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RESEARCH ARTICLE

Toward a Unified mHealth Platform: A Survey of Current User Challenges and Expectations

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ABSTRACT Mobile health (mHealth) applications have become ubiquitous and have enabled self-monitoring to help provide better health outcomes. However, the wide availability of mHealth apps introduces new challenges when users need to download and use several apps. While past app evaluations have highlighted many issues, the surrounding work is limited. This study aims to analyse the current user challenges and expectations from future mHealth apps. This information is important to inform and guide the design of better and more attractive mHealth platforms of the future. For our empirical investigation of user feedback, we designed an anonymous online survey using key dimensions from the Mobile Application Rating Scale (MARS), the Technology Acceptance Model (TAM) and the Value Proposition Canvas. Our survey was distributed via online channels such as Twitter and LinkedIn, and we received 70 valid responses that indicated challenges such as functional overlaps between different apps, unnecessary features, and poor customizability. Similarly, most respondents expressed their preference for a single platform to manage their health. These challenges suggest the need to design more capable unified mHealth platforms that can be tailored to a user's needs. While the development of such platforms raise valid questions around the increase in software complexity and privacy concerns around user data, an open design can address these concerns and offer a better experience. Overall, these findings indicate the need for more research into mHealth app design strategies where the regular use of more than one app must be considered to create better, more engaging mHealth apps.

INDEX TERMS mHealth, eHealth, mHealth apps, usability survey, user challenges, user expectations.

I. INTRODUCTION

Mobile health (mHealth) apps support healthcare through the use of mobile phones, wearables and other wireless devices [1]. Over the years, health apps have been developed for several use-cases such as managing one's weight [2], drug dosage [3], [4] and even more critical uses such as monitoring cardiac health [5]. mHealth apps together with external sensors have also enabled self-monitoring of one's health, where systems unobtrusively collect health data to provide better health outcomes, which is important for patients living in areas with limited access to healthcare [2]. Today, over 350,000 health apps are available in commercial app stores [6], with this market continuing to grow by 25% each year [7]. Similarly, mHealth apps have also seen high adoption, with the expected user base exceeding 87 million in 2020 in just the United States [8].

Apart from offering users several options, the presence of several thousand apps also introduces many challenges to the end user experience (UX). Numerous applications are

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available without any review of their contents, and thus may contain poor quality information or can also be completely irrelevant [3], [9], [10], [11], making it very challenging for users to locate applications and to make an informed decision around which applications to use [10], [12], [13]. Most apps do not offer comprehensive feature sets, which, along with proprietary hardware solutions, presents a challenge that force users to rely on more than one app [3], [12]. Unsurprisingly, a study by Velsen, Beaujean et al. indicated that the need to unnecessarily install more apps on one's phone deters users from downloading health apps [12]. Users also abandon their mHealth apps after using them a couple of times [14], [15]. Since mHealth apps collect or work with personal health data, there is a challenge of user perception around the trustworthiness of apps [16] which can also deter users from using these platforms entirely. Similarly, issues around small, restrictive mobile interfaces coupled with learnability issues [17], [18], [19] drive users away.

Past studies have evaluated mHealth apps covering several perspectives such as their usability [20], their impact on health outcomes [21], and the use of smartphone sensors for monitoring health metrics [22]. Recent studies have revealed interconnectivity and convenience as two factors impacting UX [23]. Good UX is important and well-designed app functionality would be better than using several apps. Therefore, there is a need to develop a smaller number of apps meeting several user requirements [24]. Similarly, studies around app usability have also found them to be inefficient where interfaces were not found to work well for end-users [25]. The presence of numerous sensors and wearables along with the increasing need to use more than one health app has several challenges from the end user perspective.

Past works have made contributions to understanding mHealth app usability. For example, Anderson et al. conducted a study of user experience in 2016 to provide an insight into consumer engagement with self-monitoring tools [23]. They conducted semi-structured interviews with 22 end-users having experience with several apps ranging from diabetes management to fitness apps and extracted information around app engagement, app functionality, ease-of-use and design features, and data management. The data they collected suggested self-management can be improved using mHealth apps. While the use of a wide range of apps was considered in the study, the impact to usability from using more than one app was not a key area of focus. Similarly, a 2019 study among mHealth experts and users [26] highlights the challenges around user retention, where users spend less than 30 seconds to learn how to use an application before giving up and looking for alternatives. The authors recognise the importance of usability in the success of mHealth apps and focused on the alignment of concerns and priorities between mHealth insiders and end-users to develop their suggestions. However, issues around the use of several health apps were not considered.

Usability models such as the Nielsen Model [19] are commonly used in app evaluations, but they also tend to ignore issues specific to mobile platforms such as data entry and hardware limitations. Similarly, other studies on mHealth apps, wearables and consumer expectations [27], [28], [29], [30] are restricted by their focus on specific apps or a limited audience. For instance, a 2019 study by Koh et al. [31] evaluated the acceptance and user expectations from mHealth apps for skin self-examinations and teledermoscopy to drive the development of a new app. While the study identified the usefulness of mobile apps for skin conditions along with user expectations, the study was very specific to apps for detecting melanoma. Another recent study conducted with healthcare professionals to determine their expectations with mHealth apps [32] has shown expectations of data protection and privacy with a high acceptance of app-based therapies. However, just like the others, the study was still limited to one specific domain.

Our objective in this study is to evaluate the usage pattern of end-users with several mHealth applications with the following key objectives around identifying –

- *The main challenges faced by users when using several mHealth apps (i.e., 'Pains' from the Value-Proposition canvas).*
- *User Expectations from future mHealth apps (i.e., 'Gains' from Value-Proposition canvas).*

We designed an online survey using constructs from the Mobile App rating Scale (MARS) and the Technology Acceptance Model (TAM) and the Value Proposition Canvas to help us explore the above among mHealth app users. In our previous short paper [33] we presented key findings relevant to the mobile app development community. In this manuscript, we expand on the paper and present the complete set of results and extended analysis of the collected data, targeting the broader research community. In the following sections, we present a motivating example, our survey design (section II), results (section III), our analysis and a proposed approach for mitigating these problems (section IV).

A. MOTIVATING EXAMPLE

The number of mHealth apps available today has been steadily growing, and a simple search for terms like ''mHealth'' or ''health'' returns a long list of applications. Given the number of overlaps between app features, it also becomes difficult for users to choose between them. Users often also need more than one app to meet their needs.

Figure 1 shows an example where three apps are used for managing one's weight by tracking their body measurements, exercise, and meals. The images show overlapping features around tracking these parameters (highlighted in red and green). It can also be seen that the apps offer additional, unique features; however, they may not all be used as the user requirements are limited to a few specific tasks. In this example, several applications are available, where

