Designing for Wellbeing with Health Data Tracking

Maintaining the User Perspective in Objective Data

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ABSTRACT

With integrated sensors that become smaller, cheaper and more accurate every year, our personal devices can help predict disease and give health care professionals valuable data about each individual's health. However, data gathered by personal devices are not a substantial part of patient treatment. In this literature review, I investigate how health data tracking in personal devices work, and explore how the applications should be designed to become a constructive addition to traditional health care services. Many users are eager to download health and fitness apps, but abandon them after a short time. The group that most frequently use these solutions are young, healthy people with higher education, the same group is the most likely to get any significant health benefit from using health apps. Another concern is that health apps and data tracking can potentially push healthy users in the direction of unhealthy habits of health obsession and eating disorders. For health apps and data tracking devices to be used by a larger group of people, there needs to be an increased focus on user experience. The solutions need to be designed so that they can provide users with true data about their health, are transparent of gaps in data coverage and only send out relevant and unobtrusive notifications. Other design suggestions include increasing feeling of ownership by letting the user be in charge of the data treatment and giving the user a chance to supplement objective tracking data with subjective data.

KEYWORDS: Health Data, Tracking, UX, Sensor, eHealth

1. INTRODUCTION

Do you know your resting heart rate? How many steps you take in a day or how many hours you spend sitting? Your REM sleep cycle? Your smart device does! This literature review investigates how we should design the next generation of health applications by integrating health data tracking in a way that is beneficial to the user.

In this article, health data trackers will be limited to those integrated in smartphones, activity bands and smartwatches. These are mainstream products that are frequently used by most of us and are not designed specifically for users with an illness or disability. Many of us own smartphones, and smartwatches are transitioning from a tech device for early adopters to a common everyday object. These devices are an integrated part of our daily lives and we bring them everywhere we go. Personal devices with built in tracking sensors

opens up a world of opportunities for gathering continuous data about an individual's day-to-day health that has the potential to be a supplement to traditional health services (Van den Bulck, 2015). This is confirmed by Higgins (2016) who argues that health tracking empowers patients to take charge of their personal health routines, and that health tracking opens up for personalized interventions and support outside the doctor's office.

The aim of this article is to look at the local effects of the use of health data tracking and to investigate how they can be designed to encourage individuals to be more aware of their own health. There are many pitfalls in using health apps and tracking, but carefully designed health data collection has the potential to give a more holistic and true image of a person's health than what is offered by eHealth applications today. Based on a literature review of state of the art technologies, some design guidelines for integrating tracking in health applications will be defined.

There are many methods of tracking objective data. In this article, the approaches discussed will be narrowed down to activity trackers, heart rate trackers and sleep monitors because they are frequently used, and require minimal extra equipment.

2. METHOD

This article is based on a review of literature on state of the art sensor technologies and their application in personal devices, the quantified self movement, human data tracking and human interaction with health applications. The academic literature was found by searching for scientific journals and academic articles in Scholar Literature Databases. The review is supplemented with articles from technology information websites and an excerpt from the book "Irresistible" by Adam Alter (2017).

Search words that were used in the scholar literature database were "*health data tracking", "tracking objective data"* and "*designing health technologies*". Articles on tracking objective data were later limited to tracking of sleep, heart data and activity as they are the technologies that are the most common in the non-clinical tracking devices. Articles written in the last two years were preferred and as articles with empirical studies on user experience and health data tracking or health apps are few, they were prioritized in this review.

Articles were filtered to be within the fields of psychology, assistive medicine and Human Computer Interaction rather than electronics engineering, information systems and data processing. A large portion of the studies were discovered via the reference list on other literature reviews.

3. TRACKING AND OBJECTIVE DATA

Sensors and health data tracking are ideal for gathering objective data about a person's health. There is a distinction between objective and subjective data in the medical field. Objective data is defined as values that say something about easy-to-measure symptoms or parameters, like for instance blood pressure, resting heart rate and body temperature. These data are valuable for painting an overall picture of a person's health. They do however need to be seen in context with subjective data to give any real value. Subjective data are qualitative descriptions of perceived health, usually coming directly by the patients themselves. Examples are descriptions of symptoms, feelings and emotions or medical problems and symptom scores (Tang et al., 2017). The relation between measuring subjective and objective data is illustrated in image 1.

