Autonomic Sleep Patterns in Visual Discrimination Task Improvement

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Introduction

What is Electrodermal activity (EDA)?

Electrodermal activity (EDA) provides a fine measure of sympathetic nervous system activity, one of the main branches of the autonomic nervous system, and a measure widely used in psychophysiology. Classically, EDA has been measured as skin conductance and involves attaching wired and gelled electrodes to the skin. This study uses the Q sensor, a wireless non-invasive sensor worn on the wrist that measures EDA (also called "galvanic skin response"), motion (actigraphy), and temperature.

EDA during sleep.

Studies on EDA during sleep have shown that EDA is more likely to appear elevated with high frequency "storm" patterns during deep sleep (Asahina, 1962), that EDA can distinguish wake and sleep and indicate sleep onset, and that it is not generally sufficient for identifying sleep stages (Koumans et al., 1968).

Visual Discrimination Task (VDT)

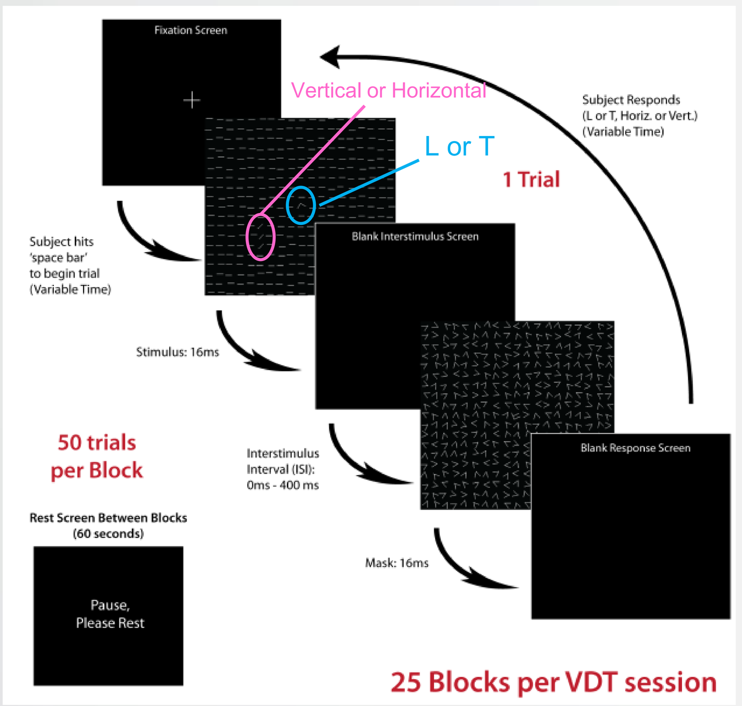


Fig. 1: Screen sample in Visual Discrimination Task (Wang, 2011)

The Visual Discrimination Task (VDT) used in this study is the same as that used by Stickgold et al. (2000) where previous studies showed that consistent and significant performance improvement became proportional to the amount of sleep in excess of 6 hours, and subjects with an average of 8 hours then exhibited a correlation in performance to SWS in the first quarter of the night, and REM in the last quarter (Stickgold et al., 2000).

Figure 1 shows one trial, consisting of 5 screens that appear in typically less than 1 second. First is a fixation screen (black with a white centered crosshair) that remains until the participant hits a key. This is followed by a 16 ms target screen, then a 0-400 ms blank "interstimulus interval" (ISI) varied over the course of the task, starting at 400ms, progressively shortened to 0ms over the 25 blocks of 50 trials, and then a 16 ms mask screen. The participant is asked to determine two features of the target screen: whether the capital letter in the center of the screen was "T" or "L" and whether an array of three diagonal bars in one quadrant of the screen was horizontal or vertical. By interpolating the ISI at which 80% accuracy was achieved on the horizontal versus vertical decision, a 'threshold' ISI (in ms) was extracted from each session of the VDT. Overnight improvement or deterioration on the VDT was then calculated as a subtraction of the AM VDT threshold from the PM threshold. One VDT session consists of 25 blocks with 50 trials in each.