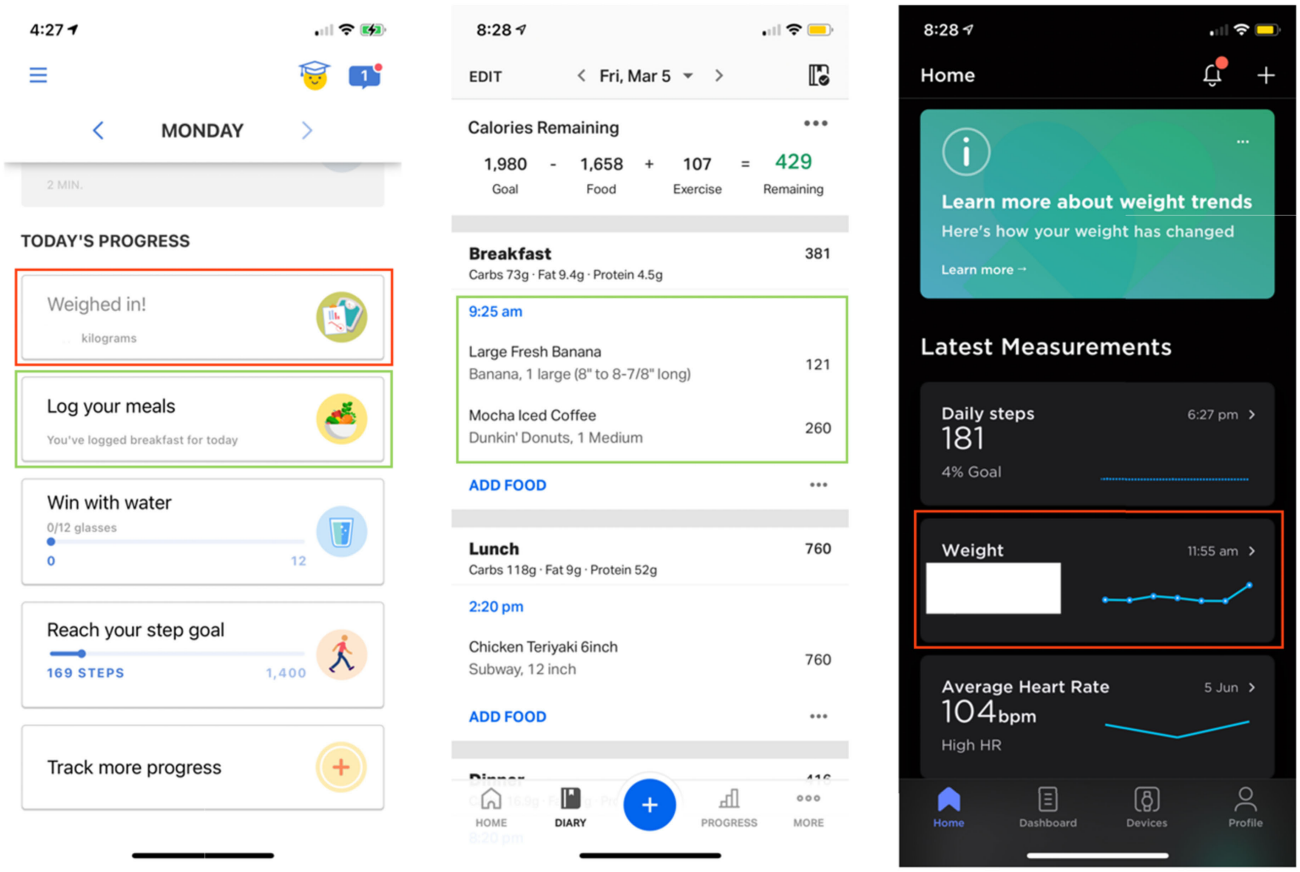

FIGURE 1. Screenshots from three apps showing overlapping features for tracking weight (highlighted in red) and meals (highlighted in green).

some are more suitable for certain activities. Noom,[1] a popular weight-loss coaching app, offers limited weight and meals tracking features. However, other apps like MyFitnessPal[2] may be preferable as they offer a much more comprehensive food database. Such apps can be better alternatives for tracking nutrition. Similarly, Fitbit and Withings offer hardware that integrate with their own apps[3],[4] to help track physical metrics such as weight, heart rate and body composition. Several apps, including the above, offer basic exercise tracking features. However, specialised apps such as Strava[5] offer better features for more specific workouts such as running and cycling. Unfortunately, they all would provide different experiences and would require users to juggle between different interfaces and designs to meet the same health goal. Similarly, users may need to enter similar data manually across their apps, further degrading the UX. Although the major smartphone operating systems (iOS and Android) offer robust data sharing mechanisms through frameworks like Apple Health[6] and Google Fit,[7] not all apps have these features implemented.

In this scenario, while one app may provide some basic functionality, a better, more detailed health insight could be obtained by combining them all. In this paper, we present a survey validating these challenges and our hypothesis.

II. METHODOLOGY

Our questionnaire is based on 1) the Technology Acceptance Model (TAM) constructs (Usefulness and Ease of Use); and 2) the Mobile App Rating Scale (MARS) constructs (Design and Aesthetics, Engagement and Functionality). These were aligned with 3) the value proposition canvas (focusing on the needs of users and gains of the technology). The following subsections briefly discuss the evaluation frameworks and the design of our survey.

A. EVALUATION FRAMEWORKS

As TAM, MARS and the Value Proposition Canvas have proven useful in identifying challenges around adopting and using existing mHealth apps, and evaluating app quality, a combination of these frameworks was chosen for

[1]https://play.google.com/store/apps/details?id=com.wsl.noom
[2]https://play.google.com/store/apps/details?id=com.myfitnesspal.android
[3]https://play.google.com/store/apps/details?id=com.fitbit.FitbitMobile
[4]https://play.google.com/store/apps/details?id=com.withings.wiscale2
[5]https://play.google.com/store/apps/details?id=com.strava
[6]https://www.apple.com/au/ios/health/
[7]https://developers.google.com/fit

identifying challenges faced by end-users and understanding expectations from future health services.

The TAM was introduced in 1989 to measure two variables around the use and acceptance of technology – perceived usefulness and perceived ease of use [34]. The framework has been applied in several studies and has been extensively used for evaluating the UX and understanding the adoption of mHealth platforms [35], [36], [37].

The MARS is a tool for evaluating the quality of applications and explores factors around engagement, functionality, aesthetics, information quality and subjective quality [38]. The scale has been widely used for evaluating the quality of a wide range of health apps, from drug reference to apps for cancer patients to weight management [39], [40], [41].

The Value Proposition Canvas is another tool used to assist with the development of services that consumers would want to use [42]. The canvas is divided into two parts – the Value Proposition and the Customer Profile, and we focus on the customer profile to explore the 'Pains', or challenges faced by end-users, 'Gains', or the expectations from future applications. These two segments identify different aspects of service development and include the 'Customer Profile' and a 'Value Map'. The customer profile describes the Customer Jobs (what users want to achieve), pains (challenges faced by the users in performing tasks) and gains (the expected benefits), while the Value Map describes the proposed values/benefits related to the Customer Profile [42]. Although the framework is designed for developing businesses by connecting them with customers, it has also been used for identifying the value proposition in eHealth applications [43].

B. SURVEY QUESTIONNAIRE

Our survey was divided into four sections to collect data on (1) Usage patterns to identify user objectives and app types (conforming to the app usage lifecycle and the value proposition canvas); (2) App discovery and acceptance (aligning with the app usage lifecycle); (3) Challenges around the use of several mHealth apps (aligning with the 'Pains' component of the value proposition canvas); and (4) Expectations from future health apps (aligning with the 'Gains' component of the value proposition canvas). Categories (1) and (2) were subjective, giving the users flexibility in their responses. Since our focus is on the need to use several mHealth apps and the challenges they introduce, categories (3) and (4) used a five-point likert scale to understand challenges users face and their expectations. Our survey focused on 5 key dimensions - 1) Discovery and Acceptance; 2) Functionality; 3) Design and Aesthetics; 4) Usability/Ease-of-use; and 5) Data Management. The full set of questions asked in the survey is listed in Appendix I.

C. TARGET USERS

We aimed to target a more tech-savvy population who may currently use or have experience with several mHealth applications. Recent studies on user engagement with mHealth apps have identified most participants in the age range of 18 to 40 [44], [45]. However, as we also wanted to include the elderly, our target group for this survey was participants above the age of 18, with functional English and some experience with using mHealth applications. Experience with using wearables or other peripherals would have offered additional details, but it was not a requirement. The inclusion of fitness and wellness apps allowed a larger group of respondents to participate in the survey, while also eliminating any potential bias that could be introduced by considering only medical applications such as drug reference or disease management apps.

D. DATA COLLECTION

Given the COVID-19 restrictions and limitations around interacting with end-users in person, an anonymous online survey was considered the most appropriate to reach a wide group of mHealth app users while also ensuring confidentiality of the participants. The survey was completely voluntary and Qualtrics[8] was chosen as the platform for the quantitative survey. Once approval from the university's ethics committee was obtained, an anonymous link was created and distributed through online channels such as Twitter, LinkedIn, and Facebook. Our recruitment strategy included snowball sampling where respondents were encouraged to forward the survey link to others who might also be willing, potential participants [46]. The survey was active from July through September 2021, and we received 82 responses. To ensure valid results, eligibility questions were included in the survey, which were then used to filter out disqualified participants. The collected data after the initial cleaning was then verified manually by the first author and subsequently analysed.

