

User Research

Fluctuations in electrodermal activity reveal variations in single trial brain responses to painful laser stimuli - A fMRI/EEG study

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In a recent psychophysiological study using simultaneous electroencephalography/functional magnetic resonance imaging (EEG/fMRI) to investigate pain processing in the human brain we also sought to evaluate the usefulness of recording galvanic skin response (GSR)/electrodermal activity (EDA) during the course of the experiment. Our questions/objectives were a) is it possible to obtain single-trial EDA data in response to experimental pain during echoplanar functional magnetic resonance imaging? b) what is the cortical representation of electrodermal activity in response to experimental pain? c) can the psychophysiological measured EDA further inform fMRI (and EEG) analysis? d) analysis of the changes in GSR as an intraindividual single-trial valid pain indicator for the simultaneous EEG/fMRI recording.



Figure 1: EDA measurement

The galvanic skin response (GSR) measures sweat gland function and can be used to capture the response of the autonomous/sympathetic nervous system to a wide range of external stimuli. In essence, an increase in EDA represents a decrease in the skin's impedance that is mainly caused by the filling with sweat of the sweat ducts in the dermis and epidermis (Fowles, 1986). EDA is associated with arousal in response to various types of stimuli such as novelty, intensity, emotional content and significance (Critchley, 2002). In the context of experimental pain, it has been shown that markers of sympathetic arousal, including EDA, correlate with subjective ratings of pain (Chapman et al., 2001, 2002).

This measure can be considered as simple and reliable. Repeated within-subjects GSR measurements exhibit common features in wave shapes and habituation patterns. However, in the context of a simultaneous EEG/fMRI experiment, EDA measures are more difficult to obtain and safety issues are pertinent. We performed extensive tests on the new EDA

sensor in 3-T scanner (Trio, Siemens, Erlangen, Germany). We investigated 12 healthy male subjects, all right-handed. A total of 60 painful laser stimuli (using a thulium laser, duration 1ms, intensity 600mJ) were applied to the dorsum of the left hand. The pseudo-randomized interstimulus interval was 8-12 seconds. Every third stimulus was skipped to allow the hemodynamic response to return to baseline. The fMRI BOLD response as well as continuous EEG and EDA data were recorded simultaneously.

EDA was measured as a skin conductance response in constant voltage technique. Silver-silver chloride electrodes were placed at the palmar middle phalanges of the index and middle finger of the hand contralateral to the stimulation side (Figure 1). The measurement site was prepared according to recommendations given by Fowles et al. (1981). Electrode paste and the MR-capable sensor (Brain Products GmbH, Germany) were subsequently applied. The skin conductance response (SCR) signal was recorded in DC mode by means of a bipolar BrainAmp ExG MR amplifier (Brain Products GmbH, Germany) simultaneously with the continuous EEG. As EDA and EEG data were recorded together in the same file, the same artifact correction procedures were applied to the EEG and EDA raw data: gradient artifact correction was performed using modified versions of the algorithms proposed by Allen et al. (2000), where a gradient artifact template is subtracted from the EEG using a baseline-corrected sliding average of 20 MR volumes. In addition a bandpass filter of 0.016 Hz to 5 Hz was applied to the EDA data. Data was then downsampled to 250 Hz. Laser stimulus-related EDA data processing was performed in a time frame of between 1 and 8s after laser stimulus onset. The single-trial EDA amplitude was calculated as the peak-to-peak difference between the negative and positive extreme value within this window.

We observed an event-related increase in skin conductance (EDA) that peaked 4860 ms after painful stimulation. A single-subject, single-trial experiment is depicted in Figure 2. A sample EDA stack plot of a single-subject experiment is

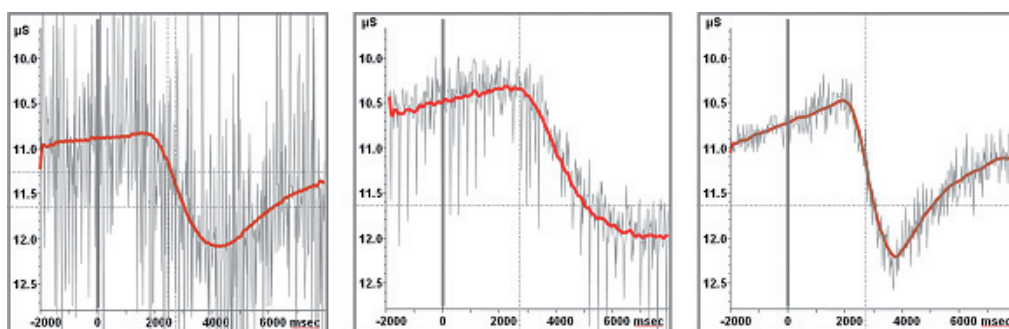


Figure 2: A single-subject, single-trial EDA measurement (red: after gradient artifact correction).

a: prototype EDA sensor; b: new sensor with long electrode cables; c: new sensor with shorter electrode cables

shown in Figure 3. We used the EDA data in two different ways for BOLD modelling. First we sorted trials according to their EDA amplitude into trials with a high vs. trials with a low EDA response. The fMRI contrast trials with high EDA vs. trials with low EDA at group level showed activation in areas consistent with pain processing. See Mobascher et al., *NeuroImage* 2008 for further details. We next used the single-trial EDA response as an additional regressor for fMRI BOLD to clarify which brain regions would covary with the EDA response from trial to trial. Again, structures that were previously shown to be involved in cortical pain processing were activated. For fur-

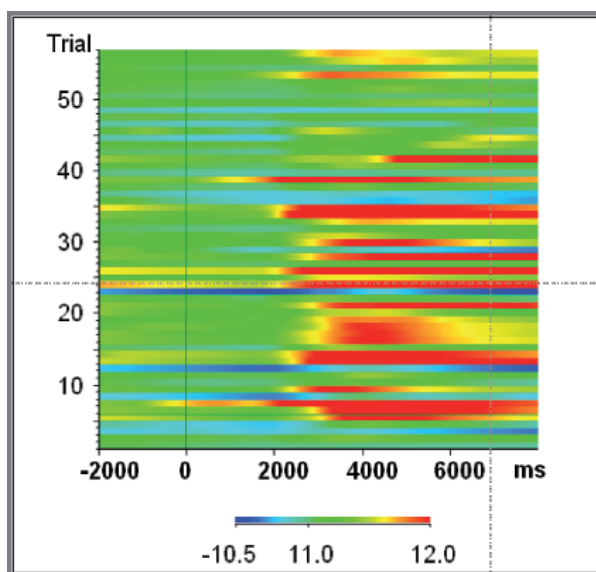


Figure 3: Stack plot of a single-subject experiment

ther details and discussion of the findings see Mobascher et al., *NeuroImage* 2008.

In our pilot study published in *NeuroImage* (2008) we used a prototype EDA sensor. At that stage of the project data analysis required the above-mentioned gradient artifact correction procedure to obtain a high-quality EDA signal that could be analyzed at single-trial level. Subsequent optimization of the hardware, namely improved shielding and shorter electrode cables, resulted in an EDA raw signal that was already largely artifact-free and did not require any gradient artifact correction procedures. ●

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