Comparison of ambulatory EDA from forearms and calves.

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Introduction

What is Electrodermal activity (EDA) and how is it measured?

EDA provides a fine measure of sympathetic nervous system activity. Classically, EDA has been measured as skin conductance and involves attaching wired and gelled electrodes to the skin.

Surprising recent findings

- Our and other teams have recently measured EDA on long term placing electrodes on non-traditional, distal forearm locations (Fig. 2)
- Some new findings have been identified like the possibility to characterize seizures [1], sleep [2], stress in call centers [3].
- Therefore it is important to validate other non-traditional locations for EDA measurements, like back-calf, which may be more comfortable than distal forearm for around-the-clock continuous monitoring and may also lead to novel findings based on long-term EDA signal collected from multiple body locations.

Methods & Analysis

Participants

18 females and 14 males aged between 16 and 50

Procedure

- Each participant was invited to a session lasting about 80 minutes composed of three parts (physical task, cognitive task and emotional task) which were each followed by 10 minute breaks when the participant relaxed while sitting quietly (Fig. 4).
- During physical task participants walked up and down stairs
- During cognitive task participants were first asked to repeatedly subtract the number 7 from the number 4000 and to say the result loudly. A buzzer was sounded if they made a mistake. The serial arithmetic test was followed by a Stroop color word test lasting 2 minutes.
- The emotional task began with an anticipation event when it was announced to participants that they will be watching a horror movie (*28 days later*). Then after 1 minute waiting in anticipation, a 5-minute scene extracted from a horror movie was shown.

Devices

During experiment the users wore the Q sensor, a wireless non-invasive sensor on their wrists and calves.

Measures

- Q sensor measures EDA, motion (actigraphy), and temperature.
- After the experiment the participants answered questions about the comfort of wearing sensor at different sites, their handedness and frequency of sport practice .

Data analysis

- We evaluated correlation of EDA signal from wrists and calves during 3 tasks. We applied a low-pass filter to each EDA raw signal (1024-point Hamming window, 3Hz cut-off frequency) to reduce motion artifacts and electrical noise. Then Pearson's correlation coefficients and the corresponding p-values were calculated for the filtered signal to compare each pair among the 4 sites within each person.
- To analyze EDA signal evolution during the physical task, we calculated the time elapsed from the start of the physical task to the moment when the filtered EDA signal reaches 10% of its maximum during the physical task.

Motivations

- Understanding of EDA signal patterns and correlations at different body locations is very important to study different mental disorders and the human emotional state [5].
- Classical EDA measurement sites (Fig. 1) are not suitable for collecting long-term EDA signal in ambulatory settings.
- EDA sensors placed at the back-calf (Fig. 3) can enable more comfortable, around-the-clock measurements with reduced motion artifacts and stigmatizing comparing to other recently proposed locations (Fig. 2).

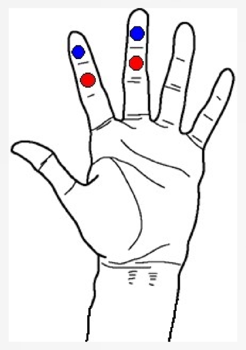

Fig. 1: Traditional, electrode locations for EDA measurement are on the medial (red) and distal (blue) phalanges of the fingers.

Fig. 2: Recently the value of long term monitoring of EDA with electrodes placed on distal forearm (red) has been demonstrated.

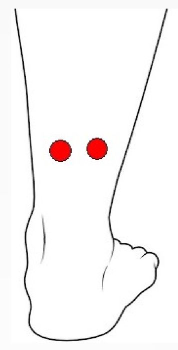

Fig. 3: We compared EDA signal collected from back-calf (red dots) and distant forearms and we evaluated the comfort of sensor placed on this location.

Results

According to data from 32 participants, all multi-site median correlations are above 0.5 for all seven measurement periods. During the Physical and the Emotional tasks the coefficients are especially high ($\tilde{r}$ > 88), whereas during the Cognitive task only the bilateral signals (CL-CR and FL-FR) are correlated above 0.75.

