# Contagion of Physiological Correlates of Emotion between Performer and Audience: An Exploratory Study

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**Abstract.** Musical and performance experiences are often described as evoking powerful emotions, both in the listener/observer and player/performer. There is a significant body of literature describing these experiences along with related work examining physiological changes in the body during music listening and the physiological correlates of emotional state. However there are still open questions as to how and why, emotional responses may be triggered by a performance, how audiences may be influenced by a performers mental or emotional state and what effect the presence of an audience has on performers. We present a pilot study and some initial findings of our investigations into these questions, utilising a custom software and hardware system we have developed. Although this research is still at a pilot stage, our initial experiments point towards significant correlation between the physiological states of performers and audiences and we here present the system, the experiments and our preliminary data.

## 1 Introduction

As computers and mobile devices become simultaneously smaller and more powerful they are also being incorporated into everyday objects and our day to day lives. This move towards 'ubiquitous' computing means that these embedded devices are used in very diverse situations and environments, that may require some degree of context awareness from the device. One branch of research into context aware interactions is what is known as 'affective' computing, using emotion or 'affect' as an information and interaction channel for an electronic device or system [1]. This may allow appropriate responses from a computer system based on factors such as happiness, sadness, frustration or stress. Machine recognition of emotional state is not a trivial matter and research continues in a number of directions, such as facial emotion recognition, vocal analysis and posture analysis [2]. Our research has chiefly focused on physiological indicators of emotion (biosignals) and changes in emotional state such as patterns in heart rate variability and galvanic skin response [3]. While it is difficult to attempt to assign a given emotion to a particular physiological state, as opposed to say facial indicators of emotion, biosignals do have the advantage of being largely outside conscious control and thus may be viewed as a more 'direct' connection with

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the subject. It is also relatively easy to detect subtle continuous changes in physiological (and by extension emotional) state, allowing for more nuanced interactions.

## 2 Music and Emotion

Emotions are a powerful force in driving human decision making and action, frequently overpowering intellect or logical reasoning [4] and with the capability to affect our interpretation and perception of events or content [5]. Music has been shown to have the capability to induce emotions in the listener [6] with corresponding physical [7] and physiological effects [8].

While most previous research into the emotional power of music has focused on structural and cognitive aspects, the neuropsychological underpinnings are only now being properly explored, with alternative mechanisms, such as those posited by Juslin and Västfjäll in [9], such as brain stem reflexes, visual imagery, episodic memory and musical expectancy now thought to also play a role in evocation of emotion. Also among these alternatives is the possibility of emotional contagion, in which emotion is engendered in the listener corresponding to the perceived emotional content or intent of the music, such as a dissonant piece with harsh timbres and fast tempo suggesting anger. There is some evidence to support this induction of mood through perceived affect of musical stimuli [10] and listeners often report a sensation of 'chills' from particular pieces of music with a strong personal or emotional cachet [11] that may also be an indicator of emotional peak experiences.

However most of these experiments have taken place in laboratory settings using prerecorded musical examples and on a one-to-one basis, with little consistency in subjects responses to given pieces of music. So far little work has been done (on a physiological level) in examining group experiences of musical performance in a concert setting and it is our belief that more data gathered simultaneously from multiple participants in this ecological setting may shed some light on what causes and modulates our emotional responses to music.

We also hypothesise that there is a degree of emotional contagion between the performer and the audience, with a performer/players affective state influencing the affective state of the audience. This may be observed through channels such as the previously mentioned facial or posture indicators, through affective modulation of performance style and technique or through as yet unknown channels of affective communication.

It is important to stress that using low level biosignals like GSR or HR we are unable to definitively infer a given affective state in the subject monitored, such as happiness or boredom. We are however able to detect gross *changes* in state and to suggest a *probability* of a given state (with accuracy dependent on variables such as number of signals monitored and context). There may also be variables external to the monitoring environment (for example events that occurred during the subjects day prior to monitoring or feelings of illness) that will affect the biosignal readings.

