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PreventDark: Automatically Detecting and Preventing Problematic Use of Smartphones in Darkness

Wenjie Ruan[§], Quan Z. Sheng[§], Lina Yao[†], Nguyen Khoi Tran[§], and Yu Chieh Yang[§]
[§]School of Computer Science, The University of Adelaide, Australia
Email: {wenjie.ruan, michael.sheng, nguyen.tran}@adelaide.edu.au
[†]School of Computer Science and Engineering, UNSW, Australia, Email: lina.yao@unsw.edu.au

***Abstract*—Smartphone adoption has increased significantly and users can access the Internet, communicate, and entertain themselves anywhere and anytime. However, the negative aspects of smartphone overuse on young adults are being increasingly recognized recently. One such serious problematic usage is peering at brightly lit screens in dark, which can cause sleep loss and resultant health problems. In this paper, we investigate the potential of exploiting sensors embedded in smartphones to detect and prevent such unhealthy habit by measuring the ambient light intensity and detecting the smartphone motion. We implement our system through an Android APP, called *PreventDark*. We show the feasibility and accuracy of our developed system by experiments on different android smartphones. Field experimental results indicate our system can significantly prevent and decrease the problematic use after intervention with up to 93.6%, particularly in the dark residential environments.**

I. Introduction

As smartphones are more widely used in daily lives and their capabilities are constantly improving, the number of people who use smartphones and the extent of their usage continue to grow. According to a recent survey [1], 80% of the world's population has mobile phones and one-third of them own smartphones. Thus, smartphones have now become an integral part of the daily lives of many individuals. However, negative aspects of their use have emerged, such as the disruption of social interactions. In addition, researchers have found close relationship between their overuse and poor mental health (e.g., sleep deprivation and attention deficits) [2]. Interactive characteristics of smartphones contain inducing and reinforcing features that promote excessive usage behaviors [2]. One of most problematic phone-using habits that can directly harm to human health is to constantly peer at bright phone screens under dim ambient light. There's a growing body of research that suggests *"peering at brightly lit screens at night disrupts the body's natural rhythms and raises the risk of medical conditions linked to poor sleep, including obesity, heart disease, strokes and depression."*[1] More extremely, based on a report[2], a 26-year-old man who texted his girlfriend for hours in the dark has to go for an emergency surgery after his retina detached from the back of his eyes.

[1]www.theguardian.com/science/2013/may/22/peering-bright-screens-dark-harm-health
[2]www.dailymail.co.uk/health/article-2646136/Could-using-phone-night-cause-blindness.html

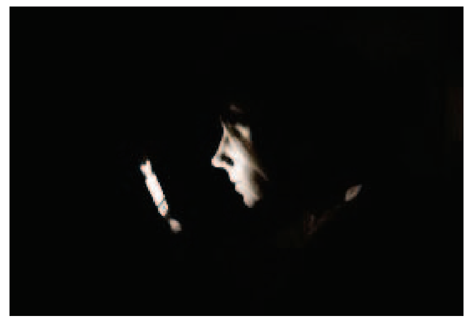

Fig. 1: Using phone in dark is bad for user's eyes

This emerging issue has motivated us to develop *PreventDark*, a smartphone-based system that can automatically detect and intervene users to constantly use smatphones in a dark environment. To achieve such functionality, we need to tackle two practical problems: i) how to measure the intensity of ambient light, and ii) how to detect the user is currently using the smart-phone. Fortunately, most smart-phones have rich built-in sensors (e.g., accelerometers, proximity sensor, gyroscope etc.) that can measure motion, orientation, and various environmental conditions. These sensors are capable of providing raw data with high precision.

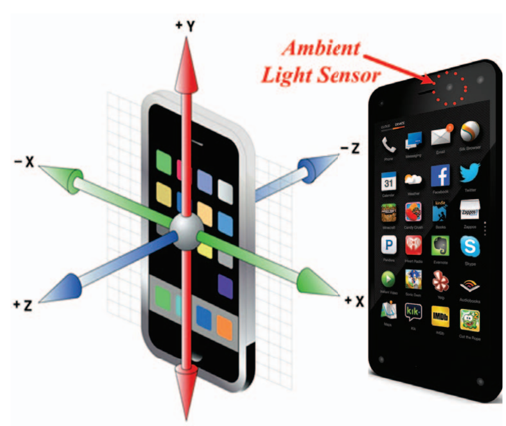

Fig. 2: Three-axis accelerometer and light sensor

Illustrated by Figure 2, the 3-axis accelerometer can monitor three-dimensional device movement, and the light sensor can detect the light intensity in the ambient environment near the phone. In this paper, we first off-line collect the accelerometer readings when a user is using the smart-phone in various scenarios, such as playing phones while walking, sitting, standing and lying down. Then, based on the collected data, we learn a variation threshold and retrieve recent phone-screen touching records to distinguish whether the user is actively using a smartphone currently. We also collect the light sensor readings when the smart device is under different ambient light environments (e.g., no light, with bed lamp on, and with ceiling lamp on). Accordingly, we choose a light lux threshold to decide whether the ambient is dark enough. In summary, our main contribution lies in that we develop a smartphone-based system by utilizing off-the-shelf sensors in the device, which can effectively detect and prevent problematic usage of smartphone in dark environments. To the best of our knowledge, our proposed system is a first few on preventing unhealthy usage of smartphones in darkness.

