

---

# Clockwise: Inferring Chronotype and Daily Patterns from Smartphone Use

## Abstract

Rhythms guide our lives. Our biological clocks tell us when we need to sleep, eat and wake. Our use of technology can interrupt and obstruct these rhythms, making it difficult for our bodies to get what they need to stay healthy and balanced. This project is investigating whether it is possible to detect disturbances in individuals daily behavior by using low-level smartphone interactions. The advent of widespread smartphone ownership means much behavior and daily routines are mediated through this channel. We are investigating whether soft-sensor data can be used to automatically determine individual chronotype, daily rhythm and sleep-wake patterns. Is it possible, for example, to determine whether you are better suited to working in the morning or the evening based on how often you unlock your phone and switch between applications? This research aims to capitalize on the high levels of ownership and use of smartphone devices amongst college students to find novel and low cost methods to passively monitor well-being and productivity. If successful, this approach may have broader applicability ranging from personal well-being monitoring to physician directed interventions.

## Author Keywords

Chronotype, Daily Rhythm, Soft-Sensing

## ACM Classification Keywords

H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous.; H.1.2 [User/Machine Systems]: Human factors.; H.5.2 [User Interface]: Evaluation/Methodology.

## Introduction

There has been an increased interest in identifying the relationship between the daily rhythm, chronotype and various aspect of mental health. DeYoung et al. [3] associates morning type personality with more agreeableness and activeness while evening type personality is found to be more extrovert [7], innovation seeking [4] and increased risk of behavioral problem [5]. It has been also suggested that there might be a strong relation between eveningness and suicidality connected by impulsivity [11].

Struggling against one's chronotype (i.e. getting up early when you are a night owl) while sometimes necessary is not desirable and can result in social jet lag and even lead to long term health problems. Chronotype in both healthy and clinical population is usually assessed by Morningness-Eveningness Questionnaire (MEQ) [6]. This score from the questionnaire can be used to differentiate among morningness, eveningness and neither personality. Much behavior is now mediated through technology, particularly in the case of young people. This means that it may be possible to automatically detect not only chronotype but the subsequent dissonance between an individual's lived experience and their chronotype.

Recent studies have also found that college students typically receive inadequate amounts of sleep and have volatile sleep-wake patterns. This behavior can result in increased stress, consumption of alcohol and drugs to help

with sleep, poor academic performance and even car accidents [12]. Survey and laboratory studies suggest that a number of factors, such as social and academic demands, affect the pattern of the sleep-wake cycle of healthy college students [10].

While recent studies have provided a description of the sleep pattern of college students, there has been no work to our knowledge looking at identifying novel interventions to address sleep disturbance and social jet lag, although many studies have identified a need for such initiatives [9].

Our research aims to capitalize on the high levels of ownership and use of smartphone devices amongst college students to find novel ways to cheaply, accurately, and continuously collect real-time data on behavioral factors associated with chronotype and daily rhythm. To achieve this we will focus on soft-sensing on smartphones, looking at low level interaction patterns (e.g. how often a person unlocks their phone, how often they search the Internet, how often they switch between applications).

Our goal is to investigate whether phone use might provide a low level measure for assessing levels of sleep, chronotype and social jet lag. This approach has promise given the high degree of smartphone use particularly among young people.

Our Research Questions are:

- What is the baseline pattern of Android phone use in college students?
- How accurately can college students recall their phone use patterns?
- Can smartphone interaction patterns be used to assess daily rhythm and chronotype?
- Is it possible to build a personalized classifier that

can predict stressful situation from phone usage data?

- Might an increased awareness or feedback of fluctuations in smartphone use have promise as a possible intervention to address sleep disturbance and irregular daily rhythms?

Living a rhythmic life in tune with your chronotype is essential for sleeping well, productivity and health. Maintaining stable daily routine and sleep-wake patterns are recommended for treating many illnesses such as mood disorders. Findings from this research hence may have broad applicability in both clinical and non-clinical settings.

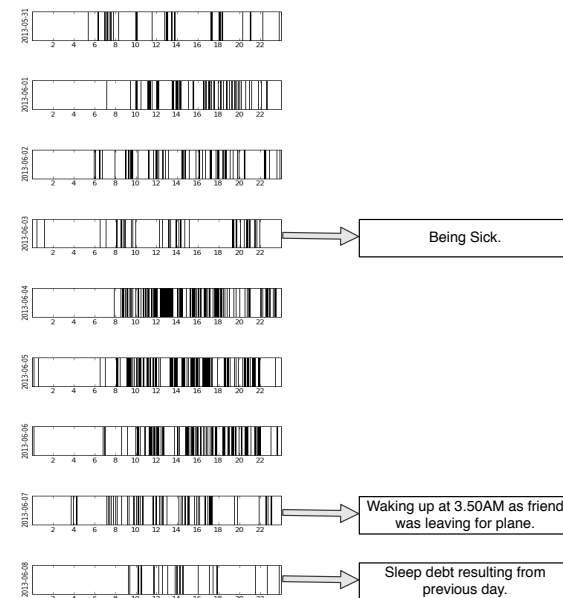
### Work In Progress

For this project, we have customized FunF [1] framework for collecting usage-data from Android devices. Our application collects data about call, sms, location, browser search, browser history, application usage and screen usage. Sensitive data like browser history or sms recipient are one-way hashed for maintaining privacy. Given the goal of the project, we focus on unobtrusive and power-conservative data collection. In a Samsung Galaxy Nexus, battery usage by our application is around 4% per day.