## 3 Methodology

We carried out two experiments in different live performance environments, with separate subject groups. 9 random audience members were selected in each session to participate in the experiments, who were invited to sit in chairs augmented with sensors to detect physiological signals [12]. The musical program included 3 contemporary pieces during which the performers were measured with bio-sensors; a piano improvisation (12min), an interactive electronic piece ‘Stem Cells’ (12min) and an electroacoustic piece diffused by the composer ‘Imago’ (25min). The three performers’ biosignals were recorded simultaneously with the audience.

**Fig. 1.** ECG (HRV) and GSR sensors used audience biosignals recording.

During the experiments we monitored two physiological signals known to be correlates of emotional state: Galvanic Skin Response (GSR) and Heart Rate Variability (HRV). GSR, also known as electrodermal response, is a method for measuring the conductance of the skin using an ohmmeter. Electrodes are situated in the palms or fingertips of the hands, where the eccrine glands, regulated by the sympathetic nervous system (SNS), produce sweat that varies the conductivity measured by the ohmmeter. Although one of the main evolutionary functions of the SNS is to regulate body temperature, since early studies researchers have correlated changes in GSR to different stimuli associated with emotional responses, such as film [13] and music [7].

HRV is a feature extracted from an electrocardiogram (ECG) signal, which measures the electrical impulses produced by the heart during each beat. Heart Rate Variability refers specifically to the changes in the beat-to-beat interval of the heart. In other words, a heart rate of 70 beats per minute (bpm) is an average over time of fluctuations between successive heartbeats, and these may vary significantly from the 70 bpm. Several studies have observed patterns in HRV that are associated with emotional states, yet there is much controversy in the scientific publications regarding correlation with specific emotions. Nevertheless, there is agreement that HRV patterns change when compared to neutral state [10]. In a previous study we found interesting differences in HRV patterns between different emotional states for musicians performing the same musical piece [14]. BioControl[1] signal acquisition devices were used to capture physiological signals, which were streamed wirelessly at 250 [Hz] to signal recording computers, via the Wi-microDig[2] and Arduino[3] microcontrollers. In order to assure synchronicity between physiological, visual and audio signals, every sample of data was time stamped with a time code index which operated independently as part of a recording system protocol developed by the authors. The recorded physiological signals were processed offline using MATLAB and the GSR signals were low pass filtered (29th order FIR filter with 3 [Hz] cut-off frequency) and HRV was extracted, using an algorithm created by the authors, that measured the RR interval between beats (from the QRS waveform). In order to carry out a real-time evaluation of the performance, signals were analyzed using a Max/MSP[4] patch that allowed the visualization of all physiological signals, audio and video material simultaneously (see Fig. 2 and [14]).

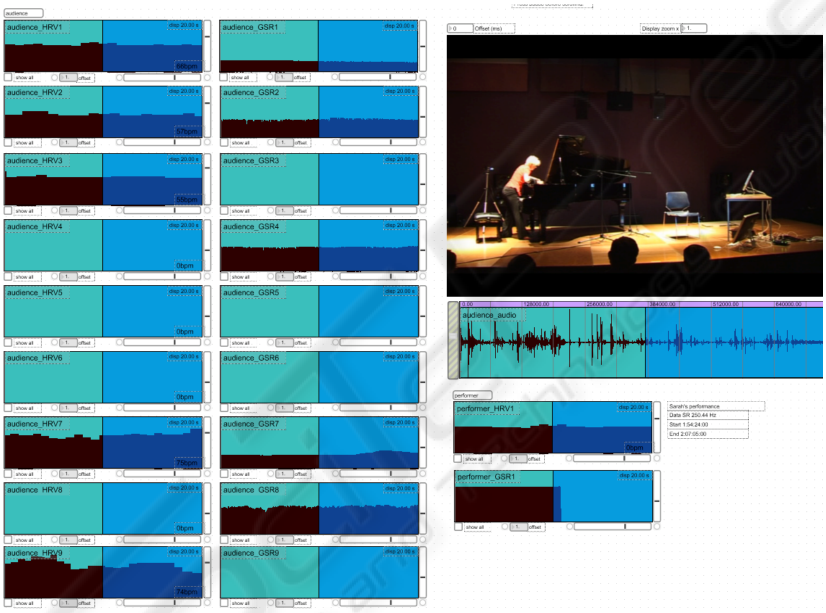

**Fig. 2.** Visualization tool created in Max/MSP to provide continuous analysis of the physiological and audiovisual data. The figure shows 10 channels of ECG and GSR data (9 audience members and 1 performer) plus the audiovisual recordings.

