Expectations of users and non-users of wearable sensors and mobile health applications

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Abstract
Patient self-management is vital to improved health outcomes for patients with chronic diseases. The objective of this study was to understand the role of wearable sensors in patients' self-management. A survey encompassing factors related to motivation in mHealth was conducted. Ease of use and sensory accuracy was found most important when choosing a wearable. Manual registration of most health-related information is unpopular, although some exceptions exist. Respondents valued sensor accuracy and easiness in manual registration and usage of mHealth systems. Further research is needed to pinpoint what ease of use exactly is, and how ease of use can be improved.

Keywords
mHealth, eHealth, self-management, chronic disease, persuasive design

INTRODUCTION

Persons with chronic diseases could benefit from using mobile health (mHealth) tools for self-management. Various devices, ranging from wearable sensors and apps integrated in smartphones, to health specific devices (e.g., glucometers) exist. The range of output from these devices, and the possibility for long-term unobtrusive monitoring, makes these devices uniquely supportive for continuous chronic disease self-management [1]. Fan et al. [2] recently published a review assessing the usability and effectiveness of mHealth apps in chronic disease self-management and concluded that mHealth technologies are as good as traditional care.

However, there seems to be a lack of motivation from most users to keep using these health apps over a long period of time [3]. Attig et al. [4] assessed reasons for physical activity tracker attrition and found that lack of motivation was one of the main reasons for no longer wearing such trackers. For persons with chronic disease, continuous use of physical activity trackers are reported to improve their health management [5].

Therefore, as mitigation measure and to further support the effort in self-management of chronic diseases, this study aimed to identify what features and factors motivates people with and without chronic disease to use mHealth apps and sensors.

METHOD

An anonymous online survey was distributed physically at a Swiss conference and on multiple social media fora related to diabetes and sickle cell disease, as well as a more general site not related to chronic disease. A total of nine online platforms were used. The survey was constructed based on 16 in-person interviews, out of which 12 persons had a chronic disease [3]. Announcements were either in English, Norwegian, or French, depending on distribution site. Respondents answered questions about what motivates them to self-manage their own health or disease. The survey had seven themes with the following headings: 1) background and health goal questions, 2) use of wearables and sensors, 3) use of mobile apps, 4) data-logging, 5) data sharing and data integration, 6) social media and entertainment factors, and 7) demographic questions including age, gender, and chronic disease diagnosis.

Here we report about the use of wearables, apps and sensors, and data logging and registration. Table 1 gives the sub-set of questions used in this study, with answer options. Question using Likert scales (question 7, 9, 10, 14, 15) gave answer options from 1-4 (where 1 was the lowest score). "Don't know" was also an option.

The online survey was open for data collection between November 2018 and March 2020. Primary results comparing those with and without chronic diseases [6, 7] and investigating the role of caretakers [8] have been previously published.

A request for ethical approval was reviewed at the Regional Ethics Committee (REK) and found to be exempt from their purview (ref. 2017/562).

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The 18th Scandinavian Conference on Health informatics, Tromsø, Norway, August 22-24, 2022. Organized by UiT The Arctic University of Norway. Conference Proceedings published by Linköping University Electronic Press at https://doi.org/10.3384/ecp187.

Data was analysed using the software RStudio [9]. We report descriptive results, and for group comparisons we used Welch's t-tests and chi-square tests, were appropriate.

No.	Question
	Background
5	Have you ever used a wearable device for collecting activity or other health data? (*Yes, No*)
28	Do you have a chronic disease? (*Diabetes, Sickle-cell, No, Don't want to answer*)
	Wearables and sensors
6	Which of these technologies for health tracking do you regularly use? (*Multiple choice*)
7	How important are these features for you when choosing a wearable device? (*Likert 1-4, Don't know*)
8	Which features would motivate you most to use a wearable sensor longer? (*Single choice)*
9	How important are these specific health related features for you when choosing a wearable device? (*Likert 1-4, Don't know*)
	Mobile apps
10	How important are these features when choosing a mobile health app? (*Likert 1-4, Don't know*)
11	How do you decide if a mobile app is trustworthy? (*Multiple choice*)
	Logging/registration
14	If you are required to do manual logging (registration) in a health mobile app, how important are these criteria for you? (*Likert 1-4, Don't know*)
15	How willing would you be to manually log or register the following types of data? (*Likert 1-4, Don't know*)

Table 1. Selected questions from questionnaire.

