| AAPG2019 | ORPHEUS | | PRC |
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| Coordinated by : | Lionel PAZART | 42 months | 442 K€ |
| CES 37 « Sciences de la vie, Neurosciences intégratives et cognitives» | | | |

# Orpheus: neurophysiological correlates of emotional sharing in groups of music performers and listeners

## I. Pre-proposal's context, positioning and objective(s)

**Objectives**

We aim **to clarify the neurophysiological mechanisms underlying intra- and inter-group emotional sharing,** using the experimental model of public musical performances. The second aim is to provide a set of **novel methods to evaluate in real time the emotional synchronization of multiple individuals** through neurophysiological recording devices coupled with artificial intelligence algorithms.

**Hypothesis**

Our hypothesis is that emotions may be transmitted in a precise timeframe from performers to listeners, resulting in "emotional communion" when both groups are synchronized.

For musicians, emotional sharing during musical performance would involve attentional sharing, rhythmic/harmonic/temporal coordination and synchronization processes, resulting in emotional contagion.

For both audience and musicians, , emotional sharing would also involve processes mediated by the endogenous opioid system, more precisely relationships between oxytocin and dopamine in the mesocortico-limbic system, enhancing the effect of mere co-presence.

**State of the art & Positioning**

In various domains group cohesion is essential to achieve optimal performance: it contribute to the team's sense of efficacy and allows to perform well in daily work ( Zaccaro et al., 1995; Barsade, 2002; Heuzé et al., 2006; Myers et al., 2007). Collective efficacy is directly linked to a high level of interaction and a high level of cooperation resulting in increased **synchrony of the team members** (Bandura, 1997; McNeill, 1995). Emotions shared by team members have an essential role (Páez et al., 2015) because the primary function of emotions is social coordination (Anderson et al., 2003). Thus, team synchrony is expected to increase through the **emotional contagion between members**.

Although group cohesion can enhance group performance, **mechanisms underlying the propagation of emotions in groups remain largely unexplored.** Not only are the physiological mechanisms that trigger emotional synchronization unknown, but no method exists to measure emotional synchronization in large groups of individuals in a direct and objective way. Tools assessing and improving collective sharing of emotions would open avenues of applications for enhancing group performance.

Physiologically, it is now well accepted that oxytocin has a significant biological role in social emotion (Love, 2014), and it is therefore plausible that oxytocin release be the molecular basis of a group cohesion. Such a role is highly suspected in the field of music (Chanda and Levitin, 2013). Indeed, while dopaminergic action in the reward system is closely related to emotional pleasure aroused during musical listening at the individual level (Salimpoor et al., 2011), the location of oxytocin's receptors throughout the mesocorticolimbic dopamine system places oxytocin in an ideal position to influence dopaminergic pathway. Socio emotional sharing is therefore likely to be supported by the opioid endogenous system implicating both oxytocin and dopamine pathways (Tarr et al., 2014).

**Methodology to achieve the objectives**

The main constrain of studies in ecological conditions is the stability required by physiological and neurophysiological recordings systems used for emotion research. To overcome these constraints, project ORPHEUS proposes to study human emotional interactions in the ecological framework of a **classical music orchestra playing musical pieces in front of an audience**.

It is well known that **sharing music with others is a model of synchronization** creating social bonding in an audience (Dunbar, 2012; Overy, 2012) which involves sophisticated levels of cooperation and synchronization between musicians. Such a framework can allow not only to measure physiological parameters in a relatively reproducible conditions, but also to use neuroimaging tools advantageously to evaluate emotional contagion.

Different functions in the group can be compared (fig 1): emotional synchronization between performers (active vs active relationships), between performers and listeners (active vs passive), and among the listeners (passive vs passive). In particular, while most of previous research has focused on musician-to-musician sensorimotor synchronization or joint action, (Lindenberger et al., 2009; ; Babiloni et al., 2012; Sänger et al., 2012, 2013; Müller et al., 2013, 2018; Aucouturier and Canonne, 2017) and on audience-audience synchronization (Panksepp, 1995; Anderson et al., 2003; ; Liljeström et al., 2013; Bernardi et al., 2017; Han et al., 2017), only limited work has examined emotional synchronization between performers and listeners. Different emotional pathways may be involved in the different functions of the group.

