ActionGSR: A Combination Galvanic Skin Response–Accelerometer for Physiological Measurements in Active Environments

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Abstract

The galvanic skin response (GSR), also known as electrodermal response, measures changes in electrical resistance across two regions of the skin. Galvanic skin response can measure arousal levels in children with autism; however, the GSR signal may be overwhelmed by the vigorous movements of the children. This paper introduces ActionGSR, a wireless sensor capable of measuring both GSR and acceleration simultaneously in an attempt to disambiguate valid GSR signals from motion artifacts.

1 Introduction

The galvanic skin response (GSR) may help assess the internal state of a child with autism. We seek to measure physiological responses, such as the galvanic skin response, of children with autism in natural environments. Our goal is to use machine learning algorithms to correlate changes in the electrodermal response to the occurrence of vigorous autistic self-stimulatory behaviors. Unfortunately, the GSR signal is often overwhelmed by vigorous movement preventing accurate measurement (from a single GSR sensor) in real-world environments. This paper introduces *ActionGSR* a prototype wireless sensor capable of measuring both GSR and acceleration simultaneously to potentially allow measurement of an individual's GSR in active, non-laboratory environments.

The galvanic skin response measures changes in electrical resistance across two regions of the skin. The electrical resistance of the skin (which is typically large and varies slowly over time), fluctuates quickly during mental, physical, and emotional arousal. These states of arousal are related to the activation of the sympathetic branch of the autonomic nervous system. During a sympathetic response eccrine glands in the skin produce ionic sweat lowering the resistance of the skin and increasing conductivity. The change in conductivity can be used to infer differing arousal states in individuals.

Unfortunately, this phasic change of skin conductivity can be overwhelmed by motion and changes in pressure applied to the electrodes on the skin. The location of the electrodes and the path length between the two electrodes can also influence the sensitivity of the readings. If the subject is highly active, motion artifacts can quickly distort the GSR readings (Figure 1(a)). Without knowledge of the underlying motion, the GSR signal could be misinterpreted. However, with the accompanying acceleration information, compensations can be made.

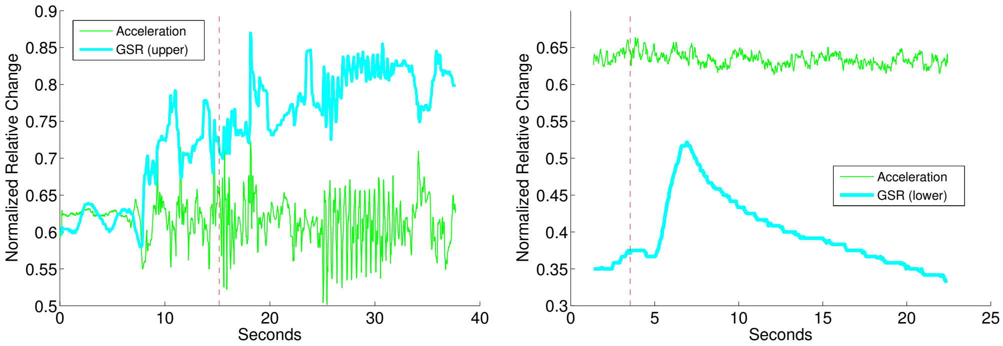
2 Related Work

Several affective computing research projects utilize the GSR to help infer a users affective state. The StartleCam is a wearable system that uses the phasic component of skin conductance as a trigger to save images surrounding events when the user is startled [2]. Although the StartleCam is a completely wearable system, during the experiments, users remained seated while they were exposed to auditory stimuli. The seated stationary posture reduces motion artifact noise in the GSR signal. Healey leveraged this fact to monitor stress levels while driving a car[1].

The Conductor's Jacket used a GSR sensor in combination with other physiological sensors to correlate symphony conductor's emotional state with phrases in music [3]. Nakra noted that the vigorous motion of conducting interfered with the GSR signal. Picard and Healey investigated affective sensing in ambulatory environments [1]. During the ambulatory experiments, subjects wore physiological sensors, including a GSR sensor on the palm and foot, while performing a cycle of sitting, walking, jogging, and coughing. Motion artifacts influenced the GSR signals; however, correlations were found between the multiple sensors. These correlations can help compensate for motion artifacts.