RESULTS

Participant characteristics

Among the 814 who responded to the survey, 300 (37%) indicated to have a chronic disease and 490 (60%) indicated not to have a chronic disease. Twenty-four (3%) respondents left this question unanswered. 272 (33%) respondents used sensors in their smartphone, 285 (35%) respondents used physical activity trackers, 255 (31%) respondents used mobile health apps, and 185 (23%) respondents used health specific measurement devices, e.g., glucometers. Multiple responses were possible. 281 (35%) respondents stated not using any wearable sensor, activity tracker, or mobile health app. Of those 85 (30%) indicated to have a chronic disease and 184 (65%) stated no chronic disease.

Motivation for prolonged use of apps and sensors

We first looked at what motivates respondents to wear and use a sensor for longer periods (Question 8), stratified into those with previous experience with wearable devices for physical activity tracking or other health tracking, and those with no previous experience (Question 6).

Relevant personalized feedback was a main motivator for 42.5% of respondents; whereof 38% with a chronic disease and 49% without a chronic disease. This group difference was significant; $\chi2 = 40.953$, $p < 0.001$. The second rated motivator was *ease of use* with 36.4% of respondents having this as their main motivation; whereof 43% with a chronic disease and 34% without a chronic disease. This group difference was significant; $\chi2 = 4.268$, $p = 0.039$.

Access to aggregated data and *social media integration* were not main motivators. Table 2 shows, when ignoring those answering, "don't know" or "other", that the ranking of the motivations was similar among those already using mHealth technology and those not yet using it (Question 6). The difference was statistically significant with a small effect size; $\chi2 = 37.323$, $p < 0.001$, Cramer's $V = 0.219$; mainly due to those not yet using any device answering, "don't know/other".

	Not using any device (n=281)	**Using at least one device** (n=533)
Relevant personalized feedback	113 (40%)	233 (44%)
Ease of use/non-disruptive	95 (34%)	201 (38%)
Access to aggregated summarize data on the population level	10 (4%)	25 (5%)
Social integration (e.g., Facebook)	0 (0%)	14 (3%)
Don't know/Other	50 (19%)	40 (8%)

Table 2. Question 8, Motivating factors grouped by those who have ever used a wearable device (Question 6).

Next, we looked at which features were most important to the respondents (Question 7). Answers were given on a 4-point Likert scale. Across the six features 11-20% responded with "Don't know" or left the field blank.

Figure 1 shows the rating of the six features, with *sensory accuracy* and *easy to use* being rated as very important by most respondents, and irrespective of whether they already use or not use wearable sensors. *Access to data* and *ergonomic design* were also rated as important features whereas *known brand* was least important. *Notification* on the mobile phone was rated as somewhat important. Respondents with and without a chronic disease rated these six features similarly.

All figures give boxplots where the black line is the median response, the black dot the mean, grey triangles are outliers, and the boxes represent the range between the 25th and 75th percentile

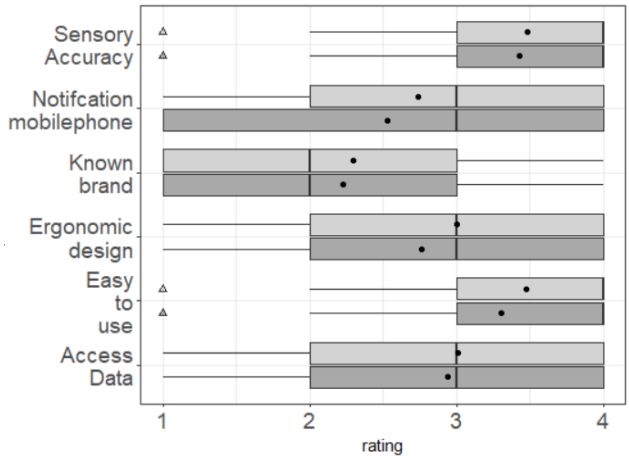

Figure 1. Question 7. Rating of importance for six mHealth features.