Full Disclosure: Picard is a full professor at MIT and also co-founder, chief scientist, and chairman of Affectiva, the company that made the sensors used to collect the data in this study. She participates fully in MIT's monitoring of conflict-of-interest procedures.

Motivation

It is now easy to get long-term monitoring of electrodermal activity (EDA) during natural sleep at home. This research examines whether strong "storm" patterns in the EDA might relate to performance on a visual discrimination task and whether these patterns relate to objective and subjective sleep quality.

Data & Analysis

Twenty-four healthy university students (ages 18-22, 16 males) participated in three nights of measurements: in a "homey" sleep laboratory, a hospital GCRC, and at home, wearing the Q sensor on the wrist each night. Each night (PM) they trained on a different version of the VDT, slept, and were tested the next morning (AM). Sleep in the sleep lab and GCRC were also monitored with standard PSG. We evaluated task improvement by overnight change in VDT performance. EDA "storms" were identified when EDA exhibited > 6 peaks per minute. We obtained standard PSG sleep staging as well as both subjective and objective sleep quality evaluations. We analyzed the correlation between EDA storms and task improvement, sleep stage times and sleep quality.

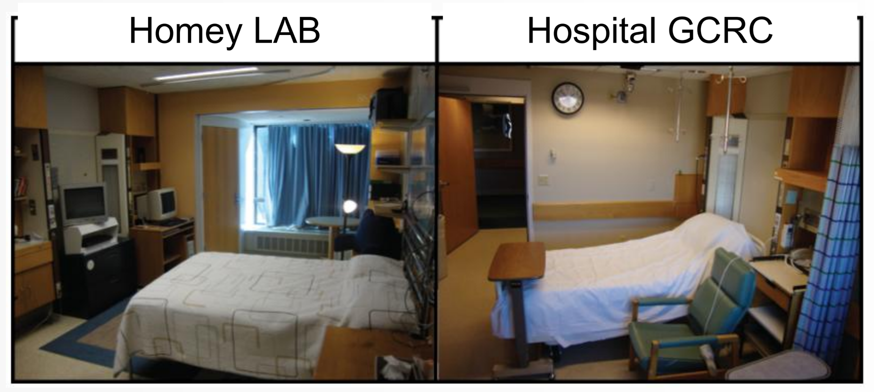


Fig. 2: Homey LAB (Left) and Hospital GCRC (Right) sleep environments (Wang, 2011)