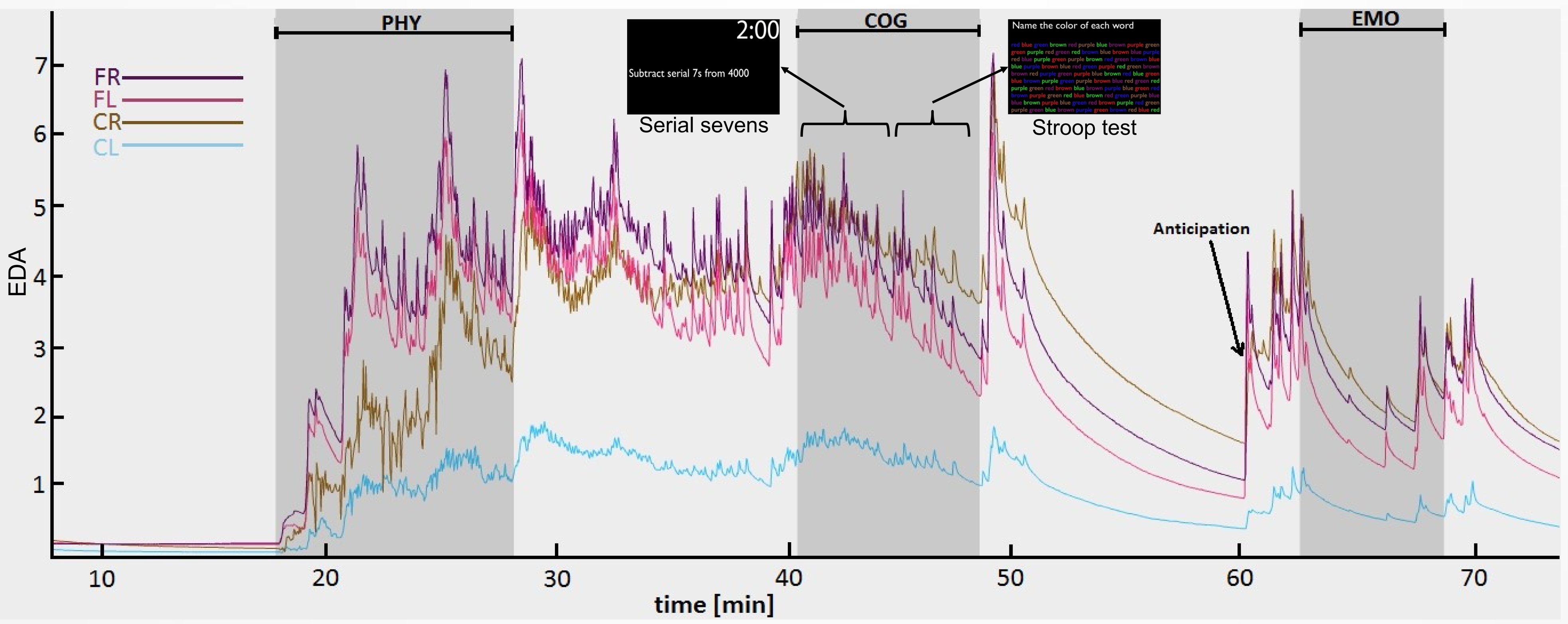

Fig. 4: EDA measurement for one participant during the entire experiment composed of physical (PHY), cognitive (COG) and emotional (EMO) tasks. Each line corresponds to a different measurement site: Calf-Left (CL), Calf-Right (CR), Forearm-Left (FL) and Forearm-Right (FR).

