Skin Conductance as a Measure of Fatigue in Different Tasks

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Abstract

Electrodermal activity (EDA) or galvanic skin response refers to electrical properties of the skin that are controlled by the sympathetic nervous system through sweat glands [1]. Although EDA has long been known to be an indicator of stress, arousal, and emotion, few systematic studies of EDA variation across subject, task, and fatigue level have been conducted. EDA is generally thought to have two components: a background tonic level that may reflect individual characteristics and global subject state and a more rapidly varying phasic level that measures more short-term response to environmental factors [2]. In order to analyze the relationship between skin conductance and fatigue while performing tasks, we used data from a research study in which participants were asked to perform different tasks on multiple days at different states of fatigue. Our results suggest that the phasic signal is highly dependent on participant's fatigue state and the task being performed.

Goals

- Assess the effect of task and fatigue on skin conductance.
- Develop tools for assessing subject fatigue level and task difficulty based on skin conductance measures.

Methods

We used continuous deconvolution as implemented in Ledalab [3] to separate tonic background from phasic response [1, 4] as shown by the following screenshot:

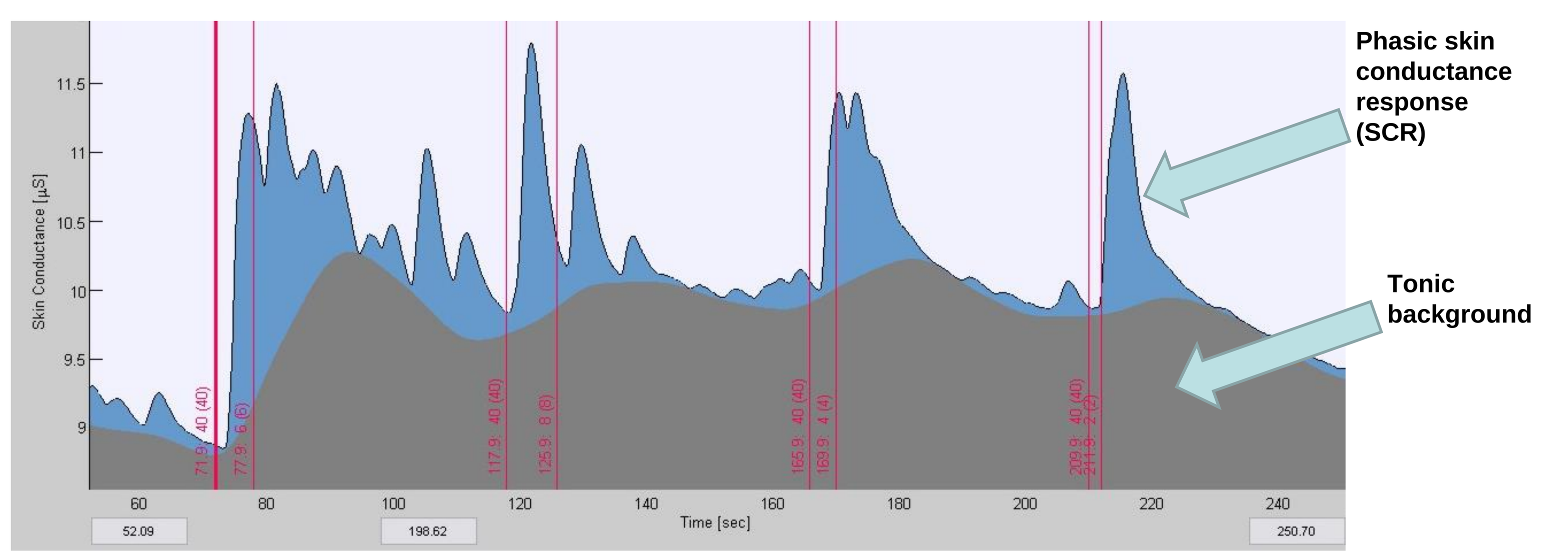

Figure 1: Image taken from the Ledalab documentation found at *ledalab.de*. It depicts a subject's skin conductance, including the background tonic level, and the phasic response.

We then plotted box plots of the mean and standard deviation of the phasic driver for each dataset, segregated by task and by fatigue level. We also performed an analysis of variance (ANOVA) using subject, task, and fatigue level as factors.

Data

Seventeen subjects were asked to perform a series of tasks on multiple days (typically 9) corresponding to different initial degrees of fatigue. Tasks included a lane keeping task, a psychomotor vigilance task, a distracted driving task, and a resting task. The subject's skin conductance was measured with an Empatica E3 [5]. The experiments were conducted at *National Chiao Tung University and data was provided courtesy of Professor Chin-Teng Lin.*

Dependence of phasic driver on fatigue

The results indicate that skin conductance responses in the phasic driver component were diminished when the subject was highly fatigued. EDA responses were greater when the subject had low or normal fatigue.

