SIEMPRE

Social Interaction and Entrainment using Music PeRformancE

SIEMPRE

First series of experiments

Version	*Edited by*	*Changes*
1.0	Didier Grandjean, Kim Torres-Eliard, Carolina Labbé	First draft.
1.1	Alessandro D'Ausilio, Leonardo Badino, Luciano Fadiga	Added IIT contribution
1.2	Antonio Camurri, Corrado Canepa, Paolo Coletta, Donald Glowinski, Giovanna Varni, Gualtiero Volpe	Added UNIGE pilots and joint contributes.
1.3	Panagiotis Papiotis, Marco Marchini, Esteban Maestre, Alfonso Perez	Added UPF contribution

TABLE OF CONTENTS

INTRODUCTION

This deliverable describes the first series of experiments performed in the first year, and a preview of a subset of the experiments planned in the second year. Each experiment or group of experiments are listed and described according to the template produced in Geneva and described in the D1.1 Research Requirements.
The results of this first series of experiments will be described in D4.1 “Results from the first series of experiments and first evaluation report”, and will be used to refine the second series of experiments.
The outline of the second series of experiments here included will be updated and extended during the second year, and will be described in D2.2 “Second series of experiments”.

1. SUBJECTIVE RATINGS

A major objective of the SIEMPRE project is the understanding of the mechanisms underlying the communication between performers and listeners. There are different ways of investigating self-reports from an audience depending on what we want to explore. For instance, Likert scales, adjectives checklists and free reports are among the most used (Zentner & Eerola, 2010). Although these are the methods that are used the most, the answers given by listeners are often delayed and more importantly, all these methods are static and therefore unable to account for the dynamic aspects of music and emotion. However, it seems necessary to capture this time flow to better understand the emotional responses to music. Thus, we suggest using mainly continuous self-report methods through studies conducted in the SIEMPRE project. The pioneering studies by Emery Schubert (2001, 2004) in this field demonstrated the effectiveness and the reliability of continuous measurements. The main advantage offered by these continuous measurements is that we can follow the subjective ratings of individuals at each time point and thus make a link between these dynamic judgments and the study of musical structure or acoustic parameters presents in the signal in order to better understand the mechanisms underlying the subjective feeling or the perception of the emotions expressed by music.

This new method, called “dynamic judgments”, will be used in different musical contexts (laboratory context vs. concert/ live performance) both for emotions expressed by music and felt emotions.

We present below the first wave of pilot studies with preliminary results we obtained with this method in collaboration with different groups of professional musicians during both live performance and laboratory contexts.

1.1 Dynamic judgment of the audience during live performance

Title	-Quartetto di Cremona : Dynamic judgment of the audience during live performance (19/07/2010) -Ambronay Festival (11/11/2010) -Quatuor Terpsycordes : 27/11/2010)
Question of interest	Investigation of the agreement of the audience on emotional dimensions expressed by music during a live performance (exploratory study)
Leaders	UNIGE-CH
Other SIEMPRE groups involved	-
Referent scenario	Scenario 3, audience evaluation.
Research objectives	There is an important distinction in the literature between emotions felt by the listener, induced by music, and emotions expressed by music, represented in music (Scherer & Zentner, 2001; Evans & Schubert, 2008). There are several evidences showing that individuals are able to attribute emotions expressed by music (Fritz et al., 2009; Curtis & Bharucha, 2010; Vieillard et al., 2008) and because of the high degree of subjectivity in the measurement of emotions felt by the listener, the study of emotions expressed through music have the advantage of a certain measure of objectivity because it is easier to agree on the emotions expressed by the music in comparison with emotions felt by listener (Campbell, 1942, in Schubert, 2004). Gabrielsson and Juslin (2003) also highlight that agreements between people are obviously higher when auditors evaluate the emotions expressed by music that when they are asked about their impressions and personal feelings. Using the GEMS model, nine-factorial model of musical emotions proposed by Zentner, Grandjean & Scherer (2008), and a dynamic approach, we propose to investigate the dynamic emotional judgments of different pieces of music in a live performance context.
Theoretical hypotheses	These studies are a first attempt to investigate the reliability of dynamic judgments during concerts. We will investigate how the reliability is function of the intensity of emotions reported.
Operational hypotheses	We predict a higher reliability during the most emotional parts of the musical performances compared to the parts less emotional.
Relationship with the objectives of the project	Investigate affective responses of the audience during live performance. Understand the characteristics in musical structure and acoustic parameters that make a strong agreement between participants for emotions expressed by music.
Time schedule	The measures were recorded at the end of 2010. The analyses are

<table>
<tr><td></td><td>in progress. Publication is planned during the second half of 2011.</td></tr>
<tr><td>Methods</td><td></td></tr>
<tr><td>Participants</td><td>-Quartetto di Cremona :12 music lovers (3 men)
-Ambronay Festival : 9 music lovers (4 men)
-Quatuor Terpsycordes : 11 music lovers (3 men)</td></tr>
<tr><td>Materials</td><td>Material:
-Computers and Flash interface for judgments
-Quartetto di Cremona → pieces of music :
Bela Bartok, String quartet n4 in C major, Sz 91

<table>
<tr><td>Movement</td><td>Dimension of interest</td></tr>
<tr><td>Allegro</td><td>Power</td></tr>
<tr><td>Prestissimo</td><td>Wonder</td></tr>
<tr><td>Non troppo lento</td><td>Sadness</td></tr>
<tr><td>Allegretto pizzicato</td><td>Tension</td></tr>
<tr><td>Allegro Molto</td><td>Tension</td></tr>
</table>

Robert Schumann, String quartet n3, op.41
<table>
<tr><td>Movement</td><td>Dimension of interest</td></tr>
<tr><td>Andante espressivo-allegro molto moderato</td><td>Wonder</td></tr>
<tr><td>Assai agitato</td><td>Power</td></tr>
<tr><td>Adagio molto</td><td>Peacefulness</td></tr>
<tr><td>Finale- allegro molto vivace</td><td>Joyful activation</td></tr>
</table>

-Ambronay Festival → “Il Diluvio Universale”, M.A Falvetti

-Quatuor Terpsycordes → pieces of music:
W.A. Mozart, String Quartet n14, KV 387
<table>
<tr><td>Movement</td><td>Dimension of interest</td></tr>
<tr><td>Allegro vivace assai</td><td>Joyful Activation</td></tr>
<tr><td>Allegro</td><td>Tenderness</td></tr>
<tr><td>Andante Cantabile</td><td>Wonder</td></tr>
<tr><td>Molto Allegro</td><td>Wonder</td></tr>
</table>

H. Dutilleux, Ainsi la Nuit
<table>
<tr><td>Movement</td><td>Dimension of interest</td></tr>
<tr><td>1st movement</td><td>Tension</td></tr>
<tr><td>2nd movement</td><td>Tension</td></tr>
</table>

F. Schubert, The Death and The Maiden
<table>
<tr><td>Movement</td><td>Dimension of interest</td></tr>
<tr><td>Allegro</td><td>Power</td></tr>
<tr><td>Andante</td><td>Sadness</td></tr>
<tr><td>Scherzo</td><td>Power</td></tr>
<tr><td>Presto</td><td>Power</td></tr>
</table>
</td></tr>
<tr><td>Data format</td><td>Excel files and Matlab matrices.</td></tr>
</table>

Experimental protocol/procedure	Each participant was paid for his participation. A place in the Church/Abbatiale/Concert hall was reserved for them and each participant had a computer and a cursor to do the task. The main instruction was: "Please rate how the music expresses…" followed by the emotional dimension of interest (Wonder, Power, Tenderness, Peacefulness, Tension, Sadness, Nostalgia, Transcendence, Joyful activation). The musicians were in front of them and participants had to judge the intensity of the emotional expressiveness of music during the course of the music.
Measures	Dynamic judgments (Flash interface) → a measure of judgment is taken every 250 ms.
Results	
Descriptive results	The analyses are in progress.
Inference statistics	The analyses are in progress.
Additional results	-
Discussion	To be developed.

1.2 Dynamic judgment of a small audience during Workshop

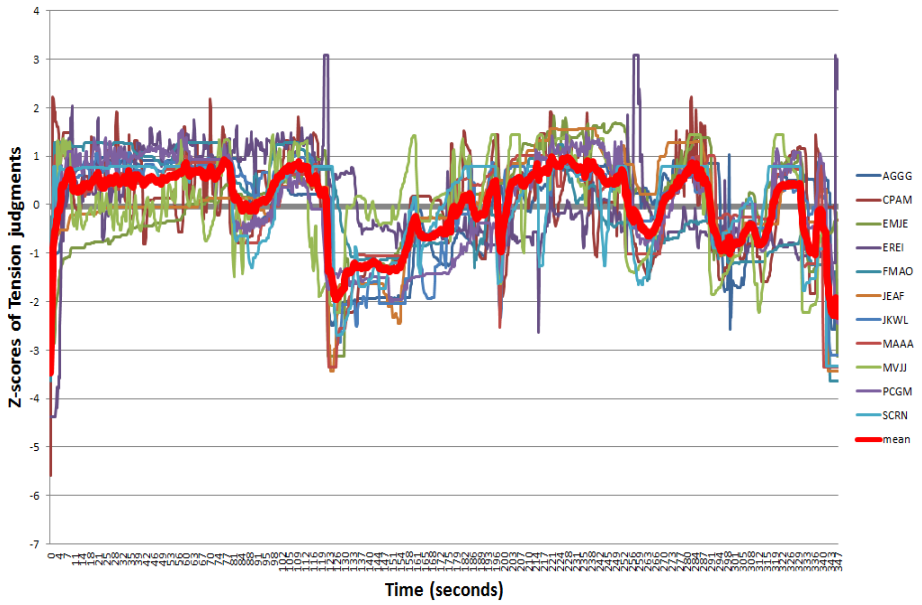
Title	Dynamic judgments on emotional dimensions expressed by music: Quartetto di Cremona (Workshop 20/07/2010)
Question of interest	Testing the reliability of dynamic judgments performed by an audience on emotional dimensions expressed through music.
Leaders	UNIGE-CH
Other SIEMPRE groups involved	IIT
Referent scenario	Scenario 3, audience reactions.
Research objectives	There are several evidences showing that individuals are able to attribute emotions expressed by music (Fritz et al., 2009; Curtis & Bharucha, 2010; Vieillard et al., 2008). Gabrielsson and Juslin (2003) also highlighted that agreements between people are obviously higher when listeners evaluate the emotions expressed by music that when they are asked about their impressions and personal feelings. Using the nine dimensions of the GEMS model (Zentner, Grandjean & Scherer, 2008), we propose to investigate the dynamic judgment of the audience.
Theoretical hypotheses	Audience will show high reliability on emotional judgments showing a similar way to process musical performances in laboratory and during live performance.
Operational hypotheses	We will investigate the degree of reliability of dynamic judgments for the GEMS dimensions.

