
<td>Median</td>
<td>14.5</td>
</tr>
<tr>
<td>Limited, n (%)</td>
<td>13 (43)</td>
</tr>
<tr>
<td>Marginal, n (%)</td>
<td>5 (17)</td>
</tr>
<tr>
<td>Adequate, n (%)</td>
<td>12 (40)</td>
</tr>
</tbody>
</table>

\(^a\)Percentages are out of 30 and more than one response was allowed per respondent.
Accuracy of the GPS Technology

Accuracy of the GPS technology was calculated for the 25 participants who completed a release of information form, giving permission for the research team to access data in the HIE. During the 4-month study period, HIE use data indicated that these participants made 16 hospital or ED visits. Community health paramedics received 14 total geofence entry notifications during the study period; of these 14 notifications, 2 (14%) were from participants without a release of information for the HIE. Thus, community health paramedics received 12 geofence entry notifications for the 25 participants from whom HIE data were available. However, only 3 of the geofence entry notifications were consistent with the HIE use data for an overall accuracy rate of 19%.

Of the 16 ED and hospital visits reported by the HIE data for which community health paramedics did not receive geofence entry notifications, 4 (25%) occurred during the first month of the intervention, a time during which the research staff identified a technical issue with the mobile app and geofence entries were not being received. Of these 16 visits, 3 (19%) occurred in the window of time during which the participant was without the study-assigned smartphone as the smartphone had been stolen or misplaced but not yet replaced. It is unclear why the remaining 43% (6/14) ED and hospital visits reported by the HIE data did not result in a geofence notification entry.

Community Health Paramedic Interventions

Community health paramedics successfully reached participants to conduct follow-up and provide care coordination assistance after 79% (11/14) of geofence notifications. Of these 11 contacts, 10 (91%) lasted ≤10 minutes, and 1 (9%) contact lasted between 11 and 20 minutes. Of these 11 contacts, 3 (27%) participants reported having accompanied a friend or family member to the ED and were not seen themselves, and 1 (9%) participant reported having visited the hospital campus for a scheduled medical visit. Thus, 36% (4/11) of these geofence notifications were classified as false positives. Of the remaining 7 contacts, 3 (43%) aligned with the HIE notification data. Of the remaining 4 contacts, 3 (75%) did not align with the HIE data, as the participants did not have a release of information form on the file. It is unclear why the remaining contact did not register with the HIE.

Community health paramedics determined that 43% (3/7) of the ED visits were emergent and likely unavoidable. Reasons for the emergent ED visits included chronic pulmonary obstructive disease exacerbation, a physical altercation at a local shelter, and uncontrolled epigastric pain. Reasons for the remaining ED visits were skin irritation because of scabies infection, shoulder pain, and 2 visits for gastrointestinal illness.

Community health paramedics judged each of these 4 visits to be due to ambulatory care–sensitive conditions that could have been appropriately managed in the outpatient setting.

Depression

There was a significant difference in depressive symptoms between baseline (mean 16.9, SD 5.8) and exit (mean 12.7, SD 8.2; t(19)=2.892; P=.009), indicating fewer depressive symptoms at the 4-month exit.

Medication Adherence

At baseline, scores on the ASK-12 ranged from 14-30 (mean 20.5, SD 4.4). Among those who completed the 4-month intervention, there was a significant difference in medication behavior between baseline (mean 2.4, SD 1.4) and exit (mean 1.5, SD 1.5; t(17)=2.47; P=.03), indicating that at the 4-month exit visit, there were fewer barriers to taking medications.

Social Support

There was no significant difference in social support between baseline (mean 3.2, SD 1.1) and exit (mean 2.9, SD 1.3; t(15)=1.25; P=.23).

Experience With and Acceptance of Technology

At baseline, 50% (15/30) of participants reported having a mobile phone. Of these 15 patients, 12 (80%) had current wireless service (4/12, 33% participants had pay as you go service plans; 3/12, 25% had prepaid plans, 3/12, 25% had month-to-month contracts; and 2/12, 17% had free minutes through government-funded plans). Of the 15 participants with mobile phones, 13 (87%) reported that their mobile phones could support both SMS text messaging and mobile apps. At the exit interview, participants agreed that the smartphone app was easy to use (mean 4.4, SD 1.0), that they had the knowledge to use the smartphone app (mean 4.6, SD 0.5), and that they planned to continue using both a smartphone (mean 4.5, SD 0.6) and GPS technology (mean 4.4, SD 0.5). The acceptance of technology questionnaire indicated that participants had a high level of agreement at baseline and exit with items such as having the resources and knowledge to use smartphone technology and being comfortable with the health care team being alerted about ED or hospital use. There was a significant increase in agreement level from baseline (mean 3.9, SD 0.8) to exit (mean 4.4, SD 0.5) for the item, “My friends would encourage me to use this Smartphone app.” Participants’ agreement level increased for several other items, such as having the knowledge and resources to use GPS technology from baseline to exit, but not significantly. Table 3 summarizes the participants’ technology acceptance at baseline and the 4-month exit interview.
Table 3. Perceptions of acceptance of technology at baseline and 4-month exit interview.

