The issue of compliance in personal informatics: a case study of sleep

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Abstract

The increased sophistication of embedded capture and access technology and the growth of communities such as the Quantified Self that advocate for the proliferation of these tools has brought personal informatics to the masses. However, personal informatics tools and methods are still far from ubiquitous. In this paper I discuss ways to incentivize use and improve compliance of personal informatics tools. As a case study, I describe a tool that I am in the process of developing. This tool measures sleep using the accelerometer found in many smart phones, by placing the phone on a bed sheet during sleep. The tool also tracks habits related to sleep, such as mood, and provides daily feedback, with progress logging and correlation analysis tools. The implication of this tool for public health and psychotherapy are discussed.

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Author Keywords

Quantified Self; capture and access, sleep, actigraphy, insomnia, mobile phones, ubiquitous computing

ACM Classification Keywords

D.2.2; D.2.10; I.1.2

Introduction

I have tracked everything from my mood, sleep, exercise, alcohol use, caffeine use, and diet and I have used various tools to track these behaviors, such as, iPhone applications, the Zeo headset, and recently, the Jawbone UP bracelet. The problem is that I use these devices for a few weeks, but I soon lose my incentive and stop complying. Even for the Jawbone UP, which is a non-invasive device that requires minimal effort to use, I often forget to press the single button on the device that indicate to the device that I am going to bed, resulting in my sleep not being tracked. As the Quantified Self organizer for Washington DC, I frequently hear similar anecdotes. Moreover, one of the largest contributors of weak efficacy for behavioral interventions of various mood and sleep disorders is patient compliance [1].

For personal informatics to grow as a field it must address the problem of compliance. Four ways to address the problem of compliance include: (a) develop technology that is increasingly embedded in everyday interactions with the environment, (b) reduce the costs of data collection and increase its benefits, (c) engage a social community, and (d) be scientifically validated.

In this paper, I will use an iPhone application that measures sleep, called Proactive Sleep, as a case study for how to address the problem of compliance in personal informatics. While the application that was developed does not address all the route causes of low compliance, it includes a new method of embedded data collection, useful examples of data visualization for improving perceived benefit to the user, engagement with friends and family, and it is based on scientific methods and findings.

Embedded capture and access

Embedded capture and access means seamlessly and unobtrusively collecting data while the user participates in everyday activities [2-4]. The Jawbone Up is a good example of embedded capture because it collects pedometer data using something that people frequently wear – a bracelet. Proactive Sleep utilizes embedded capture by tracking sleep based on an activity that many people already engage in – setting an alarm clock. Setting the alarm clock initializes the tracking of sleep, at which point the application detects whenever the phone's accelerometer is activated. By placing the phone on the bed sheet during sleep, actigraphy data is collected throughout the night. Sleeping with the phone on the bed sheet may or may not be an example of embedded capture, yet the practice is increasingly commonplace.

The application uses the actigraphy data that it collects to determine when the user awakens during sleep. People naturally wake up throughout the night as they pass through the stages of sleep. The algorithm for detecting sleep/wake is still being refined, but it works similar to previously validated algorithms, which use an Actiwatch to measure actigraphy. For these validated algorithms, the actigraphy data was found to be highly correlated with polysomnography data, with correlations greater than r^2 = .90 [5-6]. There are various deviations to how sleep/wake is detected, but generally, the method is as follows: zero-crossing threshold detection [7] is used to calculate the 10 seconds of each minute with the largest integrated acceleration. This results in each minute being associated with a maximum number of zero-crosses, known as counts. Each minute is categorized as sleep/wake by taking the weighted average of four minutes before the current minute, the current minute, and two minutes after the current minute as predictors

$$D = P(0.010_{A-4} + 0.015_{A-3} + 0.028_{A-2} + 0.031_{A-1} + 0.085_{A0} + 0.015_{A+1} + 0.010_{A+2})$$

Equation 1. The logistic regression equation used by Jean-Louis, Kripke, Cole, Assmus, and Langer (2001) to predict sleep/wake. If D is greater than or equal to 1 then the minute is determined as awake. P is the scaling factor for the polynomial. A represents the minute, where A-4 is the activity score for four minutes before the current minute, etc.