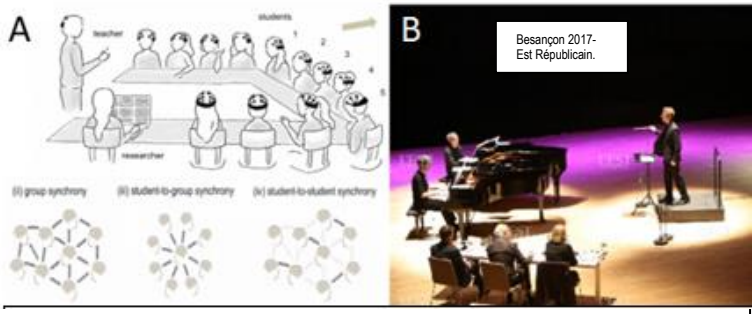


**Fig 1.** Similar functions in a group : **A.** interaction in a classroom (Dikker et al. 2017); **B** International Conductors Competition

**The model of the classical music orchestra will provide a stable practical and theoretical environment** allowing to understand basic and higher-order mechanisms involved in emotional synchronization before testing our hypothesis in a real working interaction situation.

Methodologically, new hyperscanning methods are currently being developed in the community, and have already demonstrated a high level of neuronal synchronization in dyads or groups in different fields, in airline pilots (Astolfi et al., 2011), or musicians (Lindenberger et al., 2009; Babiloni et al., 2011, 2012; Sänger et al., 2012, 2013; Müller et al., 2013, 2018; Aucouturier and Canonne, 2017) but no objective methods had been developed to measure the emotional synchronization. In that respect, the **recording of cerebral activity with electroencephalography hyperscanning methods** (EEG), coupled with **physiological recordings,** would present an interesting solution for the emotional analysis of groups (Balconi, 2017).

The ORPHEUS project consists of 6 work packages:

**WP0: management and coordination** *(42 months). Lead: Inserm.* Active throughout the project, WP0 will ensure the efficient governance and coordination of all partners.

**WP1: Role of oxytocin on emotional sharing mechanisms in groups of listeners and performers** *(Lead: EA 481, Partners: Inserm, STMS; M1 to M8).* In a unique to date pharmacological study on emotional sharing in a group, the experiment will be a crossover study of the effect of oxytocin versus placebo (nasal spray) on the emotions felt by 4 listeners when musical pieces are performed by a quartet. Listeners will receive oxytocin or placebo (random group) for a total of four sessions spaced one week apart (wash-out period); two sessions will be conducted in group listening and two additional sessions in individual listening. Blood samples (plasma oxytocin and dopamine levels) will be taken from each musician and listener before and after each listening session, as well as neurophysiological parameters: heart rate variability (HRV), galvanic skin responses (GSR), brain activity with wireless EEG and video monitoring of facial expressions. EEG hyperscanning analysis methods, physiological signals and facial expression data will quantify the interactions between performers, performers and the listeners, and between listeners. During the experiment, a self-declaration of the emotions felt by the audience will be collected by a four-response box (neutral, low pleasure, intense pleasure, thrill) in real time.

**WP2: Moving to the real-world: the role of ecological conditions on the intensity of emotional sharing** *(Lead: EA 481, Partners: Inserm, STMS; M9 to M14).* By the end of the WP1, we can identify physiological and temporal-spatial neuronal mechanisms of emotional synchronization to set up an analysis method of emotional synchronization. WP2 aims to test these results in ecological conditions during a concert performance of a classical music orchestra (agreement already obtained with the "Orchestre Régional de Bourgogne Franche-Comté"). The experiment will involve four groups of 10

people: 1/musicians, 2/listeners from audience, 3/a control group (outside-control) placed individually outside of the concert hall, watching and hearing the concert on a real-time video broadcast, 4/a control group (inside-control) sitting among the audience, but equipped with anti-noise headsets and blindfolded. EEG and physiological parameters (HRV, GSR and facial expressions) will be recorded with the same devices as WP1 simultaneously. In addition, a sociological analysis of the participants' live experience will be realized on interviews, and behavioral analysis based on videotapes.

**WP3: Set-up of an interface able to assess in real time a group emotional sharing** *(Lead: FEMTO-ST, Partners: EA 481, Inserm, STMS; M9 to M20).* Based on the analysis of multi-individual joint neurophysiological data collected in WP2, partner FEMTO Institute will develop an automatic diagnostic tool based on case-based reasoning system and artificial intelligence. This tool will quantify in real time the amount of emotional connection between individuals and thus provide a novel and much-needed apparatus to do experimental work on group cohesion.

