Some Challenges in Activity and Sleep Monitoring for Personal Informatics

Blaine A. Price
Centre for Research in Computing
The Open University
Milton Keynes, MK15 0AY, UK
B.A.Price@open.ac.uk

Marian Petre
Centre for Research in Computing
The Open University
Milton Keynes, MK15 0AY, UK
M.Petre@open.ac.uk

Yvonne Rogers
Centre for Research in Computing
The Open University
Milton Keynes, MK15 0AY, UK
Y.Rogers@open.ac.uk

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Abstract
In this position paper we review a range of activity and sleep monitoring devices and discuss some of the challenges they raise for personal informatics research.

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Personal Informatics, activity monitoring, sleep monitoring, lifelogging

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Personal Informatics, activity monitoring, sleep monitoring, lifelogging

Activity Monitoring Devices
Recent years have seen accelerometers drop in price and they can now be found in a huge variety of consumer devices from game controllers to smart phones. Smart phones are an ideal device to act as an activity monitor since the user normally carries it with her at all times and it can passively and automatically measure activity in a non-intrusive way. At time of writing, however, smartphones are not practical as activity monitors as both iPhone and Android apps

Figure 1: FitBit showing flower on OLED display briefly after a button push

Figure 2: BodyMedia FIT Armband

using the accelerometer (mostly pedometers) do not work well running in the background and would drain the battery in less than a day if left running.

A more practical device currently available in the US is the FitBit [1] (see Figure 1), a small battery powered wireless device with a small OLED display and a 3D accelerometer. It is worn in the same manner as a pedometer, clipped to the torso on a belt, pocket, or undergarment, and automatically synchronizes time and step counts when its base station is in range and connected to a PC or Mac running the FitBit software. The data is uploaded to the user's private area on the FitBit website where number of steps taken in each 5 minute interval are recorded along with the estimated number of calories burned based on previously entered height, weight and gender information. The device is relatively non-invasive as and requires little effort from the user other than remembering to clip it to their body every day and charge the device about once a week.

Another accelerometer-based activity monitor is the BodyMedia FIT armband [2] (see Figure 2, also marketed as BodyBugg [3] and Ki Fit [4]). It has no user interface other than a single button, two small LEDs indicating whether it is on and its power state, and a small speaker which plays tones to indicate switching on, off or syncing. This is a somewhat more intrusive device day and night (removed only for bathing, charging and syncing the device). In addition to the accelerometer movement, the device also logs galvanic skin response, heat flux, and body temperature in order to give a more accurate calorie burn calculation. The device we tested required a manual sync by removing the device, connecting a cable and running a web-based Java program to upload data to the manufacturer's website in the user's private area. The website stores the calories burned per minute using a proprietary calculation based on data from the device and previously entered gender/height/weight data.

Although not intended as an activity monitor, the Vicon Revue (formerly Microsoft SenseCam) [5] lifelogging camera contains, in addition to its VGA colour still camera, an accelerometer, temperature sensor, light sensor and PIR proximity sensor. Although promoted by classic lifelogging proponents as a visual lifelogger [8], its primary use so far has been as a memory aid for those suffering disease or injury induced memory loss. However, recent work [10] has looked at using the accelerometer data to log activity for individuals to encourage non-sedentary behavior. The other sensors could also be used to infer more information about activity such as time spent indoors or outdoors and time spent in excessively cold or warm environments. Easily the most expensive device, it is worn in a manner similar to a necklace (see Figure 5) and is relatively non-invasive but requires daily manual syncing with a cable.

