A safe and artefact free device for monitoring galvanic skin conductance during fMRI

P. Erhard[1], and D. Leibfritz[1]
[1]Dept. of Chemistry, University of Bremen, Bremen, Germany

Introduction: Galvanic skin conductance (GSC) measurement has been used since the late 1880th [1] some times for "lie detectors", but later in psychological research for reliable monitoring of arousal and changes in arousal due to applied stimuli [2]. The galvanic skin resistance (GSR) method relies on the fact, that arousal causes excretion by the perspiratory glands, which in turn increases the conductivity of the skin. The GSC is measured between two electrodes on the palm of the hand or on the index and the middle finger. Recently it became essential to monitor galvanic skin conductance during functional magnetic resonance imaging (fMRI) experiments. Shastri [3] was pioneering this work by developing one of the first MR compatible GSC devices. We used a copy of this device successfully in low field whole body MR Systems but noticed problems with occasional electric stimulation related to gradient switching when using the device in a 3T head scanner. This holds true even if resistive carbon cables are used. These findings led to the development of a new device.

Method: We hypothesized that gradients induce a current into the leads from the electrodes to the GSC device. BOLD fMRI is usually performed using a gradient echo EPI pulse sequence with relatively long echo time (typically 30ms at 3T). This long echo time combined with a desirable short acquisition time leads to periods where no gradient switching takes place (Fig.1, arrows, compare to [4]). We designed our device in a way that the electrodes are not connected to the GSC circuit, when gradient switching takes place. This disconnection is realized by use of PhotoMOS switches. These switches have a very high isolation resistance of 1000MΩ, a low on resistance of less than 30Ω, and the gate is powered via a combination of an LED and a photo cell (Fig. 2). Time intervals where nor GSR is recorded are bridged by a sample&hold circuit. The rest of the GSC device consists of a tunable Wheatstone bridge and a state of the art physiology amplifier. No filtering of the signal neither in the circuit nor in the acquisition software is being used so far. Gradient timing is deduced from a one volume prescan with identical timing. Periods without gradient switching are automatically detected using a home made program which calculates apattern for both for the timing of the PhotoMOS switches and of the sample&hold circuit. In our experimental setup we use a "power 1401" by Cambridge Electronic Design™ both for the timing and GSR data acquisition. We performed phantom studies with a bottle with a standard MR phantom from the manufacturer for MRI and a resistor as a phantom for skin resistance. Initial measurements on human subjects were performed as well.We recorded GSC and fMRI simultaneously in our 3T head scanner, GSC alone and fMRI alone in order to detect any detrimental interaction between the two modalities.

Results and discussion: It turned out that the timing parameters between the PhotoMOS switches and the sample&hold circuit differed considerably, hence the timing had to be fine tuned in order to make the device work properly. Measurements on the resistor alone led to reliable data. Phantom measurements in the scanner while simultaneously acquiring fMRI data led to GSR data that was free from gradient artefacts. Experiments without operation of the switches led to immediate saturation of the physiological amplifier by imaging gradients. At this point in time, skin conductance can be sampled for periods of 14 msec for each slice with 55ms TR, hence approximately 25% of each TR period can be used to acquire GSR data. The sampling rate is approximately 18s^{-1}. Due to the fact, that the scanner is operated inside a Faraday cage, the acquired GSR signal is very clean. The measurements with human subjects showed some noise that might be attributed to vibrations and physiology and signal fluctuation due to heart beat. The GSR data of human subjects during fMRI show some contamination with gradient induced signals. No change in the fMRI signal could be detected due to simultaneous operation of the GRC device and no electric stimulation of the hand was observed.