<table>
<tr><td></td><td></td></tr>
<tr><td>Relationship with the objectives of the project</td><td>Investigate the agreement in the audience regarding the emotional dimension expressed by music.</td></tr>
<tr><td>Time schedule</td><td>The recordings were performed in the end of 2010; analyses are in progress; the publication is planned for the end of 2011.</td></tr>
<tr><td>Methods</td><td></td></tr>
<tr><td>Participants</td><td>11 music lovers (3 men).</td></tr>
<tr><td>Materials</td><td>Material:
- Laptops and Flash interface
-Pieces of music, the mean duration of the musical excerpts was 6’33’’:
B. Bartok, String quartet n4 in C major, Sz 91;
R. Schumann, String quartet n3 in A major , op.41;
J. Haydn, String Quartet n2 op. 54.

The audience was asked to evaluate the emotional intensity on different GEMS dimensions. The Quartet performed the following movements:

<table>
<tr><td>Order</td><td>Movement</td><td>Dimension</td></tr>
<tr><td>1</td><td>Bartok, V: Allegro molto</td><td>Tension</td></tr>
<tr><td>2</td><td>Schumann, I: Andante Espressivo-Allegro molto moderato</td><td>Tenderness</td></tr>
<tr><td>3</td><td>Haydn, I: Vivace</td><td>Joyful activation</td></tr>
<tr><td>4</td><td>Schumann, III: Adagio molto</td><td>Peacefulness</td></tr>
</table>
</td></tr>
<tr><td>Data format</td><td>Excel files and matrices under Matlab format</td></tr>
<tr><td>Experimental protocol/procedure</td><td>Eleven people were paid 50 CHF for their participation to the computer task of dynamic judgment after the thermographic measures (cf. pilot 1). The workshop took place in a musical room at the University in Geneva. Participants were placed in front of the thermographic camera and the musicians.</td></tr>
<tr><td>Measures</td><td>We performed subjective judgments on continuous scales.</td></tr>
<tr><td>Results</td><td></td></tr>
<tr><td>Descriptive results</td><td>Dynamic judgments of dimensions from GEMS:

In order to investigate the reliability of dynamic judgments we developed a Flash interface allowing us to ask listeners to evaluate dynamically the emotions expressed by musical excerpts. The raw scores of each participant were z-scored to evaluate the reliability of the dynamic judgments (see Fig. 1).</td></tr>
</table>

	 Fig. 1: Example of the dynamic judgment (z-scores) of the audience on the "Tension" dimension for the Allegro Molto of the String Quartet n4 in D major by B. Bartok (x-axis: time; y-axis: intensity of the emotion expressed by music).
Inference statistics	The analyses are in progress, we are using parametrical analysis such as ANOVAs and permutation tests allowing to test differences despite unknown shape of distribution of statistical indicators.
Additional results	The dynamic judgments will be also analyzed using PCA and multiple regressions based on acoustic parameters and musical structures.
Discussion	To be developed.

1.3 Recordings and judgments of different types of musical expressiveness

Title	Recordings and judgments of different types of musical expressiveness with a professional violinist (14/11/2010)
Question of interest	Construct of musical stimuli in order to investigate the agreement of people on an emotional dimension expressed by music during a dynamic task. Understand the acoustic characteristics and the musical cues related to these dynamic judgments.
Leaders	UNIGE-CH
Other SIEMPRE groups involved	-
Referent scenario	Scenario 3 (audience)
Research objectives	Studies have highlighted the importance of several acoustic and musical cues in order to attribute an emotion to the music: mode (Hevner, 1935), tempo (Peretz et al., 1998), articulation (Juslin, 1997), loudness (Juslin, 2000), melodic contour (Schubert, 2004), pitch (Curtis & Bharucha, 2010), rhythm (Thompson & Robitaille, 1992), harmony (Hevner, 1936). We propose to investigate different acoustic parameters (such as fundamental frequency or distribution of energy) and musical characteristics in the music score (impact of the intervals, melodic contour, nuances, articulation) and relate these cues to the dynamic judgments of people. In this context, we conduct recordings with a professional violinist and asked him to play different pieces for violin with three types of expressiveness: an academic mode, a natural mode, an emphatic mode.
Theoretical hypotheses	The music score stays the same through the different types of expressiveness and we should find therefore differences between acoustic parameters in the different musical excerpts.
Operational hypotheses	The experimental conditions of expressiveness will impact on emotional judgments: emphatic will be judged more expressive by listeners and these increase of emotionality will be related to a set of acoustic parameters (see above).
Relationship with the objectives of the project	Better understand the steps in the attribution of an emotional character of the music, in the process of perception.
Time schedule	The recordings of musical performances were performed at the end of 2010; the analyses are in progress; we plan to publish the results during winter 2011. These recordings will be used in fMRI experiments in 2011.
Methods	
Participants	For the recordings : Renaud Capuçon For the experiments : 79 music lovers

Materials	Pieces of music : 1) Mozart, violin concerto n°3 in D major, K.216, Allegro (1st mvt) : Joyful activation a) Capuçon version b) Academic mode c) Emphatic mode 2) Franck, sonate for violon and piano in A major, FWV 8, Allegro (2nd mvt) : Sadness a) Capuçon version b) Academic mode c) Emphatic mode 3) Bach, Partita n°2 in D minor, BWV 1004, Allemande (1st mvt) : Nostalgia a) Capuçon version b) Academic mode c) Emphatic mode 4) Gluck, Orphée et Eurydice Mélodie : Tenderness a) Capuçon version b) Academic mode c) Emphatic mode 5) Beethoven, violin concerto en D major, op.61, Larghetto (2nd mvt) : Peacefulness a) Capuçon version b) Academic mode c) Emphatic mode 6) Sibelius, violin concerto in D minor, op.47, Allegro moderato (1st mvt) : Wonder a) Capuçon version b) Academic mode c) Emphatic mode 7) Mendelssohn, violin concerto n°2 en E minor, op.64, Allegro molto appassionato (1st mvt) : Tension a) Capuçon version b) Academic mode c) Emphatic mode 8) Schumann, violin concerto in D minor, Op. Posth. : In Kräftigem, Nicht Zu Schnellem Tempo (1st mvt) : Power

	a) Capuçon version b) Academic mode c) Emphatic mode 9) Massenet, Méditation de Thaïs : Transcendence a) Capuçon version b) Academic mode c) Emphatic mode
Data format	
Experimental protocol/procedure	The recordings with the professional violinist took place at the Brain and Behavior Laboratory in Geneva. The total of the recording duration were about 3 hours. We asked to Renaud Capuçon to play 9 different pieces for violin (cf materials) related to the 9 dimensions of the GEMS model. The length of each musical excerpt is about 2-3 minutes. We also asked him to play the pieces with 3 different types of expressiveness: an academic mode, a natural mode (his natural manner to play during a concert for example), an emphatic mode. While he was playing, 4 cameras recorded him at different angles of views and a microphone was placed one meter away from him. These recordings permit us to conduct two experiments in a laboratory context: RC1 and RC2. During the RC 1 experiment, participants had to judge the intensity of the expressiveness in the music during a task of dynamic judgment and after each musical excerpt they have to rate the emotional dimension (based on the GEMS model) the most relevant for the excerpt that they listened, using little sliders. During the RC 2 experiment, participants were asked to judge the emotional dimension expressed by music through time, based on the same dynamic interface. After the dynamic judgment of each musical excerpt, participants had to judge the expressiveness of the music using a slider from "not intense" (=0) to "very intense" (=100).
Measures	Dynamic subjective judgments on continuous scales.
Results	
Descriptive results	The analyses are in progress.
Inference statistics	The analyses are in progress.
Additional results	-
Discussion	To be developed.

1.4 Evaluation of the qualitative judgment of felt emotions, listening individually and as a group and investigating rhythmic entrainment.

Title	Pilot 1: Initial investigation
Question of interest	The initial investigation will focus on testing subjective measurements that assess Quality of Experience(QoE) for a non-live setting that can later be refined and tested in a live setting. Measures of QoE might prove to be synchronized with other measures (e.g. physiology) and offer additional explanation to the experience of live performance.
Leaders	QUB, UNIGE-CH
Referent scenario	Audience
Research objectives	The first experiment will serve two functions; firstly as a pilot and technical test for the later studies which follow but also as comparison with future results we find in a live setting. The aims can be stated as follows: 1) Test measurement techniques that have been developed 2) Conduct the experiment so that further experimentation can progress from this basis 3) Analyze the data so as to allow comparison of results with future experiments
Theoretical hypotheses	Subjective measures of QoE will show synchronies with other types of measurements and not impact on a participant's overall experience
Operational hypotheses	1) Participants using the QoE continuous rating mechanism and the control group will have similar measures in physiology, retrospective reports and other measures of QoE. 2) Continuous engagement will correlate with the retrospective questionnaire's values for quality of experience, physiology and judges' values of engagement.
Methods	
Participants	Groups of 12 participants will be tested simultaneously as an audience, recruited via opportunity sampling.
Materials	Song Choice: Most songs will be selected from a previous experiment that were shown to have a strong impression on the listener (both physiologically and subjectively). However at least four songs will be chosen as they can be performed live in the subsequent experiments.
Data format	
Experimental protocol/procedure	In the experiment 12 participants (or groups of 12) will be invited to the SIEMPRE lab at QUB and form an audience. They will listen to approximately eight excerpts or full

	songs chosen by the researchers through the room's speakers. Prior to this they will fill in a small questionnaire determining their musical expertise, general listening habits and other participant data. All of the audience will have physiological measurements taken of heart rate, heart rate variability and galvanic skin response. Half of the participants will also rate their responses to the music on a continuous qualitative response mechanism developed at QUB. After each song all participants will complete a questionnaire which will cover a number of important areas to the quality of experience during the song. Recording of the audience will be done (video and audio) and after the experiments judges will be asked to continuously rate the perceived audience level of engagement (or whatever term is used in the continuous response mechanism for the audience).
Measures	Physiological Measures: All participants will be fitted with a number of sensors placed on the fingers which measure their heart rate, heart rate variability and galvanic skin response. Continuous Qualitative Response: The interface itself will most likely be a slider device with a spring mechanism which will require increased force to move to higher values (negatively scaled). The concept it will ask participant's to rate will be engagement. Retrospective Questionnaire: The version employed in this experiment will be a draft and the results will help to shape subsequent versions. It will include items on liking and familiarity as well as a range of measures on QoE from different literatures. Post-Recording Rating: After the experiment external judges will study the video and audio of the experiment and rate the participants on levels of engagement using the continuous qualitative response mechanism.
Results	
Descriptive results	Visualization of the continuous data will be very useful in the initial investigation and will be used in conjunction with other descriptive statistics to get an overall picture of the results
Inference statistics	Advanced correlation techniques will be used to investigate the relationship between participant's continuous subjective ratings of engagement, the physiological signals acquired from the group (HR, HRV, GSR), the retrospective questionnaire and judge's continuous ratings of audience

	engagement.
Additional results	Possibility of using Granger analysis to investigate indicators with different characteristics
Discussion	Results and outcomes from this experiment will inform our understanding of the research question.