III. RESULTS

A. DEMOGRAPHICS

A total of 82 responses were obtained through an anonymous survey link, which were then manually reviewed to obtain 70 complete and valid responses. Participants fell in the age range of 18-60, with the highest number of participants (64.3%, n = 45) falling in the age group of 18-30. This was followed by 21.4% (n = 15) in the 31-40 group, with the 41-50 and 51-60 age groups constituting 10% (n = 7) and 4.3% (n = 3) respectively. No participants above the age of 60 were found. Of the 70 participants, 60% (n = 42) identified as male, with the remaining 40% (n = 28) female. The participant group also included people from a wide range of educational backgrounds, with 48.6% (n = 34) having completed a postgraduate degree, closely followed by 42.9% (n = 30) graduates. A small number of High School graduates (n = 4) and those with other qualifications (n = 2) also participated in the study (figure 2).

B. USAGE PATTERN

Given the presence of numerous apps with fragmented features, one of our expectations was the use of more than one

[8]https://www.qualtrics.com/

		High School	Graduate	Postgraduate	Others	Total
18 - 30	Female	1	9	6		16
	Male	2	12	15		29
31 - 40	Female		4	5		9
	Male	1	3	1	1	6
41 - 50	Female			1		1
	Male		2	3	1	6
51 - 60	Female			2		2
	Male			1		1
Total		4	30	34	2	70

FIGURE 2. Participant demographics.

app by end-users. Our survey shows that 5.7% (n = 4) of the respondents used greater than 5 apps, with the majority having experience with 2-4 apps (64.3%, n = 45). However, a significant number of participants also reported to having used just one mHealth app (30%, n = 21). Usage experience varied slightly, with over half (51.4%, n = 36) of the respondents having used them for over a year followed by a duration of three months to a year (31.4%, n = 22). However, the weekly usage pattern indicates a somewhat uniform distribution of app launches with the reported usage ranging from a few days a week (35.7%, n = 25) to daily (31.4%, n = 22), closely followed by 20% (n = 14) of the participants indicating they use their apps rarely and only when required. 12.9% (n = 9) of the participants also indicated that they only use such applications only once a week. Figure 3 shows the usage pattern of the respondents.

Of the available app categories, fitness applications (workout, meal trackers etc.) were found to be the most popular with 42.7% of the respondents using them, followed by wellbeing applications (mental health apps, meditation etc.) with 25% of the respondents and reference services (such as exercise guides) at 22.1% of the respondents using them. Wearables have also grown in popularity with numerous different categories of devices (e.g., fitness wearables and peripherals, and clinical devices) available in the market. The high inclination towards health and fitness applications also suggests a wider use of fitness hardware and this is reflected in the responses where the most popular choices were found to be fitness wearables such as smartwatches and smart rings (51%, n = 44) and fitness peripherals like smart scales (22%, n = 19). Figures 4 and 5 show the types of apps and the reasons end-users download their mHealth apps in each age category.

On app adoption, 29% of the responses for app discovery indicate the reliance on app reviews, with the same number relying on suggestions from family and friends. Developer descriptions (19.4%) and suggestions from healthcare professionals (16.9%) had a lower preference. Similarly, for app acceptance, we found poor application design as the biggest reason why users abandon apps (24%) as the participants were unable to achieve their health goals. This was followed by a healthy competition providing similar or better features (22.1%). Other major challenges included poor user-friendliness (17.3%) and issues with data entry (16.3%).

C. CHALLENGES WITH CURRENT mHealth APPS

Although several past studies have been conducted on mHealth applications, to our knowledge, there are no works on the challenges around the use of multiple applications, and we believe our results will help fill this gap and help create more functional apps in the future.

We expected most users to agree to the need for installing and managing more than one mHealth app. However, we found a mixed response, with 32.9% of the respondents remaining neutral. Several respondents (30%) also agreed to the statement, with a smaller number disagreeing (17.1%). Additional app functionality, while useful, can also be perceived as bloat when not required by users and only pushes them away. Most respondents (45.7% agreeing with 15.7% strongly agreeing) indicated the presence of feature overlaps across different apps, along with functions they don't find useful (40% agreeing with 22.9% strongly agreeing).

A major pain when using several apps is around data management. Because of the closed nature of several apps and possibly limited data sharing between them, users may need to enter duplicate data manually across applications. Although frameworks like Google Fit enable data sharing between them, not all applications support them, with past studies showing manual data entry as one big deterrent to using mHealth apps. We observed a mixed response, with several participants (40%, n = 28) accepting manual data entry when working with a single app. However, the dislike of manual data entry across several apps was more

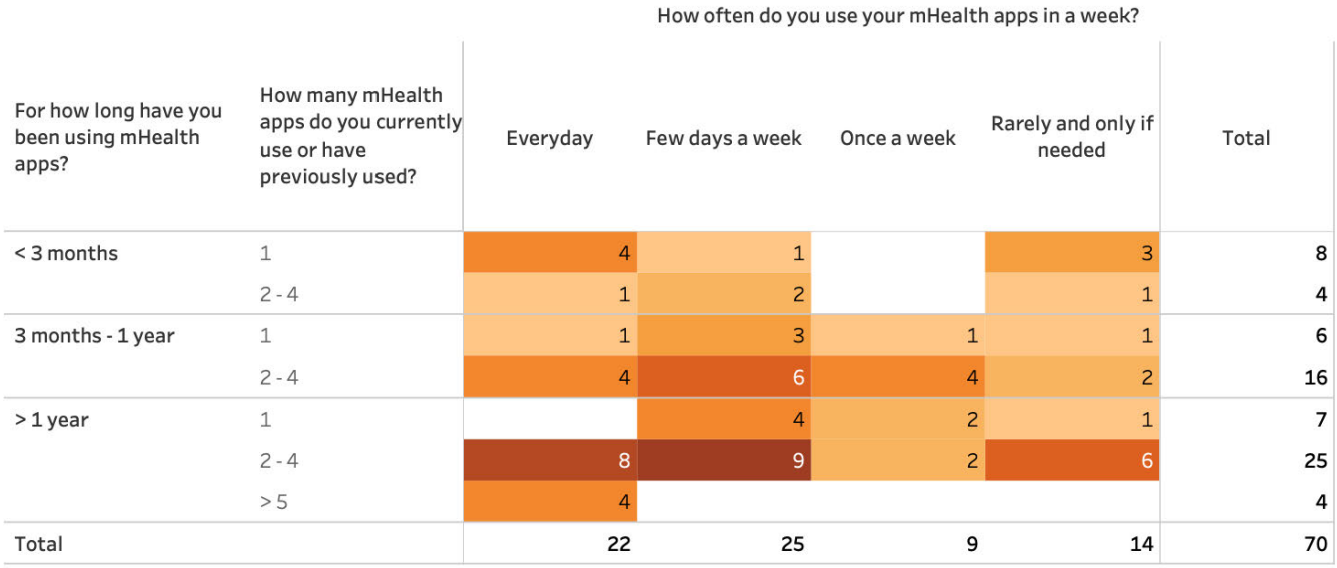

FIGURE 3. mHealth app usage pattern.

TABLE 1. Major challenges with current mHealth applications.

