Correlating Emotional Arousal to Musician Performance

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ABSTRACT- **Music elicits variations in emotion that trigger sympathetic responses, alter electrodermal activity (EDA), and lead to physiological arousal. In this study, we designed and developed a wearable acquisition system to record emotion-induced physiological arousal. The device monitored EDA, heart rate, respiratory rate, and muscle activity. The EDA sensor was designed to measure skin conductance over a dynamic range. Heart rate and muscle activity were acquired with noninvasive surface electrodes. Respiratory rate was quantified using a piezoelectric belt that measured changes in chest expansion. After optimizing sensor placement, the instrumentation and wiring were sewn into a jacket-like garment. A wireless telemetry system captured the outputs of the sensors and transmitted the signals to a monitoring station for unobtrusive data acquisition. In a preliminary study, music performances were used to trigger emotional stimuli and assess the level of physiological arousal. The results demonstrated modulated heart and breathing rates and an increase in EDA activity during musical performance, suggesting a physiological arousal response. Overall, the development of a wearable acquisition system coupled with a low-cost EDA sensor facilitated emotion research by allowing unobtrusive data collection without causing discomfort or distraction.**

I. INTRODUCTION

Assessment of psychophysiological parameters provides insight into the bridge between music-induced stimuli and physiological arousal. Continuous, noninvasive monitoring of physiological parameters such as heart rate, breathing rate, electrodermal activity, and muscle activity can be used to detect modulations in the sympathetic activity of the autonomic nervous system; certain modulations indicate emotional arousal. A sympathetic response increases the amount of standing sweat in the sweat ducts and causes a gradual diffusion of sweat though the pores. Therefore, the resistance encountered by an applied current at the surface of the skin is directly modulated by the activity of the sympathetic nervous system and constitutes an accessible measurand that can be examined by noninvasive methods. The development of a technique for long-term monitoring of EDA facilitates the recognition of the origins of varying electrodermal levels and responses. Electrodermal level is associated with the tonic discharges of sympathetic innervations and thermoregulatory factors and causes slow changes in the electrical activity of sweat glands. Electrodermal responses correlate with transient discharges of sympathetic activation due to cognitive and emotional stimuli[3]. Variations in electrodermal levels between individuals necessitate the design of appropriate sensor modules that quantify transient low-amplitude electrodermal responses with sufficient resolution. Sympathetic responses also increase heart rate through activation of the accelerator nerves, which elevates the demand for oxygenation and thus the respiratory rate. Careful analysis of alterations in these physiological parameters with respect to the subject's level of physical activity allows the differentiation between emotion-induced and movement-induced physiological arousal.

The acquisition of these parameters is often achieved using commercial data acquisition systems that are costly and require extensive expertise to use. Furthermore, the presence of hampering wires restricts subjects' mobility and causes undesirable discomfort. The objective of this study was to develop a low-cost sensor-jacket which allows wireless transmission of multiple physiological parameters to a remote station for unobtrusive evaluation of emotional arousal.

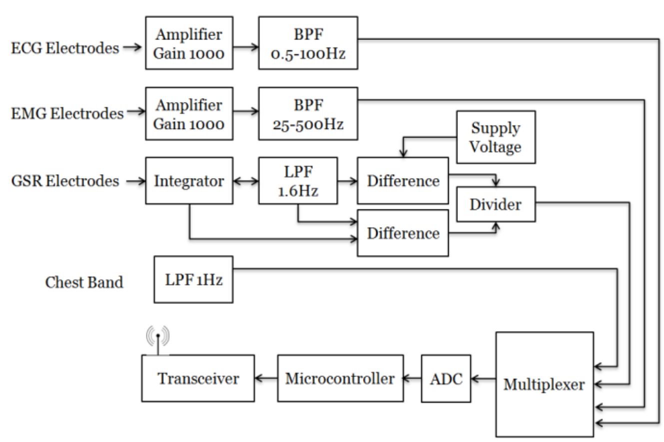

Fig. 1. data acquisition hardware system

II. METHODS

The development of our wearable sensor-jacket was achieved through careful design and integration of appropriate sensors and instrumentation with a wireless data transmission system to ensure accurate acquisition of physiological measurands including heart activity, muscle activity, electrodermal activity, and respiratory rate. Skin conductance was measured over a dynamic range using an automatic bias control method implemented by an integrator circuit and a low pass filter in feedback configuration[3]. Skin conductance was computed by conditioning the outputs of the integrator and the filter using analog components to ensure compatibility with various acquisition systems. Heart rate and muscle activity were captured using surface electrodes. A piezoelectric belt (Braebon 0528) was employed to detect varying levels of chest expansion that reflect respiratory effort. An electret microphone (CUI Inc. 2742WBL) was used to capture sound and facilitate the correlation of observed physiological responses with specific events triggering the stimuli. Filtering and conditioning circuits were first investigated utilizing PSpice simulations to ensure functionality and apply necessary optimization measures. Alternative designs were assessed to produce low-cost analog conditioning units without compromising performance. The signals were multiplexed, digitized, and transmitted using a wireless telemetry system (Clevemed BioRadio 150). Figure 1 demonstrates the components of the data acquisition hardware.