Regarding health specific measurements/features (Question 9) rated on a 4-point Likert scale, *physical activity tracking* was rated as most important, followed by *predicting/preventing deterioration of health*, *alerts*, and *managing the disease*. Notably, even within the chronic group, *physical activity tracking* was rated highest, followed by *managing the disease*, *alerts,* and *predicting/preventing deterioration of health*. Mean values and standard deviations, for all participants and only those with a chronic disease, are given in Table 3. The chronic group (M = 3.12) rated those four features higher than the non-chronic group (M = 2.92), Welch's t-test: t(2259.6) = 4.8106, p < .001, 95% CI [.119, .284].

	All participants	Chronic group
Physical activity tracking	3.29 (0.91)	3.23 (0.95)
Predicting/preventing deterioration of health	2.92 (1.07)	3.03 (1.04)
Alerts	2.92 (1.05)	3.08 (1.05)
Managing the disease	2.85 (1.14)	3.14 (1.08)

Table 3. Question 9 answer option scores. Mean score (SD)

Specifically for choosing a mobile health app, we asked how important; simplicity/usability; functionality/features; price; trust/security/privacy; and personalization (tailored features) were (question 10). As Table 4 shows, all features were rated as important (mean score over 3, maximum possible score was 4).

	Chronic	Non-chronic
Simplicity	3.50 (0.775)	3.55 (0.694)
Trust, Security, Privacy	3.39 (0.896)	3.47 (0.847)
Functionality	3.33 (0.961)	3.39 (0.840)
Price	3.15 (0.979)	3.23 (0.904)
Personalization	3.15 (0.979)	3.02 (0.916)

Table 4. Question 10 answer option scores. Mean score (SD)

Following up on *trust, security, and privacy* we asked on which feature they would decide about the trustworthiness of a mobile app (Question 11). 457 respondents (56%) would use personal *experience* or other people's experience for judging trustworthiness, 430 respondents (53%) would base it on *certificates*, 359 respondents (44%) would decide

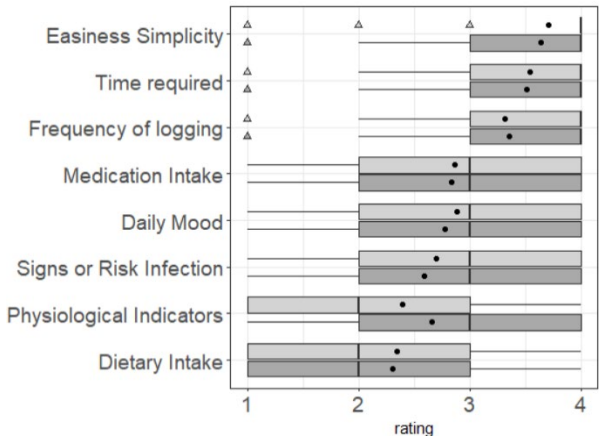

Figure 2. Question 14. Important criteria for motivating manual registration.

it based on *product specifications* and/or *provider reputatio*n, and 260 respondents (32%) would use Google Play or AppStore *ratings*.

Next, we looked at manual registration and logging. We asked about the importance of three features if required to do manual registration (Question 14); *easiness / simplicity, time required, and frequency of logging*. We also asked about how willing they are to manually register (Question 15) *daily mood, dietary intake, medication intake, physiological indicators and signs or risk* of infection. Both were answered on a 4-point Likert scale.

Figure 2 shows that *easiness/simplicity, time required, and frequency of logging* are rated as very important for manual registration. Nearly all respondents with a chronic disease strongly agreed that manual registration must be easy and simple (M = 3.64, SD = 0.68). Respondents were most willing to register their *medication intake* and *daily mood*, followed by *signs or risk of infection* and *physiological indicators*. They were least willing to register their *dietary intake*. Participants with a chronic disease (M = 2.66) were more willing to register *physiological indicators* than respondents without a chronic disease (M = 2.4), Welch's t-test: t(576.45) = 3.143, p = 0.0018, else the groups did not differ.