1.5 Dynamic judgments of self-reported subjective feeling to classical music depending on expressive style.

Title	**Dynamic judgment of self-reported subjective feeling to classical music depending on expressive style (Capuçon II)**
Question of interest	**To investigate how different versions of the same piece affect the listener in terms of his/her subjective feeling of emotion and entrainment.**
Leaders	**UNIGE-CH**
Other SIEMPRE groups involved	
Referent scenario	**(ii) music-listener**
Research objectives	**To compare dynamic judgments of subjective feelings and self-reported explicit entrainment to 9 pieces between 3 different versions (academic, emphatic, natural) and compare the rhythmic/acoustic variability between the versions.**
Theoretical hypotheses	**Different versions of the same piece will lead to differences in terms of subjective feeling of emotion;** **Different versions of the same pieces will lead to differences in terms of entrainment;** **Differences in terms of rhythmic variability between the versions could act as a mediating variable for both entrainment and subjective feeling of emotion.**
Operational hypotheses	**Different versions of the same piece will lead to different intensities of felt emotion in the listener;** **Different versions of the same pieces will lead to different intensities of self-reported explicit entrainment;** **Differences in terms of rhythmic variability between the versions could act as a mediating variable for both explicit entrainment and self-reported subjective feeling.**
Relationship with the objectives of the project	**Entrainment.**
Time schedule	**Experiment in progress.**
Methods	
Participants	**Total expected = 72.**
Materials	**27 music tracks = 9 pieces for solo violin * 3 versions (emphatic, academic, natural);** **Dynamic judgments java platform (Rosset);** Empathy Questionnaire (EQ), Baron-Cohen & Wheelwright (2004); **12-item explicit entrainment questionnaire (not published);** **Geneva Emotional Music Scale (Zentner, Grandjean & Scherer, 2008)**
Data format	**To be determined.**
Experimental protocol/procedure	
Measures	**Self-reported subjective feeling of emotion;** **Self-reported explicit entrainment;** **Self-reported empathy.**

Results	
Descriptive results	
Inference statistics	
Additional results	
Discussion	

2. EXTRACTING VALUABLE FEATURES FROM AUDIO AND INSTRUMENTAL GESTURES

Within the context of the SIEMPRE project, issues such as entrainment, inter- and intrapersonal synchronization, and musical leadership can be clarified and analyzed through the study of low-level characteristics of the captured performance, namely the audio produced and the instrumental gestures performed by the musicians in order to produce the aforementioned sound. Furthermore, an accurate note-level alignment between the performance and the score it is based on can provide a steady reference by which the performance is measured and compared.

In this first series of proposed experiments, the goal is to study synchronization in terms of intonation (realization of pitch accuracy) and tempo adaptations for the string ensemble scenario. This will be carried out using audio recordings as well as motion-captured instrumental gestures from each performance; the performance is time-aligned to its relevant score using state-of-the-art algorithms and computational tools in order to measure, at the note level, differences between performances in different experimental cases. Through the analysis of these differences we can extract quantitative features that characterize the synchronization, entrainment, and leadership aspects of the performance.

2.1 Analysis of intonation adjustments among violinists

Title	Analysis of intonation adjustments among violinists
Question of interest	Based on the September recordings carried out in Barcelona at the MTG-UPF, the main investigation will focus on observing and analyzing the way violinists adjust their tuning while performing in an ensemble. This will provide important information on detecting the functional relationships (i.e. leadership) within the ensemble.
Leaders	UPF
Referent scenario	String Quartet
Research objectives	To observe the mechanisms through which violinists achieve satisfactory intonation among themselves, since the violin is a fretless instrument. Furthermore, to investigate whether these mechanisms can provide a ground truth for leadership detection.
Theoretical hypotheses	In a violin ensemble, good intonation is achieved through adjusting one's pitch to that of another musician; this experiment will prove that the order in which the musicians adjust their intonation is a strong indication for musical leadership.
Operational hypotheses	1. Intrapersonal intonation is highly dependent on the interpersonal intonation of the ensemble. 2. For a given musical phrase (which could extend to include the whole piece), one musician maintains his/her intonation, while the other musicians adjust to his/hers.
Relationship with the objectives of the project	Studying intonation as a factor driving the interpersonal synchronization of the participants (as a part of auditory cues, rules and conventions).
Time schedule	First-second wave of experiments and milestones
Methods	
Materials	Existing recordings carried out during the September SIEMPRE meeting in Barcelona for violin duets: · Solo performance (violin 1) · Solo performance (violin 2) · Joint performance (normal scenario) · Joint performance (switched scores) Additionally, some experiments were carried out at UPF involving simpler tasks such as playing in unison.

Data format	WAVE format
Experimental protocol/procedure	The recorded audio of the performance will be aligned to the score at a detailed note level, by means of a semi-automatic technique making use of multi-modal data (including the Polhemus). In that level, the deviation from the expected pitch of each note will be extracted and compared to that of the other musician.
Results	
Descriptive results	Based on the materials mentioned above, our initial analyses show that professional, skilled musicians demonstrate an impressive accuracy in reproducing the same intonation, with little difference between solo and joint performance. Standard interdependence measures (linear and rank correlation) as well as more advanced measures (mutual information, Granger causality) failed to provide significant differentiation between the solo and joint performances. However, measures borrowed from computational neuroscience (nonlinear coupling detection) did manage to show greater differentiation between the two experimental scenarios, mainly for the case of amateur musicians (see fig.1 and 2)

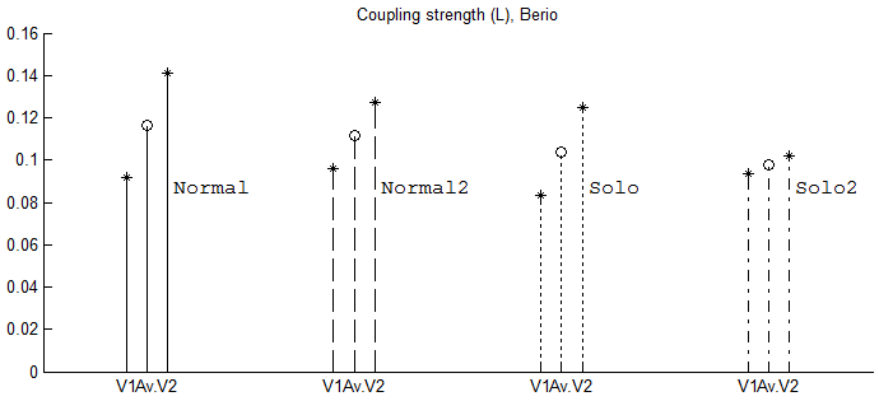
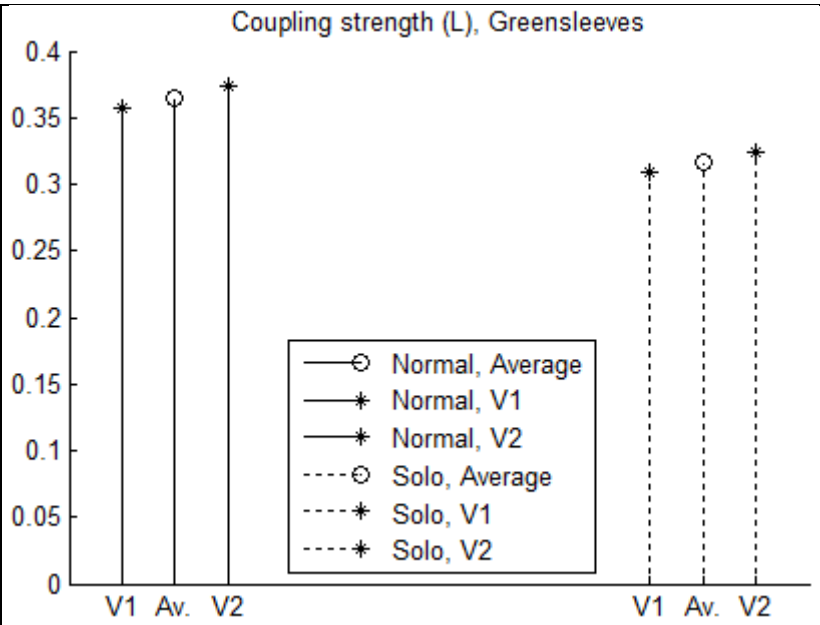


fig.1 – Overall coupling strength for two instances of Normal (joint performance) and solo recordings of a contemporary duet, amateur musicians.

	 fig.2 – Overall coupling strength for Normal (joint performance) and solo recordings of a unison melody duet, amateur musicians.
Inference statistics	Deviation (in pitch cents) from the expected pitch of each note based on standard tuning (A440 Hz) throughout the performance for each individual musician, linear and rank correlation, mutual information, Granger causality, nonlinear coupling.
Additional results	Indications about musical leadership that can be extracted through this procedure can prove useful as ground truth for leadership detection.
Discussion	To be developed.

