Improved Design for Absolute Skin Conductance Response Measurement during Motor fMRI

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Introduction

Measurement of skin conductance response (SCR) probes the sympathetic component of the autonomic nervous system[1] and may be of interest in fMRI studies that evoke autonomic responses primarily or secondarily in addition to intended volitional cortical networks. SCR signals are indirect measures of arousal, attention and emotions and have traditionally been used to measure sympathetic responses during cognitive and emotional tasks. Attention, however, has recently been shown to modulate activity in the primary motor and somatosensory cortices[2], which suggests measuring SCR during motor tasks may be useful to help characterize behaviour. In addition, others have found that the SCR signals are comparable to BOLD fMRI time series [3]. For example, temporal features in the SCR data have even be used in fMRI experiments involving active relaxation [4].

Knowledge of the sympathetic nervous system activity by means of SCR recordings could be useful to investigate heterogeneity in the fMRI data among healthy individuals as well as in clinical populations, such as stroke patients involved in motor recovery experiments. The first goal is to develop a linear self-calibrating fMRI-compatible SCR system that has a large dynamic range and is able to detect small SCR signals, since existing systems often rely on a bridge amplifier design that inherently has non-linear sensitivity. The second goal is to determine whether SCR data can be used to characterize fluctuations in the fMRI signal during a motor sequence experiment, particularly during the rest conditions.

Methods

Seven young, healthy participants were scanned on a 3 T GE scanner using spiral in-out k-space trajectories to collect T_2^*-weighted images [5]. During two six minute sessions, SCR was measured using the optoelectronic system described in Fig 1. The critical component of the system is a linear and constant current ohmmeter. The SCR data were collected and synchronized using LabVIEW software, sampling the data at 100 Hz after a digital 4th order lowpass filter (0.7 Hz). Participants performed randomized motor sequence tasks of varying difficulty by responding to a set of numbers, presented visually, with the appropriate digit sequence of the left hand in a block-design. The motor sequences were two, four or six digit movements associated with simple, intermediate and hard levels of difficulty, respectively. FMRI data were analyzed using AFNI software. Activation maps were generated using least-squares fitting to a model waveform based on 1) task timing and 2) the skin conductance fluctuations only during rest.

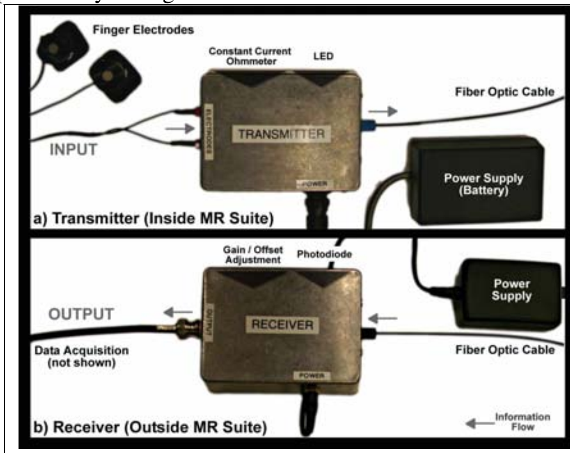

Fig 1. Skin conductance response (SCR) recording system.

Results

Over the range of typical human skin conductance values (i.e. 0.83 – 10 μS), the SCR system showed a linear relationship between input resistance and output voltage ($V = 0.35R+2.08$, $r^2 = 0.997$). The mean skin conductance observed across participants was 3.6 ± 0.85 μS throughout fMRI (range: 2.2 – 4.5 μS). Preliminary observations showed SCR during the task condition tended to decrease over the course of the experiment and across sessions. For example, during the first session, ΔSCR for trial #1 was 0.24 ± 0.166 μS, while ΔSCR for trial #8 was 0.16 ± 0.108 μS. Compared to the motor maps, activation generated using the SCR features during the rest condition were of lower significance because only half the fMRI time series was used, but nonetheless highlighted distinct brain regions (representative participant in Fig 2).

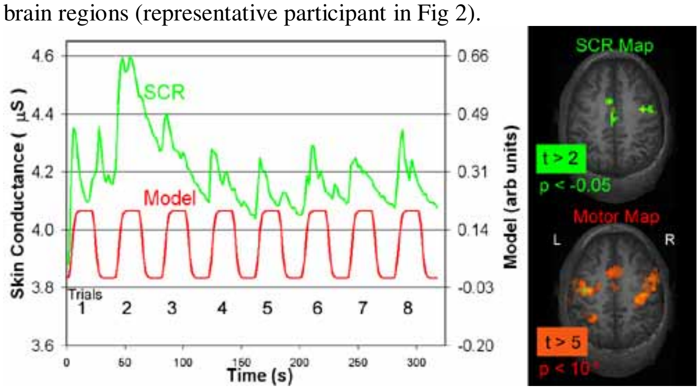

Fig 2. *Left:* SCR time series data from a single subject are shown along with the model waveform based on task timing. *Right:* Top view shows voxels that are correlated with SCR features occurring during rest conditions. The bottom view shows motor activation for the same subject.

Discussion

Attention and arousal may wax and wane during the course of a block trial, throughout the course of an experiment, or during the rest or control condition, thereby introducing confounding trends in the data that may manifest as deactivation, for example. The existence of sympathetic autonomic changes can be assessed with relative ease using SCR measurements. The SCR system described offers potential to incorporate additional behavioural information that can be used to augment the interpretation of fMRI. Future analysis will attempt to relate SCR changes to brain regions that encompass motor and attentional networks.

References

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