Due to the inherent problems of recording data in a live performance, the amount of viable audience biosignals captured varied between performances (see Table 1). This is principally caused by loss of signals due to movement artefacts and the non homogeneity of subject's physiology (in a controlled lab set-up, the equipment could be calibrated and adjusted to read biosignals of subjects with different ranges). For the

[1] www.biocontrol.com [accessed 05 November, 2009]
[2] www.infusionsystems.com [accessed 05 November, 2009]
[3] www.arduino.cc [accessed 05 November, 2009]
[4] http://www.cycling74.com/products/max5 [accessed 05 November, 2009]

preliminary results presented in the next section, a selection of the most significant physiological reactions and correlation were chosen according to the observations done with the Max/MSP patch (see Fig. 2).

**Table 1.** Detail of viable biosignals recorded during the experiments.

| Performance | Venue | GSR | HRV |
|---|---|---|---|
| Piano Improvisation | Sonic Lab, Belfast | 5 | 5 |
| Stem Cells | Sonic Lab, Belfast | 5 | 7 |
| Stem Cells | School of Music, Durham | 2 | 5 |
| Imago | School of Music, Durham | 2 | 4 |

## 4 Preliminary Results

We will present a preliminary qualitative analysis of the data recorded, which at this early stage cannot be considered as conclusive due to the limited sample size of the study.

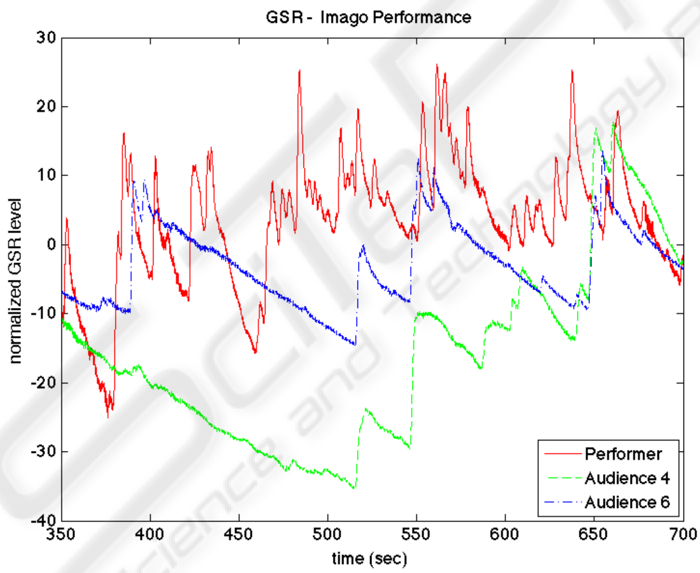


**Fig. 3.** Relative GSR levels of two selected audience members (bottom) and the performer (top). The plot shows 5 minutes of Imago, with strong correlation between both audience members and similarities with the changes in the performer during specific sections.

The continuous analysis of the GSR signals indicates a strong correlation with the musical characteristics of the performance. In the piano improvisation piece, the performer made several gestures in anticipation of the note that was to be played, which triggered increases in the GSR level of the audience. During the electroacoustic piece, the composition was played with strong dynamic changes, with long crescendos and sudden silences. This also resulted in significant changes at the GSR level (See Fig. 3). The most interesting results were observed when we overlapped the performer's GSR and HRV signals individually with each audience member. During certain passages of the musical pieces, there is strong correlation between the physiological signals. Fig. 3 to Fig. 5 show examples where this phenomenon occurred.