Conclusion: We attempted to develop an artefact free GSC device for use in the fMRI scanner. Phantom studies show very good results. The signal is stable and very little cross talk from the gradients can be observed. The device efficiently suppresses gradient artefacts from showing in the data. The main goal, to disconnect the volunteer from the possibility of electric shock has already been reached. No contamination of the fMRI signal due to simultaneous GSR measurements could be found, neither by S/N measurements, nor by comparing images. However further work needs to be done in order to fully suppress gradient related effects in human studies. This might be achieved by disconnecting the electrode cables from the physiology amplifier during gradient switching. Our design also prevents the tissue underneath the GSR electrodes from permanent depolarisation. As a downside, the setup is relatively complicated, needs fine tuning, and so far requires complex and expensive equipment. Future work will include real time gradient detection, further validation of the method, and making use of more gradient free intervals, as indicated in Fig.1.

References: [1] Neumann E and Blanton R Psychophysiology 6, 453 (1970). [2] Erhard P et al., In: Herrmann M & Thiel Ch (Eds.) Topics in Advanced Neuroimaging. (2007), pp.175-178. [3] Shastri A et al, JMRI 14:187(2001). [4] Hanson CG and Hanson LG, Proc ISMRM (2006), p.2388.

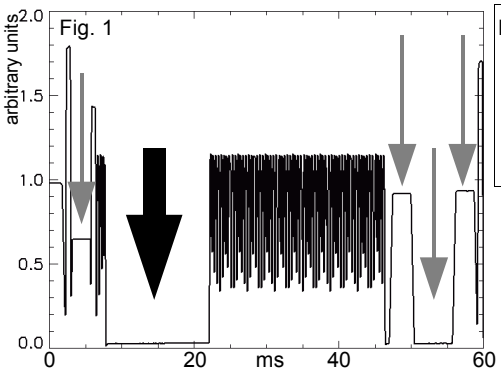

Fig.1: Summation of absolute values of EPI gradients for one slice, big arrow indicates the interval that presently is used for GSR recording. Grey arrows point at intervals that could be used in future refinements. Gradients were recorded directly off the scanners gradient control unit.

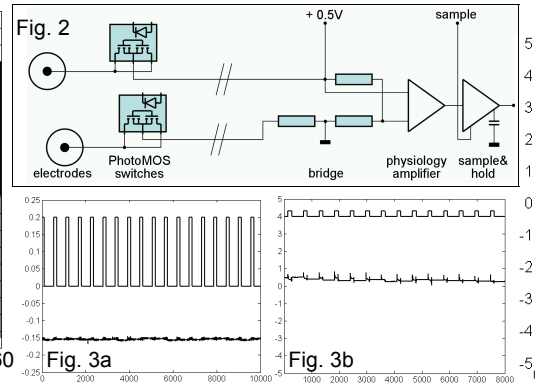

Fig.2: Principle circuit diagram of the GSC device. The digital interface is not shown. PhotoMOS switches in close proximity to the electrodes disconnect them from the amplifier circuit during gradient switching, with a resistance of 1000MΩ and isolation of 500V. The skin resistance and three resistors form the Wheatstone bridge which is followed by a high gain (1000) precision physiology amplifier with >100 dB common mode rejection. Sample&hold timing is not identical with PhotoMOS timing due to different switching characteristics. No low or high pass filtering is used.

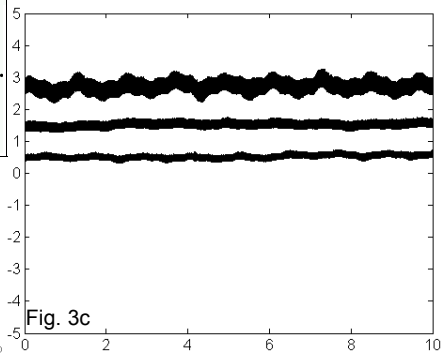

Fig.3: Data acquired with the GSC device, sampling rate: 10000s^{-1}, vertical scale: volts (a) with resistor and phantom during EPI-fMRI, bottom: GSR signal top: timing of switches; (b) human data during EPI-fMRI, bottom: GSR signal with residual artefacts, top: timing of switches; (c) scale x 10^4, human data in front of (bottom), half way inside (middle), and inside (top) the 3T scanner. Note the increase of noise due to patient bed vibrations inside B_0 and movement of the body and cables. Inside the scanner, cardiac signal is being picked up.