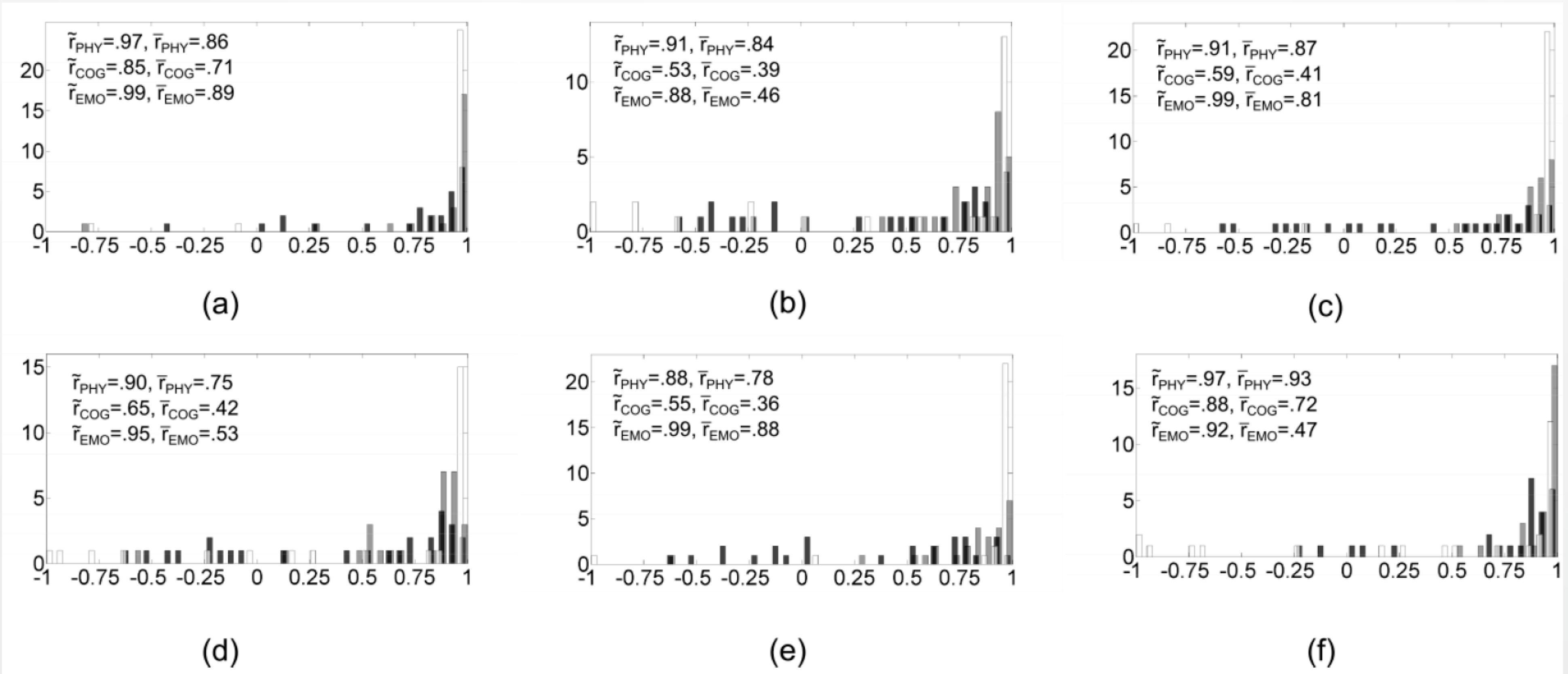

Fig. 5:Distribution of correlation coefficients between EDA measurements from the four sites: (a) CL and CR, (b) CL and FL, (c) CL and FR, (d) CR and FL, (e) CR and FR, (f) FL and FR. Each experiment consisted of the physical task (white rectangles), the cognitive task (black rectangles) and the emotional task (grey rectangles). The median values $\tilde{r}$ and $\bar{r}$ mean values of the correlation coefficients are also presented for each condition.

Conclusions

EDA measurement at the back of the calf

This work demonstrates that the back of the calf could be used for long-term comfortable and unobtrusive EDA measurement during daily activities. Participants evaluated this site as comfortable and sometimes even forgot that a sensor was attached to their calf. We observed a strong correlation between the EDA signal on the back calf and distal forearm, the latter of which was earlier shown to have high correlation with the classic palmar site for EDA recording.

Impact of sport fitness on EDA signal raising

We also observed a significant variation between participants of the time that elapsed from the beginning of the physical task until the start of its elicited SCR's (median delay equals 142 s for physically fit vs. 368 s sedentary participants, $P < 0.02$, Mann-Whitney two-tailed test). While more work is needed, including real fitness tests, to make any claims about EDA being used as a fitness measure, our data do suggest that this is an interesting area for possible future investigation.

Impact of handedness on EDA signal

Although some studies reported influence on the handedness on the skin conductance pattern, we did not find any link between participants' handedness and EDA signal regularity. We rather observed a greater correlation between sites on opposite sides of the body then within sites on the same side of the body.

Impact of task on cross-site EDA signal correlation

Our results suggest task-dependent correlation of the EDA signals from different locations. However, we cannot conclude a definitive task dependence because there is a possibility that order effects are responsible for the different EDA characteristics in each task as we chose to not randomize the order of the tasks. Nonetheless, we can expect that because the tasks are quite different, they are likely to involve different brain structures, and it is already established that the different structures can give rise to different EDA responses. The EDA signals from the four measured locations have the highest correlations during the emotional task and the smallest correlation during the cognitive task.

Literature cited

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Full Disclosure: Picard is a full professor at MIT and also co-founder 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.