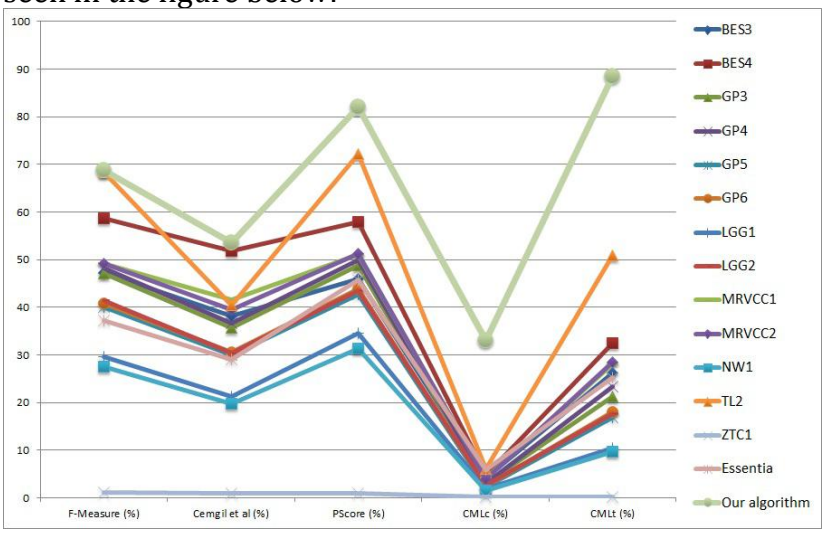
2.2 Synchronization in violin duets regarding adaptation to tempo changes

Title	Synchronization in violin duets regarding adaptation to tempo changes
Question of interest	When trying to adapt to tempo changes from a metronome signal, the two main mechanisms are that of phase correction and period correction. We would like to measure these correction mechanisms for a single musician who is listening to a metronome reference, as well as two musicians in different experimental set-ups (both listening to a metronome, musician_a listening to a metronome and the musician_b to the musician_a, with and without visual contact etc.)
Leaders	UPF
Referent scenario	String Quartet
Research objectives	To observe and model the response of the musicians to unpredicted tempo changes, both from absolute (metronome) and filtered (pre-recorded or live response) signals.
Theoretical hypotheses	The time when a tempo change occurs (beat strength), as well as the magnitude of the change (in BPM) itself triggers different response mechanisms in musicians (such as phase correction and period correction). The details (type of tempo stimulus, performed note speed) of the duet set-up as well as the assignment of functional roles affects the response of the musicians.
Operational hypotheses	1. Adaptation to tempo changes can be modeled using phase and period correction, depending on the speed of the adaptation and the parameters of the tempo change. 2. Adaptation to tempo changes depends on the type of stimulus provided (metronome click, recorded response, live response) 3. Interpersonal synchronization in terms of tempo is directly affected by the type of stimulus provided, the visual contact between musicians, as well as the parameters of the tempo change.
Relationship with the objectives of the project	Studying interpersonal synchronization in terms of tempo is directly related to the synchronization objectives of the project.
Time schedule	First-second wave of experiments and milestones
Methods	

Materials	Recordings carried out in UPF (April 2011): • Solo recordings (120 BPM) ○ Violinist 1, quarter notes ○ Violinist 1, eighth notes ○ Violinist 1, sixteenth notes ○ Violinist 2, quarter notes ○ Violinist 2, eighth notes ○ Violinist 2, sixteenth notes • Duet recordings, one metronome (120 BPM) ○ Violinist 1 with metronome ○ Violinist 1 with metronome, no visual contact ○ Violinist 2 with metronome ○ Violinist 2 with metronome, no visual contact • Duet recordings, two metronomes (120 BPM) ○ Two metronomes ○ Two metronomes, no visual contact Complementary recordings carried out in QUB (end of March 2011): • Solo recording ○ Violinist, eighth notes (120 BPM) ○ Violinist, sixteenth notes (90 BPM)
Data format	WAVE format
Experimental protocol/procedure	Onset detection and BPM estimation will be performed on the metronome clicks as well as the performed notes acquired from the recording. Bowing gesture parameters (bow velocity, bow acceleration, bow displacement zero crossing rate) will be extracted using the Polhemus MOCAP system. From the comparison of these signals we will extract the response of each musician to tempo changes.
Results	
Descriptive results	The analyses are in progress.
Inference statistics	Phase and period correction, Nonlinear interdependence measures for coupling detection
Additional results	Indications about the direction of influence in synchronization, and therefore leadership (in terms of tempo).
Discussion	To be developed.

2.3 Feasibility study regarding the Polhemus motion sensors

Title	Feasibility study regarding the Polhemus motion sensors
Question of interest	The interaction among musicians during the performance is a key aspect of the SIEMPRE project. Concepts such as leadership, entrainment and synchronization among musicians can be clarified through the acquisition of detailed instrumental gestures, as they are crucial to accurate audio analysis at the note level through the alignment between recorded data and the musical score. Furthermore, the instrumental gestures captured with the Polhemus sensors appear as the most accessible method so far for extracting mid-level information regarding bowing movement (such as bow transversal velocity or bow force) accurately aligned to note onsets & offsets, which is crucial in the search to define and study in detail the interaction-specific concepts described above (entrainment, synchronization, leadership).
Leaders	UPF
Referent scenario	String Quartet
Research objectives	Through the use of the Polhemus MOCAP system, bowing gesture parameters directly involved in the generation of sound are acquired. The goal is to investigate the relevance of these parameters and their acquisition methods to the objectives of the SIEMPRE project, as well as the low- and mid-level features that can be derived from these parameters.
Theoretical hypotheses	The instrumental gestures captured with the Polhemus sensors are important to accurate audio analysis as well as associating mid-level features regarding synchronization, entrainment, and leadership to specific note-level events.
Operational hypotheses	Note-level score-performance alignment semi-automatic techniques significantly benefits from the accurate acquisition of right-hand gesture parameters in bowed-string musical performance Instrumental gesture parameters such as bow displacement, bow velocity and bow force can be strong indicators for synchronization, entrainment, and leadership detection.

Relationship with the objectives of the project	Providing important low- and mid-level information for movement and audio features used in studying the interpersonal synchronization of the musicians participating.
Time schedule	First-second wave of experiments and milestones
Methods	
Materials	Existing recordings carried out during the September SIEMPRE meeting in Barcelona for violin duets, additional recordings carried out at UPF.
Data format	WAVE
Experimental protocol/procedure	Existing MTG-UPF techniques for the acquisition and analysis of instrumental gestures and audio applied to the recordings carried out in September as well as a potential new recording. Audio features extraction and score-performance alignment performed with and without the use of instrumental gestures, in order to do performance comparisons. Moreover, mid-level parameters from instrumental gestures (such as bow velocity and bow force) aligned to the score and studied at a detailed time level, to demonstrate their importance to the quantitative analysis of interaction concepts already discussed (see Relationship with the objectives of the project).
Measures	Instrumental gestures using the Polhemus MOCAP system, Qualysis 3D motion capture, Audio recordings
Results	
Descriptive results	Regarding audio feature extraction augmented with instrumental gestures, it was seen that instrumental gestures improve the accuracy of feature extraction algorithms (audio-score alignment, tempo estimation) as seen in the figure below:  Fig.1 – Graphical comparison of the tempo tracking algorithms submitted for MIREX 2010 and our algorithm.

	A number of trials were made using the current Polhemus setup, for the case of violin duos, and even though the performers did in general show certain degree of adaptation to the wires, they would have preferred a wireless sensing system (such as the Qualysis system). Also, setups involving only two musicians appeared feasible, but in cases where more musicians are to be involved, using wired sensors is perceived as to affect the performance. One of the most important measures was the time needed for setting up the sensors and calibrating each of the instruments, resulting too long as to be used in real concert situations. It can therefore be concluded that, although the use of Polhemus-captured instrumental gestures add a significant amount of accuracy in the extraction of audio features as well as the extraction of mid-level features derived from the gestures themselves, the improved accuracy does not in all cases merit the trade-off in intrusiveness and set-up times for the joint experiments.
Inference statistics	F-measure, P-score, Cemgil et al evaluation (for the comparison between audio-only and audio-plus-gestures feature extraction)
Additional results	
Discussion	Following our findings it was decided that, in the scope of joint experiments with partners, it is more convenient to acquire (using Qualysis) a sub-set of bowing gesture parameters with less accuracy, by following part of the method given in (E. Schoonderwaldt and M. Demoucron, "Extraction of bowing parameters from violin performance combining motion capture and sensors,"J. Acoust. Soc. Amer., vol. 126, no. 5, pp. 2695–2708, Nov. 2009.). This method requires the placement of four markers on each instrument (two on the bow and two on the instrument body), and through these markers the following features can be extracted: • Bow transversal displacement • Bow transversal velocity • Bow transversal acceleration • Bow-bridge distance • Skewness

3. MUSICIANS' MOVEMENT ANALYSIS

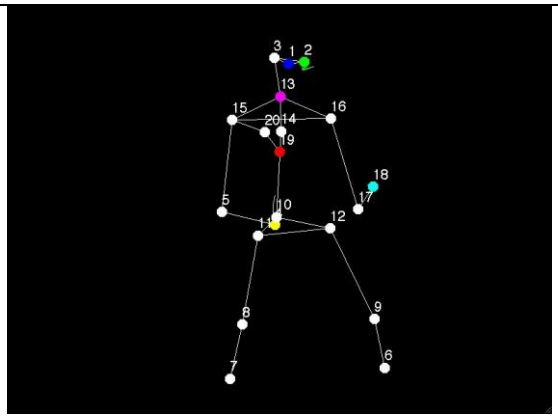
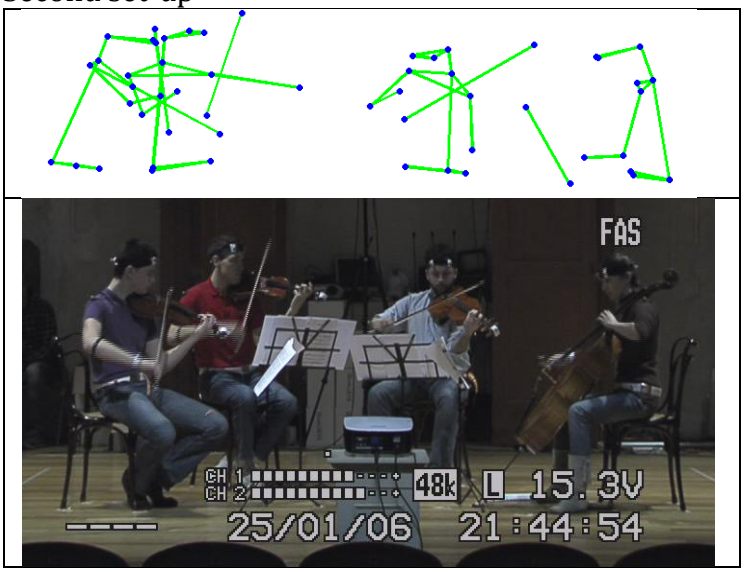
Here we aim to use a rather different approach by studying music orchestras or quartet in an ecological rehearsal scenario thus excerpting no particular interference on participant's behavior. Here, we will record violinists' bows and conductor's baton kinematics via an unobtrusive passive infrared optical system. The rationale is that movement kinematics of one individual must have some statistical relation with the kinematics generated by another individual, to let us infer coordination between them. We will search for directed influences, and modulation thereof, among actions of the participants without imposing any artificial constraint. Furthermore we will record muscle activity to extract other parameters that are not measurable with simple kinematics, such as force and joint stability via muscle co-contraction. Measurement of muscle tension is commonly achieved using surface electromyography. Surface electromyography measures muscle activity by detecting the electrical potential that occurs on the skin when a muscle is contracted.