One issue with using this algorithm is that it is made for an Actiwatch, not a smart phone that is placed on a bed, resulting in less sensitive detection of actigraphy. While an empirical study to determine the equation for smart phone actigraphy is yet to be conducted, after testing the application with various individuals and environments, I was able to produce data that was similar to what might be expected from a sleep session (see Figure 1). This is an example of embedded access because the user is presented with their prior night of sleep based on the common act of turning off an alarm.

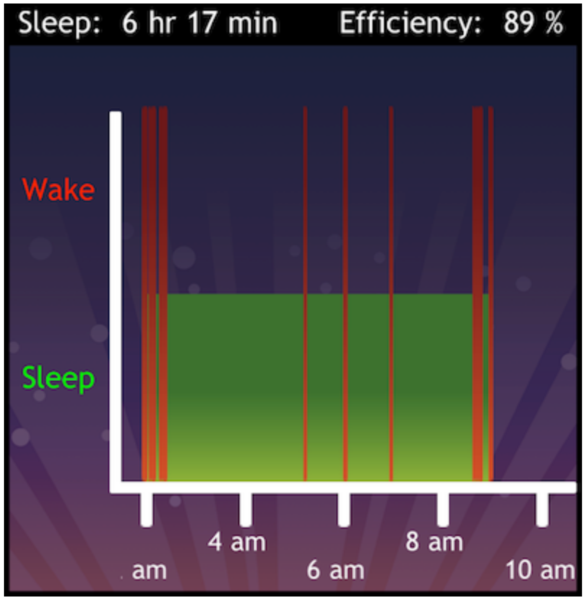

Figure 1. Output from the Proactive Sleep application after sleeping with the phone on my bed sheet. The red, longer lines indicate awakenings and the green, shorter lines indicate sleep. Sleep efficiency can be used as a measure of insomnia and it is the percentage of time spent sleeping in bed.

Reduce cost and increase benefit

There is a cost to any amount of time spent inputting data into a personal informatics device, where the longer it takes to input data, the less likely users are to comply. However, if the benefit of using the device outweighs these costs, then decreased compliance can be mitigated [8]. The Jawbone Up is a good example of a device that has very low time cost, but lacks in perceived benefit (e.g. the device does not provide feedback or suggestions on how to improve behavior).

The Proactive Sleep application addresses the issue of cost by tracking awakenings simply by placing the phone in a bed sheet. This is opposed to how sleep clinician typically measure sleep quality, by asking their patients to write down an estimate of their awakenings in a sleep diary. As a result, the cost of tracking sleep is reduced and the data are potentially more accurate.

To improve on the perceived benefit to the user, the application provides daily feedback on the optimal times to go to bed and wake up for the next night of sleep. This calculation is made based on a predefined sleep goal that the user can set and the bedtime and sleep amount from the previous night of sleep. Additionally, the user can view their data over multiple days and enter in additionally information on their mood, diet, exercise, nicotine use, caffeine use, and alcohol use. This information can then be used to identify the factors that affect one's sleep.

Engage a social community

It is more difficult to engage the social community for the field of sleep than a field like exercise, where it is more common for users to compete and motivate one another. While the Proactive Sleep application includes the functionality of posting sleep to Facebook, this feature is seldom used. This issue can potentially be addressed by developing a web-based infrastructure where users can back-up their data and compare their findings to one another. Such a system can be used to provide users with information on how their sleep compares to other users in their age group, and help users identify new and effective ways that they can improve their sleep. This may encourage users to increase their compliance in using the device by providing them with more benefits and a community that they can reach out to.

Scientific validation

If the Proactive Sleep application can be used to improve the detection of insomnia, then sleep clinicians can recommend the device to their patients. Acceptance by the medical community of personal informatics devices can thereby dramatically increase compliance. However, many devices are not scientifically validated, and in some cases make claims that have not been proven. For example, some applications claim that they can detect sleep stage based on body movements. Further testing is still needed to improve on the accuracy of the sleep/wake detection algorithm to detect insomnia. Yet if an equation can be validated, then future work can determine if the application can administer behavioral interventions for insomnia, which have been shown to be equally as effective as prescription medicine [9].

Conclusion

Four ways to improve compliance were identified: embedded capture and access, reduced costs and increased benefits, social engagement, and scientific validation. While the Proactive Sleep application does not address all of these issues, it presented a novel method of detecting sleep/wake patterns and increasing perceived benefit of tracking sleep data.

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