Let Me Listen to Your Brain: Physiology-based Interaction in Collaborative Music Composition

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Abstract
The use of physiology-based interaction in collaborative scenarios is a rapidly developing area of research that has a strong potential for innovative applications. This aspect of Physiological Computing has become an important topic for our research group, where we focus on the enhancement of collaborative music generation experiences by combining explicit, gestural interaction with implicit, unconscious interaction using physiological signals. By following this approach, we aim to develop new expressive multimodal interfaces capable of bringing meaningful collaborative experiences for both entertainment and clinical applications.

Keywords
Physiological Computing, Hybrid BCI, Collaboration, Tangible User Interfaces, Tabletops, Reactable, music, sonification, biofeedback, meaningful interaction.

ACM Classification Keywords
H5.3 [Information interfaces and presentation]: Group and Organization Interfaces---Collaborative computing; C.0 [General]: Hardware / Software interface;

General Terms

Design, Human Factors, Algorithms, Measurement, Performance, Reliability, Experimentation.

Introduction

Example use case: "Bill and George, are composing music together using a tangible tabletop interface. Among of objects (pucks) available for generation, control and filtering of sounds, they see "physiopucks" labeled with brain and heart icons. When Bill places a brain-labeled physiopuck on the surface of the table, it reveals his physiological signals to George via generated sound and visual feedback on the tabletop surface. George uses this sound to compose music, but it also helps him to depict Bill's lack of interest. Also, by observing Bill's facial expressions, it is clear that he feels sleepy. These signs lead George to generate faster rhythms, and he suddenly notices that Bill's brainwaves start to sound different, and a tepid smile on his face conveys that now they are going in the right way.[1]"

The use of brain and body signals in Human Computer Interaction (HCI) is becoming increasingly popular and widespread, mostly due to sensors portability and configuration as wearable devices [1]. However, most of the studies on physiology-based interaction focus on single-user scenarios, and bio-signals usage in collaborative experiences and Computer-Supported Collaborative Work (CSCW) is still in its beginnings.

The collaborative aspect of Physiological Computing has become one of the main research topics for us at the Musical and Advanced Interaction team (MAIn - within the Music Technology Group at the Universitat Pompeu Fabra of Barcelona). At MAIn we focus on collaborative music systems that combine explicit, tangible interaction and implicit, unconscious interaction based on physiology sensing equipment. We hypothesize that these unconscious signals will enhance users experiences in collaborative tasks.

For our studies, we have built a multimodal system that connects in a novel manner Brain-Computer Interfaces (BCI) and heart-rate sensors with a Tangible User Interface designed for real-time sound generation and control. We chose TUI's, as they can be easily configured as multi-user environments, shaping shared spaces that foster collaboration. They are also capable to represent simultaneously implicit and explicit interaction through audiovisual feedback. Finally, music performance offers an archetypical collaborative scenario and represents one of the densest forms of human communication [2].

Current state: The Working Prototype

Our first multimodal interface for collaborative sound performance uses Starlab's Enobio[2], a wireless electroencephalogram (EEG) and electrocardiogram (ECG) device. Those signals are use for real-time sound generation and control (implicit interaction) in combination with the Reactable, an interactive music instrument based on a tabletop surface and physical objects (explicit interaction)[2]. The system's sound-processing model mainly depends on EEG and ECG signals. The former is used to measure alpha-theta brain rhythms (4 to 12hz) that are displayed as a sound synthesis through a sonification engine, whereas

1 Video presentation available on www.vimeo.com/14675468

2 www.starlab.es

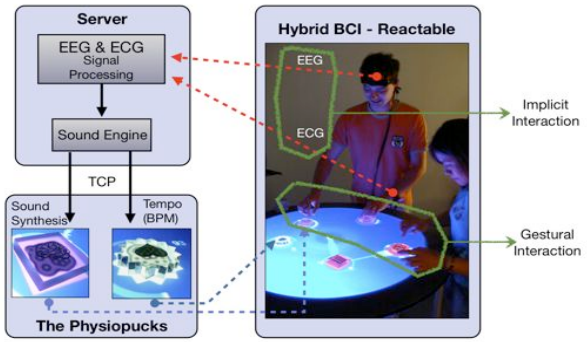

Figure 1: Multimodal Collaborative System. The physiological signals are measured and linked to *Physiopucks* for sound generation and control. The Reactable works as a shareable surface for collaboration.