<table>
<thead>
<tr>
<th>Item</th>
<th>Baseline, mean (SD)</th>
<th>Exit, mean (SD)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have the resources necessary to use smartphone technology</td>
<td>4.4 (0.5)</td>
<td>4.4 (1.0)</td>
<td>.86</td>
</tr>
<tr>
<td>I have the knowledge necessary to use smartphone technology</td>
<td>4.6 (0.4)</td>
<td>4.7 (0.5)</td>
<td>.28</td>
</tr>
<tr>
<td>I can get help from others when I have difficulties using smartphone technology</td>
<td>4.2 (0.7)</td>
<td>4.5 (0.8)</td>
<td>.28</td>
</tr>
<tr>
<td>I find GPS technology useful in my daily life</td>
<td>4.2 (0.8)</td>
<td>4.4 (1.0)</td>
<td>.39</td>
</tr>
<tr>
<td>I find GPS technology easy to use</td>
<td>4.1 (0.8)</td>
<td>4.3 (1.1)</td>
<td>.33</td>
</tr>
<tr>
<td>I have the resources necessary to use GPS technology</td>
<td>3.8 (1.2)</td>
<td>4.2 (1.3)</td>
<td>.29</td>
</tr>
<tr>
<td>I have the knowledge necessary to use GPS technology</td>
<td>4.1 (1.0)</td>
<td>4.6 (0.5)</td>
<td>.06</td>
</tr>
<tr>
<td>I am comfortable with my health data being stored online</td>
<td>3.6 (1.3)</td>
<td>4.1 (0.9)</td>
<td>.13</td>
</tr>
<tr>
<td>I believe my health information will be protected on a smartphone</td>
<td>3.7 (1.2)</td>
<td>3.6 (1.1)</td>
<td>.88</td>
</tr>
<tr>
<td>I am comfortable with my health care team being alerted when I go to the emergency department or hospital</td>
<td>4.8 (0.4)</td>
<td>4.7 (0.5)</td>
<td>.33</td>
</tr>
<tr>
<td>I think using GPS is a good way to notify my health care team when I visit the emergency department or hospital</td>
<td>4.5 (0.6)</td>
<td>4.7 (0.5)</td>
<td>.27</td>
</tr>
<tr>
<td>I think using this smartphone app can help me improve my overall health</td>
<td>4.3 (0.6)</td>
<td>4.5 (0.5)</td>
<td>.16</td>
</tr>
<tr>
<td>My friends would encourage me to use this smartphone app</td>
<td>3.9 (0.8)</td>
<td>4.4 (0.5)</td>
<td>.04</td>
</tr>
<tr>
<td>My family members would encourage me to use this smartphone app</td>
<td>4.0 (1.0)</td>
<td>4.1 (1.0)</td>
<td>.85</td>
</tr>
</tbody>
</table>

**Quality of Care Transitions**

At baseline, 57% (17/30) of participants self-reported at least one ED or hospital visit in the previous 30 days and completed the CTM-15. At months 1, 2, 3, and exit, 33% (10/30), 13% (4/30), 13% (4/30), and 17% (5/30) of participants, respectively, self-reported at least 1 ED or hospital visit in the previous 30 days and completed the CTM-15 for their most recent visit. The mean score for the critical understanding and management preparation domains was 4.1, indicating that participants generally agreed that they left the hospital or ED understanding how to manage medications and their health. The mean score for the preferences important domain was 4.0 (SD 0.1), which means that participants agreed that hospital staff took their preferences for health care needs into account when planning for discharge. The lowest level of agreement was with the care plan domain (mean 3.8, SD 0.0). Table 4 provides a summary of the scores for each item and domain.
Table 4. Summary of perceptions of the quality-of-care transitions using the care transitions measure (N=40 hospital or ED\textsuperscript{a} visits).