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Dimension
I always need to install and manage more than one app to achieve my intended health goals	5 (7.1%)	12 (17.1%)	23 (32.9%)	21 (30%)	9 (12.9%)	Usability
I use multiple mHealth apps to achieve even one health goal (e.g., multiple fitness apps)	4 (5.7%)	19 (27.1%)	20 (28.6%)	20 (28.6%)	7 (10%)	Usability
My current mHealth apps provide additional features I don't need or intend to use	1 (1.4%)	8 (11.4%)	17 (24.3%)	28 (40%)	16 (22.9%)	Functionality
I found some overlaps between the features provided by the mHealth apps I use	2 (2.9%)	5 (7.1%)	20 (28.6%)	32 (45.7%)	11 (15.7%)	Functionality
I find inconsistencies in the screen design between different mHealth apps	1 (1.4%)	11 (15.7%)	23 (32.9%)	27 (38.6%)	8 (11.4%)	Design
I find the app features complex to use	14 (20%)	20 (28.6%)	21 (30%)	14 (20%)	1 (1.4%)	Usability
The data visualisations provided in my mHealth apps are useful and help me achieve my goals	0 (0%)	3 (4.3%)	20 (28.6%)	27 (38.6%)	20 (28.6%)	Design
I like to use conversational interfaces (e.g., chatbots) if available in my mHealth apps	11 (15.7%)	6 (8.6%)	30 (42.9%)	19 (27.1%)	4 (5.7%)	Usability
I find chatbots to be less convenient than traditional interfaces	1 (1.4%)	13 (18.6%)	27 (38.6%)	20 (28.6%)	9 (12.9%)	Usability
I am happy to manually enter data in mHealth apps	10 (14.3%)	20 (28.6%)	12 (17.1%)	23 (32.9%)	5 (7.1%)	Data Management
I am happy to manually enter data across the several mHealth apps I use when needed	20 (28.6%)	19 (27.1%)	12 (17.1%)	17 (24.3%)	2 (2.9%)	Data Management
I am happy to store my health data on the cloud	9 (12.9%)	10 (14.3%)	23 (32.9%)	18 (25.7%)	10 (14.3%)	Data Management
Overall, my mHealth apps help me to achieve my health goals	2 (2.9%)	5 (7.1%)	21 (30%)	31 (44.3%)	11 (15.7%)	Functionality

pronounced, with more than half the participants responding in the affirmative (55.7%, n = 39). Most users (40%, n = 28) also accepted storing their health data on the cloud, which can also indicate their desire for simplified data management. On conversational interfaces, most users remained neutral. However, while several participants (32.9%, n = 23) accepted chatbots in their applications and like to use them, an even bigger number (41.4%, n = 29) found them to be less convenient. Table 1 summarises the responses obtained around user challenges.

D. EXPECTATIONS FROM FUTURE mHealth APPS

End users expect convenience and considering the importance of health/fitness/wellness data, we were not surprised to find that a unified mHealth platform is preferred over several standalone applications (44.3% strongly agree, 34.3% agree). Given the challenges associated with the use of several mHealth apps, a strong preference for high levels of feature customizability was observed (34.3% strongly agree, 44.3% agree) where users can personalise a single app with features they need.

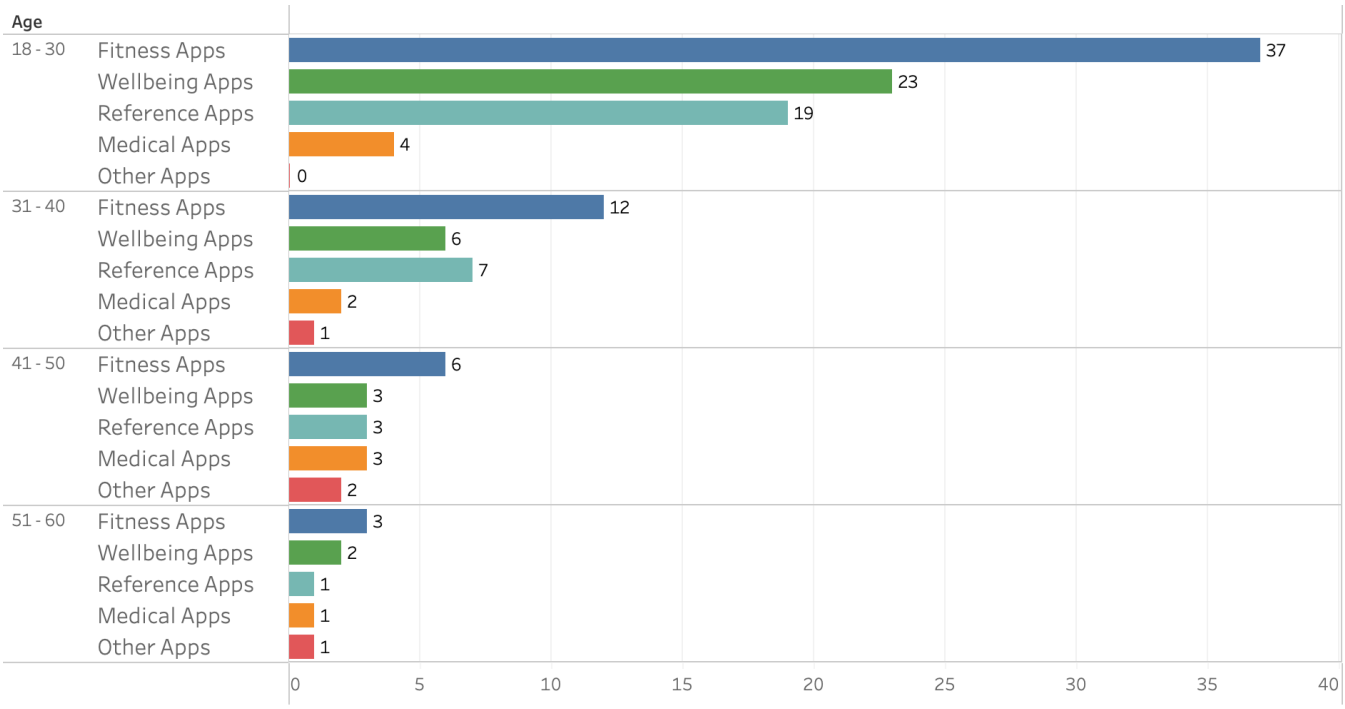

FIGURE 4. Categories of apps used by the participants in each age group.

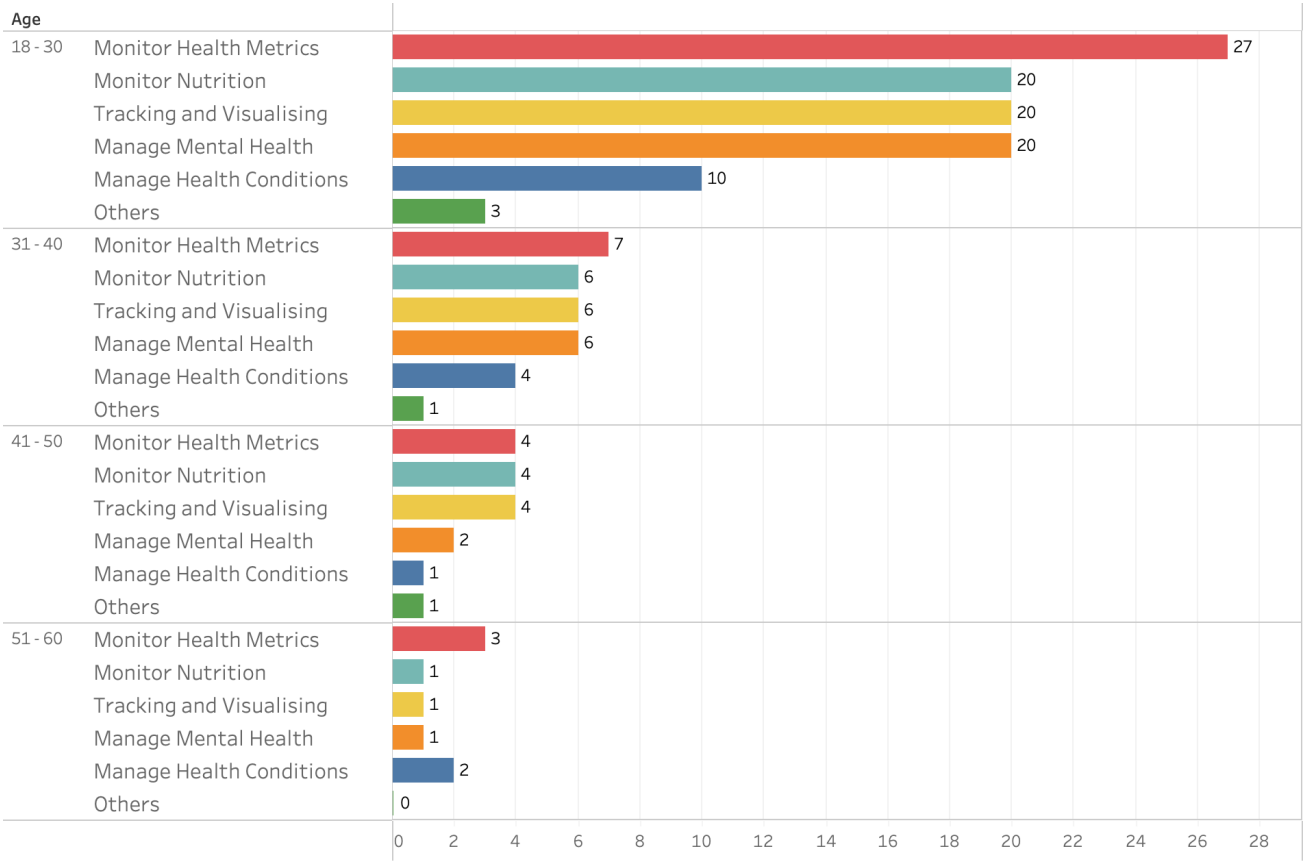

FIGURE 5. Main goals of using mHealth apps in each age group.

