Emovere: Designing Sound Interactions for Biosignals and Dancers

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ABSTRACT

This paper presents the work developed for Emovere: an interactive real-time interdisciplinary performance that measures physiological signals from dancers to drive a piece that explores and reflects around the biology of emotion. This document focuses on the design of a series of interaction modes and materials that were developed for this performance, and are believed to be a contribution for the creation of artistic projects that work with dancers and physiological signals. The paper introduces the motivation and theoretical framework behind this project, to then deliver a detailed description and analysis of four different interaction modes built to drive this performance using electromyography and electrocardiography. Readers will find a discussion of the results obtained with these designs, as well as comments on future work.

Author Keywords

Emotion, Physiology, Dance, Sound, Biosignals, Biofeedback, EMG, ECG.

ACM Classification

C.3 [ARTS AND HUMANITIES] Performing arts (e.g., dance, music), H.5.5 [Information Interfaces and Presentation] Sound and Music Computing D.2.6 [Programming Environments] Interactive environments.

1. INTRODUCTION

The project *Emovere* has studied emotion in order to generate an interdisciplinary performance that utilizes body processes in order to create a piece that reflects on the biology of emotion. The performance elaborates on the exploration of a series of corporal patterns from emotional states and the physiological measurement of the electrical signals that are generated by the human body. These physiological changes drive an interactive design that alters and modulates the sound environment of the piece. The body of the performer is presented then as a flux of information; vibrations, signals, gestures and tensions, which are affected by the amplification of its internal processes, modify an environment that is in constant movement, displaced and unpredictable.

Emovere measures electrocardiography (ECG) and electromyography (EMG) of four dancers, which are processed and then mapped to a series of sound objects in order for the performers to be constantly modulating and shaping the sound environment of the piece. This creates a dynamic and unpredictable soundscape that is mediated by the corporal state of the performers, which in turn is affected by their volitional movements and self-induced emotional states.

This performance was the result of an interdisciplinary creative research project, lasting over 18 months. During this time, a team directed by Francisca Morand and Javier Jaimovich, which involved dancers, composers, sound designers and visual artists, among others, developed a methodology based on a lab setting, where different ideas could be tested and discussed among the multidisciplinary team. The first phase of the project involved the development of different creative materials that included several sound objects, interaction modes, software tools and choreographic structures that formed the building blocks of the approximately one hour long interactive piece.

Emovere was presented at the Centro Cultural Gabriela Mistral in Santiago, Chile, having 18 performances with an audience of over 1200 people. This project was funded by three different government and university funds for research and creative practice between June 2014 and March 2016.

2. BACKGROUND

At the origin of the word emotion is movement, change, transition; *emovere*, which means to displace, mobilize, to remove the body from its state. With emotions, the body turns into action: the heart pounds, flutters, stops and drops; palms sweat; muscle tense and relax; blood foils, faces blush, flush, frown and smile [4]. Emotions are all of this and much more: they are a revelation of life at the center of our entire organism; the expression of a quest for balance, showing the exquisite adjustment and miniscule corrections in order the keep our organism whole.

Biosignals in performance arts have been present for over fifty years, since artists in the 1960s such as Alvin Lucier started to experiment with medical instrumentation to create novel compositions. However, very little documentation and few literature reviews have been written regarding compositions and performances that use physiological signals. This can be attributed to a large number of artists that have ventured into composing for biosignals for one or two pieces, and then continued their artistic work in a different area [16]. It was only in the second half of the 1990s that researchers, artists and instrument designers have suggested and attempted to utilize physiological indicators of emotion in music performances. This has probably been due to the difficulty involved in measuring emotions in the laboratory [18]; making it only possible to envision these possibilities with the development of off-the-shelf physiological measuring devices for performance applications [12] and the emergence of the affective computing field [17].

Lucier's seminal *Music for Solo Perfomer* in 1965 inspired other composers, such as Richard Teitelbaum and David Rosenboom, who continued to explore the field of performances with biosignals in the 1960s and 1970s under the paradigm of Biofeedback, in which performers became aware of functions of the body that would normally be taken for granted. According to Miranda and Wanderley "an important aspect of biofeedback is that the analysis of the information extracted from one's body can prompt one to take an action in order to achieve a certain physiological goal. Analysis and

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action thus feed information back to each other—hence the term biofeedback" [14].

Atau Tanaka in the 1990s with the *BioMuse* [12], predominantly working with EMG sensors measuring forearm muscular tension, developed and extended the practice of performance and biosignals to a set of gestures and methodologies for this novel class of artwork [21]. Tanaka has since collaborated with performer Marco Donnarumma utilizing mechanomyogram (MMG) sensors, which capture de acoustic vibrations of muscle tissues [7]. Donnarumma's contributions have been mainly focused to the development of a *biophysical music* strategy [8], which aims to allow the composer and performer access to the sonic material of the human body in an open source framework with custom biosensors. Interested readers are referred to [1, 19, 21] for reviews of biosignals and their use in music performance.