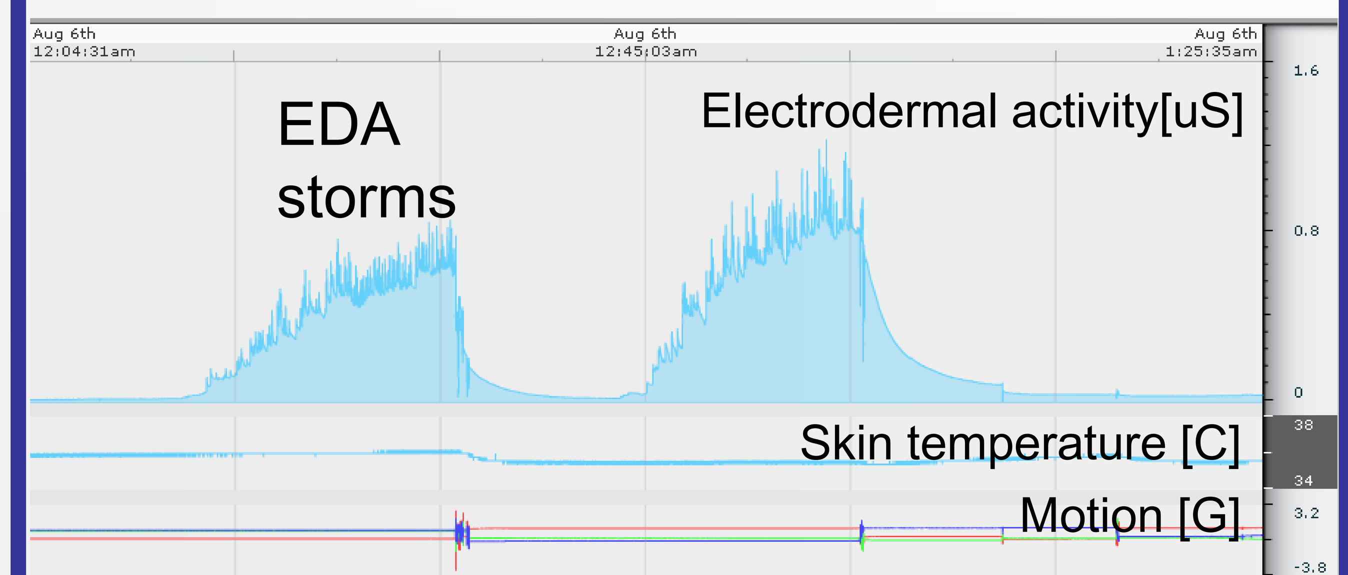


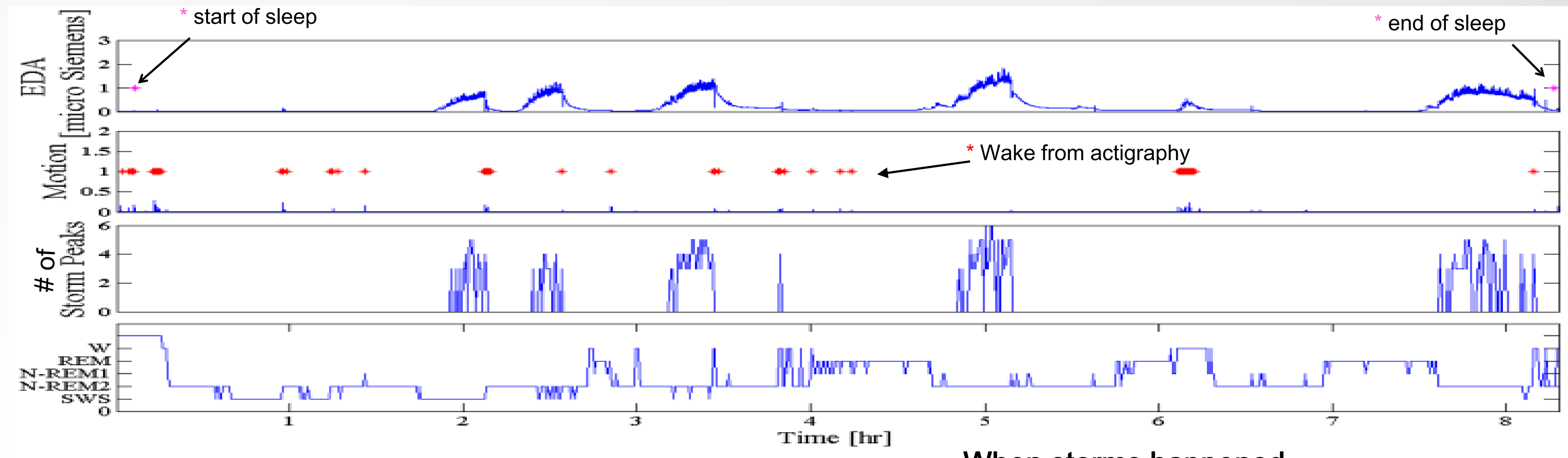
Fig. 3: EDA, skin temperature and 3-axis accelerometer, from the wrist