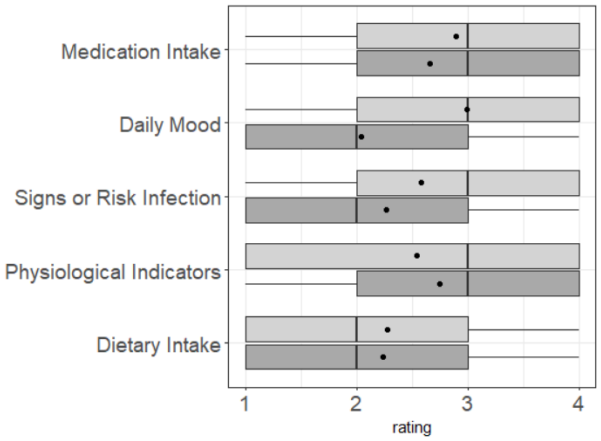

Figure 3. Question 15. Willingness for manual registration among respondents with Diabetes and respondents with other chronic diseases

Finally, we looked closer at respondents with Diabetes (n=71) and their willingness to register health-related measurements compared to respondents with other chronic

diseases (n=185). Diabetes management benefits from registering *dietary intake*.

Figure 3 shows that respondents with Diabetes were similarly unwilling to register dietary intake than respondents with other chronic diseases. Notably, respondents with Diabetes were less willing to register their *daily mood* than respondents with other chronic diseases.

DISCUSSION

As expected, *easy to use* is a highly desired feature for wearable sensors and is independent of previous experience with mHealth devices. Still, *sensory accuracy* and *personalized feedback* were rated as very important too. This is encouraging as wearable sensors shall support self-management. Notably, *personalized feedback* was more important among those not having a chronic disease. Possible explanations could be age differences or experience with feedback from wearable sensors. In the case of Diabetes, *sensory accuracy*, e.g., measuring blood glucose levels, might be regarded as one part of personalized feedback. For physical activity tracking, *personalized feedback* might be performance scores. This shows the ambiguity in what respondents might understand by *personalized feedback*.

Our survey used lay terms like *easy to use* without asking deeper what the respondents understand by this term. Not everybody may perceive small displays, colours or touch screens as easy to use, e.g., visually impaired, persons with colour deficiency, persons with Parkinson disease (e.g., [10]). Voice assistance might alleviate this, but has also its limits, e.g., persons with Amyotrophic lateral sclerosis or Huntington disease do not benefit from such features.

Over 50% of the respondents used more than one mHealth device, i.e., sensors on smartphones and physical activity trackers, or sensors on smartphones and mobile health apps. This suggests that devices are not solely used and bought for health self-management. This challenges developing tailored health apps with high sensory accuracy for automatic registration as devices vary in hardware. On the other hand, using specialized devices means to learn and use another device. Given the pace with which user interfaces of mobile devices are updated and changed, this is an enduring challenge for mHealth.

Relevant *personalized feedback* was not rated as most important among respondents with a chronic disease. This suggests that the burden of a chronic disease emphasises *simplicity* and sensory *accuracy* over *personalized feedback* in mHealth devices. *Personalized feedback* might be expected from their general practitioner.

This may touch on another important factor, namely *trustworthiness*. Do we trust the output from a digital device or rather a medical doctor? Despite the statistics favouring the digital device over the fallible human being, the opacity of how the digital device derives the personalized feedback hampers trust in technology [11, 12].

Doing manual registration and logging is part of life for many with a chronic disease. This is often the most time-consuming aspect of self-management and can feel like a burden. Technological developments have reduced the time but not eliminated it entirely [13]. Notably, diet registration is the most hindering/demotivating feature among those respondents who would gain most from it, namely respondents with diabetes. This might indicate a conflict between knowing enough about coping with the disease and freedom to live a life without constantly thinking about the disease [14]. Indeed, food is a strong reward, and removing the joy from eating by having to register one's diet, may adversely affect well-being [15].

The study has also limitations. The quantitative survey was based on qualitative interviews [3] but the factors and motivational reasons were not exhaustive as some respondents indicated *other*. However, the main factors and reasons were covered. In this report we did not control for demographic factors. Age and gender might influence adaptation of mHealth apps but this might matter less for continuing using wearable sensors and mHealth apps, hence we did not statistically control for demographic factors but future studies should.

Wearable sensors and mHealth apps should take the cost-benefits for users into account, not least from a mental health perspective.

SUMMARY

In this study, responses from 814 participants of a survey about motivation in mHealth, was used to identify factors and features that motivates people with and without chronic disease to use mHealth apps and sensors.

Users and non-users of wearable sensors expects that mHealth apps and devices have accurate sensors, to be easy to use, and providing them with personalized feedback. The latter two can be addressed by software developers, the first often also requires appropriate hardware.

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ACKNOWLEDGEMENT

We thank all respondents who answered the survey