Since conversational agents are also gaining popularity in several domains, we believed it would be a desirable addition. However, we received a mixed response with a majority (40%, n = 28) remaining neutral and the next biggest group

TABLE 2. Expectations from future mHealth applications.

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Dimension
I would prefer an mHealth app that allows me to add/remove health-related features based on my needs	0 (0%)	4 (5.7%)	11 (15.7%)	31 (44.3%)	24 (34.3%)	Functionality
I would prefer to use a conversational interface (e.g., chatbots) over a graphical interface	7 (10%)	17 (24.3%)	28 (40%)	15 (21.4%)	3 (4.3%)	Design
I would prefer to use mHealth apps with a consistent user interface design	0 (0%)	3 (4.3%)	13 (18.6%)	28 (40%)	26 (37.1%)	Design
I would prefer a single mHealth app providing me all the health-related functions I need instead of using several apps	0 (0%)	2 (2.9%)	13 (18.6%)	24 (34.3%)	31 (44.3%)	Usability
I would prefer automated data collection using peripherals or built-in sensors	3 (4.3%)	5 (7.1%)	17 (24.3%)	22 (31.4%)	23 (32.9%)	Data Management
I would prefer a single platform/application for managing my health data	1 (1.4%)	3 (4.3%)	7 (10%)	25 (35.7%)	34 (48.6%)	Data Management

(34.4%, n = 24) preferring not to use them. We noticed a strong user preference for automated data collection (64.3%, n = 45) which, while useful, can be out of reach for many due to the added cost of peripherals. Table 2 summarises the obtained responses in this survey section.

IV. DISCUSSION

Nowadays, mHealth devices and apps are being increasingly adopted by end-users. Regardless of health literacy, apps that satisfy user expectations can be expected to be used more [47]. Previous studies on the design of mHealth apps have helped gain a better understanding of users' design expectations [29], [31], [47], [48]. However, most focus on standalone applications, and to our knowledge, ours is the first study that considers the use of more than one mHealth app and expectations from future apps. We obtained 70 valid responses in our survey, which are discussed below.

A. DISCOVERY AND USAGE PATTERN

App discovery is an important part of an application's usage life cycle. Different app stores have their own discovery and app promotion mechanisms, and it is often recommended that developers provide good descriptions with eye-catching videos and images to attract users. App adoption depends not just on developer descriptions, but equally on reviews by other users of the apps. However, given the closed ecosystems preferred by many hardware manufacturers, it is also possible that users may be forced to use certain apps because of their hardware purchase and incompatibility with other services. One comment by a participant - *"...if I use the fitness app because I bought the wearable technology or do I choose the wearable based on the app/interface?"* - reflects this observation and highlights the importance of choice, where the use of open frameworks and standards should be explored for making devices and apps compatible with each other.

Most users in each age group (except 51-60) were found to have used between 2-4 mHealth apps (figure 6) highlighting the user need to install additional apps to monitor and manage their health. This, however, when coupled with overlapping (figure 8) and unused (figure 9) features, degrades the overall user experience. Users lose interest in mHealth apps if their functional and aesthetic needs are not met. App developers constantly work to introduce new features to improve usability and even functionality. However, considering the competition and the highly subjective nature of usability, even the most functional apps may not gain wide adoption if the apps are poorly designed and will lose to other services offering better features. Users were found to abandon their apps primarily because of challenges with achieving their goals, followed by competing apps offering better features. Comments from the respondents such as *"Lack of self-discipline to remember to enter data every day"*, *"...stopped using (a) nutrition diary app, as (it) was a pain to enter data every time I was eating"*, *"it took a lot of time to input data, and slowly I lost interest unless I'm really motivated"* and *"hard to stay engaged with such apps"* show the frustration around data entry driving users away, which only becomes worse with each additional app users install. This highlights the importance of investigating the use of automation around data collection and logging where feasible, and designing more user-friendly apps to ensure continued use and better user engagement.

B. CHALLENGES

We expected most of the participants to be using several health apps or at least have experience with a few. This was confirmed by the responses, where many of the respondents were either neutral (32.9%, n = 23) or indicated they needed multiple apps for managing their health (42.9%, n = 30). While using separate apps for different goals is not unexpected, it was interesting to see that several participants also felt they need to use more than one mHealth app for a single goal (figure 7) highlighting the fragmented nature of such apps and diverse user needs. Although the responses to this question were distributed mostly in a uniform manner, the largest group of users (38.6%, n = 27) noted this challenge, with the 20 participants (28.6%) affirming this statement having used 2-4 apps themselves.

Similarly, given the pattern of installing more than one mHealth app, it was not surprising that most participants

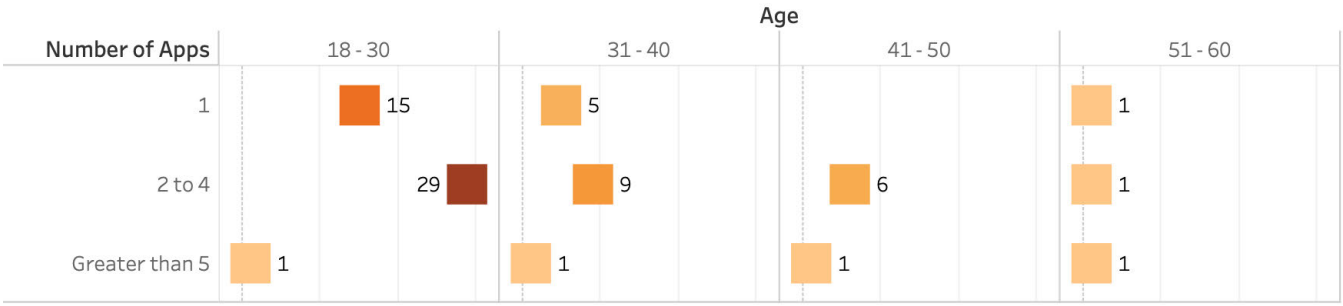

FIGURE 6. Number of apps used in different age groups.

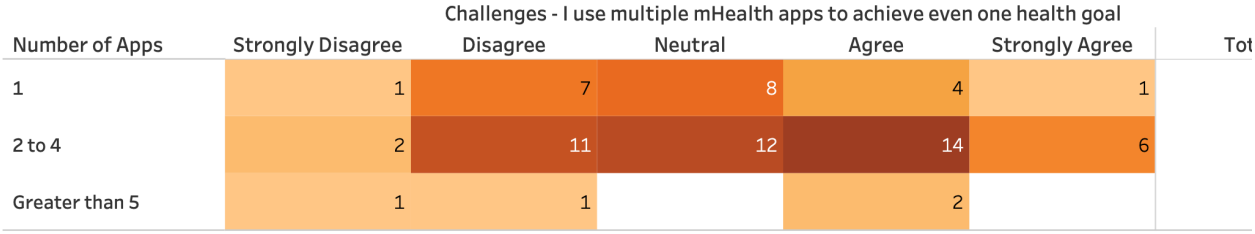

FIGURE 7. The need to use more than one app for even one goal.