Because it basically just involves counting, gathering and quantifying objective health data is easy. But it is extremely time consuming and notoriously difficult to do if you don't have the right equipment. Luckily, several devices have the technology to help us with these tasks. Even the

cheapest smart devices available at the marked often have sensors like accelerometers, GPS and gyroscopes that can be used to track and quantify health data.

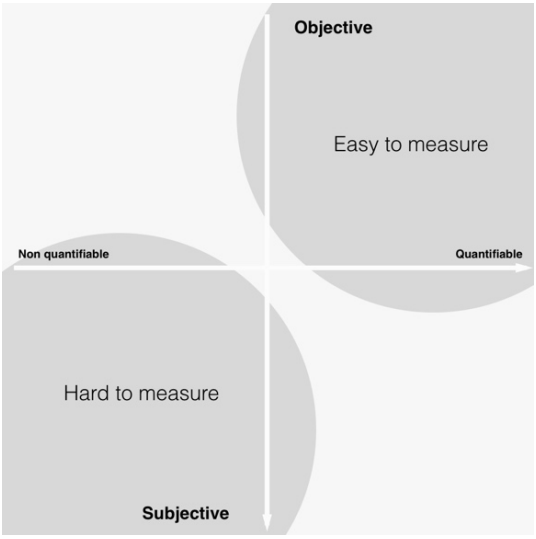

Image 1: Illustrating the relation between measuring objective and subjective data

3.1 Monitoring Sleep

How we feel can be heavily influenced by how well we sleep. The gold standard of measuring sleep is called polysomnography. The method takes in metrics from both eye movement and muscle tone throughout a person's entire night's sleep. This technology is the most accurate way of measuring sleep quality, but requires a lot of equipment and needs to take place in a laboratory. Another way of tracking sleep is through actigraphy. The method was determined to be surprisingly accurate compared to the lab method by an experiment conducted by Min et al in 2015. Actigraphy requires a wearable or smartphone with an accelerometer that measures a person's movement throughout the night. A third, less accurate method for monitoring sleep is using a smartphone microphone that listens for talking, tossing and turning (Min et al, 2015).

Sleep monitoring apps that are solely based on data from tracking are still under development. Although they can function as a supplement to self-reporting about sleep quality, it was in 2013 concluded that no existing available app was based on strong scientific evidence (Behar et al., 2013). There is no available research indicating that such an app exists per November 2017.

3.2 Measuring Heart Rate

Your heart rate is the number of heartbeats you have in one minute, and can be measured by putting two fingers on your wrist and counting the beats. Through a third-party app like Azumio's Instant Heart Rate, pulse can also be measured by placing a finger on smartphone camera lens. A study from 2016 recognized Azumio's app together with a smartphone as a reliable and valid tool to assess pulse rate in healthy, adult individuals (Mitchell et al., 2016). Another study by Wallen et al showed that the percentage error for heart rate was comparatively small across both wearable devices, such as smartwatches, and smartphones, ranging from 1–9% (Wallen et al., 2016).

Stress, physical activity and caffeine consumption are all factors that can influence our heart rate throughout a day. Wrist-worn devices like smartwatches and activity bands can detect these variations in heart rate by continuously measuring the user's pulse (Phan et al., 2015). Data about heart variability could offer a more holistic image of an individual's cardiovascular health than what would be obtained in a constructed lab setting, or from sporadic pulse measuring.

3.3 Tracking Physical Activity

Activity trackers and step counters have been available for consumers for decades. In its simplest form, accelerometers registers motion patterns and use this information to give an estimate of how many steps the user has taken in a period of time. Simple accelerometer technology is cheap and gives a pretty accurate number of the user's step count (Battenberg et al, 2017).

More advanced devices can use this technology together with a gyroscope to track orientation, altimeters to track altitude and GPS to measure distance traveled to give a more accurate view of the user's activity (Nield, 2017). The technology enables personal devices to perform tasks like measuring and separating between walking, running, outdoor biking, elliptical, swimming and less mainstream activities like golf. They can also give an indication of energy consumption, calories burned, and give the user visual and haptic feedback based on his or her activity level (Silbert for Lifewire, 2017).