**WP4: Generalization of findings in non-musical contexts** *(Lead: STMS Partners: FEMTO-ST, EA 481, Inserm,; M21 to M32).* By taking musicians and audience as a model in WP1-3, project Orpheus aims to provide new mechanistic insights, as well as novel measure tools, to study group emotional synchronization in general, non-musical contexts. To this aim, partner IRCAM will adapt their existing paradigm of "augmented conversations", in which dyads of participants (e.g. speed-dating pairs, patient-doctor discussions, etc.) interact while their voice and face are being artificially transformed to display matching or non-matching emotional expressions (Arias et al., 2018). WP4 will test the extent to which the tools developed in WP3 are sensitive to such externally-controlled alignment of emotional expressions, and whether the effects of the manipulations on the outcome of the conversations are mediated, like in WP1, by oxytocin nasal sprays.

**WP5: Scientific communication, publication and valorization** *(Lead: Inserm Partners: all; M12 to M42).* Oral communications will be done in international conferences in social and affective neurosciences (ex. ESCAN), music cognition (ex. ICMPC) and artificial intelligence (ex. IJCAI, AAAI, ICCBR). Results will be published in generalist science journals (such as PNAS or Current Biology) and/or high-level specialist journals (such as Emotion or Cognition), with a commitment to open-source and open-science. A database of data from human will be recorded on Dryad. The findings and particularly the algorithms will be assessed by valorization service of partners for transfer to the economical world.

**Ability of the project to address the research issues covered by the chosen research theme**

The Orpheus project is perfectly in line with ANR Challenge CES 37 « Sciences de la vie, Neurosciences intégratives et cognitives» to understand high-level properties of the human brain, to study relationships with others and specifically social collective emotion as well as synchronous emotional transfer from senders to receivers. It involves innovative experimental research using multimodal in-vivo tools and computational analysis with brain-machine interfaces and artificial intelligence for behavioral analysis.

**Innovative nature of the project and originality of the objectives and the methodology**

In a unique-to-date pharmacological study on emotional sharing in a group, the project will explore mechanisms underlying the propagation of emotions in group. This will lead to the development of innovative numeric tools to evaluate group cohesion and thus improve the collective efficacy of working groups. New portable neurophysiological systems coupled with informatics interface could provide a very useful solution in different applications, both educational (synchronization training for teams or groups), as well as evaluative (facilitating the sharing of emotions within working groups). This innovative feature represents a real potential for industry.

## Partnership

The ORPHEUS project federates neuroscientists, expert on audio technologies and artificial intelligence, engineer, and signal-processing and machine-learning computer scientists with sociologists.

**Dr Lionel Pazart,** MD, PhD, is the coordinator of the project. As the manager of the module on Innovative Technology of Inserm CIC1431, he collaborated on many projects (PHRC, ANR, FP7) with partners 2 and 4 on the development of innovation for Health. He also affiliated to the EA481 working

on human emotional processes through methodological approaches including psychophysiology and cerebral imagery and he is currently supervising works on synchronization and musical emotions.

**Partner 1 Inserm CIC1431** (Consortium leader): The Center of Clinical Investigation a structure that facilitates the translation of basic research into clinical practice and perform Research Implying Human Being (RIPH law). Sociologist from the CIC will analyze interviews behavioral on videotapes and facial expressions, and interpret the interactions from a socio-psychological point of view.

**Partner 2: EA481** The Laboratory of Clinical and Integrative Neurosciences of the University of Bourgogne Franche-Comté is firmly focused on basic and clinical neuroscience research about emotional regulation and emotional processes with physiological measures (ECG, GSR) as well as with neuroimaging methods (fMRI, EEG), which is essential in the project .

**Partner 3: STMS** (Science and Technology of Music and Sound, UMR9912 IRCAM/CNRS/Sorbonne University) is the country's only laboratory fully devoted to the science and technologies of music and sound, located in Institut de Recherche/Coordination en Acoustique et Musique **(IRCAM)** in Paris. It brings to the project expertise in vocal and musical communicative behaviors, as well as voice-transformation technologies to be used in WP4.

**Partner 4: FEMTO-ST** Institute CNRS (UMR 6174) Université de Franche-Comté and ENSMM and UTBM, working on both micro and nanotechnologies, robotic, informatics. The department associated with this project is the Département Informatique des Systèmes Complèxes (DISC) working on research about distributed algorithms (distributed platforms; distributed intelligence, collaborative work).

## II. References related to the project


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