Physiological signals as indicators of emotion have been explored by other researchers and performers in recent years. An interesting approach has been taken by Sebastián Mealla and colleagues from the Music Technology Group at Barcelona. Mealla et al. incorporated *physiopucks* to the Reactable [20]. In the Reactable, tangible sound generator objects called *pucks* interact with the system and each other by controlling different aspects of the sound synthesis (e.g. pitch, tempo, reverberation). Mealla et al. measure EEG alpha-theta frequency bands and HR from performers, which are mapped to sound generators and tempo control respectively. What is interesting about this approach is that the authors have tested if *physiopucks* enhance motivation, creation and collaboration.

The work presented in this paper differs from previous experiences, as it aims to understand the physiological changes experienced by performers under the influence of specific emotional states.

When working with biosignals as emotion indicators, one of the major difficulties is the fact that physiological systems have many different functions within the body, which means that for a same emotional event there might be little repeatability in the physiological response [18]. Furthermore, "emotions are in part a function of novelty; consequently, the exact same input will generally not produce the same response over time. However, we can expect a similar input with the same level of novelty to produce a similar response in somebody over time" [17].

For *Emovere*, dancers were trained in an emotional induction technique titled Alba Emoting [2, 3], which is a method developed to help recognize, induce, express and regulate six basic emotions: fear, sadness, erotism, joy, tenderness and anger. The training consisted on introducing the performers in the postural, respiratory and facial patterns associated with each emotion. The objective behind this bottom-up induction approach is for the subject to reproduce the body's corporal state that is connected with a basic emotion, which will help to induce and experience this emotion. The technique is a common-practice among actors, but it has been applied to other performers, such as dancers and musicians, as well as for coaching businessmen and in psychotherapy [11]. The technique utilizes five successive levels of intensity for each emotion, being level one the lowest intensity level experienced, and five the strongest. For example, a level-five anger pattern requires higher muscular tone across the body, a more intense facial expression and a stronger respiratory cycle than a level-one induction pattern.

3. PRE-PROCESSING OF BIOSIGNALS

The premise for *Emovere* is to drive the sound environment of the piece using only physiological signals from the four dancers. In order to achieve this, three electromyogram (EMG) sensors and one electrocardiogram (ECG) sensor from infusionsystems[1] were positioned on the body of the performers (see Figure 1). These sensors were connected to a Bluetooth microcontroller transmitting each signal at 250 [Hz] to a computer dedicated to the processing and mapping of the biosignals.

Figure 1. Each *Emovere* performer had three EMG sensors positioned in the left and right biceps, and in one quadriceps, as well as one ECG sensor positioned in the torso.

Even though originally electrodermal activity (EDA) sensors were tested, due to their widespread relationship with emotional responses [13], these were discarded because of being highly affected by movement artefacts that caused noise in the readings. This has to be particularly considered when working with dancers, where movement artefact can be a sizeable challenge while processing biosignals.

3.1 Electromyogram (EMG)

Electromyography is a technique to measure muscular activity through the detection of an electric potential generated by muscle cells when the muscles are at rest or in contraction. Nerves control the muscles in the body by electric signals (impulses), and these impulses make the muscles react in specific ways. The electrical source is the muscle membrane. Measured EMG potentials range between less than 50µV and up to 20 to 30mV, depending on the muscle under observation. An EMG detector reads signals from all neighboring muscles at the point of the recording. Hence, EMG is a complex signal with noise acquired while travelling through different tissues.

The processing of an EMG signal is typically comprised of three stages: 1) Removal of DC offset 2) Rectification, which can be achieved using half-wave or obtaining absolute values 3) Smoothing, which is usually done by applying a low-pass filter or with a contour following integrator [6]. These steps were programmed into a Max/MSP abstraction: *EMGtool* (see Figure 2), which extracted a muscular tension feature from each EMG

[1] http://www.infusionsystems.com

signal, in order to be processed and mapped to different sound objects. The DC offset values were dependent of the sensor's position on the performer, so once calibrated they presented very little variation. The filter coefficients, on the other hand, were integrated to the mapping modes because they affected the reactivity of the muscular tension being calculated, which needed to be varied depending on the mapping strategies.

Figure 2. Example of EMG signals being processed by the EMGtool.

3.2 Electrocardiogram (ECG)

Electrical waves cause the heart muscle to squeeze and pump blood to all the arteries and veins in our body. These small electrical impulses, although the largest bioelectrical signal present in the human body [5], can be sensed by electrodes attached to the skin. Electrodes on different sides of the heart measure the activity of different parts of the heart muscle, which give form to the electrocardiogram signal (ECG).