The units were implemented in sequenced stages during prototype development to allow step-by-step diagnosis of the behavior of the sub-circuits. Signal processing algorithms were developed in LabVIEW to establish parallel conformities between the experimental analog outputs and comparable real-time digital signals. The recognition of optimized sensor placement enhanced signal acquisition by lowering the origins of interference, noise, and artifacts. Furthermore, the selection of appropriate sensor locations within the garment reduced the length of hampering wires to the transceiver. The placement of sensors, instrumentation, and wires is depicted in Figure 2. The ECG electrodes were positioned to mimic a standard Lead II configuration which yields maximum signal amplitude. The EMG electrodes were placed directly on the biceps muscle. The EDA electrodes were attached on the forearm (proximal to the wrist) in order to cover an area with the highest possible sweat gland density. The respiratory belt was worn around the chest to reflect the varying level of chest expansion during inhalation and exhalation. After optimizing sensor position, the instrumentation and wiring were sewn into a jacket-like garment to allow simultaneous acquisition of physiological parameters with minimal discomfort to the wearer. The data were received, analyzed, and displayed at a remote monitoring station.

Prior to participation in this study, all subjects were informed of the study's objectives and methods and then provided written consent to participate. This study was approved by the Institutional Review Board of our institution. Music performance was employed to measure physiological arousal by executing a rest-perform-rest protocol. The subject rested while sitting on a chair for a period of four minutes to obtain a baseline for the desired physiological parameters. Subsequently, the subject played an instrument for approximately five minutes to observe physiological changes due to music performance. The performance started off with rhythmic song, followed by a non-rhythmic song, and ended with a faster rhythmic song. After the performance ended, the subject rested for another four minutes to allow signals to return to their baselines and achieve a controlled scenario. All data were recorded and analyzed post-hoc.

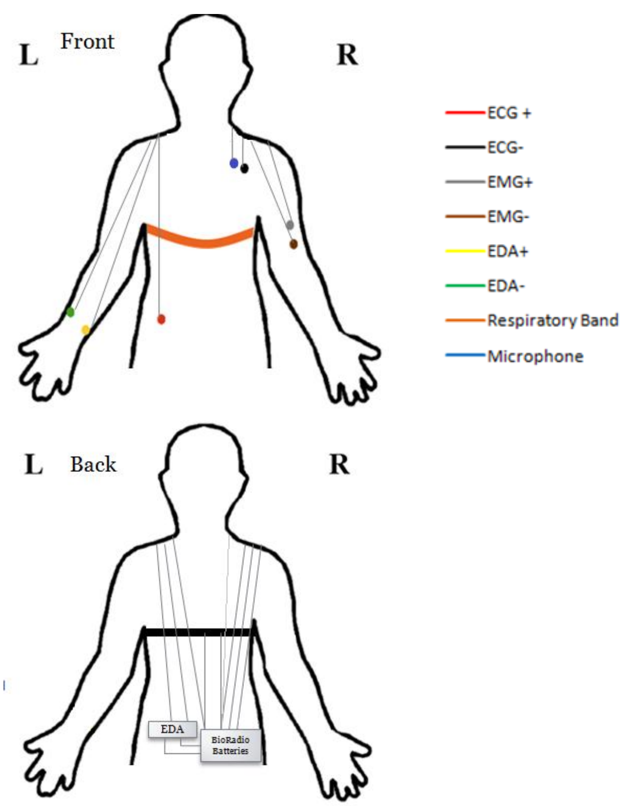

Fig. 2. palcement of sensors, instrumentation, and wires.

III. RESULTS

The results indicated physiological arousal in response to the wearer's own musical performance. Heart rate increased by approximately 10% during the performance in comparison to the resting periods. Respiratory rate increased during the performance but its exact analysis was difficult due to the piezoelectric nature of the belt which reduced signal accuracy during irregular breathing. The number of electrodermal responses and the amplitude of electrodermal level significantly increased during the performance. No significant difference was observed in the amplitude or the number of the electrodermal responses during the performance of the two rhythmic songs. From these results, it was observed that the electrodermal level increased subsequent to multiple consecutive electrodermal responses (EDA amplitude increased during performance).