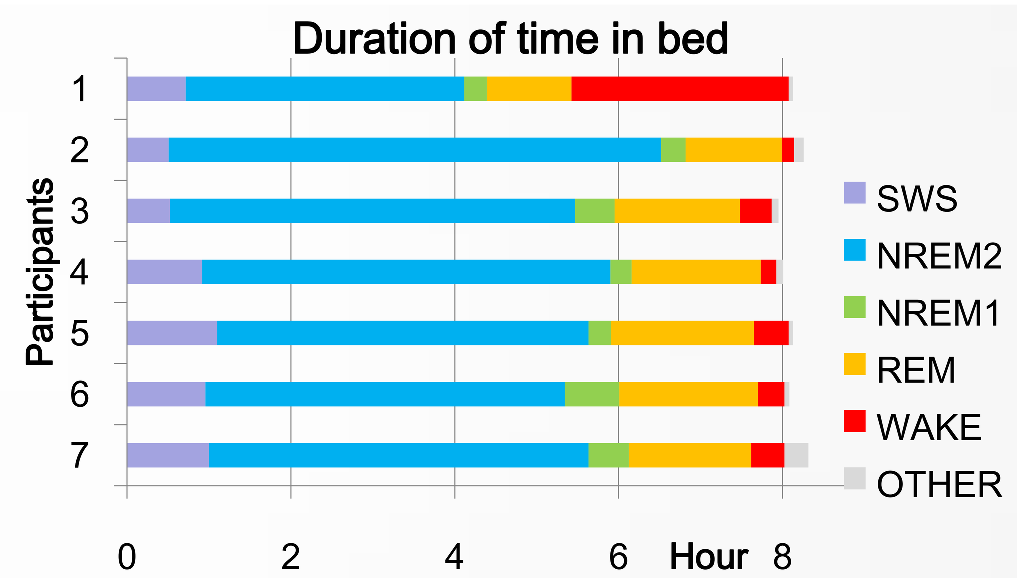
The data is analyzed as follows:

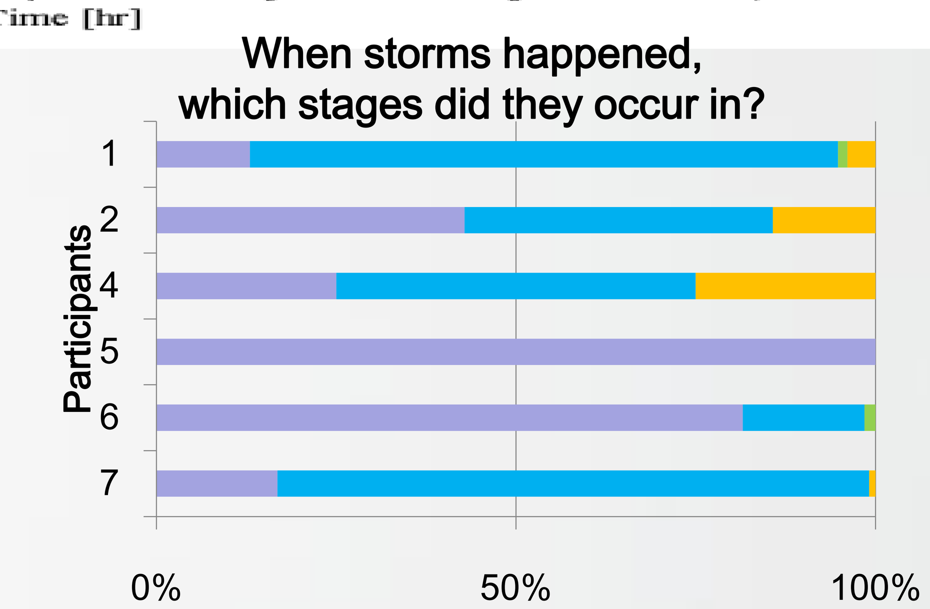
1. Pre-processing: Standard zero-crossing and Cole's function were applied to the accelerometer data to discriminate between sleep and wake. EDA data was low-pass filtered (cutoff frequency 0.4 Hz, 32nd order FIR filter).
2. We detected EDA "storm" regions, where "storm" (Burch, 1965) refers to a region of EDA with a burst of high frequency peaks. Burch originally quantified a storm as a minimum of five galvanic skin responses (GSRs)/min for at least ten consecutive minutes of sleep. In this paper, we defined "storm epochs" as a 30 second epoch with a minimum of three EDA peaks/30s. If storm epochs are adjacent or within five minutes of each other, they are combined into a "storm".