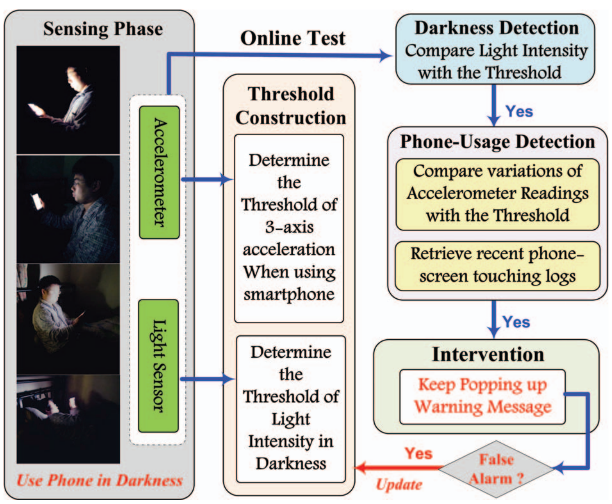

Fig. 3: System Outline

II. Proposed Solution

Figure 3 shows an overview of our system, which consists of five main phases: the *Sensing* phase, the *Threshold Construction* phase, the *Darkness Detection* phase, the *Phone-usage Detection* phase and the *Intervention* phase.

One of the key phases is to construct the thresholds for accelerometers and light intensity. As Figure 4 (a) shows, the light intensity displays different variation patterns when users plays smartphones in various light environments. Under the circumstance of bed lamp on, the detected light strength variates within a smaller range, around 20∼120 lux, comparing to the situation of the ceiling lamp on. When there is no light at all, the light intensity is pretty stable at 0 lux. Thus, based on the observations, we set the light intensity threshold as 5 lux.

According to Figure 4 (b), we can also perceive that the variation of device movement can be potentially used to distinguish people using phone in different living status [3], so we set the three variations thresholds (for accelerations in three axis) as $1m/s^2$, which means either one acceleration that variates beyond the threshold will be regarded as possibly using the device. To decrease false alarms, we also retrieve the screen-touching logs of recent 30 seconds to confirm the phone-usage. Specifically, we first detect whether current ambient light is below the light threshold, if it is, then we detect whether the variations of accelerometer readings (for the latest 30 seconds' data) are less than the acceleration thresholds. If both conditions meet, we further retrieve whether the user has touched screen within last 30 seconds. Then, if the screen being touched recently, we pop up a warning message that indicates *"Using phone in darkness is bad to your eyes"*, along with button choices *"OK"* and *"Do not remind me again"*. If the user clicks *"OK"* but still continues using the phone in darkness, the smartphone will continuously pop up an intervention message until the user stops such unhealthy behavior. Since there are possibly some emergent circumstances that require to use smartphones in darkness (e.g., checking urgent emails, making emergent calls etc.), so we set an option *"Do not remind me again"* that makes the smartphone disable detecting for 5 minutes. Later on, the detection and intervention will be automatically activated again until the user gives up such unhealthy behavior. Our solution is also energy-efficient. On the one hand, the accelerometer is occasionally activated, and the light sensor, the only always-on sensor, consumes very low power (e.g. 0.04 μA for TEMD6010FX01 Light Sensor). On the other hand, preventing phone overuse in dark can save battery power and prolong the standby time for normal use of smartphones.

III. System Implementation

The final product of this project is an Android application named *PreventDark*. The purpose of *PreventDark* is to notify user about their problematic use of smart-phone and communicate possible consequences of such behaviours. When a problematic behaviour is detected, a message that contains advice corresponding to that behaviour will be displayed in an alert box on the phone screen to remind the user about the possible consequences of continuing such behaviour. These detection processes run in background, so the detections will continue even after exiting the application interface. When the message is displayed, the user will see two buttons available for clicking. Clicking the left button exit the message box; clicking the right button makes the corresponding detection function ineffective and exit the message box. This right button is built for the situation where the user finds it annoying to see the message about frequently reappearing and want to stop receiving these notification.