<table>
<thead>
<tr>
<th>Domains and items</th>
<th>Mean (SD)\textsuperscript{b}</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Critical understanding</strong></td>
<td></td>
</tr>
<tr>
<td>When I left the hospital or ED, I clearly understood the purpose for taking each of my medications.</td>
<td>4.1 (0.8)</td>
</tr>
<tr>
<td>When I left the hospital or ED, I clearly understood how to take each of my medications, including how much I should take and when.</td>
<td>4.3 (0.7)</td>
</tr>
<tr>
<td>When I left the hospital or ED, I clearly understood the possible side effects of each of my medications.</td>
<td>4.0 (1.1)</td>
</tr>
<tr>
<td>When I left the hospital or ED, I had a good understanding of the things I was responsible for in managing my health.</td>
<td>4.2 (0.8)</td>
</tr>
<tr>
<td>When I left the hospital or ED, I was confident that I knew what to do to manage my health.</td>
<td>3.9 (1.0)</td>
</tr>
<tr>
<td>When I left the hospital or ED, I was confident I could actually do the things I needed to do to take care of my health.</td>
<td>3.8 (1.1)</td>
</tr>
<tr>
<td>Domain overall mean</td>
<td>4.1 (0.2)</td>
</tr>
<tr>
<td><strong>Preferences important</strong></td>
<td></td>
</tr>
<tr>
<td>Before I left the hospital or ED, the staff and I agreed about clear health goals for me and how those would be reached.</td>
<td>3.9 (1.2)</td>
</tr>
<tr>
<td>The hospital staff took my preferences into account in deciding what my health care needs would be when I left the hospital or ED.</td>
<td>4.1 (1.0)</td>
</tr>
<tr>
<td>The hospital staff took my preferences into account in deciding where my health care needs would be met when I left the hospital or ED.</td>
<td>4.0 (1.1)</td>
</tr>
<tr>
<td>Domain overall mean</td>
<td>4.0 (0.1)</td>
</tr>
<tr>
<td><strong>Management preparation</strong></td>
<td></td>
</tr>
<tr>
<td>When I left the hospital or ED, I had all the information I needed to be able to take care of myself.</td>
<td>4.0 (0.9)</td>
</tr>
<tr>
<td>When I left the hospital or ED, I clearly understood how to manage my health.</td>
<td>3.9 (0.9)</td>
</tr>
<tr>
<td>When I left the hospital or ED, I clearly understood the warning signs and symptoms I should watch for to monitor my health condition.</td>
<td>4.2 (0.8)</td>
</tr>
<tr>
<td>When I left the hospital or ED, I had a good understanding of my health condition and what makes it better or worse.</td>
<td>4.1 (0.9)</td>
</tr>
<tr>
<td>Domain overall mean</td>
<td>4.1 (0.1)</td>
</tr>
<tr>
<td><strong>Care plan</strong></td>
<td></td>
</tr>
<tr>
<td>When I left the hospital or ED, I had a readable and easily understood written list of appointments I needed to complete within the next several weeks.</td>
<td>3.8 (1.1)</td>
</tr>
<tr>
<td>When I left the hospital or ED, I had a readable and easily understood written plan that described how all of my health care needs were going to be met.</td>
<td>3.8 (1.2)</td>
</tr>
<tr>
<td>Domain overall mean</td>
<td>3.8 (0.0)</td>
</tr>
</tbody>
</table>

\textsuperscript{a}ED: emergency department.

\textsuperscript{b}Participants indicated their level of agreement with each item using a Likert scale from 1=strongly disagree to 5=strongly agree.

**Qualitative Findings**

Of the 30 participants, 17 (57\%) completed an exit interview. During data analysis, the first 2 authors of this study organized the codes into the following categories: (1) benefits of study participation, (2) challenges to study participation, (3) perceptions of GPS technology, and (4) suggestions for improvement.