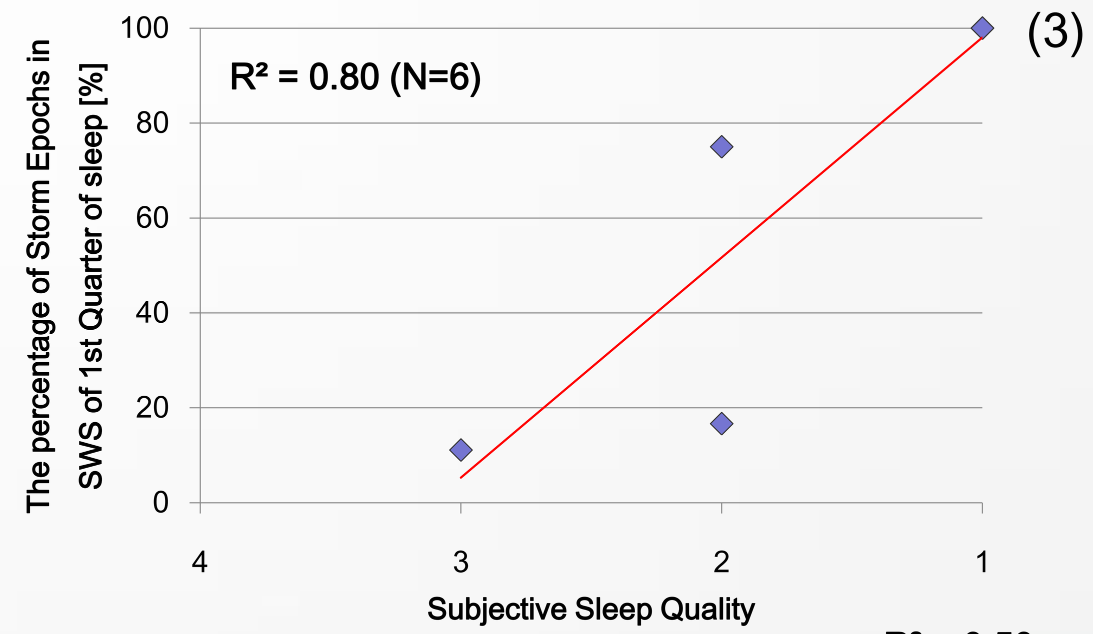
Results

According to all data from 24 participants, 36 out of 54 nights showed storms (67%). Only 7 out of 24 participants had precisely synchronized PSG and EDA, and of these 7 participants, only 6 had storms. Their storms occurred most often in Non-REM 2 and in SWS.