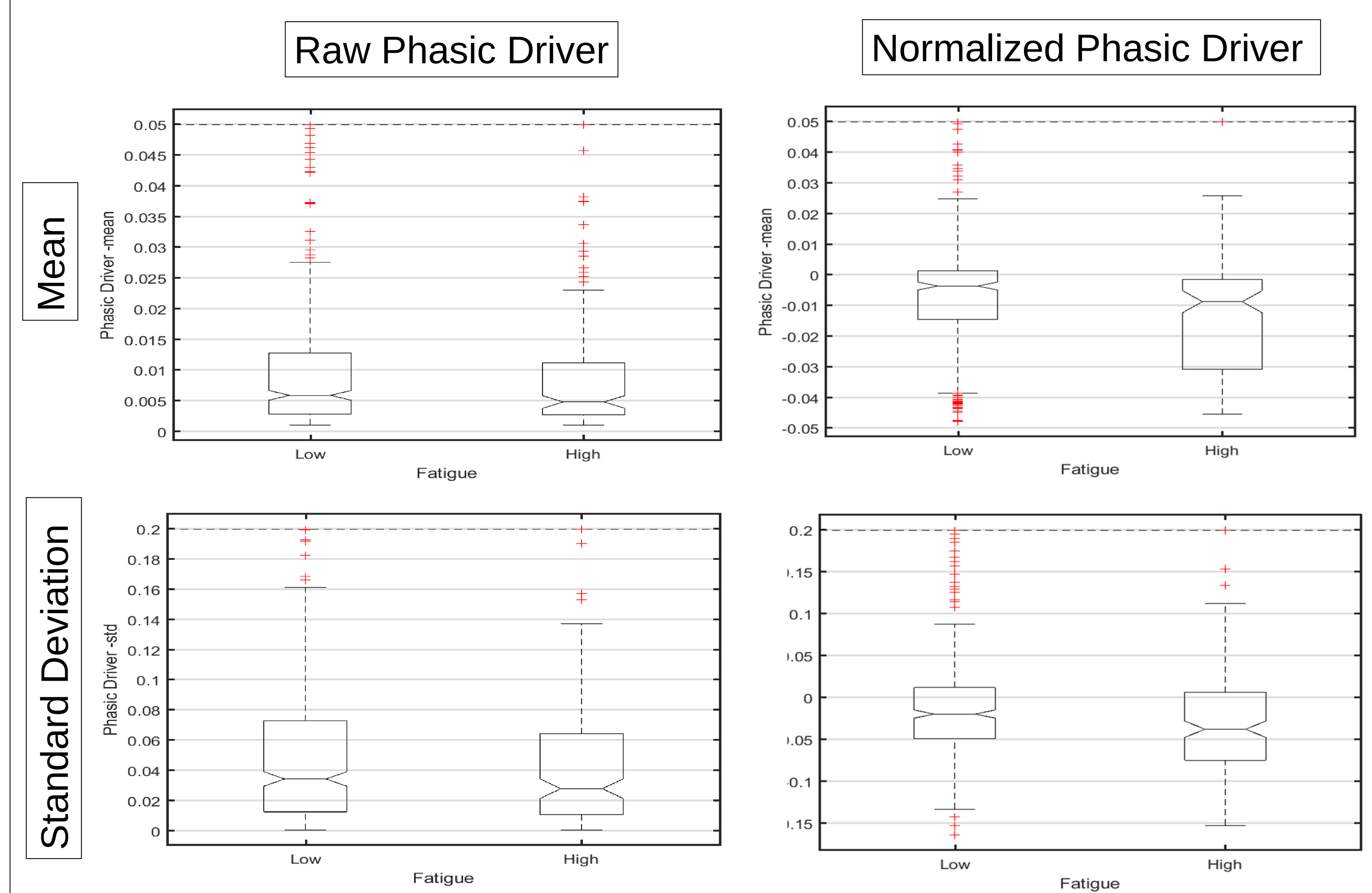

Figure 2: The mean and standard deviations of EDA at high and low fatigue (normal fatigue grouped with low fatigue). Normalized values are scaled using subtraction scaling with low fatigue as the scaling factor.

Dependence of phasic driver on task

The analysis of the phasic driver relating to tasks suggests that the phasic driver responds least to the taxing psychomotor vigilance task (PVT) and the phasic driver is largest in the post experiment rest (Rest).