Shown as Figure 4(c), to use the APP *PreventDark*, the user first needs to enter the only interface of this application by clicking the application icon. The top half of this interface displays information about the phone condition. It displays the values of the sensor data collected from the in-built Ambient light sensor and accelerometer of the smartphone.

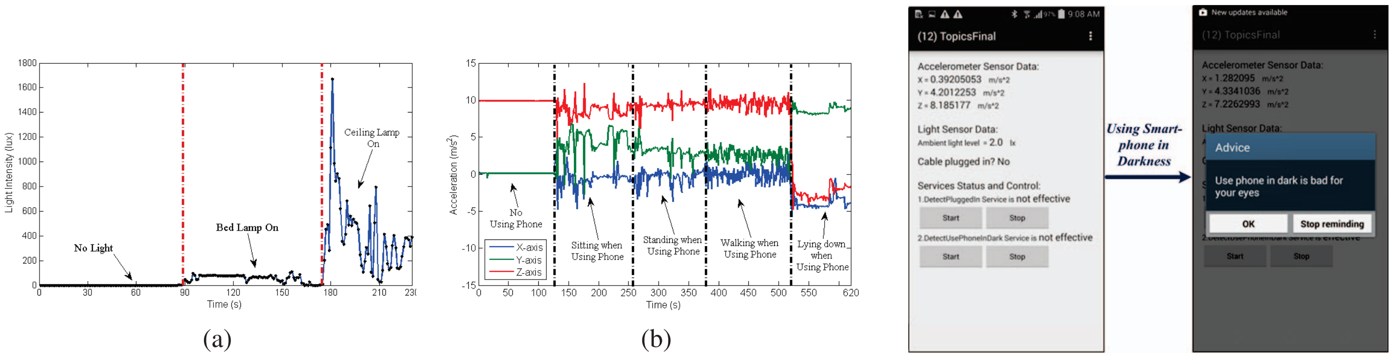

Fig. 4: (a) Light sensor readings for different light conditions; (b) Three-axis accelerometer readings in different living statuses; (c) The android APP interface

The bottom half of the interface is the "Service's Status and Control" section. This section allows the user to see whether the functions are effective and allows the user to make these services effective or ineffective. In the meantime, we successfully implement the APP as a thread running in the background, which means as long as users install it, the behaviors of using phone in darkness will automatically be detected and intervened.

IV. Evaluation

We evaluate our solution using three different brands of smartphones (*i.e.,* SONY Xperia Z1 with Android 4.4.4, ZTE v960 with Android 2.3.6 and Samsung Galaxy Core Prime with Android 4.3.1) by continuous seven days experiments. We first test whether the proposed system can properly work when turning off the lights in different rooms at night, such as the dinning room, the bathroom, the bedroom and the kitchen. We also take a series of common postures when using mobile phones in our daily lives into account, including using the phone while standing, walking, lying in bed, and sitting. We also test whether it can properly work when turning off lights in different rooms (e.g. dining room, bathroom, bedroom and kitchen etc.) at night.

TABLE I: Test performance (*Correct Detecting Times*)

Items	Standing	Walking	Lying Down	Sitting	Overall Detect Rate
SONY Xperia Z1	93	87	99	93	88.5%
ZTE v960	87	84	90	96	85%
Samsung Galaxy CP	96	93	102	102	93.6%

Overall, three subjects test each smartphone by 420 light-on-and-off events (include using phone while standing, walking, sitting, and lying in bed for 105 events each). Table I shows the correct detection times (excluding false alarms when light is still on, and miss detection when light is off) regarding different phone-using scenarios. The test performances of the three smartphones are various, among which Samsung Galaxy CP obtains overall 93.6% detecting accuracy. For the scenario of using phone while walking, the detection rate is actually slightly worse than other cases, which may lie in the fact that when walking in some locations, the shadow may block the light sensor causing a false detection despite the lamp is still on.

V. Related work and Conclusion

With the prevalence of smartphones, recently researchers have tried to identify the problematic usage patterns that are related with its overuse, such as researchers in [4] characterize relationships between usage features and phone overuse using analytic modeling and interview data. In [5], authors propose to detect the problematic use by collecting contexts and usage data from the smartphones. However, both works focus on abstracting informative features to classify the unhealthy usage based on data mining techniques rather than designing a real system to detect and intervene a problematic using behavior. Thus, this paper has designed, implemented and verified a solution to effectively detect and prevent one of the unhealthy behaviors: using smartphones in darkness. In our future work, we will investigate how to detect other problematic usage of smartphones based on built-in sensors and human-phone interaction contexts, such as using phone when driving a car, playing smartphone while walking/power charging or playing smartphone for extremely over-usage (*Smartphone Addiction*), etc. More importantly, we will study how to feasibly intervene and prevent such unhealthy, overuse behaviors by persuasive technologies.

References

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