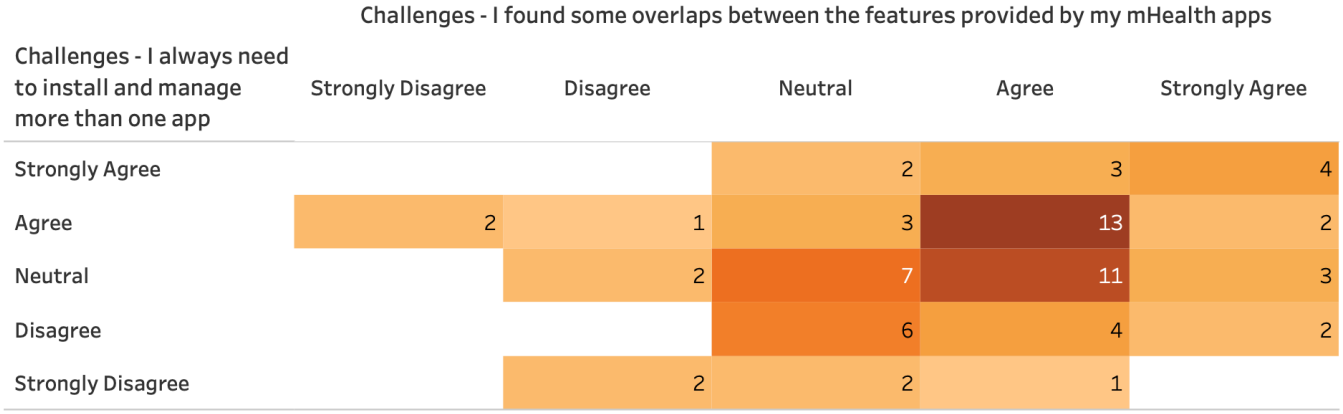

FIGURE 8. The need to install more than one app to achieve intended health goals vs feature overlaps.

reported additional features they don't use in their apps along with overlapping features between them. This relation becomes clear when the responses are put together - figure 8 shows the presence of feature overlaps in most cases, regardless of the need to install several apps. The positive responses here came mostly from those who needed to use multiple apps, which again highlights the fragmented state of mHealth app features and user acceptance of these features. While such feature similarities may be inevitable in apps in the same *domain* (i.e., weight loss, exercise etc.), it can be argued that not all feature implementations may be equally received by end users as they all would have different needs.

Figure 9 shows the presence of unnecessary features in the apps used by the participants. While this is expected when several apps are used together, additional *bloat* was also reported by participants needing just one app, indicating that mHealth apps do not necessarily need to have extra features in addition to the core functionality. Although additional functionality does not necessarily translate into degraded performance, the additions may not offer much in benefits either and can result in a higher app complexity. A respondent's comment – *"sick of having too many apps with minimal gain from each"* – outlines the challenges around unused bloat that numerous apps come with, suggesting the need for better, lighter apps that offer more value to users. While it may not be entirely feasible to develop services catering to every need, focusing on a few core functionalities as opposed to a collection of several features could offer a solution to both

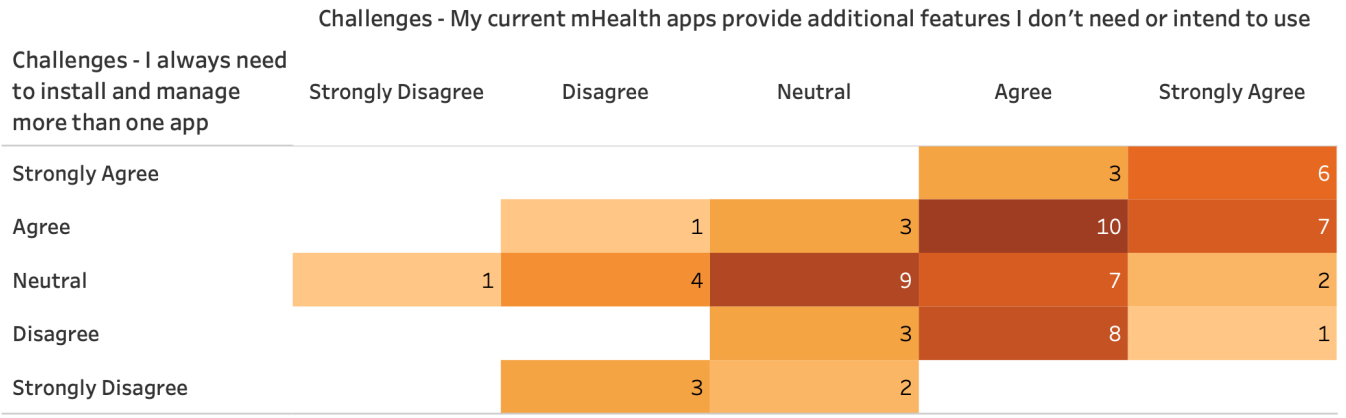

FIGURE 9. The use of several apps to achieve intended health goals vs unused feature.

unused and duplicated features across different apps in the interim. Similarly, app complexity can also cause hesitance to use mHealth services, especially among the older population, and the decreasing number of participants above 30 can be an indicator of the same. While complexity was not a major challenge among the younger group, all participants in the 51-60 age group indicated that they found apps complex to use, highlighting the need to consider the UX of the older and less tech-savvy population while designing mHealth apps.

Health data collection and entry can be automated or can be done manually, and we expected most users to find repeated manual data entry to be a challenge. However, we saw mixed opinions among the respondents, where 40% (n = 28) were satisfied with manually entering data in their apps and 42.9% (n = 30) indicated their preference for automation. However, when using more than one app, over half of the participants (55.7%, n = 39) expressed their dissatisfaction with manual data logging across the different apps they use. Although the latest versions of popular mobile operating systems support some mechanism of data sharing, such as Apple's HealthKit framework and the Google Fit framework, not all apps may support them. However, those that do can also introduce another set of challenges wherein one app overwrites data produced by others. This problem is also captured in a participant's remark – *"...a lot of apps ask permissions to write/overwrite existing health data, which doesn't properly convey the boundaries of those write operations"*. Poor quality apps may produce spurious data, affecting data reliability and hurting the overall results expected by end-users. While the iOS and Android frameworks offer control over app scopes, users are required to dig deeper into service permissions, raising the overall complexity and further exacerbating the problem. Unsurprisingly, apps were found to provide good visual representation of users' health data, indicating a liking for modern app designs. Conversational interfaces (chatbots) were found to be less convenient, further hinting at the dislike for manual data input. These user perceptions are captured in figure 10 that shows the main areas of concern, calculated using the number of users agreeing or disagreeing to the statement. Since some questions were intended to extract a negative response and some positive, an appropriate weight (-1 or +1) was considered for each question to swing the responses in the appropriate direction. These values were calculated as follows –

$$\begin{aligned} &direction \\ &\quad = weight * ((count(strongly\ agree) + count(agree)) \\ &\qquad -(count(strongly\ disagree) + count(disagree))) \end{aligned}$$

The negative values in figure 10 indicate a challenge, while the positive values show the opposite. One interesting observation that can be made here is that while chatbots were mostly seen to be less convenient, the positive value associated with a user's desire to use them (if available in their apps) indicates an overall inclination towards accepting a less convenient interaction mechanism if they satisfy their needs. Similarly, a positive value on the perceived app complexity show that the apps are not collectively seen as challenging and indicate good designs of their apps. Overall, the respondents indicated that their apps helped them reach their goals and were not too complex. However, common challenges such as the need for additional apps, unnecessary features, overlapping functionality and data entry across several apps remained. These challenges can significantly impact app adoption and acceptance, where high-quality and useful apps may not be accepted if they do not satisfy the users.