The processing of ECG signals in *Emovere* was achieved using a previous tool developed by the author, the *HRtool* [10], which besides extracting heartrate from the ECG, has the advantage of continuously assessing the quality and stability of the signal. This allows creating a mapping strategy that can consider the current state of the signal, and make decisions according to this information.

3.3 Technical Difficulties with Electrodes

A specially challenging difficulty experienced with the physiological measurements of the dancers was produced after prolonged physical activity, approximately after 20-30 minutes. The perspiration of the performers formed a low-impedance pathway between the sensors' electrodes that created a short-circuit, rendering the biosignals non-viable after this time.

This issue was partially resolved by applying alcohol to the tissue before connecting the electrodes, and also by attaching a liquid absorbing cloth between the electrodes. This solution extended the usability of the sensors; nonetheless, the physical activity of the piece had to be taken into consideration when composing the choreography, in order to regulate the perspiration of the performers.

4. EMOVERE INTERACTION MODES

Four interaction modes were created for *Emovere* in Max/MSP, based on the observation and understanding of the emotion induction technique that the dancers utilized for the performance, along with the movement qualities [9] that arose from these experiences. This process followed a heuristic methodology, which nourished from an iterative cycle of analysis, dialogue, proposals and evaluations during rehearsals. Additionally, biosignals were recorded and analyzed during the Alba Emoting training sessions, which also informed the creation of the following modes.

Each interaction mode could then be connected to different sound objects (SO) that were specifically composed to interconnect with them. For instance, dancers would get familiarized with one of the interaction modes and then use it to drive or modulate a series of SOs that worked for that mode. This allowed the composition of the performance to be separated between the sound design of the SOs and the choreography associated with different interaction modes (see Figure 3).

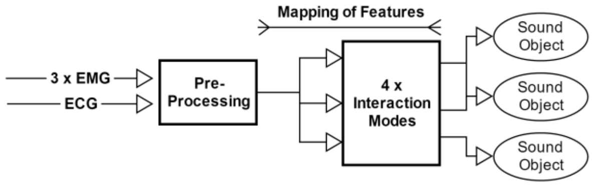

Figure 3. Signal flow and mapping diagram for each of the four dancers in *Emovere*. EMG and ECG signals for each performer were first pre-processed, and then their extracted features (such as muscular tension or heart rate) were mapped to one or more of the four interaction modes. Finally, these interaction modes modulated and varied the sound qualities of the multiple sound objects (SO) created for the performance.

4.1 Layers

Inspired by the five levels of intensity that were explored and assimilated by the dancers for each emotion pattern, an interaction mode was proposed that would use the muscular tension of the body to drive sound objects. This mode integrated the muscular tension of the three EMG sensors of each dancer to obtain an average measurement for the whole body. On the other hand, sound objects were designed in order to have five layers of sound files that had increased complexity and intensity. These sound layers were composed with the idea that they could be overlapped and looped continuously, allowing the muscular tone of the dancers to modulate the SO. Dancers would calibrate their personal intensity levels to the triggering thresholds of each sound layer, thus allowing a biofeedback loop between their bodies and the sound generation.

An extension of this mode was designed to facilitate the integration of a single SO so that could be shared between the four dancers on stage. In order to accomplish this, each dancer controlled a segment of the spectrum of the SO using layers. The SO was divided into four segments of overlapping spectrums using FFT objects in Max/MSP.

4.2 Events

A common pattern emerged from the movement qualities of two basic emotions: anger and fear. When exercising the induction of these emotions, dancers presented rapid and abrupt bursts of movement, which were accentuated by a higher overall muscular tone. The EMG of these states presented a constantly changing signal, with energy bursts that were not necessarily correlated with the movement of the performers' limbs. Based on these readings, and inspired by the flight-or-fight response associated with these two emotions [4], an interaction mode was designed so that it could capture the unpredictability and energy observed in the dancers' behavior.

The EMG pre-processing was calibrated in order to maximize the responsiveness of the muscular tension, allowing the measurement of fast and sudden spikes of EMG signal. Each EMG 'event' was then classified according to its intensity and duration, and mapped to the size and duration of grains in a sound file that were played sequentially according to the received EMG data. This configuration allowed composing the sound files with a particular intentionality, which could be choreographed with the sections of the piece. The sound files were different for each dancer, but utilized sound materials that emphasized sharp attacks and intense dynamics in order to create a sound environment that supported and enabled the emotions experienced by the dancers. For this interaction mode, only the EMG signals of the arms were utilized, in order to allow the dancers to move freely on the stage without generating sound.

4.3 Voice and Control

Because the Alba Emoting technique builds from a strong treatment of respiratory patterns, the vocal sounds generated from this process are quite rich in their emotional content. Listening to the respiration generated while inducing erotism or anger, as well as trying out different texts while changing emotions, resulted in quite a varied and wide spectrum of sound materials. This drove the idea of utilizing the voices of the performers as a central theme throughout the piece. For example, SOs used for the interaction modes presented in section 4.1 and 4.2 had recording excerpts made by the performers themselves in a series of studio recording sessions.

