Biological Rhythms and Technology

Mark Matthews[1], **Erin Carroll**[2], **Saeed Abdullah**[1], **Jaime Snyder**[1], **Matthew Kay**[3], **Tanzeem Choudhury**[1], **Geri Gay**[1], and **Julie Kientz**[3]

[1]Cornell University
Information Science
Ithaca, NY

[2]University of Rochester
ROC HCI, Dept. of Computer Science
Rochester, NY

[3]University of Washington
Human Centered Design and Engineering
Seattle, WA

CHI 2014, April 26–May 1, 2014, Toronto, Ontario, Canada.
ACM 978-1-4503-2474-8/14/04.
http://dx.doi.org/10.1145/2559206.2559230

Abstract
Biological rhythms enable living organisms to adapt and live with periodical environmental changes, such as variation in the relative position of the earth and the sun. Internal rhythms, like body temperature and sleep-wake cycle, are driven by numerous biological processes and can be maintained even in the absence of external environmental cues. These rhythms affect how we feel, think, and act. They are profoundly important for our health, quality of sleep, and mood. Yet the digital devices we use are ignorant of our biology. They respond uniformly to our touch and click. Recently there has been a considerable increase of research within the HCI community to support behavior change, personal insight, and increase productivity. This workshop will bring together researchers in sleep, well-being, and circadian rhythms to discuss the possibility of rhythm systems: technologies that play to the strengths of our biology. It will investigate how HCI can complement our biological rhythms and will focus on two areas: measurement and intervention.

Author Keywords
Biological Rhythms; Circadian; Ultradian; Infradian; Sleep; Health; Mental Illness; Wellbeing

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. J.3 Life and Medical Sciences: Health

Introduction
Our bodies are governed by rhythms. Within each of us is a circadian clock that helps us synchronize to the

solar cycle. 'Circadian' means about (circa) a day (diem). While this term is often used to denote the difference between individuals who have genetic preferences for sleeping later ("night owls") or earlier ("early birds"), it refers to any biological cycle that follows a roughly 24-hour period, including regular changes in our blood pressure, cortisol, and melatonin levels. These fluctuations affect when we sleep, eat, and have an impact on our physical and mental performance. While circadian rhythms are central to our behavior and cognition, there are other biological rhythms that have significant impacts on us. Ultradian rhythms are recurrent cycles shorter than 24 hours. For example, sleep researchers study the ultradian 90-120 minute phases of adult sleep. Infradian rhythms are cycles that are longer than 24 hours. The menstrual cycle is one example.

Disruption of biological rhythms often have serious consequences for mental and physical well-being. For example, constant change in daily rhythm due to shift work has been shown to increase risk factors for cancer, obesity, and type-2 diabetes [12]. The effects of crossing time zones can cause temporal lobe atrophy (amnesia) and spatial cognitive deficits [3]. The advent of technology and the resultant always-on ethos can cause rhythm disruption on personal and societal levels. Sleep pathologies, which can be indicative of disruption of internal biological rhythms, are reaching an epidemic level, affecting around 70 millions people in United States alone[1]. A growing area of research also relates sleep and circadian rhythm disturbance to affective illnesses, such as bipolar disorder and major depressive disorder [6].

Sleep, mood, wellbeing, cognition and circadian (and other) rhythms are inter-linked. HCI researchers have recently begun investigating solutions for addressing the challenges surrounding rhythms [13], sleep [8], and mental health [10]. A greater awareness of biological rhythms could significantly impact the design of technology to support increased well-being, productivity and higher quality of sleep. Improvements in the ease of measurement of many biological factors means there is also an opportunity for computers to play to our biological strengths. Imagine a calendar that helps you schedule activities based on when you are at your best or a lighting system that supports improved sleep.

This workshop will bring together researchers in sleep and health (including mental health) to consider how a holistic approach might be beneficial. There are important implications within HCI for measurement, feedback, and intervention, including how can technology be used to help people maintain healthy rhythms, passively measure them, and provide nuanced human-computer interactions.

Workshop Goals

- Promote shared understanding of biological rhythms and identify key opportunities across disciplines
- Forge an interdisciplinary network of researchers working in inter-related fields
- Exchange expertise to expand the potential scope of current practices in relevant fields
- Examine interaction paradigms that be used for providing feedback about individual rhythm and support rhythm entrainment.

Related Work

Biological Rhythms

While circadian rhythms are biological, they can be synchronized with external cues, known as Zeitgebers (or "time-givers"). Sunlight is the most prominent Zeitgeber, but other cues such as social routines [5] and

[1] http://www.cdc.gov/sleep/about_us.htm

the availability of resources like food [11] can help synchronize internal clocks. There is also a genetic component that directs circadian rhythms called "chronotypes" [2]. Exposure to light at the right time helps bring our internal day closer to the solar day, but false Zeitgebers can disrupt our circadian system. The blue light that our electrical devices emit can have a negative impact on our sleep if they are used close to bedtime.

An example of software that supports circadian regulation and consequently sleep, is f.lux[2] which focuses on reducing exposure to the stimulating effects of blue light at night by gradually changing color temperature of the display to coincide with the sun. This is illustrative of how a broader consideration of biological rhythms can inform the design of rhythm-aware technologies.

The central presence of technology in modern life means that much of our behavior and daily routines are mediated through this channel. Such usage patterns might be indicative of behavioral factors associated with chronotype and daily rhythm. In particular, given the habit inducing aspect of smartphone usage, low level interaction patterns (e.g. how often a person unlocks the phone) may be used to cheaply, accurately and continuously collect real-time data that reflects personalized internal time.