3.1 Pilot of EMG recordings in musicians

Title	Pilot of EMG recordings in musicians
Question of interest	To define EMG electrodes placement and investigate the response pattern between emphatic and academic performances
Leaders	IIT
Other SIEMPRE partners	
Referent scenario	Single violinists
Research objectives	
Theoretical hypotheses	Musical expressivity can be inferred by measuring motor behavior (position data). EMG data can better inform about the dynamical aspects of motor behavior and thus be a more sensible index of it.
Operational hypotheses	Multi channel EMG will be used to extract motor synergies accounting for most of the variance observed in these two opposing behavior (academic versus emphatic). Furthermore we'll investigate the contribution of musical expertise to the temporal and spatial distribution of those motor synergies.
Time schedule	First series of experiments
Methods	
Participants	1 student
Materials	1 musical piece (3 minutes each)
Data format	Analog multi-channel data (15 Channels at 2Khz) in MatLab format
Experimental protocol/procedure	The student musician will play the same pieces at least 6 times, and by forcing two different expressive conditions. In the first they'll have to follow a metronome and reduce the expressivity. In the second, they will have to use an emphatic expressivity.
Measures	EMG signal recorded on left/right finger flexor/extensor, left/right biceps and triceps, left/right deltoid and right pectoralis, left/right tibialis, left/right soleus
Results	To be done.
Descriptive results	To be done.
Inference statistics	To be done.
Additional results	To be done.
Discussion	To be done.

3.2 Quartet Preparatory experiments (MoCap)

Title	Quartet Preparatory experiments (MoCap)
Question of interest	(i) Identify the minimal set of MoCap Qualisys markers to measure non-verbal social communication in a group of musicians. (ii) Ensure the reliability of the measures (iii) Test the SIEMPRE architecture for multimodal synchronized recordings of ensemble music performance. (iv) Optimize the setup procedure: positions of MoCap Qualisys cameras for quartet scenario, time to put markers, schedule performance conditions, customization of markers, positioning of microphones and videocameras.
Leaders	UNIGE
Referent scenario	Quartet
Research objectives	Conduct a fast development cycle of experiments
Theoretical hypotheses	A reduced number of MoCap markers and other eMAP features are sufficient to study non-verbal social behaviour in music ensemble
Operational hypotheses	
Time schedule	First series of experiments
Methods	
Participants	String quartet: students from the Music Conservatory Paganini.
Materials	Music score selection: Schubert *Streichquarte*t: 2min fragment characterized by a variety of writing styles (isorhythmic parts, polyphonic phrasing with dialogic nature); music scales, arpeggio, cadenzas.
Data format	SIEMPRE multimodal synchronized data format
Experimental protocol/procedure	A variety of performance practice conditions (e.g., scales, arpeggio, selected music score, simulated incipit and cadenza of musical phrases) are used to test robustness and generalization of low-level measures.
Measures	[Individual] Head movement, face direction, shoulders and trunk orientation, arms movement, iliac, sacrum, sternum. [Group] polygon relating musicians' head COG (polygon COG, polygon area, other parameters on dynamics), relative orientation of face, trunk and shoulders. Use of the Qualisys motion capture system, Eyesweb platform and professional video cameras.
Results	
Descriptive results	First set-up

	 . Second set-up  Reflective markers of the Qualisys system are placed in upper-part body joints to extract behavioural data.
Inference statistics	Technique to partial out redundant information given by markers; Linear and Nonlinear dimensionality reduction, feature extraction techniques (e.g., PCA, ICA, embedding procedure).
Additional results	
Discussion	This experiment is (i) preparatory to the successful and robust implementation of the subsequent experiments in SIEMPRE using the project platform and in particular integrating the Qualisys motion capture system; (i) a test of the main features, in particular of synchronization, of the multimodal recording SIEMPRE platform.

3.3 Individual Vs Social behavior in music performance

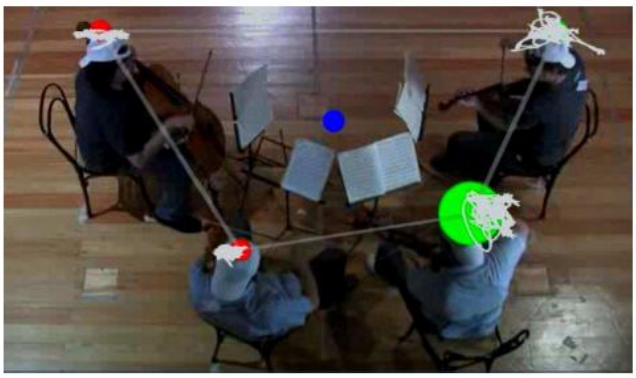
Title	Individual Vs Social behavior in music performance
Question of interest	Which multimodal variables explain the difference between a soloist performance versus the same performance with accompaniment in an ensemble?
Leaders	UNIGE
Referent scenario	Quartet
Research objectives	To study which eMAP signals explain the difference between the performance of a melody alone or accompanied by an ensemble.
Theoretical hypotheses	A reduced set of eMAP features explains Social Vs. Individual behaviour in music performance.
Operational hypotheses	We focus on upper-body measures (see *SIEMPRE Preparatory Experiment*), audio from music instruments and in a second step on physiological signals.
Time schedule	First and second series of experiments
Methods	
Participants	String quartets: Music Conservatory Quartet, Quartetto di Cremona
Materials	Music: melodia accompagnata (Mozart) or the Schubert piece where theme fragments are distributed over the four voices. Simple scales performed with expressive/emphatic style.
Data format	SIEMPRE multimodal data recordings format
Experimental protocol/procedure	(i) individual performance of the melody (first violin and second violin playing individually the solo performance); (ii) ensemble performance of the melody accompanied by the other musicians.
Measures	The experiment starts from results obtained in the *SIEMPRE Preparatory Experiment*, which defined a minimum set of Qualisys markers and tested the SIEMPRE platform for multimodal synchronized recordings. Measures are only on the soloist musician, and include upper-body movement kinematics: head, shoulders, arms movement (position, speed, acceleration). Use of the Qualisys motion capture system, Eyesweb platform and professional video cameras, contact microphones on each music instrument. Low-level signals will enable to extract mid-level features, e.g., rigidity/fluentness of upper-part of the body. In a second phase, physiological signals will be used to measure intra-personal synchronization and correlation with other expressive behavioural signals (e.g., rigidity). Post-Performance rating After each performance a questionnaire about the quality of

	execution and about the quality of the ensemble coordination is filled up separately by each musician.
Results	
Descriptive results	
Inference statistics	Data analysis will be conducted on the recorded multimodal data using different techniques, including Multi-Scale Entropy, applied to upper-body features, audio expressive features, expressive movement features (fluidity, rigidity). In a second phase, intra-personal synchronization of movement, audio and physiological signals will be considered.
Additional results	Frontal video camera recordings of the soloist and audio of the soloist can be used as stimuli with subjects to assess the differences in the first violin between solo Vs ensemble performance conditions.
Discussion	To be done.

3.4 Series of experiments on synchronization and leadership

Title	Series of experiments on synchronization and leadership
Question of interest	Live performances of string quartets are analyzed to study cues explaining synchronization and leadership. The following research issues will be investigated: - Whether different expressive and social contexts affect interpersonal synchronization. - Whether in the case of changes in the context, the group of musicians is able to re-establish the synchronization. - Whether synchronization is observed in one modality and also across the various modalities. - Which cues explain the emergence of leadership in the group.
Leaders	UNIGE
Other SIEMPRE partners	
Referent scenario	Quartet
Research objectives	Investigate the emergence of synchronization and leadership in a music ensemble, starting from the analysis of audio signals, of body movement of musicians and of physiological signals.
Theoretical hypotheses	Movement kinematics, audio, and physiological signals can be used to explain synchronization and leadership.
Operational hypotheses	Study and individuate a reduced set of eMAP signals.
Time schedule	Second series of experiments
Methods	
Participants	2 string quartets: expert (Quartetto di Cremona), violin students (from the Music Conservatory Paganini of Genoa). Other cases include the mix of expert and student musicians (e.g., first violin expert with three students)
Materials	Various music materials, based on classical music: e.g., Schubert *Streichquarte*t: 2min fragment characterized by a variety of writing styles (isorhythmic parts, polyphonic phrasing with dialogic nature).
Data format	
Experimental protocol/procedure	Examples of procedures include the following: Individual performance of each musician playing their own musical section. Ensemble performance (quartet playing full piece in a concert-like performance) Expert / Student inclusion : if considering a student quartet, one musician will be replaced (e.g., first violin) by an expert one; if considering a student quartet, the first violin will be replaced by an expert. [DoW-Part B, p.10 – scenario 1, condition 4]

Measures	Kinematics Measures include the following: [Individual]Upper-body movement kinematics including head, shoulders, arms movement (position, speed, acceleration), leaning forward/backward, direction of face and of trunk. [markers individuated in the Jan-April rehearsals] [Group] polygon relating musicians' head COG (polygon COG, polygon area, other parameters on dynamics) and vectors of mutual directions of the face and of the trunk of each musician. Use of the Qualisys motion capture system, the EyesWeb XMI platform and professional video cameras with the extensions developed in the first year of the project, integrated in the SIEMPRE platform. Post-Performance rating After each performance a questionnaire about the quality of execution and about the quality of the ensemble coordination is filled up separately by each musician. Personality questionnaire To assess the personality profile of participants, the Big Five Inventory (BFI, John et al., 1991) and a Dominance Scale (DS) derived from the IPIP will be administered (http://ipip.ori.org/newCPIKey.htm#Dominance). The BFI is a 44-item questionnaire designed to measure the Big Five (*Extraversion, Agreeableness, Conscientiousness, Nevroticism and Openness*) dimensions, while DS assesses dominance attitude. Both BFI and DS consist of short phrases with relatively accessible vocabulary and participants are asked to rate the extent to which they think that the item describes them on a 5-point Likert scale. -Use of frontal video camera recordings and of the point-light display animations for audience measurements.
Results	
Descriptive results	Visualization of the continuous data on dominance as animations overlaying videos.

