Structure of Electrodermal Responses During Sleep

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Introduction

Spontaneous electrodermal responses (EDRs) during sleep, or sleep storms, have been observed since the 1960s [1,2].

With results counter-intuitive to an emotional arousal interpretation, these studies have found that sleep storms occurred most frequently during slow wave sleep and least frequently during REM sleep [1,3,4].

However, little is known about the sleep EDR structure.

Previous studies have used features that summarize peak rate as the number of peaks appearing in a window of time and found that periods of high frequency EDRs were most probable in the first half of the night [3]; however, this analysis technique completely ignores any historical dependence.

We used the state-space generalized linear model (SSGLM) [5] to investigate the structure of EDRs during sleep.

Data Collected

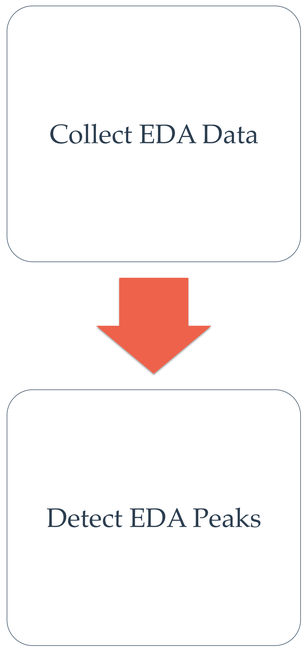
11 participants (10 male)
30-day study

Two sensors (one on each wrist)
- actigraphy and
- electrodermal activity

Self-reported sleep timing in an online survey

Sleep periods were determined using actigraphy data and surveys [6]

Methods and Results



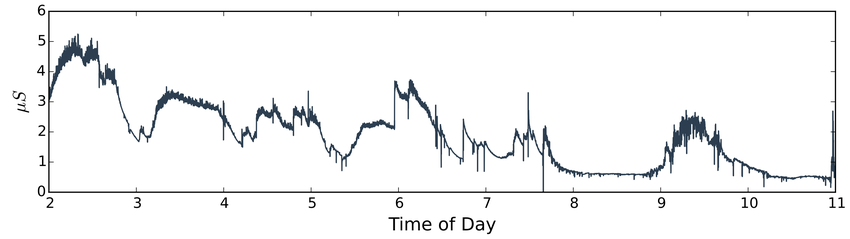


Figure 1: *Example electrodermal activity (EDA) data during sleep from the wrist*

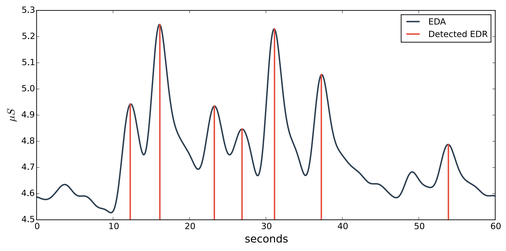


Figure 2: *Example of detected EDA peaks*

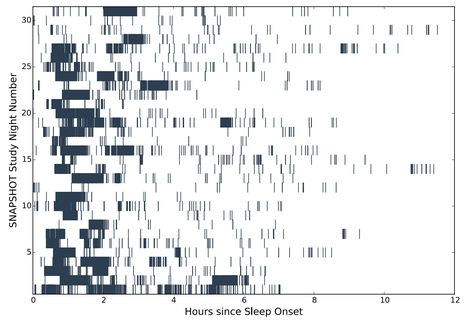


Figure 3: *An example of 30 days of detected EDA peaks during sleep for one participant*

Peak rate depends on between-night and short-term history

$$\lambda(l\Delta|\theta_k, \gamma, H_{k,l}) = \lambda^S(l\Delta|\theta_k)\lambda^H(l\Delta|\gamma, H_{k,l})$$

current time

$$\log \lambda^S(l\Delta|\theta_k) = \sum_{r=1}^{R} \theta_{k,r} g_r(l\Delta)$$

time parameters — *time since sleep onset function*

$$\log \lambda^H(l\Delta|\gamma, H_{k,l}) = \sum_{j=1}^{J} \gamma_j n_{k,l-j}$$

history parameters — *binary indicator of observed peak*

	% of nights with significant difference in EDR Rates	
Participant	$\lambda_{0\text{-}90\text{min}} > \lambda_{90\text{-}180\text{min}}$	$\lambda_{0\text{-}90\text{min}} < \lambda_{90\text{-}180\text{min}}$
1	**67.90%**	21.40%
2	35.50%	**64.50%**
3	6.70%	**56.70%**
4	37.50%	**46.90%**
5	**40.00%**	36.70%
6	44.80%	**55.20%**
7	17.20%	**79.30%**
8	32.10%	**67.90%**
9	48.40%	48.40%
10	40.60%	**56.30%**
11	21.40%	**53.60%**

Conclusions

Using the SSGLM provides a framework to compare the rates of EDRs during different time periods of the night. This work provides a baseline for what pattern of EDRs are typical in a healthy college-age population. The methodology can be extended to model EDRs during sleep in other populations and used to compare differences.

Acknowledgements

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References

[1] L. Johnson and A. Lubin. "Spontaneous electrodermal activity during waking and sleeping." *Psychophysiology*, 3(1):8–17, 1966.

[2] A. Koumans, B. Tursky, and P. Solomon. "Electrodermal levels and fluctuations during normal sleep." *Psychophysiology*, 5(3):300–306, 1968.

[3] A. Sano, R. Picard, and R. Stickgold. "Quantitative analysis of wrist electrodermal activity during sleep." *International Journal of Psychophysiology*, 94(3): 382-389, 2014.

[4] J. Onton, D. Kang, and T. Coleman. "Visualization of Whole-Night Sleep EEG From 2-Channel Mobile Recording Device Reveals Distinct Deep Sleep Stages with Differential Electrodermal Activity." *Frontiers in Human Neuroscience*, 10, 2016.

[5] G. Czanner, U. Eden, S. Wirth, M. Yanike, W. Suzuki, and E. Brown. "Analysis of between-trial and within-trial neural spiking dynamics." *Journal of neurophysiology*, 99(5):2672–2693, 2008.

[6] L. Barger, E. Flynn-Evans, A. Kubey, L. Walsh, J. Ronda, W. Wang, K. Wright, and C. Czeisler, "Prevalence of sleep deficiency and use of hypnotic drugs in astronauts before, during, and after spaceflight: an observational study." *The Lancet Neurology*, 13(9): 904-912, 2014.