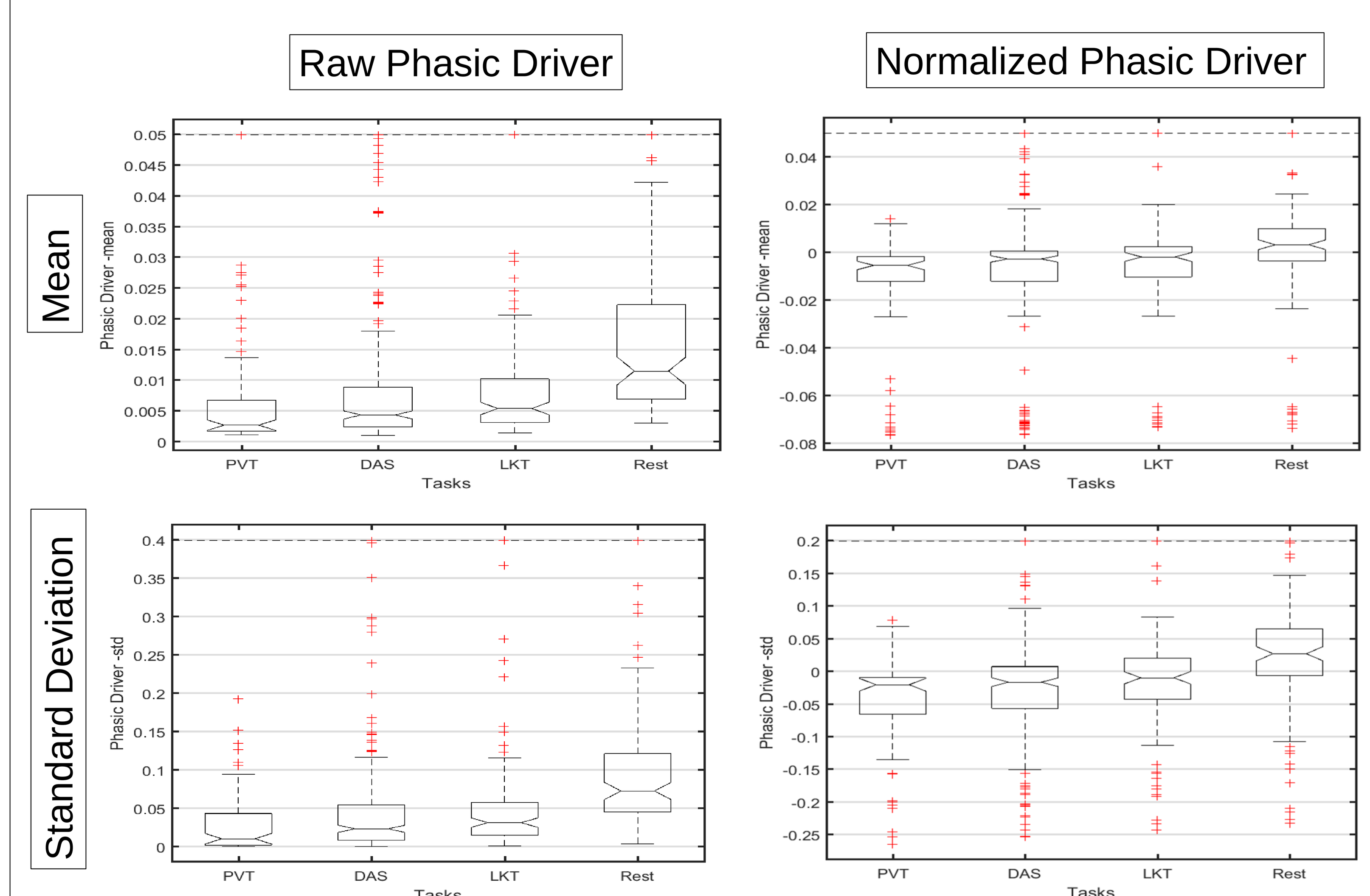

Figure 3: The mean and standard deviations of EDA subjects while performing different tasks. Normalized values are scaled using subtraction scaling with low fatigue as the scaling factor.

Statistical significance of dependence

The results of the ANOVA suggest that the phasic driver is highly dependent upon the subject, the task the subject is performing, and the subject's level of fatigue as shown by the table of significance values.

P-Values

	Subject	Fatigue	Task
Subject-Fatigue-Task	0.0335	0.0119	0.0032
Subject-Fatigue-Task with Subtraction Scaling	$5.5004*10^{-8}$	0.0101	0.0047
Subject-Fatigue	0.0412	0.0097	
Subject-Fatigue with Subtraction Scaling	$4.7627 * 10^{-8}$	0.0077	
Subject-Task	0.0534		0.0027
Subject-Task with Subtraction Scaling	$3.1740*10^{-8}$		0.0038
Fatigue-Task		0.0304	0.0041
Fatigue-Task with Subtraction Scaling		0.0045	0.0040

Table 1: The results of the ANOVA for subject-fatigue-task, subject-fatigue, subject-task, and fatigue-task.

Conclusion

The results of our analysis suggest that there does exist a correlation between the EDA data and subject, task, and fatigue. At high fatigue and during highly strenuous tasks, the mean and standard deviation of the phasic driver was lower than the corresponding results for low fatigue and less strenuous tasks. This suggests that skin conductance can be a useful measure of fatigue and task-related stress in practical applications.

Acknowledgements

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