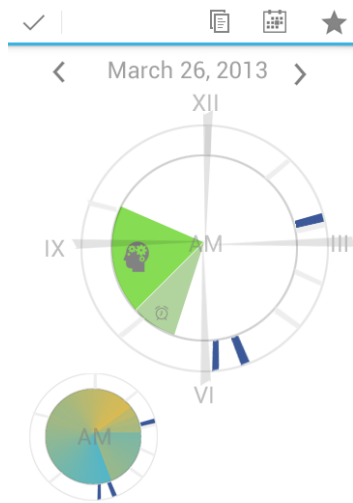
We are currently building analysis tools to infer about the chronotype and daily rhythm. Figure 1 shows the phone-usage pattern from an early participant. To infer about circadian rhythm of individual we are going to use the existing works from psychiatric research — Pittsburgh Sleep Quality Index [2], Epworth sleepiness scale [8] and MEQ [6] — to establish baseline.

We are interested not only in inferring but also providing

feedback about daily rhythm, chronotype and sleep-wake pattern in a meaningful way that can help increase users awareness of their existing patterns and suggesting strategies to change them. For example, being aware of personal rhythm might help a student to identify cues for peak productivity. For feedback and visualization we are currently working on a number of designs that can be deployed in smartphone. We are also interested in providing feedback through wearable devices and are exploring displaying individuals “inner” time on a smartwatch.



**Figure 1:** Phone screen usage patterns. Anomaly in sleep pattern often reflects in the phone usage for this participant.



**Figure 2:** A sample paper based prototype for providing feedback about chronotype. The visualization relates personal 'inner-time' with external clock time.

## Doctoral School Program

Given the preliminary stage of this work, the doctoral school (DS) program in UbiComp would be a great opportunity to reach out to a wider community. It is a significant challenge to identify effective and unobtrusive approaches to provide users with engaging visual feedback about their daily rhythms. It would be of tremendous help for me to talk about different aspects of this system with research experts from highly relevant domains. Given the community, DS would be the ideal place for me to discuss these and other related issues. Receiving feedback and critiques from research leaders in UbiComp would help improve my work and move it forward in the most fruitful direction.

## PhD Information

*Adviser:* Tanzeem Choudhury, Associate Professor, Information Science, Cornell University.

*PhD Start Date:* Fall, 2011

*Expected date of completion:* Spring, 2015

## References

- [1] Aharony, N., Pan, W., Ip, C., Khayal, I., and Pentland, A. Social fmri: Investigating and shaping social mechanisms in the real world. *Pervasive and Mobile Computing* 7, 6 (2011), 643–659.
- [2] Buysse, D. J., Reynolds III, C. F., Monk, T. H., Berman, S. R., and Kupfer, D. J. The pittsburgh sleep quality index: a new instrument for psychiatric practice and research. *Psychiatry research* 28, 2 (1989), 193–213.
- [3] DeYoung, C. G., Hasher, L., Djikic, M., Criger, B., and Peterson, J. B. Morning people are stable people: Circadian rhythm and the higher-order factors of the big five. *Personality and Individual Differences* 43, 2 (2007), 267–276.
- [4] Díaz-Morales, J. F. Morning and evening-types: Exploring their personality styles. *Personality and Individual Differences* 43, 4 (2007), 769–778.
- [5] Gau, S. S.-F., Shang, C.-Y., Merikangas, K. R., Chiu, Y.-N., Soong, W.-T., and Cheng, A. T.-A. Association between morningness-eveningness and behavioral/emotional problems among adolescents. *Journal of biological rhythms* 22, 3 (2007), 268–274.
- [6] Horne, J. A., Ostberg, O., et al. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International journal of chronobiology* 4, 2 (1976), 97.
- [7] Jackson, L. A., and Gerard, D. A. Diurnal types, the "big five" personality factors, and other personal characteristics. *Journal of Social Behavior & Personality* (1996).
- [8] Johns, M. W., et al. A new method for measuring daytime sleepiness: the epworth sleepiness scale. *sleep* 14, 6 (1991), 540–545.
- [9] Lund, H. G., Reider, B. D., Whiting, A. B., and Prichard, J. R. Sleep patterns and predictors of disturbed sleep in a large population of college students. *Journal of Adolescent Health* 46, 2 (2010), 124–132.
- [10] Medeiros, A. L. D., Mendes, D. B., Lima, P. F., and Araujo, J. F. The relationships between sleep-wake cycle and academic performance in medical students. *Biological Rhythm Research* 32, 2 (2001), 263–270.
- [11] Selvi, Y., Aydin, A., Atli, A., Boysan, M., Selvi, F., and Besiroglu, L. Chronotype differences in suicidal behavior and impulsivity among suicide attempters. *Chronobiology international* 28, 2 (2011), 170–175.
- [12] Taylor, D. J., and Bramoweth, A. D. Patterns and consequences of inadequate sleep in college students: substance use and motor vehicle accidents. *Journal of Adolescent Health* 46, 6 (2010), 610–612.