Overall, participants reported positive experiences with study participation. They also identified several benefits, defined as any real or perceived aid or assistance from participating in the research study or having access to the unlimited use of a smartphone. Benefits included self-management support, improved social connections, and improved well-being. An example of how study participation provided self-management support is demonstrated by this quote:

\[\ldots\text{there was a time when I [...] would be confused as to whether or not I took my medicine. Sometimes I would go days without even thinking about it, you know? But now, I am confident knowing that every morning you know “Bam!”, you know it’s [daily email] right there and I had my medication and had taken it. There was never any more confusion.}\]

Social connections were facilitated by the ability to call friends and family, to stay up to date on current events by reading the news on the internet, and to use social media sites. Several participants described using the smartphone to reconnect with the family from out of state. One participant put it succinctly as follows:

\[\ldots\text{being homeless, you can be very bored sometimes with nothing to do. And, [with the phone] I had something to do. You can read the news and find out}\]
Participants also described improved well-being as they did not have to worry about paying for their smartphone, were able to travel to appointments because of bus pass on the smartphone, and felt more secure in their environments with the ability to contact the police or emergency medical services in the case of an emergency. An example of how study participation improved well-being is demonstrated by the following quote:

*It was a godsend. It really was, I mean because I didn’t have to worry about a lot of things. I could make phone calls when I needed to. It just took a lot of burden off me, knowing that I had a bus pass. I had a phone I could use you know if I got in trouble or something or was in a bad situation.*

Challenges to study participation were defined as circumstances in which participants had to navigate to access, use, and benefit from services and resources, including the research study itself. Challenges included differential treatment because of homelessness, difficulty with technology, and keeping the smartphone secure. For example, differential treatment resulted in participants having difficulty keeping their smartphones charged as business owners do not allow people experiencing homelessness to spend time charging smartphones in their establishments. Some participants also described trouble with technology, such as short battery life and slow internet service. Finally, keeping the smartphone secure required constant vigilance on the part of participants, and even with creative solutions for safekeeping, many experienced theft or damage to their smartphones. One participant expressed his desire for smartphones to be replaced up to 4 times, saying as follows:

* [...] the fact is, anything can happen out here. Like you know, I was charging my phone at Starbucks. I fell asleep, and when I woke up, my phone was stolen. Got my second phone...but I forgot to put the case back on and water hits it and its out.*

Perceptions of the GPS technology were uniformly positive, as each participant who completed the exit interview denied having concerns about the community health paramedics or research staff knowing when they visited the ED or hospital. One participant clearly articulated this by saying the following:

*...you know, that kind of thing right now is the least of my concerns. If you’re sleeping in an alley or somewhere else, you’re not really worried about somebody knowing that you’ve been to the hospital, or at least I’m not.*

Suggestions for improvement included two main subcategories: helping to complete the study requirements and tailoring the intervention. Participants suggested more teaching about using the smartphone and its functions and providing portable battery chargers to help overcome some of the technical challenges to study completion that participants faced. Participants also suggested sending daily messages via text instead of email and indicated that personalized and tailored medication reminders for their individual medication regimens would be helpful.

**Discussion**

**Principal Findings**

The results of this study contribute to a small but growing body of literature documenting the utility of mHealth interventions among people experiencing homelessness. First, our findings suggest that GPS technology is not a reliable method for tracking visits to the ED or hospital among people experiencing homelessness. The geofence notifications aligned with objective HIE use data only 18.8% of the time, indicating that the community health paramedics were unable to connect with participants to provide follow-up assistance with care coordination after most participant ED and hospital visits. This finding was surprising given recent evidence that a smartphone app used by 12 patients with low income had 75% accuracy in detecting real-time ED or hospital use over a 3-month period [36]. It is likely that the results of this study are inconsistent with this prior evidence because of variations in the real-world use of smartphones among a population without consistent access to electricity. Specifically, a strategy that participants used to preserve the smartphone battery was to power the smartphone off when it was not in use. As geofence technology relies on real-time transmission of data, it is likely that one reason entry notifications were not received was as the smartphone was turned off when the geofence entry occurred.

Despite findings that GPS technology is not reliable for real-time ED or hospital use data, overall, participants expressed positive views of GPS technology. Participants embraced the idea of GPS being used by health care and other service providers to locate them if needed and described feeling more secure with the knowledge they could be found. This is similar to findings by Liss et al [9], who found that high-risk primary care patients were willing to use GPS technology to facilitate care coordination. Findings by Liss et al [9] also align with prior work by Moczygemba et al [37], which indicate that clinicians and care managers are particularly interested in using mHealth for care coordination among high-risk patients and patients experiencing homelessness [9,13]. This is particularly important as community health paramedics indicated that 57% (4/7) of ED or hospital visits were likely nonemergent visits that could have been addressed in the outpatient setting. Collectively, these findings suggest the need for app development and refinement as the GPS location tracking apps that are currently in the market do not have face validity or the specific functionality needed for use in the health care setting.