C. EXPECTATIONS

This segment of our survey was designed using the *Value Map* construct from the Value Proposition Canvas to help understand the expectations from future mHealth apps. While interviews or free text fields would have allowed us to gather more detailed information around user expectations, we chose to use a likert scale format for the questions to simplify the survey and make it more user-friendly for our respondents. We started with a few expectations on user preferences,

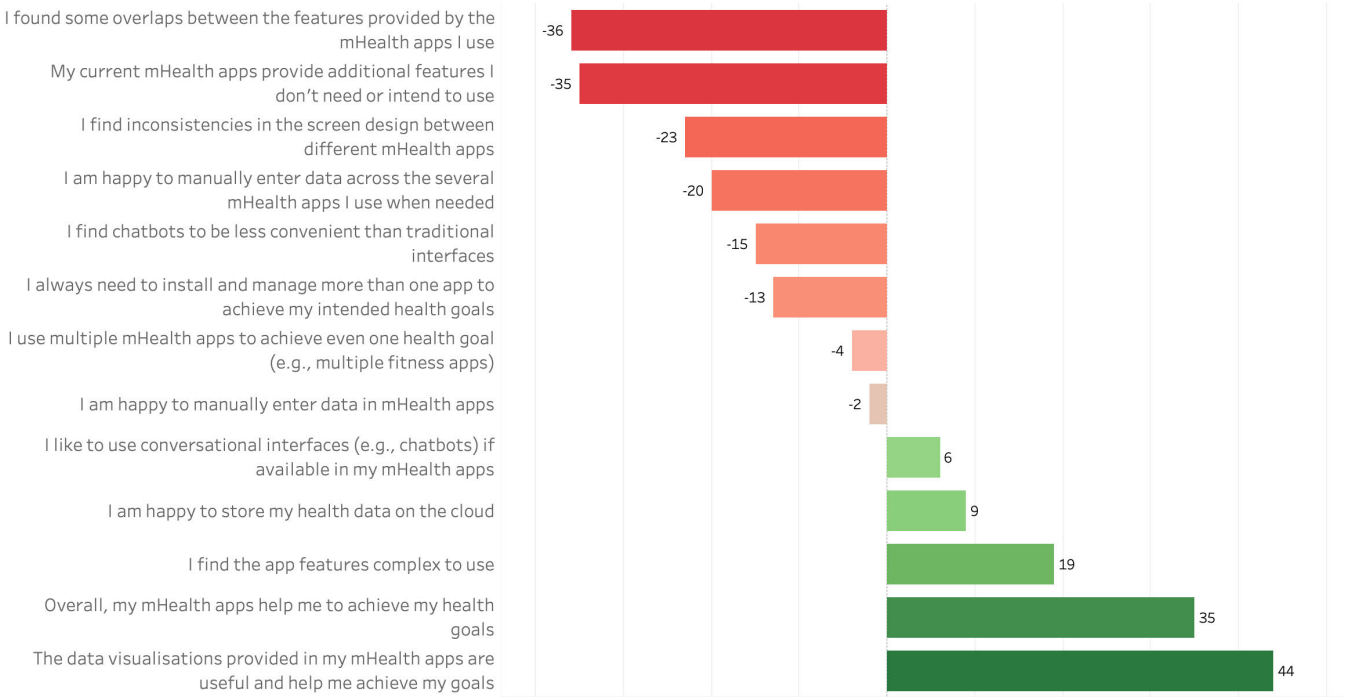

FIGURE 10. Priority of user responses to challenges - the negative values indicate that the users found the statements to be a challenge.

particularly around the use of several apps, presenting challenges such as feature overlaps and unnecessary 'bloat'. Most respondents (78.6%, n = 55) indicated their preference for feature-level customisation, where app functionality can be modified as required. Similarly, most participants preferred a single app offering all the features they require (78.6%, n = 55). This was expected as such applications can eliminate the need for managing several apps. However, the participants remaining neutral (15.7%, n = 11) or disagreeing (5.7%, n = 4) suggests an apprehension towards potentially more complex apps, as also indicated by the preference of consistent and familiar user interface designs. While this is understandable, new applications do not have to be more complicated and user-friendly designs can attract more users, as evidenced by the interest shown by the participants.

Although logging data manually was not considered as a serious challenge, most respondents (64.3%, n = 45) indicated a preference for sensors suggesting that while they are not required, the convenience they offer has a strong influence, making automation a "good-to-have" addition. Sensors, however, can also introduce additional challenges as purchasing peripheral devices can greatly increase the cost. The remark – *"...is there any way to not need to invest in more devices to make mHealth apps useful?"* – indicates users' aversion to spending more and highlights the need to develop and integrate more cost-effective sensors with smartphones. However, unlike sensors, the idea of using conversational agents (i.e., chatbots) was not as well received, with most respondents (40%, n = 28) remaining neutral and most of the remaining participants (34.3%, n = 24) expressing their dislike. This is not surprising given the significant amount of additional work users need to do to complete a given task.

Most users (84.3%, n = 59) expressed their preference of a single mHealth platform with only a few of the opposite opinion, possibly because of concerns around a single platform having control over all their health information. This is also evident from participant comments on challenges not addressed in the survey where they express their concerns over privacy and security of health data - *"Data should be managed locally but can be backed up to an external hard drive/laptop/desktop. Is shareable with (a) doctor - but not in the cloud (privacy and security risks are way too high)"* and *"...I am weary to use them because of data security (however, I think this is a whole other issue). In terms of sensitive personal data, I am extra risk averse."*. However, these concerns can be addressed by using open-source systems that are fully transparent around data storage and management. Offering functionality for restricting data to one's own local system instead of sending sensitive information elsewhere over the internet is also desirable. Overall, a single, customisable app was observed as a general preference among. Following the same approach as the challenges gives us the priority of user expectations (figure 11).

In our previous short paper [33], we discussed challenges around unnecessary and redundant features and presented a potential solution through the use of *feature toggles* to provide user-customisable app features. Figures 10 and 11 show the collective perceived challenges and expectations, and

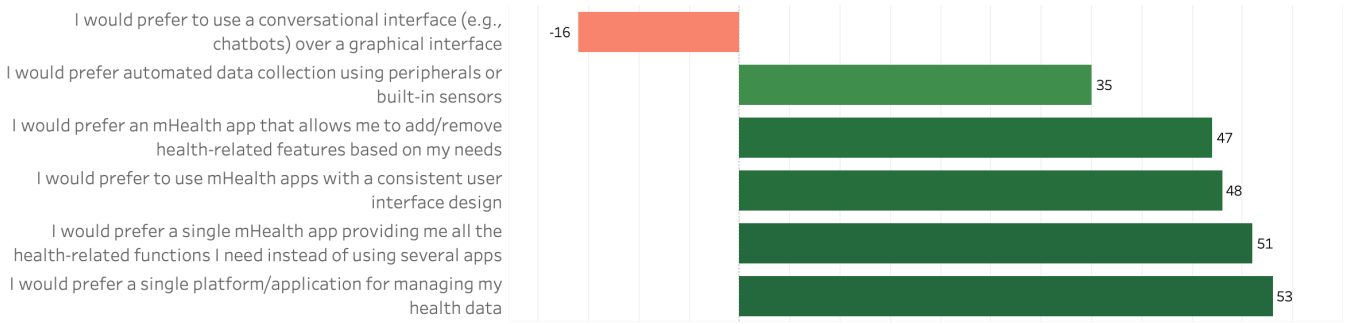

FIGURE 11. Priority of user expectations from future mHealth apps.

introduce a few additional implications which are discussed below-

- **The need for better mHealth app designs –** Future apps need to find a balance between offering more control to users for customising features apps according to their needs without negatively affecting overall complexity. While current web app frameworks have blurred the lines between native and web apps, they often lack support for several new mobile platform features. However, considering how current hybrid app designs blend the best of the other approaches, such designs can offer better solutions to the user challenges.
- **Design Consistency –** Most of the participants noted their observation of inconsistent app designs and indicated their preference for consistent and uniform interfaces. While design consistency may not be feasible across apps created by several independent developers, a common design guideline needs to be introduced to promote more consistency and *familiarity* between apps.
- **Data storage and management -** While manual data entry is not a major challenge, it can quickly turn into one when the same data needs to be manually logged in separate apps. lthough platforms like Apple Health and Google Fit offer a common framework for managing health data, limited implementation by commercially available apps can translate into a requirement of manual data inputs, degrading the UX. Privacy and security of sensitive user data is of the highest priority and although these platforms offer secure storage, some store user data online[9] which, as mentioned earlier, may not be preferred by everyone.
- **Conversational interfaces -** While some users may find conversational interfaces interesting, they are collectively seen as less convenient in their current form, depending on the use-case. Although well-designed chatbots have much to offer in areas like mental health, more work needs to be done to understand how such interfaces can be adopted to varying user requirements to complement user-customisable app functionality we discussed previously [33].
- **A unified mHealth platform –** The above implications along with user responses indicate a strong preference for a unified, customisable mHealth platform. There is a need to explore the designs for single "super-apps" which can support several features that can be added or removed by end users. Successful commercial apps like WeChat[10] can be used for inspiration to create a unified mHealth platform and an ecosystem of install-free single-function micro-mHealth apps.

