Rhythms of Attentional States, Mood, Stress, and Online Activity Throughout the Day

Gloria Mark and Yiran Wang
Donald Bren School of Information and Computer Sciences
University of California, Irvine
gmark@uci.edu

ABSTRACT
In this paper we report on recent studies using a mixed-methods approach for capturing people's attentional states, mood, and stress, as it varies throughout the day. This approach uses computer and phone logging, biosensors, experience-sampling, and surveys. The biosensors and probes complement the computer-logged data by revealing the user perspective in terms of their attentional state, mood, and stress level. We have found general patterns of mood and stress in conjunction with ICT usage. In the workplace, patterns were found showing how attentional states of being focused and bored vary by hour and by day. Among college students, we found patterns showing that stress increases throughout the day. The time that people end their activity for the day affects their stress the following day. Thus, these studies reveal that there are patterns of attentional states, mood, and stress that vary in conjunction with time, activity and context. Further research is needed to determine how they might be affected by biological rhythms.

Author Keywords
Multitasking; sensors; heart rate variability; stress, mood, focus.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Studies of ICT use and its relation to mood and stress have generally been done either with surveys, through ethnographies, or in laboratory settings. While self-reports of attitudes can be valid, self-reports in surveys of ICT usage have been shown to be prone to memory biases [1]. Laboratory experiments create an abstract model of the world yet it can be difficult to contextualize the findings. Ethnographies can provide rich contextual information, yet they lack precision on detailed ICT usage and are labor intensive for yielding longitudinal data on multiple users. To overcome these methodological shortcomings, and to understand how ICT use, mood and stress varies over time in real-world environments, with colleagues and students, we have been using a mixed-methods approach to directly measure ICT use and stress.

METHODOLOGY

The mixed methods approach includes computer logging, biosensors, experience-sampling, and surveys. While logging yields precision data on phone and computer usage, biosensors and probes complement the logged data by revealing the user perspective in terms of their attentional state, mood, and stress level. To date, we have captured data in the following contexts:

- 32 knowledge workers for five days each in a large corporation [3, 4]
- 48 college students for seven days each, during their waking hours [5]. This study is ongoing.

We use the following methods:

- Computer logging to capture beginning and end time of each active window.
- Cell phone logging of active apps, phone calls, and text messages.
- Biosensors to capture stress using the Affectiva wrist monitors which detect the EDA signal, and heart rate monitors (HRM), which measure heart rate variability, shown to be associated with stress (see 1).
- SenseCams as a proxy for face-to-face interaction. These are lightweight cameras worn around the neck and take continual photos about every 15 seconds.
- Experience sampling methodology (**ESM**) to capture mood as it changes throughout the day. Participants were randomly given probes on their computer screens and phones throughout the day and asked to rate how they felt *right now*, using measures of valence: negative to positive, (-200 - +200) and arousal: low to high, (-200 - +200), and with respect to what they were just doing: 'how engaged they were' and 'how challenged they were'

(on a 6-point scale). In another study using ESM, we asked participants what they were doing now, how stressed they were, and their valence.

- Beginning and end of day surveys to capture attitude and mood, e.g. using the PANAS mood scale.

All data is then synched together based on the timestamps. Thus, at any point in time, it is possible to assess what computer windows the participant is using, whether they had a face-to-face experience, what their stress level is, and what their mood is. Because data collection is continuous, it enables the investigation of how patterns of attention, mood and stress change over time vis-a-vis ICT usage and other external events (e.g. F2F interaction).

RESULTS

Here we will briefly present a few of the results that show how patterns of mood, stress, and activity exhibit rhythms. These results are from recent studies that will all appear in 2014 [3,4,5]. For the analyses we used either linear mixed models or generalized linear mixed models, which incorporates random effects, i.e. it takes the correlations of individual responses into account and therefore accounts for individual differences.

Knowledge workers: attentional states throughout the day

First, we report on a study of attentional states of 32 knowledge workers, tracked *in situ* for five days each [4]. As described, participants received ESM probes randomly throughout the day based on a set of decision rules (e.g. if they were 2 minutes or longer in email, a probe would pop up.). Responses were then combined to the ESM dimensions of *engaged* and *challenged* to create a theoretical framework of different attentional states. High ratings of both engagement and challenge were considered to be a state of *focus*. Low ratings of both engagement and challenge were characterized as a state of *boredom*. High engagement and low challenge characterize *rote work*. Figure 1 shows how, for 32 knowledge workers measured over five days each, we found regular patterns. Focus peaks at 3 p.m. and boredom peaks first thing in the a.m. (8-9 a.m.). In terms of day of the week, participants report being most bored on Mondays, with a higher level of focus (with no differences between days) on Wednesdays, Thursdays, and Fridays. Further details on this result and other results of attentional states can be found here [4].