3 Hardware

The ActionGSR system (Figure 2) consists of 4 main sections: sensors (accelerometers and GSR), a Bluetooth ra-



(a) Subject highly active

(b) Subject less active

Figure 1. Normalized GSR-acceleration measurements and corresponding auditory stimuli. Increased GSR response occurs 3-5 seconds after stimuli (dashed vertical line).

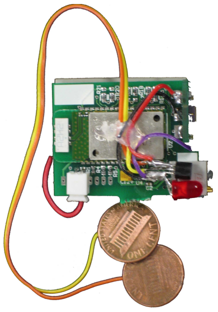


Figure 2. ActionGSR

dio, a PIC microcontroller (PIC 16F876), and a power supply. Each sensor is sampled at 50 Hz by the microcontroller via an on-chip 10-bit analog-to-digital converter. It has dimensions 17.78 × 7.62 × 2.54 mm and weighs 22.68 g.

Accelerometers: The system uses two perpendicularly mounted dual–axis Analog Devices ADXL202JE accelerometers to sense movement. These accelerometers are capable of sensing ± 2 G static and dynamic acceleration in the plane of the integrated circuit.

Galvanic Skin Response: The electrodermal activity is detected with a simple DC amplifier. A low voltage is applied to one electrode. A small amount of current flows to a second electrode mounted nearby. A Darlington transistor amplifies this signal which is then digitized and processed by the microcontroller. Manual adjustments are made using a potentiometer for individual conductivity differences.

Bluetooth Radio: The Bluetooth radio is a Taiyo Yuden serial port replacement module. This module handles the transport and protocol details of the Bluetooth connection. The microcontroller communicates with the radio via a standard serial connection.

Power Supply: The system is powered by a single 3.6 V 700 mA lithium ion battery. This provides enough power for the system to run for 15-20 hours. The system consumes 210 mW while waiting for a connection and 120 mW while sending data.

4 Initial Experiments and Discussion

Our initial experiments involve the first author wearing the ActionGSR sensor collecting GSR-acceleration data while performing various activities: mimicked autistic behaviors, practicing Kung Fu, and working on a laptop. For each hour trial the electrodes and sensor were placed on her waist and held in place by the waistband of her pants. While wearing the sensor, blasts of white noise stimuli, similar to those used in the StartleCam experiments, were played at random times to elicit a startle response in the GSR signal. Figure 1(a) is a 45 second window of x-axis acceleration and GSR readings from the ActionGSR sensor during an hour of vigorous activity (similar to severe autistic self-stimulatory motions). Based on the acceleration data, the GSR signal should be ignored during the bursts of rapid motion experienced from 15–18 seconds and 25–32 seconds. However, in many situations, correlations between the two signals may provide useful information and preclude discarding the entire GSR signal as noise. In contrast to the vigorous activity, Figure 1(b) is a 25 second window of gentle activity with lower acceleration and cleaner GSR signal. In this figure, the startle response to the white noise stimulus is visible at approximately 6 seconds.

In the future, we hope to perform experiments in more depth over a variety of domains. Currently, there are some potential issues with the ActionGSR sensor design. First, the skin conductance of an individual experiences tonic changes over extended periods of time. The ActionGSR sensor does not automatically adjust to these changes like the GSR Handwave sensor [4]. Second, a potentiometer on the ActionGSR sensor must be manually adjusted for each individual wearing the sensor. Third, the ActionGSR sensor uses a DC sensing signal that may be more susceptible to noise and drift than would a sensor utilizing AC.

Despite these short comings, our preliminary results are promising. The accelerometers and the 10-bit A/D converter of the ActionGSR sensor provides enough resolution to allow GSR measurements to be taken from areas of low eccrine gland concentration (such as the waist) during periods of both high and low activity.

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