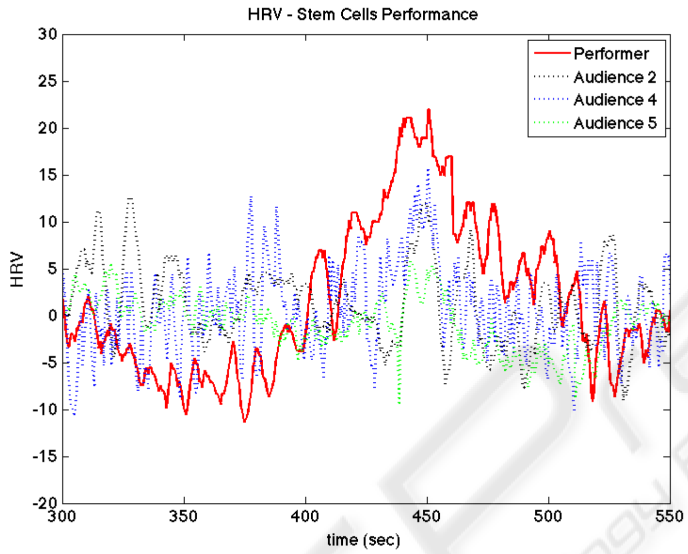


**Fig. 4.** HRV for performer (top) and three selected audience members (bottom) during 2.5 minutes of *Stem Cells* in Durham. The plot shows a simultaneous increase and posterior decrease in HR for both performer and audience at 450 seconds approximately.

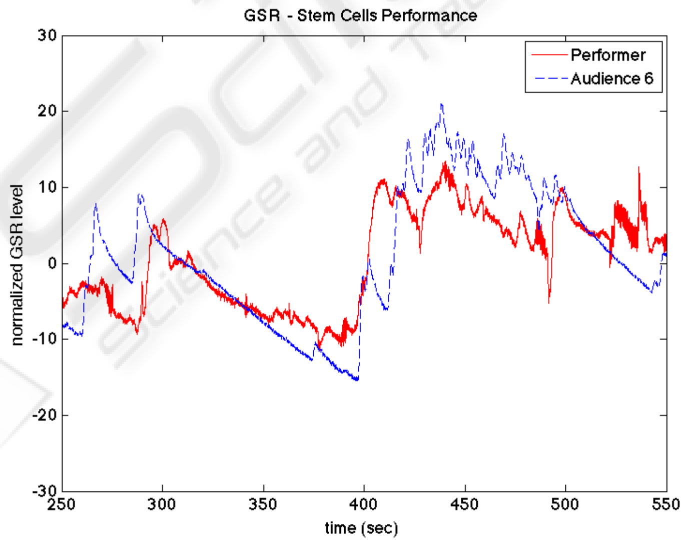


**Fig. 5.** GSR signals for performer and one selected audience member. The plot shows a strong and continuous correlation during 5 minutes of *Stem Cells* in Durham.

## 5 Discussion and Conclusions

We have presented a novel approach to the study of physiological correlates of emotion between performer and audience. Preliminary results indicate significant levels of correlation, both for GSR and ECG signals. Yet, further studies are needed in order to obtain conclusive results. The use of additional physiological features, such as respiration rate and depth, has given interesting results previous studies [8] and is suggested to be incorporated in future experiments.
The actual mechanisms by which emotional contagion occurs are still largely undefined (some indicators may be found in [15] and [16]) but a theory which is currently showing promise is that of 'mirror' neurons in the brain, which mimic externally perceived actions or conditions with a corresponding impulse in a related part of the observers brain e.g. seeing someone running causes neurons responsible for movement to fire in the brain of the observer [17].
Auditory or visual cues are also likely to have an effect on a participant's affective state and there are indicators in our findings suggesting correlations between visually led anticipation and changes in GSR. We have also found links between sudden or extreme auditory events and physiological changes (some of which may be explained by the 'startle response' [18 page 647]). Analysis of video recordings in conjunction with the time-stamped biophysical data allows us to link specific auditory or visual events with corresponding physiological changes and isolate periods in which there are physiological changes in the absence of such cues.
One of the biggest problems in working in an ecological scenario such as a live concert is the constraints imposed by time and the nature of an invited audience, which reduces the option for calibration and changes of materials in case of any technical problems. Nevertheless, we believe that methodologies as the one presented in this study are an important step towards creating a more natural environment where questions addressing the complex relationship between music, emotion and physiology are not affected by a laboratory set-up.