Knowledge workers: mood throughout the day

Using the same data from 32 knowledge workers, tracked over five days, we examined how online and offline (F2F) interactions affect mood throughout the day. We found that people are happiest (as measured by valence in the ESM probes) at the time that they experience F2F interactions, compared to Facebook interactions. However, when asked to reflect at the end of the day on their mood, we found that the amount of Facebook use throughout the day is positively associated with an overall positive feeling at the end of the day. These results suggest that online and offline interactions contribute differently in affecting people's moods throughout the day. For further details on this study, see [3].

College students: stress and ICT usage

In a study of 48 college students, tracked for 7 days over all waking hours, we show how stress changes throughout the day. Stress was directly measured by participants wearing HRMs continually in all waking hours. Heart rate variability (**HRV**) is considered a valid indicator of

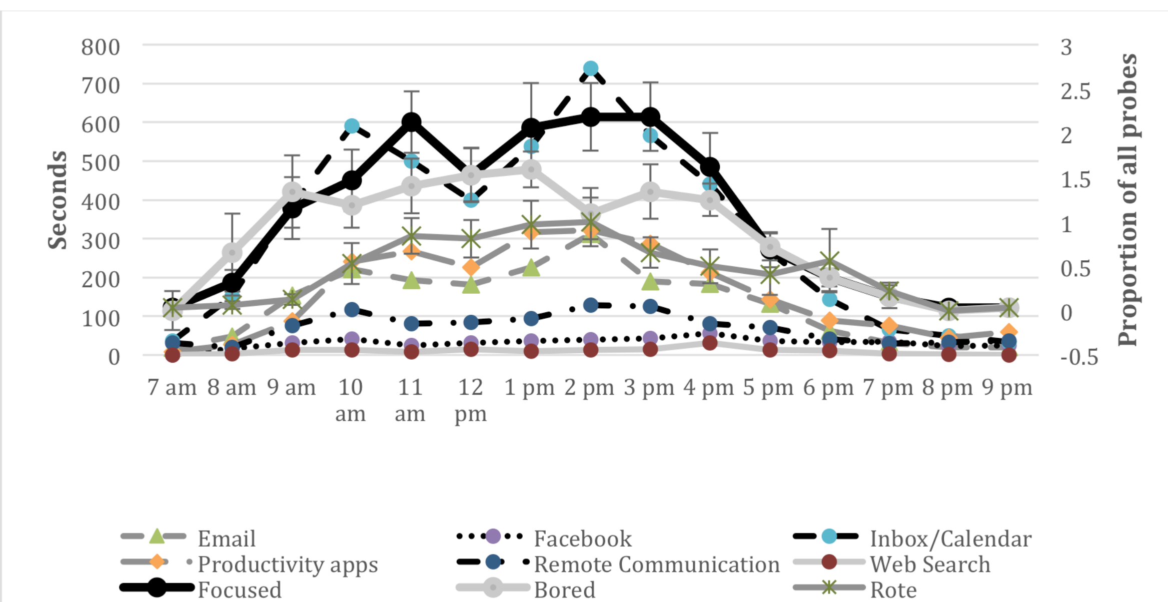

Fig. 1. Rhythms of boredom and focused states, and online activity throughout the day . N=32 knowledge workers. From Mark et al. [4].

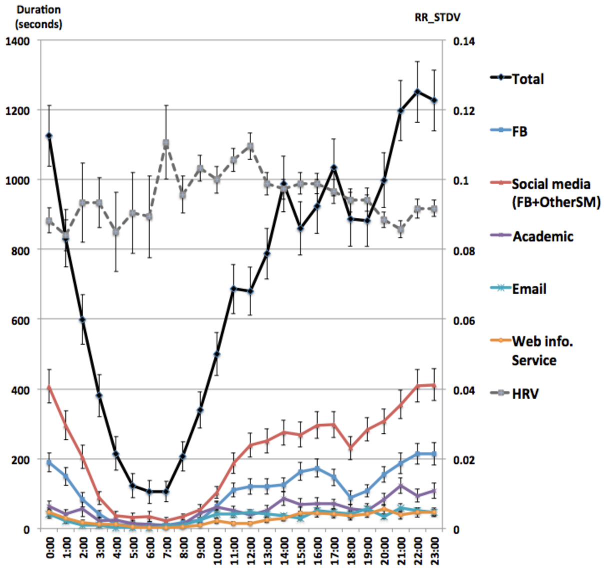

Figure 2. Avg. usage of different online activities and HRV, over 24 hours. The right axis is for HRV. Note the HRV measure is inversely related to stress. Error bars are SE. This figure is from [5].

mental stress and is used extensively in research and clinical studies (see [1] for a review). HRV refers to the variations in instantaneous heart rate and R-R (intervals between consecutive beats). Contrary to intuition, the *lower* the measure of HRV (i.e. the lower the sd in R-R), the higher the amount of stress is experienced.