Sleep Monitoring Devices

A significant component of human activity involves being relatively inactive: sleeping. The quality of sleep is certainly recognized as influencing an individual's performance during waking hours and many activity monitors double up as basic sleep quality monitors. Although serious sleep problem analysis requires quite a lot of invasive lab-based monitoring sensors, one of these lab-based measurements, actigraphy [7], is accepted as a basic measure of sleep quality. It relies on frequency of wrist movement over time to detect

Figure 3: WakeMate Wristband


Figure 4: FitBit in sleep wristband activating sleep mode

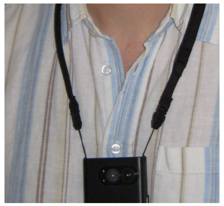
Figure 5: ViconRevue lifelogging camera (formerly Microsoft SenseCam)

whether someone is awake, in light sleep, or deep sleep. A number of consumer products are now sold to help individuals monitor their sleep level so that their morning alarm clock wakes them when they are in a light sleep phase, even if this is 30 minutes before their desired wake time, so that they feel more refreshed on waking than if they are suddenly awakened from a deep sleep phase.

Perhaps the simplest, cheapest, and least invasive of these are the smartphone based apps (e.g., SleepCycle on iPhone, or GentleAlarm on Android). These apps are simply switched on before going to bed (usually plugged into a charger) and placed on the top corner of the mattress. The phone's accelerometer detects movement as the user moves around in their sleep gathering measurements similar to wrist actigraphy. Although likely less accurate than other systems, these methods are completely non-invasive, and automatic other than remembering to switch on the app and alarm each night.

The FitBit activity monitor also doubles as a sleep monitor although without the light-sleep-cycle alarm has to clip it to a soft wrist band then press and hold the button to indicate the start of sleep (see Figure 4) and repeat the process when waking up to indicate the smartphone apps, this device automatically uploads the sleep data to the users private area on the manufacturer's website indicating, minute by minute the periods of deep sleep and activity (lighter sleep). The activity time at the start of the sleep period is subtracted from the total sleep time to indicate how long the user took to get to sleep and the activity periods indicate how many times they "woke" in the night.

A similar device in terms of automation and intrusiveness is the WakeMate wristband (see Figure 3). It is a Bluetooth device which needs to be switched on each night and off each morning and the user's smartphone (iPhone or Android) needs to be running a custom app to record the movement data all night. Like the smartphone based sleep monitors, this also features an alarm mode to wake the users in a light sleep phase and the data appears on the user's phone and on the user's private area of the manufacturer's website with a higher granularity of movement data than FitBit's standard display.

The Bodymedia armband is the most automatic of the actigraph-based sleep monitors in that it detects when the user is lying down and reports similar statistics to the other devices on the user's private area of the website. It is also possibly the most intrusive as it needs to fit snugly on the bicep and is much bulkier than the other devices.

One of the more unusual sleep monitoring devices is the Zeo [6] system, which involves the user wearing a headband device while sleeping (see Figure 6). Moderately intrusive but fully automatic, this proprietary system purports to detect when the user is awake and in different stages of sleep, including REM sleep which actigraphy cannot detect. Detailed statistics and graphs are reported wirelessly to the bedside clock which can be set to wake the user during a light sleep period. Data can be saved to an SD card and uploaded to a computer or the manufacturer's website for further analysis.

Figure 6: Zeo headband

Some Challenges

Balancing Automation, Engagement, and Intrusiveness

Although previous work suggests that increased automation in personal informatics systems may lead to a decrease in engagement [11], the manual components for most of the systems we tested were due to a shortcomings of the system or hardware design (e.g. pressing the FitBit buttons to indicate start/stop of sleep, or using cabling and running special software to sync the BodyMedia armband or ViconRevue camera). We would argue that engagement can be created through prompts and other more traditional "nudge" techniques [9] and that more automated and less invasive mechanisms are likely to succeed in adoption as long as the data is good enough.

How Much Data is Enough?

Our initial work in comparing calorie counts from the activity monitors discussed here show very small differences between each device as well as the "ground truth" as noted by devices and observations external to the user. We are extending our studies to include our own smartphone apps and to compare each of these devices against each other with a wider pool of participants to determine the minimal data that can be collected in the least intrusive and most automatic way. If a simple automated smartphone or clip-on pedometer can provide roughly the same data as more expensive devices collecting more varied data using more manual and intrusive means then there will be more opportunities for people to adopt personal informatics technologies.

Data Standards for Personal Informatics

In comparing these devices, we found the biggest challenge was access to data. Our research agenda also includes working towards standards for personal informatics data interchange.

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