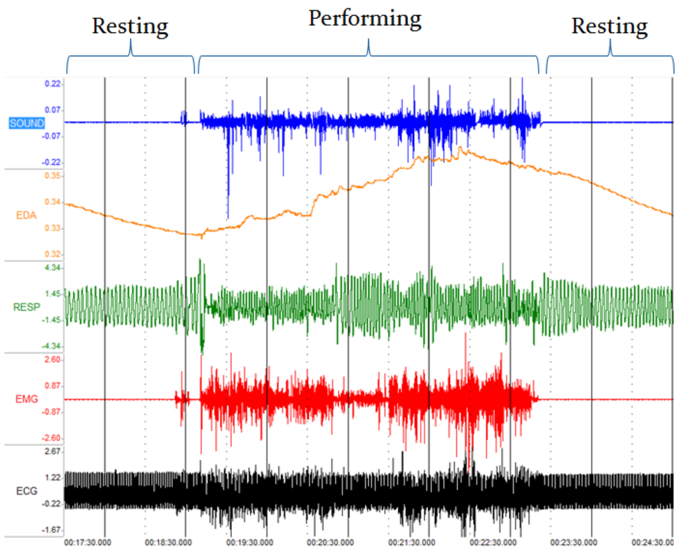

Fig. 3. acquired physiological data.

IV. DISCUSSION

Our wearable sensor jacket contains hardware and software that enables wireless transmission of physiological data for continuous monitoring and storage. The hardware includes sensors, amplifiers, filters, conditioning circuits, power supplies, a transceiver, and a laptop computer to acquire analog signals and digitize them for transmission and storage. The accompanying software provides the means for uninterrupted monitoring of physiological signals by allowing visualization and basic analysis of the data. The jacket was employed to assess psychophysiological parameters that grant insight into the bridge between emotion-induced stimuli and physiological arousal. Continuous monitoring of physiological parameters provides a noninvasive approach to detect modulations in the sympathetic activity of the autonomic nervous system. A low-cost sensor-jacket capable of remote monitoring of physiological signals without causing subject restraint was successfully designed and prototyped.

Sensors and instrumentation were integrated into clothing to develop a wearable sensor-jacket for unobtrusive assessment of physiological signals. Heart rate, breathing rate, electrodermal activity, and muscle activity were successfully acquired and transmitted to a monitoring station. Simultaneous acquisition of the aforementioned parameters did not produce any significant cross talk between signals and the generation of clean waveforms was evident. The ECG and the EMG were properly filtered and processed to obtain quantifiable data that could be readily analyzed. Improving the respiratory rate signal accuracy could be achieved using a strain gage belt that does not exhibit leakage current. These belts would be more optimal as the signal does not drop to baseline following a static deflection.

The electrodermal activity sensor was developed using low-cost and simple circuits that yielded an output signal with excellent resolution. The commercial EDA sensors are very costly and only compatible with specific acquisition systems such as Biopac and Thought Technology. The designed EDA sensor is compatible with various acquisition systems including MATLAB and LabVIEW as the output is fully conditioned using analog components. The sensor is capable of detecting both transient and tonic changes in the electrodermal activity over a dynamic range. Although the output of the sensor was limited by the voltage supply to 9μS, saturation was never observed since the measured skin conductance levels did not exceed ~2.5 μS. However, the electrodes had to be relocated to the wrist from the palms since the Bioradio was not capable of transmitting signals greater than 2μS. Overall, the use of simple components to develop the EDA sensor rendered an alternative with superior benefit-to-cost ratio.

The preliminary study confirmed the functionality of the sensor-jacket by allowing for unobtrusive assessment of data during a music performance. Modulated heart rate and electrodermal activity was observed during performance and correlated to events using the EMG and sound signals. Respiratory rate was difficult to analyze due to the employment of the piezoelectric belt which was associated with less accuracy during irregular breathing. The increased heart rate and the number of electrodermal responses suggest physiological arousal during performance.

V. CONCLUSION

The integration of instrumentation and wiring into clothing enabled unobtrusive psychophysiological assessment by reducing discomfort and distraction. Optimization of sensor placement, selection and implementation of appropriate power supplies, and precise composition and sewing of the garment were among the critical steps that contributed to the accuracy and quality of the wearable monitoring system. The employment of low-cost electronic components facilitated the accessibility of device capable of measuring emotional arousal. Overall, the proposed design caused minimal impedance to subject's movement while allowing unobtrusive acquisition of imperative psychophysiological signals.

ACKNOWLEDGMENT

This work was done with the support of a grant by Academic Affairs at TCNJ through the MUSE program.

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