Fig. 2 shows that, averaged over all participants and over all complete days, total computer usage rises continually throughout the day; there is a consequent similar rise in use of social media, Facebook, and email through evening. Stress (as measured by HRV which is *inversely* related to stress level) is comparatively low in the morning (about 7 a.m.), and increases through the rest of the day. Thus, as computer usage rises, stress rises as well. For further details on this study see [5].

College students: end of day activity, stress and ICT usage.

Much attention has been given to how sleep habits and late night activity of college-age students affect performance, health, and well-being, e.g. [7]. Here we examined how the time that students end their activities for the day relate specifically to stress, multi-tasking and computer usage on the following day. In particular we looked at whether late night "evening types", cf [6] may have different ICT usage patterns compared to people who are not late night "evening types." Thus, we investigate whether the time that one ends activity for the day is related to stress and ICT usage the *next* day.

Participants were instructed to wear the HRMs all waking hours and to take them off before they went to bed. We considered the later timestamp (computer activity ceasing or when the HRM was taken off) as a measure we call 'end of day activity.' While we cannot ascertain exactly when participants went to sleep, we can calculate a precise time (i.e. the later timestamp) of when online activity ended and when the HRM was taken off. This could be a reasonable proxy for close to the time when participants went to sleep. To reduce error even further, we grouped the timestamps estimating end of day activity into three wide time bins. Informed by the average time that college students go to bed (midnight), we used this as one cutoff point. We also used 2 a.m. as our second cutoff point following Monk et al's classification of "evening types" [6]. We created three time intervals: before midnight, 12 a.m.-2 a.m., and after 2 a.m. Single days of four people who removed their HRMs early in the evening were excluded from the analysis. We only used data from nights before weekdays, and excluded Friday and Saturday nights as they may have different late night activity patterns.

Males who end their activity the latest (after 2 a.m.) have the highest stress the next day, whereas females who end their activity the earliest (before midnight) have the highest stress the next day. Males use the computer significantly later than females $F(2,3653)=3.10$, $p<.05$. Those who use the HRM or computer latest (after 2 a.m.) spend the longest duration on the computer the following day, and also do the most window switches.

The happiest participants the next day (as measured by positive affect in the end of day PANAS surveys) are those who end their activity between midnight and 2 a.m. Those with the most negative affect are the ones who end their activity the earliest. For further details on this study see [5].

Future work

We are currently experimenting with adding location tracking using the Moves application for mobile devices. This would allow us to look at how patterns of movement affects mood and stress. It is also possible, for example, that certain locations on campus show patterns of association with high stress. This would then lead us to investigate what those factors are that might contribute to stress in those locations. The EDA data is also being analyzed to see what features of the EDA are most predictive of stress.

SUMMARY: RELATION TO WORKSHOP

Thus, these studies reveal that there are patterns of attentional states, mood, and stress that vary throughout the day. It is not clear whether these patterns are due to contextual factors or whether there are some internal biological rhythms or cognitive processes that exist to explain part or most of the results. While we have found that ICT usage and multitasking is significantly related to stress, it explains only part of the variance. We are therefore interested in attending the workshop to share these results and discuss them, and to learn more about others' results to gain a better understanding of biological rhythms. We are particularly interested to understand more about how stress is affected by biological rhythms.

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REFERENCES

1. Acharya, U.R., Joseph, K.P., Kannathal, N., Lim, C.M., and Suri, J.S. Heart rate variability: A review 2006). *Med & Bio Engin & Comp* 44(12), 1031–1051.
2. Collopy, F. (1996). Biases in retrospective self-reports of time use: An empirical study of computer users. *Management Science*. 42, 758-767.
3. Mark, G., Iqbal, S., Czerwinski, M., and Johns, P. (2014). Capturing the Mood: Facebook and Face-to-Face Encounters in the Workplace. *Proceedings of CSCW'14*, Baltimore, MD, ACM Press.
4. Mark, G., Iqbal, S., Czerwinski, M., and Johns, P. (2014). Bored Mondays and focused afternoons: The rhythm of attention and online activity in the workplace. *Proceeding of the thirty-second annual SIGCHI conference on Human factors in computing systems (CHI'14), ACM Press.*
5. Mark, G., Wang, Y., and Niiya, M. (2014). Stress and multitasking in everyday college life: An empirical study of online activity. *Proceeding of the thirty-second annual SIGCHI conference on Human factors in computing systems (CHI'14), ACM Press.*
6. Monk, T., Buysse, D., Potts, J., DeGrazia, J. and Kupfer, D. (2004). Morningness-eveningness and lifestyle regularity. Chronobiol Int'l, 21(3), 435–443,
7. Thomée, S., Härenstam, A., and Hagberg, M. (2012). Computer use and stress, sleep disturbances, and symptoms of depression among young adults–a prospective cohort study. BMC psychiatry, 12(1), 176.