	 Example: The dynamics of the polygon individuated by the heads of the players and of its Center of Gravity characterize the contraction/expansion of the group and its behavior as a single organism.
Inference statistics	Analysis of leadership and synchronization will be faced by theoretical frameworks: for example, multi-scale entropy (MSE), a non-linear technique to quantify the behavior complexity, is used in the case of leadership; Recurrence Quantification Analysis is used in the case of synchronization and leadership.
Additional results	To be done.
Discussion	To be done.

3.5 Pilot of an orchestra section

Title	Pilot of an orchestra section
Question of interest	Entrainment and leadership (conductor and musicians)
Leaders	IIT
Other SIEMPRE group	UNIGE
Referent scenario	Orchestra scenario
Research objectives	
Theoretical hypotheses	Movement kinematics can be used to extract the dynamical pattern of communication among orchestra players
Operational hypotheses	Acceleration profiles of markers movements can be used to compute causal influences (Granger analysis), information flow (information transfer). Trajectories of markers are used to measure the synchrony within each section of musicians and between the two sections.
Time schedule	First wave of experiments
Methods	
Participants	8 professional musicians + 2 conductors
Materials	5 short musical pieces (1-2 minutes) repeated 3 times
Data format	Raw marker position data in MatLab format
Experimental protocol/procedure	Musicians play the pieces with the two conductors.
Measures	Position data via the Qualisys system will be acquired. Reflective markers are placed on the upper tip of the bow and on the conductors' baton.
Results	To be done.
Descriptive results	To be done.
Inference statistics	To be done.
Additional results	To be done.
Discussion	To be done.

3.6 Orchestra section Experiment

Title	Orchestra section experiment
Question of interest	Entrainment and leadership (conductor and musicians)
Leaders	IIT-UNIGE
Other SIEMPRE group	
Referent scenario	Orchestra scenario
Research objectives	
Theoretical hypotheses	Movement kinematics can be used to extract the dynamical pattern of communication among orchestra players
Operational hypotheses	Acceleration profiles of markers movements can be used to compute causal influences (Granger analysis), information flow (information transfer) and synchrony among musician and from conductor to musicians.
Time schedule	Second wave of experiments (November 2011)
Methods	
Participants	String Orchestra from Music Conservatory of Genoa; 4 first violins section, 4 second violins section, 2 viole, 2 celli and 1 contrabbasso. At least 2 conductors.
Materials	Few short musical pieces (less than 2 minutes each). Music pieces characterized by specific musical structure (e.g., isorhythmic and phrasing features) in order to facilitate the verification of hypotheses. Simple musical scales or arpeggios played with instructions on expressivity will be also considered.
Data format	Raw marker position data.
Experimental protocol/procedure	1 session for setup (possibly without musicians). 1 session with all musician and at least two conductors. Students play the pieces (at least 3 repetition each) in two conditions. In the first they play as a quartet, whereas in the second they are lead by an external professional conductor. The design will include only one factor "Lead" on two levels (No conductor, Conductor). Furthermore, we will apply perturbations to the audio-visual communication between musicians and between conductor and musicians. Perturbations/Conditions may include the following: - Baton with light, in dark conditions: conductor does not see but listen to the orchestra. - The visual contact between conductor and musicians only by means of high-resolution and high-speed video. Manipulations of rhythm (artificial accelerando and/or rallentando) and other agogic instructions on loudness (crescendo/diminuendo) and articulation (from staccato to legato and viceversa) will be considered.

Measures	Position data via the Qualisys system will be acquired. Kinematics of the instrument (bow and possibly violin body) by means of Qualisys markers, and markers on the conductor (baton, hand, head) will be considered.
Results	To be done.
Descriptive results	To be done.
Inference statistics	To be done.
Additional results	To be done.
Discussion	To be done.

4. AUTONOMIC NERVOUS SYSTEM (ANS) MEASURES IN THE SIEMPRE PROJECT

One of the main pillars of the SIEMPRE project is the recording of the audience emotional entrainment. As shown in deliverable 1.1 there are several well-established methods that can measure such kind of data. In fact, the consortium will effectively use these methods.
However, during the fruitful brainstorming we had during the kick-off meeting a novel idea, proposed by IIT, emerged. We realized that we could record large audiences emotional entrainment via thermographic images. Such approach is potentially very powerful although there are several computational and technical issues with no solution yet.
In fact, although thermography proved very useful in clinical medicine, very little has been done in the study of emotional responses of patients or healthy subjects (Murthy, Pavlidis, 2006; Sun, Pavlidis, 2006; Fei, Pavlidis, 2006; Garbey et al., 2007; Shastri et al., 2009; Fei, Pavlidis, 2010; Murthy et al., 2010; Jarlier et al, 2011). One possible reason for this is that qualitative or simple analyses such as hand-drawn regions of interest mean temperature of a still thermogram, are quite easy. These methods may be sufficient in clinical environment but are inadequate for the accurate measures required in basic sciences. In fact the emotional state triggered by a stimulus certainly evolves in time, and may migrate on the subject's body thus forming complex patterns of temperature changes. Furthermore, it's necessary to extract relevant features in a semi-automatic manner for large amounts of data. Thus far few applications have been shown such as those presented by the group of Pavlidis (Pavlidis et al., 2002a; Pavlidis et al., 2002b; Pollina et al., 2006). The works of Pavlidis mostly revolves around deception research, showing a great potential for the use of thermography in measuring automatic emotional responses. However there are several issues with movement artifacts and which features are most relevant for the detection of emotional states changes.
Therefore, we decided to invest part of the first year in exploring the use of thermography in these contexts. The results of such research may prove extremely influential for both the advancement of the SIEMPRE project agenda and also a larger community exploring the use of thermography in affective neurosciences. Here follows a list of on going research projects about these issues.

4.1 Pilot of thermographic measures of large audiences

TitleRiTitle	Pilot for thermographic measures of large audiences
Question of interest	Synchronization of the audience in terms of thermographic responses to music in an ecological scenario
Leaders	IIT
Other SIEMPRE group	UNIGE
Referent scenario	Audience scenario
Research objectives	Thermography enables a distal and unobtrusive measure of facial temperature. Feasibility study regarding the possibility to measure multiple individuals at the same time as a mean to measure audience emotional entrainment.
Theoretical hypotheses	Overall facial temperature will fluctuate according to expressive features extracted from audio traces
Operational hypotheses	We will extract temperature-related and auditory-related features via data-driven only methods and we'll search for correlations between any of these temporal series
Time schedule	First wave of experiments
Methods	
Participants	30
Materials	Real piano concert held at Carlo Felice theater in Genova (24/05/2010)
Data format	Raw thermography data or converted to MatLab
Experimental protocol/procedure	Subjects were not informed about the thermographyc recording. They were attending a regular piano concert. Faces cannot be recognized in the images, thus no privacy issues arose.
Measures	Thermographic images will be preprocessed to automatically detect artifacts and remove spurious temperature changes due to participants' movements. Afterwards we will extract global and local (automatic facial tracking) temperature fluctuations in time. Furthermore auditory expressive features will be extracted by using MirToolbox for MatLab.
Results	The first analyses are running. Various methods of segmentation and statistical comparison are under testing (see Figures below)