Sleep

The study of sleep is complex. The quality of sleep is affected by three factors: a homeostatic oscillator, our circadian system, and our social time. Sleep circadian rhythm disruption (SCRD) occurs when our circadian system falls out of synchrony with the sun cycle. SCRD is associated with a range of illnesses including increased stress, heart disease and diabetes.

[2] http://justgetflux.com/

Much work in sleep from a HCI perspective has been in commercial products like Fitbit and Zeo, or mobile apps like SleepCycle that focus on measuring sleep quality. Choe et al. [4] offer a summary of design opportunities for sleep in HCI, which includes recommendations from literature on "sleep hygiene." This would include adhering to constraints on daytime activities. ShutEye [1] realizes some of those ideas by offering a glanceable display that allows people to quickly see whether certain activities (like exercise or drinking caffeine) will affect their sleep schedule depending on time of day. In other words, it attempts to convey the effect of these activities on a person's sleep rhythm. Zhenyu et al. have looked at unobtrusive sleep monitoring by looking at smartphone usage patterns to predict when a person is sleeping [15].

Mental Health & Well-Being

Within the HCI community there has been a growing focus on technologies to support wellbeing. These approaches have ranged from improving measurement techniques using passive and active measurements [10] to supporting therapeutic interventions [9].

Recent research provides substantial evidence that circadian rhythms are central to many mental illnesses including bipolar disorder, schizophrenia, and depression. Abnormalities in sleep timing and behaviors have been highly associated with a number of psychiatric disorders including bipolar. As a result, the stabilization of sleep and circadian rhythms have been postulated as a means for reducing symptoms and intervention for psychiatric and neurodegenerative diseases [14]. Given digital technology often impacts our rhythms, considering how it could be used to support them would be a valuable contribution. One example is MoodRhythm, a mobile app to passive and actively sense daily rhythms and encourage circadian rhythm stability [13].

Discussion

Biological rhythms are multiple and overlapping. They control the rise and fall of a range of physiological factors over the short, medium and long-term. Their variations have a direct impact on our behavior, cognition and our action. Groups of researchers in HCI are investigating sleep, healthcare (including behavior change) and mental health. These fields could greatly benefit from interdisciplinary collaboration. Such efforts could lead to considerable opportunities for improved measurement of health, productivity and performance, as well as more effective interventions. At a higher level, consideration of how digital technologies can play to the strength of our rhythms represents a new opportunity for personal computing. This workshop represents the first step in this effort.

References

[1] Bauer, J.S., Consolvo, S., Greenstein, B., et al. ShutEye: encouraging awareness of healthy sleep recommendations with a mobile, peripheral display. CHI '12, (2012), 1401–1410.

[2] Belle, Mino DC, Casey O. Diekman, Daniel B. Forger, and Hugh D. Piggins. "Daily electrical silencing in the mammalian circadian clock." *Science* 326, no. 5950 (2009): 281-284.

[3] Cho, Kwangwook. "Chronic 'Jet Lag' produces temporal lobe atrophy and spatial cognitive deficits." *Nature neuroscience* 4, no. 6 (2001): 567-568.

[4] Choe, E.K., Consolvo, S., Watson, N.F., and Kientz, J.A. Opportunities for Computing Technologies to Support Healthy Sleep Behaviors. CHI 11, (2011).

[5] Ehlers, C.L., E. Frank, and D.J. Kupfer, Social zeitgebers and biological rhythms: a unified approach to understanding the etiology of depression. Archives of general psychiatry, 1988. 45(10): p. 948.

[6] Harvey, Allison. "Sleep and circadian rhythms in bipolar disorder: seeking synchrony, harmony, and regulation." *American Journal of Psychiatry* 165, no. 7 (2008): 820-829.

[7] Jagannath, Peirson, and Foster. "Sleep and circadian rhythm disruptions in neuropsychiatric illness." Curr Opin Neurobiol, 23(5), 888-894.

[8] Kay, M., Rector, K., Greenstein, B., Wobbrock, J.O., Watson, N.F., and Kientz, J.A. PVT-Touch : Adapting a Reaction Time Test for Touchscreen Devices. PervasiveHealth '13: Conference on pervasive computing technologies for healthcare, (2013).

[9] Lu, Rabbi, Chittaranjan, Frauendorfer, Schmid Mast, Campbell, Gatica-Perez, and Choudhury. "StressSense: Detecting Stress using Unconstrained Acoustic Environments using Smartphones." UbiComp 2012.

[10] Matthews and Doherty. "In the mood: engaging teenagers in psychotherapy using mobile phones." CHI 2011.

[11] Stephan, F.K., The "other" circadian system: food as a Zeitgeber. Journal of biological rhythms, 2002. 17(4): p. 284-292.

[12] Stevens, Richard G., et al. "Meeting report: the role of environmental lighting and circadian disruption in cancer and other diseases." *Environmental Health Perspectives* 115.9 (2007): 1357.

[13] Wulff, Katharina, Silvia Gatti, Joseph G. Wettstein, and Russell G. Foster. "Sleep and circadian rhythm disruption in psychiatric and neurodegenerative disease." Nature Reviews Neuroscience 11, no. 8 (2010): 58

[14] Voida, S., et al. MoodRhythm: tracking and supporting daily rhythms. in Proceedings of the 2013 ACM conference on Pervasive and ubiquitous computing adjunct publication. 2013. ACM.

[15] Zhenyu, Lane, Cardone, Mu Lin, Choudhury, and Campbell. Unobtrusive Sleep Monitoring Using Smartphones. Pervasive Health 2013.