D. LIMITATIONS

Given the highly subjective nature of usability, the main limitation of our study comes from the way it was designed – i.e., focusing more on fixed options with little support for subjective input. While an interview would have offered a better platform for collecting the required information, it was challenging to implement given the local restrictions around COVID-19. Although online interaction could have had a similar effect, recruitment proved to be a challenge and would have limited the number of responses. While opting for an anonymous online questionnaire offered more convenience to participants and allowed a larger number to participate, we only received 70 complete responses from people between the ages of 18 and 60, with most participants falling in the 18-30 age group. We acknowledge that our limited results may have not collected the complete picture and is a threat to validity. We acknowledge that more in-depth studies with more participants in the same and different groups would be required for better understanding of user expectations around the use of several health applications.

Overall, despite the advancements in mobile app designs, our results show the validity of previously raised concerns and their relevance today and suggest a need for innovative application designs that provide complete control to the apps' users. Similarly, given the benefits of hybrid apps, we suggest a hybrid platform that allows end users to customise their app to their liking. Our interpretation of these expectations is being implemented in a unified hybrid platform that breaks down different features into micro-mHealth applications that can be added or removed as required. The platform is

[9]https://support.google.com/fit/answer/10066791

[10] https://www.wechat.com

currently under development and can be found in our GitHub repository,[11] an evaluation of which is planned in our upcoming work to analyse its impact on the overall acceptance of such platforms.

V. CONCLUSION

The presence of, and easy access to several thousand mHealth apps along with the need to use several apps to manage one's health goals hints at challenges around feature overlaps, issues with data entry/management and additional features not required by all. To investigate these challenges and user expectations, we designed an anonymous survey targeting adult users of mHealth apps which obtained 70 valid responses highlighting the users' need to use more than one mHealth service, with many arguing for the need to use several apps even for achieving one goal. This also indicates the presence of unused features in each app along with redundant features between different apps, suggesting the need for customisable apps that allow feature-level personalisation allowing one to remove this duplication. Participants also indicated their dislike for repetitive data entry, especially when the same data is entered into several apps. With these challenges, it was not surprising that the participants mostly indicated their preference for a flexible, unified platform to achieve their health goals. Although the development of such unified platforms introduces a set of technical challenges around data and functionality management within the platform, they can offer several benefits to the community. For instance, a uniform design language for platform features and third-party plugins, and easier access to health insights can help end users manage their health goals more effectively. This can be achieved by minimising clutter and unnecessary bloat, thereby improving overall usability of the users' mHealth app *ecosystem*. Similarly, the ability to extend platform functionality via third-party plugins can also be helpful for mHealth app developers, as they can focus more on improving single features building on, and collaborating with other platform plugins instead of developing complete systems from scratch.

While such a unified health platform may offer a better overall experience, their development raises valid questions around the increase in the overall complexity of the platform and privacy concerns of a single platform holding all the data. As there is a lack of such application designs in the mHealth domain, the current challenges and user expectations highlight the need for more research and advocacy for developing a unified mHealth application framework. Overall, we hope that our findings will guide the design and development of novel mHealth platforms to have a positive impact on the acceptance and adoption of mHealth services.

APPENDIX 1 - SURVEY QUESTIONNAIRE

A. DEMOGRAPHIC DETAILS

1) What is your age?
   a) Below 18
   b) 18 - 30
   c) 31 - 40
   d) 41 - 50
   e) 51 - 60
   f) Above 60
2) What is your gender?
   a) Male
   b) Female
   c) Others
   d) Prefer not to say
3) What is your highest education degree?
   a) High School
   b) Graduate
   c) Postgraduate
   d) Others

B. USAGE PATTERN

1) How many mHealth apps do you currently use or have previously used?
   a) 1
   b) 2 - 4
   c) Greater than 5
2) What kinds of health/fitness/wellness applications do you currently use or have previously used?
   a) Reference apps (informational resources, exercise guides etc.)
   b) Fitness apps (workout trackers, meal trackers etc.)
   c) Wellbeing apps (including mental health, meditation etc.)
   d) Medical apps (disease reference, drug dosage reference etc.)
   e) Others
3) For how long have you been using mHealth apps?
   a) Less than 3 months
   b) Greater than 3 months, but less than 1 year
   c) Greater than 1 year
4) How often do you use your mHealth applications in a week?
   a) Everyday
   b) Few days a week
   c) Once a week
   d) Rarely and only if needed
5) Why do you use mHealth apps?
   a) Monitoring health metrics (e.g., heart rate, blood pressure etc.)
   b) Managing health conditions (e.g., diabetes, tracking meditation etc.)
   c) Monitor nutrition (e.g., tracking calories, macronutrients, micronutrients etc.)
   d) Tracking and visualising personal goals and progress (e.g., weight loss)
   e) Others
6) Do you use wearables or peripherals to monitor your health/fitness/wellness? If not, please select 'No'. (Options include fitness wearables, peripherals and clinical wearables)

[11] https://github.com/benphilip1991/del-container

a) Fitness wearables (e.g., smartwatches, rings etc.)
b) Fitness peripherals (e.g., smart scales, bed sensors etc.)
c) Clinical devices (e.g., glucometers, blood pressure cuffs etc.)
d) No

C. USER AWARENESS AND APP DISCOVERY

1) How did you discover the right mHealth app for your need?
   a) App reviews by other users
   b) App screenshots and description
   c) Suggestions from family or friends
   d) Suggestion by healthcare professional
   e) Others
2) If you don't use an mHealth app anymore, what was the main reason for abandoning it?
   a) Issues with data entry
   b) It did not help me achieve my goals
   c) The app was not user-friendly
   d) I found another app with better features
   e) Others

D. CHALLENGES USING mHealth APPS

*(Answers from a scale of 1-5 where 1 is **strongly disagree** and 5 is **strongly agree**)*

1) I always need to install and manage more than one app to achieve my intended health goals
2) I use multiple mHealth apps to achieve even one health goal (e.g., multiple fitness apps)
3) My current mHealth apps provide additional features I don't need or intend to use
4) I found some overlaps between the features provided by the mHealth apps I use
5) I have found inconsistencies in the screen design between different mHealth apps
6) I find the app features complex to use
7) The data visualisations provided in my mHealth apps are useful and help me achieve my goals
8) I like to use conversational interfaces (e.g., chatbots) if available in my mHealth apps
9) I find chatbots to be less convenient than traditional interfaces
10) I am happy to manually enter data in mHealth apps
11) I am happy to manually enter data across several mHealth apps when needed
12) I am happy to store my health data on the cloud
13) Overall, my mHealth apps help me achieve my health goals

E. EXPECTATIONS OF mHealth APPS

*(Answers from a scale of 1-5 where 1 is **strongly disagree** and 5 is **strongly agree**)*

1) I would prefer an mHealth app that allows me to add/remove health-related features based on my needs
2) I would prefer to use a conversational interface (e.g., chatbots) over a graphical interface
3) I would prefer to use mHealth apps with a consistent user interface design
4) I would prefer to use a single mHealth app providing me all the health-related functions I need instead of using several apps
5) I would prefer automated data collection using peripherals or built-in-sensors
6) I would prefer a single platform/application for managing my health data

F. ADDITIONAL COMMENTS

1) Any comments on challenges not addressed in this survey?
2) Any comments on expectations not addressed in this survey?

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