4. DO USERS ACTUALLY WANT TO BE TRACKED BY THEIR DEVICES?

A study from 2014 found that nearly a fifth (19%) of smartphone users have downloaded at least one health app. However, 26% of the apps downloaded are used only once and 74% are abandoned after the 10th use (Consolvo et al, 2014). A 2015 study that asked users looking to download an eHealth app about the most important feature found that over 45% of the respondents answered tracking as the most important feature (Murnane et al, 2015).

4.1 The Quantified Self Movement

The *Quantified Self Movement* is an example of a group of early adopters of health tracking. The movement started in San Francisco in 2007, when Gary Wolf launched the blog "Quantified Self" (Quantified Self, 2017). Their goal is for individuals to gain more knowledge about themselves with help from technology.

4.2 Self-Monitoring

An increasing interest in self-monitoring and quantifying one's own health has been an important pull-factor for the emergence new sensor technology (Shull, 2014). Better, cheaper, smaller and more robust sensors integrated in portable devices allow consumers to make use of high quality medical technology as a part their everyday lives. These technological advances have enabled new technologies for human analysis and intervention, and might in the future be more important in quantifying health data than laboratory equipment (Shull, 2014). According to Shull, one of the main advantages of sensors in personal devices is that they are able to measure the users in their own environment and thus eliminating constructed lab settings.

4.3 User Effort and Retention Rate

Fairly accurate self-report of walking and heart rate is possible. But it comes with substantial user effort, making it infeasible as a long-term data collection strategy. Research has shown that the 30-day retention rate for using health and fitness apps is only 47% with a usage of 2.7 times per week on average. Laboriousness was reported as one of the main factors for ending use of health apps (Rabbi et al., 2017). This is confirmed by Consolvo et al's study on adoption rate and user effort. Their research showed a clear tendency between low effort and high adoption rate (Consolvo et al., 2014).

5. CONSIDERATIONS WHEN DESIGNING EHEALTH APPLICATIONS

A study from April 2017 concluded that the largest group of health app users were young, healthy, university educated people from high income families. The same group was the most likely to get any significant health benefit from using health apps. The study showed that the most important factor for adopting eHealth applications was higher education (Carroll et al, 2017). In their current state, wearables and eHealth technology is more likely to be purchased and adopted by people who already lead healthy lifestyles and want to document and quantify their progress (Piwek et al., 2016). This is confirmed by Shüll, who claims that not only are personal health technology products primarily used by healthy people, they are also designed for them (Shüll, 2016).

5.1 Facilitating Unhealthy Behaviors

For users that do not need a lifestyle change, quantifying personal health data could be counterproductive. Health and fitness apps can be useful tools for weight loss and lifestyle change, but they can also trigger unhealthy behaviors by creating a dependency on quantifying and logging health data, illustrated in figure 1. With sensing technologies, users can track and monitor their diet and activity level in a more personalized, discreet, mobile and quick way with much less effort (Tan et al., 2016). A study from 2017 showed that health apps promoting activity and healthy calorie balance, was frequently used by people diagnosed with anorexic behaviors as a tool to help facilitate their eating disorders. Being able to quantify data triggered an obsession that had a negative impact on their physical and mental health (Eikey and Reddy, 2017). The interaction pattern is illustrated in image 2.

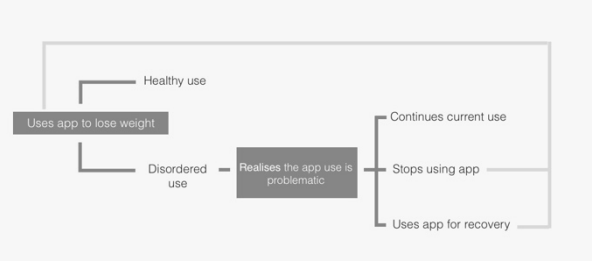

Image 2: Patterns of weight loss app use, adapted from image by Eikey and Reddy (2017)

5.2 Gaps in Tracked Health Data

Health data tracking can in some cases have a negative effect on users, both mentally and physically. Although smartwatches and smartphones can detect many physical factors that are a part of the user's health, there are no sensing technologies that are sophisticated enough to paint the entire picture. Especially not the part of our health that is affected by mental factors (Schüll, 2016).