## References


1. R.W. Picard, Affective Computing, MIT Press, 1997.
2. A. Kleinsmith and N. Bianchi-Berthouze, "Recognizing Affective Dimensions from Body Posture," Lisbon, Portugal: Springer-Verlag, 2007, pp. 48-58.
3. A. Haag, S. Goronzy, P. Schaich, and J. Williams, "Emotion Recognition Using Biosensors: First Steps towards an Automatic System," Affective Dialogue Systems, 2004, pp. 36-48.
4. M. Scheutz, "Surviving in a Hostile Multi-agent Environment: How Simple Affective States Can Aid in the Competition for Resources," Advances in Artificial Intelligence, 2000, pp. 389-399.
5. R. Zeelenberg, E. Wagenmakers, and M. Rotteveel, "The impact of emotion on perception: bias or enhanced processing?," Psychological Science: A Journal of the American Psychological Society / APS, vol. 17, Apr. 2006, pp. 287-291.
6. J.A. Sloboda and P.N. Juslin, "Psychological perspectives on music and emotion. Music and emotion: Theory and research," Music and emotion: Theory and research, New York: Oxford University Press, 2001, pp. 71-104.

7. J. Panksepp, “The emotional sources of "chills" induced by music.,” Music Perception, vol. 13, Win. 1995, pp. 171-207.
8. J. Kim and E. André, “Emotion Recognition Based on Physiological Changes in Music Listening,” IEEE transactions on pattern analysis and machine intelligence, vol. 30, 2008, pp. 2067-2083.
9. P.N. Juslin and D. Västfjäll, “Emotional responses to music: the need to consider underlying mechanisms,” The Behavioral and Brain Sciences, vol. 31, Oct. 2008, pp. 559-575; discussion 575-621.
10. J.A. Etzel, E.L. Johnsen, J. Dickerson, D. Tranel, and R. Adolphs, “Cardiovascular and respiratory responses during musical mood induction,” International Journal of Psychophysiology, vol. 61, Jul. 2006, pp. 57-69.
11. O. Grewe, R. Kopiez, and E. Altenmüller, “Chills as an indicator of individual emotional peaks,” Annals of the New York Academy of Sciences, vol. 1169, Jul. 2009, pp. 351-354.
12. N. Coghlan and R.B. Knapp, “Sensory Chairs: A system for biosignal research and performance,” Proceedings of the 8th International Conference on New Interfaces for Musical Expression, Genova: 2008, pp. 233-6.
13. S.D. Kreibig, F.H. Wilhelm, W.T. Roth, and J.J. Gross, “Cardiovascular, electrodermal, and respiratory response patterns to fear- and sadness-inducing films,” Psychophysiology, vol. 44, Sep. 2007, pp. 787-806.
14. J. Jaimovich and R.B. Knapp, “Pattern Recognition of Emotional States During Musical Performance from Physiological Signals,” Proceedings of the 2009 International Computer Music Conference, Montreal, Canada: 2009, pp. 461-4.
15. E. Hatfield, R. Rapson, and L. Le, “Primitive emotional contagion: Recent research,” The Social Neuroscience of Empathy, The MIT Press, 2009.
16. R. Neumann and F. Strack, “"Mood contagion": the automatic transfer of mood between persons,” Journal of Personality and Social Psychology, vol. 79, Aug. 2000, pp. 211-223.
17. Rizzolatti, G. and Craighero, L., “The mirror-neuron system,” Annual Review of Neuroscience, 2004, pp. 169-192.
18. J.T. Cacioppo, L.G. Tassinary, and G.G. Berntson, Handbook of Psychophysiology, Cambridge University Press, 2007.