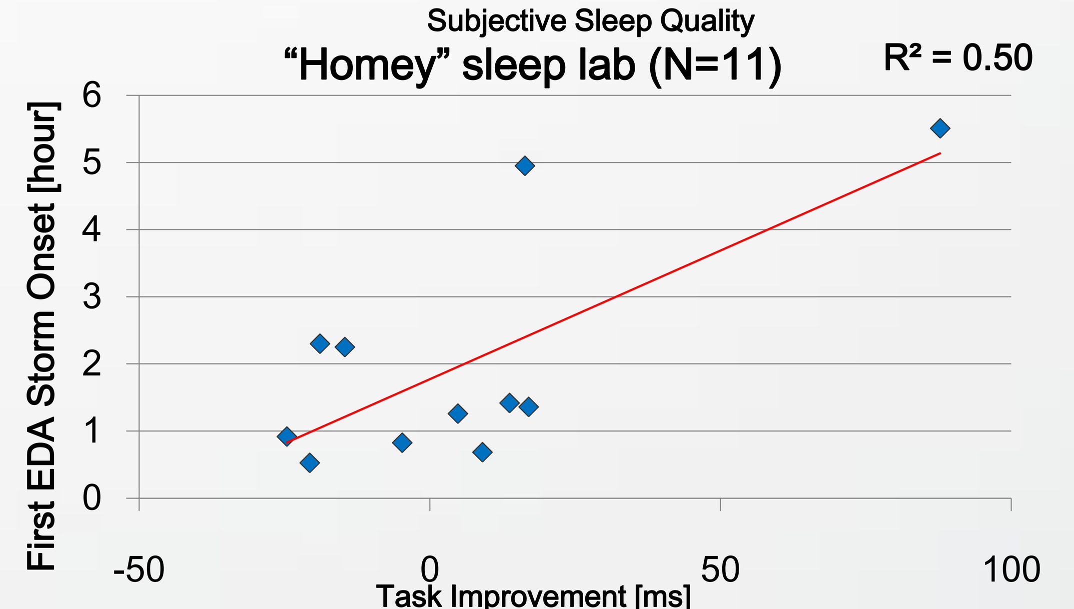


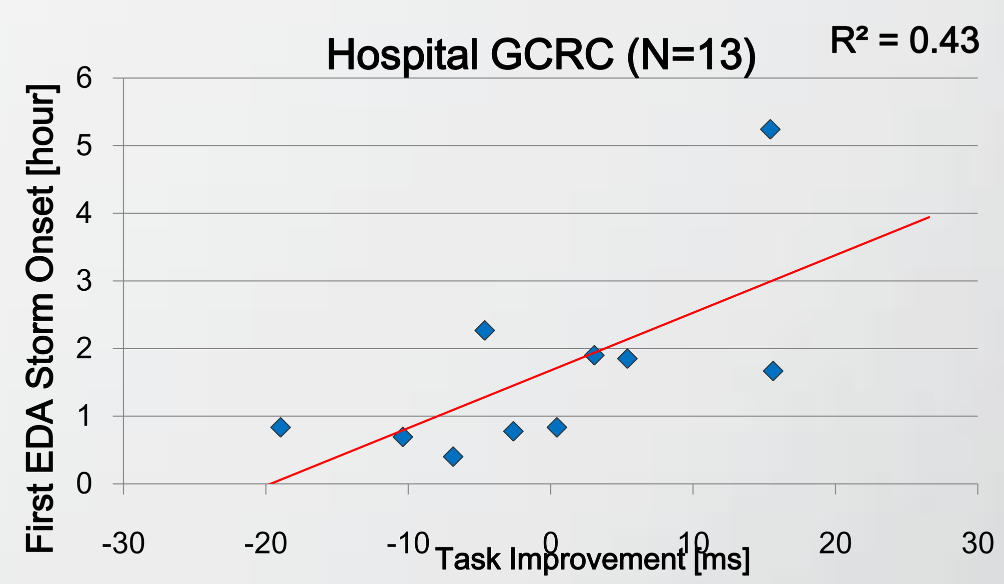






In the six subjects who had storms and for whom precisely synchronized PSG and EDA data were available, a higher percentage of storm epochs in SWS in the 1st quarter of the sleep was associated with greater subjective sleep quality ($p<.05$). For lab and hospital nights, the longer the time before the first EDA storm arrived after sleep onset, the better the task improvement ($p<.05$).





Conclusions

We measured continuous EDA, actigraphy, sleep and overnight improvement on a visual discrimination task (VDT) in healthy college students, and found correlations between EDA storming, task improvement, sleep stages and sleep quality (from overnight PSG). The wearable EDA sensor showed overnight VDT improvement while used in the laboratory and in the hospital. More synchronized subject data is needed to be confident of the findings.