5.2.1 Sensor Technology is not Perfect

Even though sensor technology is becoming more and more advanced, it is not perfect. It can be tempting to design health applications that focus on activities that the sensors in the device can detect accurately, but it is then very likely that it won't cover the entire range of the user's health (Consolvo et al., 2014). Other sources of error can be the user taking some time off from using the device, lending the device to someone else or the device's battery running out before the user finishes the activity.

5.2.2 Only Detecting a Narrow Range

According to Consolvo et al, the biggest downside of tracking devices is the narrow range of activities they can detect. There are many devices available on the market with accurate sensor technologies, but they cannot explicitly detect every single activity, give as much precise information of heart health as EKG or give a clinically accurate analysis of the user's sleep quality. Finally, the study from 2014 showed that none of the companies making popular trackers allowed users to correct errors in their own data (Consolvo et al., 2014). This key point will be readdressed later in the article.

5.2.3 Leading to Less Activity

Houston was one of the first physical tracking apps for personal use when it was designed back in 2005. It used a pedometer to track the number of steps taken in a day, and the users could choose whether or not they wanted the data to be shared. An issue with the Houston app was that it did not separate between high intensity activities like running and low intensity activities like casual strolling; because it was not designed to record anything else than the number of steps taken in a day (as seen in image 3). Some participants in the study decided to not do physically demanding activities like biking, swimming or tennis because they did not get any credit for it in the app. The app was not transparent enough about only

tracking walking, so for participants who already had high activity levels, Houston actually had an opposite effect; it discouraged them from being active (Consolvo, 2009).

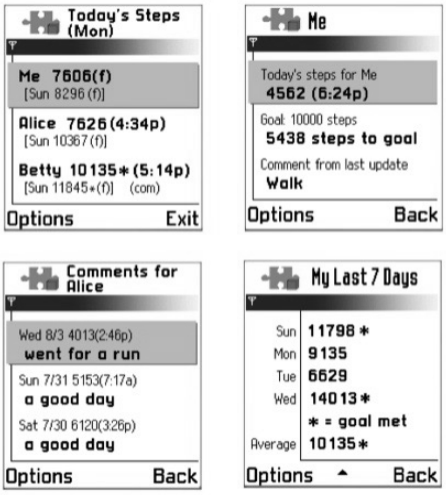

Image 3: Screenshots from the Houston App (Consolvo et al., 2014)

5.3 Overpowered by Numbers

An experiment from 2016 found that even though activity tracking by counting steps made the participants walk more, the tracking also made them enjoy walking less than before (Etkin, 2016). Although the numbers were motivational factors, they would in some cases became more important than enjoying the actual walk. Notifications and social encouragement are actively used to retain users and make them spend more time using the app, which is beneficial to the developer, but might not always give much additional value to the user. In the book "Irresistible", Adam Alter discusses how we become more and more addicted to our phones. Acts like health tracking can encourage compulsive behaviors, and how the apps are designed to trigger them. He claims that this is because the increased connectivity in several platforms of our can overpower the act of actually living our lives. Making the numbers more important than the activities themselves, and our smart phones' opinion more important than our own perceptions (Alter, 2017).

5.4 Triggering Stress

Because they are so easy to compare, quantify and beat, numbers can be a huge stress factor in people's lives. In some cases, the technology might even appear to take control over the users, rather than the users controlling the technology. Users of eHealth technology have reported skipping runs if the battery in their smartwatch is flat (Longevity.media, 2017), only feeling rested if they have registered eight REM cycles on their Sleep Cycle app and getting stressed out, and consequently a higher pulse from seeing that their heart rate was measured to be a little higher than usual (Lewis for nature.com, 2013). The conflicting effects of sleep apps are confirmed by Van den Bulck (2015), who proposes the term 'chronorexia' to describe obsession with healthy sleeping measured by electronic personal devices.

