Utility of an MR-Compatible Skin Conductance Measurement System during fMRI of a Difficult Motor Task

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Introduction

Previous fMRI studies have demonstrated how the inclusion of independent behavioural metrics adds to the interpretation of brain activation patterns. One example is the skin conductance response (SCR) that occurs due to changes in autonomic sympathetic arousal. Previously, SCR has been used in conjunction with fMRI in mood and cognition experiments (Williams, Brammer et al. 2000; Shastri, Lomarev et al. 2001). However, SCR could provide a useful complimentary measure during motor tasks of varying difficulty or attentional demands, particularly in the case of patients with impaired motor function. This study evaluated the functionality of a custom-built system for SCR measurement during fMRI. Experiments involving a complex motor task illustrate the importance of SCR data during fMRI analysis.

Materials and Methods

Skin conductance data were collected using a custom-built optoelectronic SCR system with standard Ag/AgCl electrodes placed on the distal part of the index and middle fingers of the right hand (Fig. 1). The SCR system consisted of a Wheatstone bridge circuit, a preamplifier (Gain = 1000), and multiplexing hardware to convert the electrical signals to optical signal. Subjects were instructed to keep the right hand still throughout the experiment. SCR data were collected using LabVIEW software at a sampling rate of 1000 Hz. A trigger pulse ensured the scanner and collection software were time-locked. Subsequent SCR data were normalized and filtered using a 4^{th} order Butterworth filter with low and high frequency cutoffs of 0.01 Hz and 0.3 Hz, respectively.

Six young, healthy, right-handed subjects were submitted to fMRI using a GE Signa Eclipse 3.0 T MRI system. A single 5 min scanning period was executed with alternating 20 s blocks of task and rest. The task involved abduction-adduction of the ring and middle fingers, followed by a similar movement with the index and little finger. Subjects were instructed to perform the movements on their non-dominant (left) hand repeatedly as fast as they could for the length of the task block. The instructions were given immediately prior to fMRI so that the subjects were equally naïve to the task and had no opportunity to practice.

FMRI data were analyzed with AFNI using two different correlation waveforms. The first waveform (HD, Fig. 2b; green line) was a convolution of the task/reference waveform (Fig. 2b; orange line) with a hemodynamic response function, while the other utilized each subject's individual SCR signal (Fig 2a).

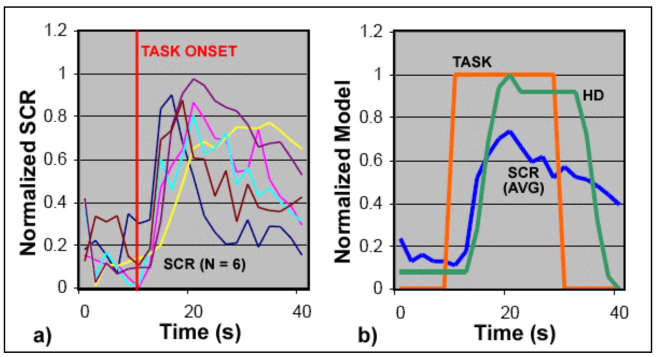

FIG. 2. a) Normalized and filtered SCR for the first trial for each subject **b)** Model waveforms used in the fMRI analysis

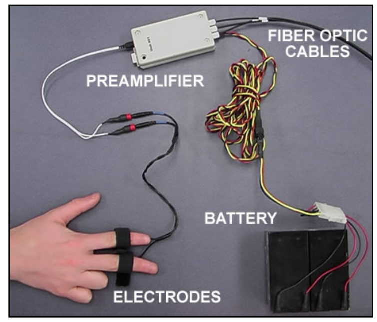

FIG. 1. MR-compatible optoelectronic system for SCR measurement.

Results

All subjects found the task difficult to perform, as quantified by an average score of 6.67 (strong) on the Borg Scale of Perceived Exertion (1-10). Subjects did however report slight improvements in task performance over the 5 min period. SCR data show a marked increase in skin conductance immediately following task onset with a peak value occurring around 8 sec later. The first task block (Fig 2a) exhibited the largest SCR change from baseline, and subsequent SCR changes decreased over the course of the experiment. Group fMRI activation maps (Fig. 3) showed expected brain activity in motor areas such as the right primary motor cortex (M1), but to varying degrees depending on which correlation waveform was used. The SCR waveform proved to be more sensitive to motor function than the HD waveform (see contrast map Fig. 3c) at the same statistical threshold. Specifically activation was captured better in the supplementary motor area (SMA) and the insula, areas associated with motor planning and attention.

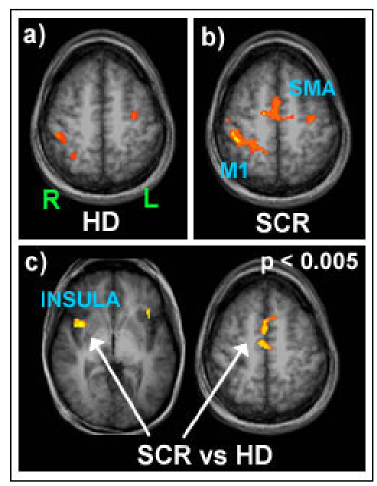

FIG. 3. Group (N=6) activation maps produced by correlating the fMRI data with hemodynamic (HD) and skin conductance response (SCR) waveforms

Conclusions

The optoelectronic SCR measurement system produced robust, reliable SCR signals from all subjects during fMRI. The SCR exhibited a similar lag to the hemodynamic response, however produced an increased set of activated brain regions. In addition to the motor network, correlation with SCR identified functional areas associated with the attentional demands of the task, including the insula and SMA. Future work will employ the system in other fMRI studies, for example, examining motor task difficulty in subjects recovering from stroke. Physiological measures such as SCR are useful for extracting extra information from fMRI time series. They better model the behavior of the subject, and as such, can provide important additional insight and more robust activation maps.

References

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