Furthermore, the inclusion of the voice within the piece enabled to address a design complexity common to interactive performances that utilize biosignals. That is, the difficulty for spectators to understand the interactions behind a performance when the mappings occur at an internal level. In other words, changes in muscular tension and heartrate variability are physiological manifestations that are (ordinarily) imperceptible to the outside world. The strategy for *Emovere* was to create an interaction mode that would provide this connection to the audience, giving information about how the piece was constructed.

Figure 4. Performer recording voice for his own interaction mode.

An interaction mode was designed so that it could capture the voice of the performers on stage, and immediately transfer this sound to their bodies. The dancers would then modulate their own-recorded voices with a granular synthesis technique that accentuated the unpredictability and volatile nature of their physiological signals, while being traversed by emotions and choreographed movements on stage. The sounds of their own voices would then be disordered and scrambled in time, but still allowing the audience to associate the sound environment being generated and the body of each performers.

4.4 Heartbeat and Biofeedback

The heartrate (HR) changes measured during the emotion induction technique sessions presented a wide range. One of our dancers presented a HR that could oscillate between 55 and 130 beats per minute (BPM). This, of course, depended not only on the emotional state being experienced, but also on the age, gender and physical characteristics of the performer. Nonetheless, the simple exercise of listening to the heartbeat of the performer while self-inducing different emotions emerged as quite a compelling experience. The opportunity to amplify this internal process, in such a crude manner, was the motivation behind the interaction mode designed to work with basic emotions and HR.

The idea behind this mode was to allow for the performers to experience intense levels of basic emotions, without focusing on the sonic results of the performance. This can be classified to be more of a reactive design than an interactive one, but it is important to consider that there is a biofeedback loop when internal physiological signals are being sonified and amplified, which can affect their behavior [14].

The heartbeats of the four performers were treated as one musical instrument, which would trigger a series of percussive and sustained notes. The mode was designed so that the sound composition could shift between more direct and percussive biofeedback sounds to sustained and abstract notes. Additionally, the system could be configured to trigger sounds not on every heartbeat, but every two, three or more heartbeats, which was scored to coordinate a coherent artistic poetic with the choreography.

A practical challenge for working with ECG involved measuring the HR of the performers only when standing relatively still. The sensors utilized were quite sensitive to motion artefact, which meant that the choreography had to consider a slower tempo and pauses in order to facilitate the HR readings. Nonetheless, this was treated as an advantage, because this mode was particularly used for working with sadness, which presented a very restricted quality of movement.

5. DISCUSSION AND CONCLUSIONS

This paper has presented the results of an exploratory approach towards the design and creation of sound interaction modes developed for a dance and biosignals performance piece. These designs have been informed and inspired by the Alba Emoting emotion induction training carried out by the dancers of the performance.

The four interaction modes utilize electrocardiography and electromyography to map physiological changes present in the corporal patterns of dancers to a series of sound objects composed specifically for Emovere. This resulted in an approximately 1-hour long performance that was driven entirely from the biosignals of the dancers.

Originally, the first attempts to connect the dancers to sound parameters were thought as if they were musicians that were playing an instrument. For example, first exercises intended to familiarize the dancers with the sensors involved controlling a sound's amplitude with the right-arm EMG, and frequency with left-arm EMG. This was rapidly discarded due to the dancers not being familiarized with a musical-performer training. Even though this could have been foreseen, it is crucial to approach a project of this nature with the understanding that different disciplines, in this case dance and music, have distinct working methods and artistic backgrounds that need to be conciliated in order to obtain truly interdisciplinary results. For *Emovere*, for example, it was important to work with the dancers' bodies as a whole, even when separating parameters for different parts of the body.

In this regard, this project resulted particularly successful in its integration around a laboratory space, during the first phase of development. In here, a common language emerged at the center of the disciplines involved that allowed the emergence of the artistic material of the piece. The interaction modes presented in this paper were the result of the dialogue and discussions produced in an open working environment, which then evolved to becoming the structures behind the main sections of the performance.[2]

[2] Excerpts and examples of the interaction modes presented in this paper can be found at *http://www.emovere.cl*

Finally, even though *Emovere* proved to be a compelling and exciting project and performance piece, we believe that the relationship between the themes and materials utilized have only been explored at a surface level. There is a profound body of work that can still be developed, organized and systematized when looking at the biology of emotion of dancers. Future work in this area will explore the use of different sensing systems that can integrate physiological signals with movement [15] as well as experimenting with MMG signals [8], in order to better articulate and understand the dancer's movements and behaviors with their internal physiological processes.

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