6. SENSE OF CONTROL AND OWNERSHIP

Digital tracking products and applications promise to help their users take the guesswork out of everyday living by supplementing real-time experiences and perceptions with objective data and visualizations. Many manufacturers draw lines between *the data the user produces* and *who he or she is*. These trackers are quantifying personal, sometimes even intimate things and it can be problematic for users to see their own lives visualized. Especially if they find that the data is incorrect (Schüll, 2016).

6.1 Accessing Raw Data

As of 2014, FitBit was the only popular tracker that provided an API (Consolvo et al, 2014). The API only provides third parties with daily data, i.e. steps taken in a day or average heart rate. They do not provide intraday data such as each walk a person takes in a day or the heart rate for a particular run. The 2014 study also showed that none of the companies provided raw data. Users

were not even allowed to access their own raw data (Consolvo et al., 2014). There are several third party "ActivityHacker" scripts on GitHub that claim to let the user extract raw data from trackers, suggesting that most health tracker manufacturers do not allow users to access their own raw data as of November 2017.

6.2 Who Owns the Data?

As mentioned earlier in the article, a 2014 study showed that none of the companies making popular trackers allowed users to correct errors in their own data. The study also showed that most applications that base data collection on tracking, do not allow users to add additional data into the same application (Consolvo et al., 2014). Some third-party apps like fitness tracking app *Strava* allow users to remove parts of, or manually add to the data that is found within the application, but without altering the raw data. This can be problematic for the User Experience because personal data tracking is likely to not always be perfect. If a user discovers an error, or some external factor that might disrupt the data set, it can be discrediting of the system when the user is unable to alter the raw data to correct the error.

6.3 Notifications, advice and reminders

When asked about features of health apps, 12% of users reported notifications as the most important. Overall, notifications were ranked third after sensor tracking and a chance to set personalized goals (Murnane et al., 2015). A study by Dennison et al from 2013 showed that notifications in health apps often triggered negative emotions. Although they were designed to help users reach their goals, the notifications reminded the users of the goals they were not reaching, triggering negative emotions towards themselves and subsequently towards the app. The purpose of the reminders was to encourage users to use the app actively, and in turn help them improve their health. Instead, they contributed to desertion of the app, leaving the user with minimal lifestyle change. Participants described irritation and disappointment towards inaccurate, untimely and irrelevant notifications or advice (Dennison et al., 2013).
In contrast, a study from 2015 showed that carefully designed notifications increased the logging frequency in a group of 60 health app users from 12% to 63% (Bentley and Tollmar, 2013). Bentley and Tollmar defined three key factors for the success of tracking promoting notifications. In order for reminders to be constructive, they need to be non-interrupting, user configurable and followed with a simple activity in the app.

6.4 Living Databases

Many health and fitness trackers are marketed towards users who want to "*take control of their own health*" (Schüll, 2016). However, Shüll states that it is important to remember that humans are not "living databases", and a day consists of more than just heartbeats, steps, stairs climbed or turns and tosses during a night.

7. DISCUSSION

With increasingly better sensing technologies, health tracking in personal devices can be a constructive supplement to traditional health services. There is however little research indicating that commercial health apps have a real value in patient treatment in their current state (Torous and Roberts, 2017). The main advantage, with health data tracking in personal devices is that they could help predict disease before the user becomes sick and provide health care professionals with important data from non-clinical settings, which can be useful supplements to traditional health care.

Findings from Consolvo and Murnane shows that there is a desire for health apps with integration against sensors in smartphones and smart watches. However, since the solutions are being downloaded, but also abandoned within a short time frame, we could assume that they just do not hold high enough quality. A key to enhancing the quality of these solutions is through user-centered design.

Many users download health apps for the reminders and advice that can help them improve their health, but the same reminders are also guilty for many abandonments. There is a fine line between keeping users interested and reminded to use the app, and annoying them until they abandon it (Bentley and Tollmar, 2013). Some applications tend to send out notifications reminding users of what have not been doing. E.g. when Azumio tells the user that "it's time to measure your pulse" or FitBit vibrating to tell users that they have walked less than 250 steps the preceding hour. These reminders could be helpful for users who sometimes forget to do the things their devices want them to do, but for users who only sporadically use the solution, the notifications will probably have little to no effect.