the heart rate is mapped to the Beats Per Minute (BPM) in the Reactable (figure 1). The EEG-based sound synthesis and heart rate tempo control are presented to the performers as physical objects called *physiopucks*, which fulfill the main characteristics of multimodality, we would expect from the combination of tangible and physiological interfaces, as listed above:

- Continuity: fluid music performance without losing continuous physiological monitoring.
- Direct access: direct sound operations using physiological signals, and by manipulating the *physiopucks* on the surface of the table.
- Expressivity: Explicit representation of discrete physiological states by means of sound, graphics and physical objects.
- Distribution: Foster a collaborative musical experience where users can manipulate simultaneously their own physiological signals and those coming from the bodies of other participants. Measures and Results

To assess the effect of physiology-based interaction in collaborative music experiences, and to evaluate the performance of the proposed system, we consider different types of measures: (1) Time Measures: e.g., how long does it take to complete a task using the system; (2) Subjective Measures: motivation and performance measures, and emotional experiences during the task; (3) Physiological Measures: recording and assessment of EEG, ECG, electrodermal activity (EDA) that would characterize psychophysiological states (emotions, cognitive load); (4) Visual Recording: for behavioral observation (gestures, facial expressions); (5) Music Performance and Aesthetics: using similarity metrics between a reference audio sample and recorded trials from participants.

Our first study was based on a task-oriented experiment for collaborative music composition with 32 users (for the details on the experimental design and results see [3]). It involved pairs of participants with specific roles: one *user* (explicit interaction), that operated the Reactable pucks with its hands; and one *emitter* (implicit interaction) that manipulated the standard pucks but also provided the physiological signals for the *physiopucks* (figure 2).

For this initial experiment, subjective measures were assessed using a post-test questionnaire based on a 5-point Likert Scale. It included 10 different factors concerning motivation and collaborative performance such as *Challenge, Confidence* and *Leadership*.

The study has revealed four main effects of physiology-based interaction applied to a collaborative performance.

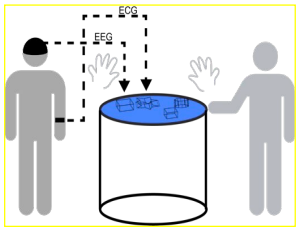

Figure 2. Emitter (left) and User (right). Design implemented in task-oriented experiments.

First, it has shown similar levels of reported *Challenge* for both types of participants (*emitters* and *users*). Second, the introduction of a physiology-based feature to the Reactable did not affect the *Confidence* levels into the collaborative performance. Third, the significances detected in *Challenge* and *Confidence* measures lead us to confirm that *emitters* were able to perceive unconsciously whether the audiovisual feedback was linked to their physiological signals or not. Finally, a Control Group, were *emitters* worked with prerecorded EEG and ECG signals, not only had lower *Confidence* ratings, describing the system as less responsive and controllable, but also showed the loss of *Curiosity* demonstrating the lack of motivation in the task.

Topics for discussion

Based on our initial studies, we would like to discuss the following issues related to "*Meaningful Interactions with Physiology*" topic of the workshop:

- Implicit and unconscious interaction for collaboration: in our system the physiological signals allow the addition of implicit cues by means of visualization and sonification. How this will enhance collaborative experiences? Does it affects communication and shared control?
- Multimodality: we combine physiological and gestural input techniques to achieve multimodal, collaborative user experiences. How distributed is the control between interfaces? Is the collaboration symmetric between users with different knowledge and skills? How physical actions will influence the quality of the recorded physiological signals?
- Expressiveness & Intuitiveness: our system aims to foster expressivity in real-time performance. At the same time, the applied mappings account for a rapid recognition of real-time biofeedback information. What level of mapping complexity can be used to sonify and visualize continuously changing affective states?
- Ergonomics: the proposed system uses wireless, non-invasive technology apt for live performance in real world experiences. What is the trade-off between hybrid BCI devices and expressiveness?

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