There was a significant decrease in depression symptoms from baseline to exit, which aligns with the qualitative findings where participants reported improved well-being and an overall positive experience with the intervention at the study exit. In contrast, a 1-month, pre-post study of homeless young adults (aged 18-24 years) who participated in a remote mental health intervention, which included SMS text messaging, did not find a difference in depression symptoms [38]. This may be as it takes longer than 1 month to see a difference in depression symptoms, although this finding warrants further study. The results also indicate an improvement in medication adherence as measured by the ASK-12. These findings support the findings
of Morawski et al [39], in which the use of a smartphone app resulted in improved medication adherence among patients with hypertension. Participants in this study viewed the daily email question regarding medication adherence as a helpful reminder that supported adherence. The data also suggest that participants used their smartphones as a self-management support tool by downloading specific medication adherence apps or by setting alarms to help with medication management. This use of the smartphone as a tool is also evidenced by overall high scores regarding acceptance of technology at baseline and exit.

Although there was no significant difference in social support between baseline and exit, the qualitative data suggest that the smartphone had an impact on participants’ social connections. Prior evidence clearly indicates that social support can have a protective influence on multiple health outcomes among people experiencing homelessness [40] and that mobile phones are critical for individuals experiencing homelessness to maintain social connectedness to family and friends [41]. Thus, measuring social support in future studies investigating mHealth interventions among people experiencing homelessness is important for ascertaining a holistic picture of the benefits of smartphone technology among the homeless population.

Overall, the participants rated care transitions from the ED or hospital to the community fairly high. However, the results suggest that specific aspects of transitions could be improved. For example, in the critical understanding domain, two items related to understanding what and how to manage health on discharge and one item related to medication side effects scored lower than the remaining domain items. Future studies could investigate adapting the mHealth intervention to provide targeted follow-up post-ED or hospital discharge as well as specific guidance related to medication side effects to maximize adherence and optimize outcomes. Furthermore, the care plan domain scored the lowest among the four domains. This further supports the need to adapt the intervention to provide two-way communication between people experiencing homelessness and service providers to ensure that needed follow-up care is received in a timely and accessible manner.

Study Limitations
The findings of this study should be interpreted with caution because of the study’s limitations. Participants were recruited from one city in a large, southern state using convenience sampling; therefore, the generalizability of the findings is unknown. Furthermore, participants were recruited from community sites, which may have biased the results. The pre-post design is subject to bias, and as study participants were selected on the basis of their PHQ-9 score, it is possible that regression to the mean occurred for the depression symptom outcome. There were also baseline differences in PHQ-9 scores between the groups that did and did not complete the study ($t_{21}=-2.17; P=0.02$) with the group that did not complete the study having a higher mean score at baseline than the group that did finish. The small sample size, although sufficient for answering this study’s research questions, may further limit the generalizability of the findings.

Future Directions
The findings from this study point to several directions for future research. First, based on participants’ responses to the daily email medication adherence message and their stated preferences for SMS text messages, a subsequent study tested an expanded SMS text messaging intervention. That study also included testing the use of remote location services preinstalled on the smartphone to locate participants during business hours. The findings also suggest that in addition to unlimited access to a smartphone, access to unlimited transportation can facilitate the ability of people experiencing homelessness to self-manage chronic illness. Thus, future research could investigate the impact of providing accessible transportation on health outcomes and use. Finally, because of the shortcomings of GPS technology in communicating real-time health care use information for people experiencing homelessness and as there is an operational HIE in the local area, future research investigating care coordination should incorporate the HIE to ensure transmission of objective use data. Qualitative findings also suggest that mHealth interventions, particularly unlimited access to a smartphone and bus pass transportation, have numerous benefits for well-being and the ability of people experiencing homelessness to meet social needs. These concepts need to be explored quantitatively in future studies. Furthermore, coupling access to a smartphone and transportation with health care programs should be pursued at a policy level for local programs [42,43].

Conclusions
mHealth interventions are acceptable to people experiencing homelessness and positively affected depression symptoms and medication adherence. Objective data from the HIE provided more accurate ED and hospital use information compared with alerts relying on predefined geofences. Despite this, participants favorably viewed GPS technology, warranting further exploration of GPS technology as a tool for facilitating care coordination among people experiencing homelessness.

Acknowledgments
The authors gratefully acknowledge the partners who made this study possible. This includes the Sunrise Community Navigation Center, First United Methodist Church of Austin, Austin-Travis County Paramedics, and Integrated Care Collaborative. The authors also thank Azova, a digital platform for this study.

Conflicts of Interest
None declared.
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