This literature review shows that a great challenge with the tracking-based eHealth apps that are available today, is that they are primarily used by healthy, young university graduates. It is likely that one of the reasons for this is that they are essentially designed for that group (Shull, 2014). For users that do not really need a lifestyle change, health apps could function more like "*a solution in search of a problem*", or possibly even push healthy users in the direction of unhealthy habits of health obsession and eating disorders.

Popular health and lifestyle apps like Strava, Lifesum and Azumio use information visualization, social media, reinforcements such as virtual rewards and gamification as motivation. Users can share their data and compete with others (or themselves) to reach their health or fitness goals. These external motivators are great if you are good at something, but for users that really *need* a lifestyle change, these features could scare them away from the applications.

Many health applications can generate visual feedback using the user's health data, but something is not necessarily true just because it can be quantified and visualized. Numbers are easy to trust, compare and beat, but humans are much too complex to be described with only numerical values from tracked data. An example could be measuring whether a user had a good run solely based on GPS coordinates, pulse data and values from a pedometer. Other factors like e.g. the weather, the runner's mood and whether he or she got a blister from the run can say just as much about the perceived quality of the run.

Most of the currently available health apps and wearable electronics are not transparent enough about gaps in data coverage, which could possibly provide the user with wrong information about his or her health. Leading the user to feel less ownership over the data, as well as discrediting and abandoning the application. The user should look at the numbers or the visualizations and think "this is me!" rather than "this is someone I do not want to be" or possibly even "who is this?". If that is not the case, the user should be able to correct or delete the data.

7.1 Design Suggestions

Based on the findings from this literature review, a set of design suggestions have been defined as a tool to help maintain the UX-perspective in health data tracking applications.

7.1.1 Let the user be in charge

Let the user decide what data to include in the data set, and what should be deleted or altered. The user should be the one to decide what data should be shared, and with whom it should be shared.

7.1.2 Let the user add subjective data

To get a true, holistic image of an individual's health, tracked health data needs to be supplemented subjective data. There are numerous factors that could influence a person's health besides what is directly objective and quantifiable.

7.1.3 *Be aware of gaps in the data set*

Not even the most sophisticated devices can cover every single metric of a person's. Make sure that the solution, including any visualizations or other types of feedback presented to the user takes this into consideration so that the user is not mislead or disappointed.

7.1.4 *Reminders and notifications should be unobtrusive and relevant*

Notifications in health apps should be designed to remind the users of things that can benefit their health. They should not remind them of how unhealthy they are, or annoy the user in any other way.

7.1.5 *The user should always understand the intention of the application and it's intended user group*

The solution should be so transparent and easy to understand that the user can make independent and informed choices based on the information that is presented.

8 CONCLUSION

Carefully designed health applications might help users stay healthier by letting the them monitor physical features at home as a part of their everyday lives instead of doing so sporadically at the doctor's office. Most of these applications are however not good enough to have any real value as they are designed today.

Research shows that most health and fitness apps are designed in a way that appeals to healthy, young people, and fail to target those who actually need extensive health care. We need more research on how they can be designed to reach the intended user groups, and more importantly how they can be designed to have an effect on each individual user's health or provide information to health care professional that is accurate enough to be used in clinical settings.

We also need more research on how health data tracking and smart devices constantly telling users about their heart rate, step count or sleeping affect their health. Both physically and mentally. There is a lot of research stating the accuracy of the devices, but not that much is done on how activity tracking affects how the user enjoys physical activity or how sleep monitoring and heart rate measuring could make the user stress more about those features than if they were not quantified.

From a user experience (UX) perspective, it is important to remember to include other factors than just numbers. More research needs to be done on what quantification does to enjoyment and how it affects the feeling of ownership of the user's data, as this can have a huge influence on both the user's motivation for using the solution, as well as on the accuracy of the data set. The suggested design principles in this article do not solve every issue with sensor tracking in health apps and smart devices, but they could help these applications become more user friendly by encouraging users to feel ownership of their own data, supplement objective data with subjective data and in general let the users be in charge of the information that is generated from their everyday lives.

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