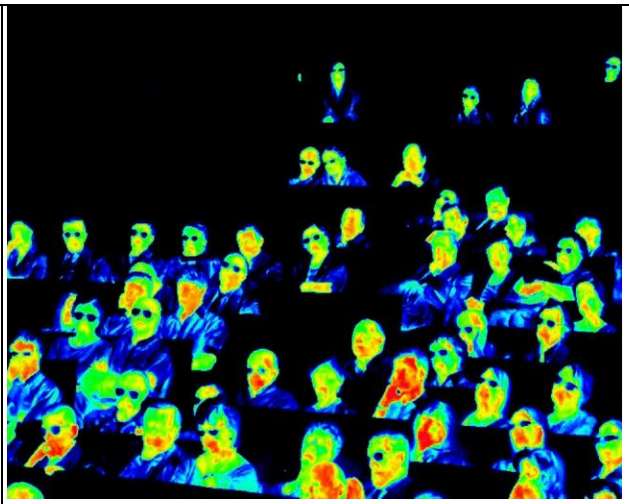


Fig. 1. The audience at the Carlo Felice Opera House Theater in Genova

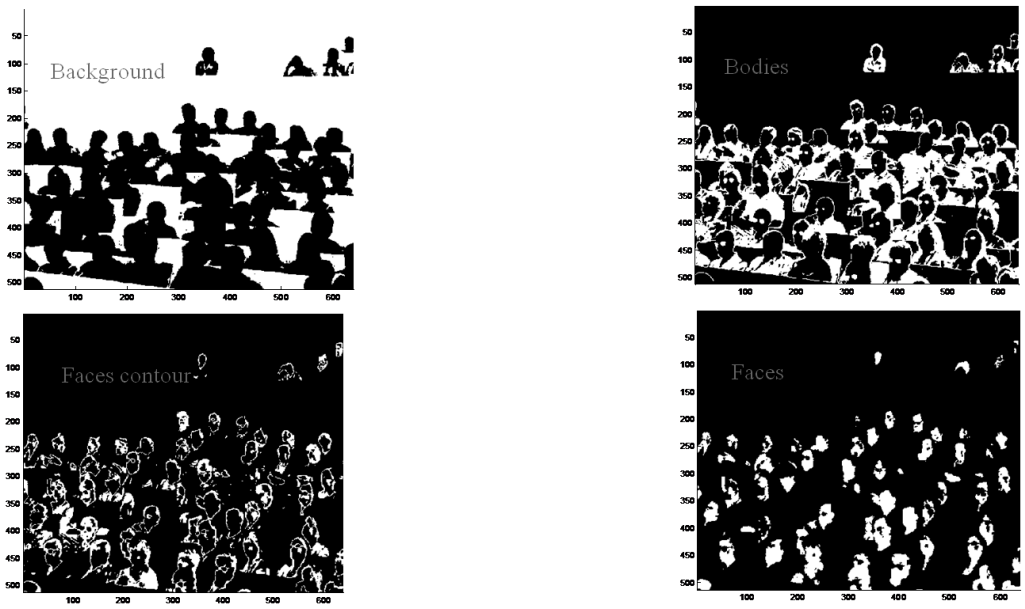


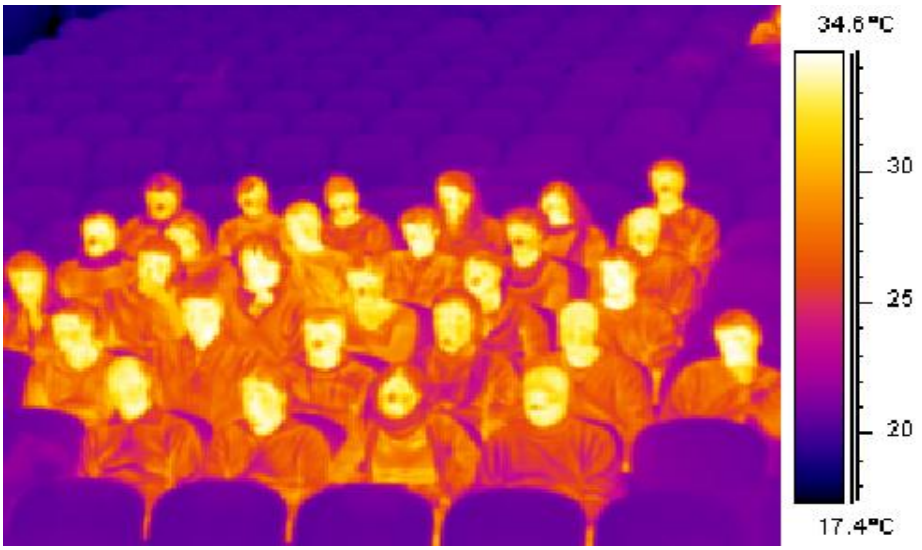
Fig. 2. Various types of segmentation

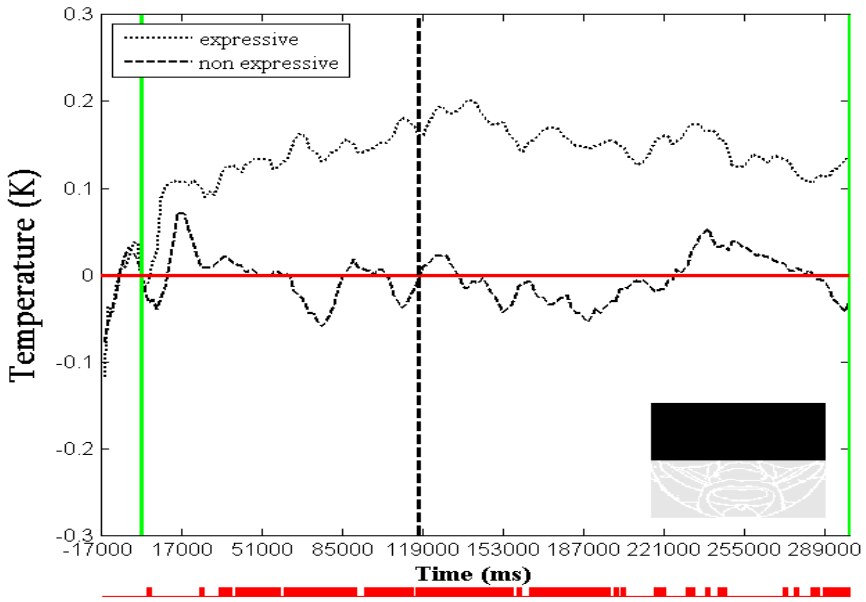
Descriptive results	Initial analyses were devoted to the implementation of a robust artifact-removing algorithm.
Inference statistics	To be done.
Additional results	To be done.
Discussion	To be done.

4.2 Pilot of thermographic measures of small audience

<table>
<tr><td>Title</td><td>Thermographic recordings of audiences during different types of musical expressiveness: Quartetto di Cremona (Workshop 20/07/2010)</td></tr>
<tr><td>Question of interest</td><td>Testing of audience reactions using thermographic patterns in faces in relation to different types of musical expressiveness.</td></tr>
<tr><td>Leaders</td><td>UNIGE-CH</td></tr>
<tr><td>Other SIEMPRE groups involved</td><td>IIT</td></tr>
<tr><td>Referent scenario</td><td>Scenario 3, audience reactions.</td></tr>
<tr><td>Research objectives</td><td>The musical expressiveness can be represented by various cues in a musical performance and might have an impact on emotional reactions of audience (Juslin, 2000). Two main types of musical expressiveness will be investigated: an academic type vs. an emphatic type with thermographic recordings of listeners' faces.</td></tr>
<tr><td>Theoretical hypotheses</td><td>We predict modulations of synchronization among the audience and modulations of peripheral reactions related to different kinds of musical expressiveness as measured by thermography.</td></tr>
<tr><td>Operational hypotheses</td><td>Higher thermographic measure correlations between listeners during the listening of emphatic style compared to academic style. Increase of thermographic measures for emphatic compared to academic musical styles.</td></tr>
<tr><td>Relationship with the objectives of the project</td><td>Understand the impact of the musical expressiveness on the reactions of the audience using peripheral reactions (one of the component of emotional processes).</td></tr>
<tr><td>Time schedule</td><td>The recordings were performed in the end of 2010; analyses are in progress; the publication is planned for the end of 2011.</td></tr>
<tr><td>Methods</td><td></td></tr>
<tr><td>Participants</td><td>13 music lovers (4 men).</td></tr>
<tr><td>Materials</td><td>Material:
-Thermographic camera SC3000

Procedure of the thermographic recordings:
Thermographic mesures were recorded during real performance of the Quartet of Cremona performing the following movements:
<table>
<tr><td>Order</td><td>Movement</td><td>Musical style</td></tr>
<tr><td>1</td><td>Schumann, IV: Allegro molto vivace</td><td>emphatic</td></tr>
<tr><td>2</td><td>Bartok, III: Non troppo lento</td><td>academic</td></tr>
<tr><td>3</td><td>Beethoven, IV: Finale</td><td>emphatic</td></tr>
<tr><td>4</td><td>Bartok, III: Non troppo lento</td><td>emphatic</td></tr>
</table>
</td></tr>
</table>

	5 | Schumann, IV: Allegro molto vivace | academic 6 | Beethoven, IV: Finale | academic
Data format	Images or matrices under Matlab format
Experimental protocol/procedure	A panel of 13 music lovers was recruited for the termographic recordings and paid 50 CHF for their participation. The workshop took place in a musical room at the University in Geneva. Participants were placed in front of the thermographic camera and the musicians.
Measures	We performed thermographic measures (in kelvins) on continuous scales.
Results	
Descriptive results	In order to test the difference of the mean of the thermographic measures between expressive and non-expressive performances we are using the NeuroTherma toolbox (see Jarlier, Grandjean, et al., in press). The analyses are in progress (see Figure 1 and 2).  Fig. 1: Example of thermographic measures with an audience. Each face is extracted and normalized before analysis.

	 Fig. 2: Example of the results we can obtain with the thermographic measures. This graph shows that the upper face (using Region of Interest, ROI analysis) is significantly hotter when musicians play in an emphatic mode. In the lower part the red points are the significant t-tests between the experimental conditions (p<.05).
Inference statistics	The analyses are in progress, we are using parametrical analysis such as ANOVAs and permutation tests allowing to test differences despite unknown shape of distribution of statistical indicators.
Additional results	We will develop also different ways to investigate the correlations across participants for thermographic results including Independent Components Analysis (ICA).
Discussion	To be developed.

4.3 Thermographyc recordings with two different cameras

<table>
<tr><td>Title</td><td>Pilot of thermographic recordings with two different cameras</td></tr>
<tr><td>Question of interest</td><td></td></tr>
<tr><td>Leaders</td><td>IIT, UNIGE-CH</td></tr>
<tr><td>Other SIEMPRE group</td><td>UNIGE</td></tr>
<tr><td>Referent scenario</td><td>Audience scenario</td></tr>
<tr><td>Research objectives</td><td></td></tr>
<tr><td>Theoretical hypotheses</td><td>Study regarding the differences between two thermocameras recording different wavelengths. Thermocameras used in similar literature are often very different according to their specifications. Between all the different characteristics, one that may result important is the range of wavelength sensitivity.</td></tr>
<tr><td>Operational hypotheses</td><td>We will record the same audience with both cameras (IIT and UNIGE-CH) presented with standardized stimuli. We will then apply the same algorithms to the raw data and we'll compare the dynamic range of the two.</td></tr>
<tr><td>Time schedule</td><td>First wave of experiments</td></tr>
<tr><td>Methods</td><td></td></tr>
<tr><td>Participants</td><td>10-20</td></tr>
<tr><td>Materials</td><td>Questionnaires:
- Personality questionnaires (for example: Italian version of the Big Five Inventory, John et al. 1991)
- GEMS (Geneva Emotional Music Scale, Zentner, Grandjean & Scherer, 2008) (italian translation)
- Positive and Negative Affect Schedule (PANAS)

Stimuli:
Visual stimuli: 3 video-clips per 3 emotions (sadness, disgust, amusement) * 3 neutral video-clips = 12 stimuli

<table>
<tr><td>Emotion</td><td>title(x)</td><td>min</td><td>sec</td></tr>
<tr><td>Amusement</td><td>I visitatori</td><td>2</td><td>9</td></tr>
<tr><td>Amusement</td><td>harry ti presento sally</td><td>2</td><td>45</td></tr>
<tr><td>Amusement</td><td>Tutti pazzi per Mary(2)</td><td>2</td><td>35</td></tr>
<tr><td>Sadness</td><td>dangerous mind</td><td>2</td><td>8</td></tr>
<tr><td>Sadness</td><td>the dreamlife of angels</td><td>2</td><td>41</td></tr>
<tr><td>sadness</td><td>Shindler's list (1)</td><td>1</td><td>18</td></tr>
<tr><td>disgust</td><td>Trainspotting (2)</td><td>1</td><td>44</td></tr>
<tr><td>disgust</td><td>seven (3)</td><td>3</td><td>19</td></tr>
<tr><td>disgust</td><td>seven (2)</td><td>1</td><td>43</td></tr>
<tr><td>neutral</td><td>previsioni del tempo</td><td>x</td><td></td></tr>
<tr><td>neutral</td><td>economia</td><td>x</td><td></td></tr>
</table>
</td></tr>
</table>

	neutral televendita x Musical stimuli : 2 types of expressiveness (academic vs. emphatic styles) * 4 dimensions from the GEMS (Nostalgia, Joyful Activation, Tension, Power) = 8 stimuli 10) Bach, Partita n°2 in D minor, BWV 1004, *Allemande* (1st mvt) : Nostalgia d) Academic mode (2'07) e) Emphatic mode (2'00) 11) Mozart, violin concerto n°3 in G major, K.216, *Allegro* (1st mvt) : Joyful Activation d) Academic mode (1'46) e) Emphatic mode (1'41) 12) Mendelssohn, violin concerto n°2 in E minor, op.64, *Allegro molto appassionato* (1st mvt) : Tension d) Academic mode (1'04) e) Emphatic mode (1'00) 13) Schumann, violin concerto in D minor, Op. Posth. : *In Kräftigem, Nicht Zu Schnellem Tempo* (1st mvt) : Power d) Academic mode (2'10) e) Emphatic mode (2'13)
Data format	Raw thermography data; may be converted to MatLab
Experimental protocol/procedure	- Participants complete the personality questionnaire - The GEMS questionnaire will be completed after first listening of each musical excerpt - Event related design
Measures	Thermographic images of both cameras will be recorded and synched with stimuli presentation. Analyses will be the same as in "Pilot for thermographic measures of large audiences" for both cameras
Results	To be done.
Descriptive results	To be done.
Inference statistics	To be done.
Additional results	To be done.
Discussion	To be done.

4.4 Thermographic measures of large audiences

Title	Thermographic measures of large audiences
Question of interest	Synchronization of the audience in terms of thermographic responses to music in an ecological scenario
Leaders	IIT
Other SIEMPRE group	UNIGE-CH
Referent scenario	Audience scenario
Research objectives	Thermography enables a distal and unobtrusive measure of facial temperature. Feasibility study regarding the possibility to measure multiple individuals at the same time as a mean to measure audience emotional entrainment.
Theoretical hypotheses	Overall audience temperature will fluctuate according to features extracted from the stimulus
Operational hypotheses	We will extract temperature-related and stimulus dynamic features via data-driven only methods and we'll search for correlations between any of these temporal series
Time schedule	Second wave of experiments
Methods	
Participants	>120
Materials	Cinema setting with a large audience watching to a movie and large audience in musical performance.
Data format	Raw thermography data or converted to MatLab
Experimental protocol/procedure	Subjects will be not informed about the thermographyc recording. They will attend a regular movie. Faces cannot be recognized in the images, thus no privacy issues arose.
Measures	Data will be acquired for three evening in a row for data consistency. Thermographic images will be preprocessed to automatically detect artifacts and remove spurious temperature changes due to participants' movements. Afterwards we will extract global temperature fluctuations in time.
Results	To be done.
Descriptive results	To be done.
Inference statistics	To be done.
Additional results	To be done.
Discussion	To be done.

4.5 Autonomic Response to Randomly Chosen Songs

Title	Autonomic Response to Randomly Chosen Songs
Question of interest	What are the relationships between the properties of a song (dynamics, rhythm, emotional intent, etc), the self-reported emotional response, and the GSR and HR response?
Leaders	QUB
Other SIEMPRE groups involved	
Referent scenario	(ii) music-listener
Research objectives	This study is a large-scale, cross-sectional study that will collect data on an individual's response to music clips from multiple genres.
Theoretical hypotheses	The hypothesis of this study is that, when an individual listens to music, there are quantifiable relationships between: 1) self-report measures including affect, demographics, familiarity, and aesthetic judgments 2) physiological measurements of GSR and HR 3) structural and sonic properties of the music
Operational hypotheses	This study proposes that there are specific ecological measures that can assess an individual's response to listening to music.
Relationship with the objectives of the project	This study directly informs all of the objectives targeted at understanding the cognitive and emotional response to music. Without understanding whether there are specific measures of relationships between and among individual listening experiences, it will be difficult to explore measures of audiences.
Time schedule	First experiment in Dublin June-August 2010, Refinement and testing in Genoa October 2010, revised version presented New York June-July 2011. Analysis started October 2010. First publication May 2012.
Methods	A computer terminal is equipped with a sensor package (Galvanic Skin Response + Pulse Oximeter), data capture device (Arduino), mouse and headphones along with custom software developed. An isolation transformer is used to ensure electrical isolation for participants ensuring their safety. Following completion of a consent form, participants are instructed on the fitting of sensors to the fingers and are asked some demographic questions and general questions regarding their musical experience (all questions are on-screen as part of the experimental software). Participants are played 3 short (approx. 1'30'') randomly selected musical excerpts, during which physiological

	signals are recorded via on-body sensors, and are then asked to answer several short questions after each excerpt. At the conclusion of the experiment session, participants are shown an image of their physiological signals plotted against the audio waveform for each of the audio excerpts. The experiment takes no longer than 10 minutes to complete. The experiment/workstation is self contained but there is an assistant/mediator on hand to help with consent forms, sensor fitting and answering any questions as well as basic troubleshooting. Recorded signals are indexed against time for later analysis.
Participants	Currently over 4000 people have participated in the experiment. They represent a broad spectrum of ages and demography.
Materials	PC workstation + Screen (minimum 2 available USB ports, excluding Mouse/Keyboard) + ethernet/modem - Headphones (ideally with high levels of acoustic isolation) - 1 x Pulse Oximeter sensor * - 1 x Galvanic Skin Response sensor * - 1 x Serial to USB adaptor cable * - 1 x Arduino+USB cable * - Internet connection+ethernet cabling to workstation - 1 x Isolation transformer (of sufficient power to handle the above) - enclosure to hide computer, cabling and sensor housings
Data format	Ascii data files
Experimental protocol/procedure	See methods
Measures	
Results	
Descriptive results	Under analysis
Inference statistics	Under analysis
Additional results	
Discussion	

5. NEUROPHYSIOLOGICAL STUDIES ON RHYTHM ENTRAINMENT

One of the difficult things about emotions induced by music is that, unlike other emotions where the driving mechanism for the elicitation and differentiation of emotional episodes is appraisal, "there is no *single* mechanism that can account for *all* instances of musically induced emotion"(Juslin & Västfjäll, 2008). The "most comprehensive attempt to delineate the various mechanisms that underlie musical emotions is the BRECVEM model (Juslin, Liljeström, Västfjäll, & Lundqvist, 2010), which postulates seven mechanisms, other than cognitive appraisal, through which music might induce emotions: namely *Brain stem reflexes*, *Rhythmic entrainment*, *Evaluative conditioning*, *Contagion*, *Visual imagery*, *Episodic memory*, and *Musical expectancy*"(Juslin, Liljeström, et al., 2010).

Since SIEMPRE is interested in at least two of these phenomena in live performance and listening: namely *entrainment* and *emotional contagion*, it makes particular sense to study these processes more in detail. In his *Seven questions, seven answers* paper Juslin (Juslin, 2011) has rightly suggested that in order to demonstrate that music can evoke "real" emotions, one should provide not only evidence that music produces reactions in some of the emotion components, but also evidence that music produces synchronized reactions in all or many of the components that define an emotional episode: that is *Autonomic physiology*, *Action tendencies*, *Motor expression*, *Subjective feeling* and underlying it all *Cognitive processes* of course (Grandjean, Sander, & Scherer, 2008).

The following experiments focus on entrainment, the process through which two oscillators synchronize. We will be looking more particularly at both brainwave and physiological entrainment to musical stimuli (as described in D1.1). Through the manipulation of the regularities in the music, we wish to determine *how* the brain entrains to the music and goes on to entrain other components in the listener thereby affecting their behavioral response to the music. Not just because the underlying neurophysiological processes are still not well understood, but also to provide evidence of synchronized responses of different components of emotion to music.

Grandjean, D., Sander, D., & Scherer, K. R. (2008). Conscious emotional experience emerges as a function of multilevel, appraisal-driven response synchronization. *Consciousness and Cognition*, *17*(2), 484-495. doi:10.1016/j.concog.2008.03.019

Juslin, P. (2011). Music and Emotion: Seven Questions, Seven Answers. *Music and the Mind: Essays in honour of John Sloboda*. Oxford University Press.

Juslin, P. N., & Västfjäll, D. (2008). Emotional responses to music: the need to consider underlying mechanisms. *The Behavioral and Brain Sciences*, *31*(5), 559-575; discussion 575-621. doi:10.1017/S0140525X08005293

Juslin, P. N., Liljeström, S., Västfjäll, D., & Lundqvist, L.-O. (2010). How does music evoke emotions? Exploring the underlying mechanisms. *Handbook of music and emotion: Theory, research, applications*, Series in Affective Science. New York : Oxford University Press.

5.1 Human Intracranial Local Field potential recordings during percussion listening paradigm (Intracranial I)

Title	Intracranial EEG recording of brain activity during a percussion listening paradigm (Intracranial I)
Question of interest	To investigate how different metrics and different tempi entrain brain areas during passive listening.
Leaders	UNIGE-CH
Other SIEMPRE groups involved	
Referent scenario	(ii) music-listener
Research objectives	To compare how different brain areas are entrained by percussion beats that vary in terms of tempo (fast/slow) and metrical structure (simple/complex) in an epileptic patient with intracranial electrodes.
Theoretical hypotheses	Tempo and rhythm are represented in (internal) brainwave rhythms which will entrain to the (external) rhythm of music; Therefore, subjecting the patient to pseudo-pieces with different tempos and meters should result in the alteration and eventual entrainment of brainwave components to the corresponding tempo, frequency or phase of the music; The observed response will be dependent on the perceived tempo of the piece rather than just the objective tempo.
Operational hypotheses	Keeping tempo constant, different metrics will lead to different brainwave entrainment responses; Different tempi for the same piece (i.e. metric) will lead to different brainwave entrainment responses; Should the perceived tempo (as determined by a tapping paradigm) be different to the objective tempo, the latter rather than the former will be related to the brainwave entrainment response should one be observed.
Relationship with the objectives of the project	Entrainment.
Time schedule	Data analysis in progress.
Methods	
Participants	N= 1, female, 17 years old, non-musician. Intracranial electrodes in: Supplementary Motor Area, Amygdala, Orbitofrontal Cortex, Anterior cingulate cortex, Hippocampus
Materials	18 beat tracks = 7 metrics * 2 tempi (90 vs 124bpm) + 1 metronome condition * 2 tempi (90 vs 124bpm) + 1 scrambled condition (no metric) * 2 tempi (90 vs 124bpm); 12-item explicit entrainment questionnaire (not

	published); Geneva Emotional Music Scale (Zentner, Grandjean & Scherer, 2008); Tempo tapping programmed with E-Prime 2 (Psychology Software Tools Inc., Pittsburgh, PA).
Data format	To be determined.
Experimental protocol/procedure	
Measures	Overall self-reported explicit entrainment for all trials; Overall self-reported subjective feeling of emotion; Intracranial EEG recordings; Heart rate.
Results	To be done.
Descriptive results	To be done.
Inference statistics	To be done.
Additional results	To be done.
Discussion	To be done.