Investigating Neural Mechanisms and Social Functions of Music in Naturalistic Settings

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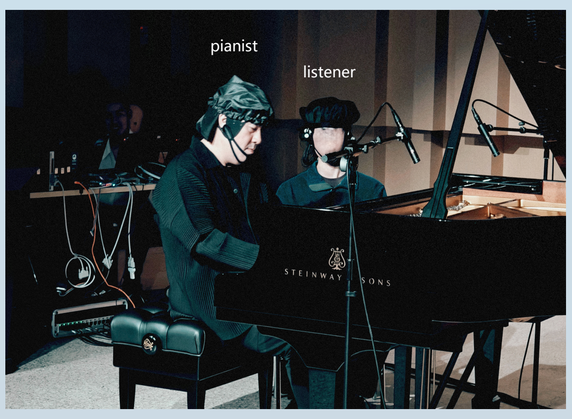
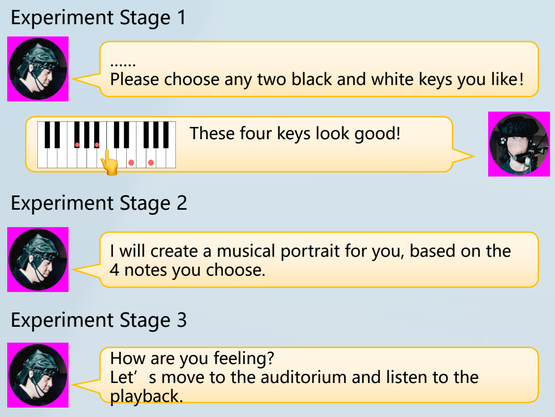
Abstract - Traditional research on music perception has primarily taken place in controlled laboratory settings, which limits our understanding of music' s role in natural environments. However, recent advancements in portable recording technologies such as fNIRS, EEG, and BIOPAC now make it possible to study neural and biological responses to music in real-world settings. We have conducted experiments in concert halls during live performances, enabling the investigation of music's social functions and group dynamics. These experiments aim to explore the neural mechanisms underlying music perception, creation, and performance by synchronizing brain and physiological responses from a group of participants in live music settings. This naturalistic approach provides insights into important aspects such as music' s social role, therapeutic effects, and its ability to mediate communication and emotional connections. Two examples from our recent studies on music neuroscience in naturalistic settings will be presented.

Experiment 1 Neurophysiological Responses to Personalized Musical Improvisation: Listener and Pianist Dynamics

In Experiment 1, a professional pianist improvised a classical piece based on four notes—two white and two black—provided by the audience, creating a unique musical portrait of the listener. During this performance, various physiological and neural responses were recorded, including EEG, heart rate variability, skin conductance, and fNIRS data. Additionally, the brain activity of the pianist was simultaneously captured using an fNIRS system.

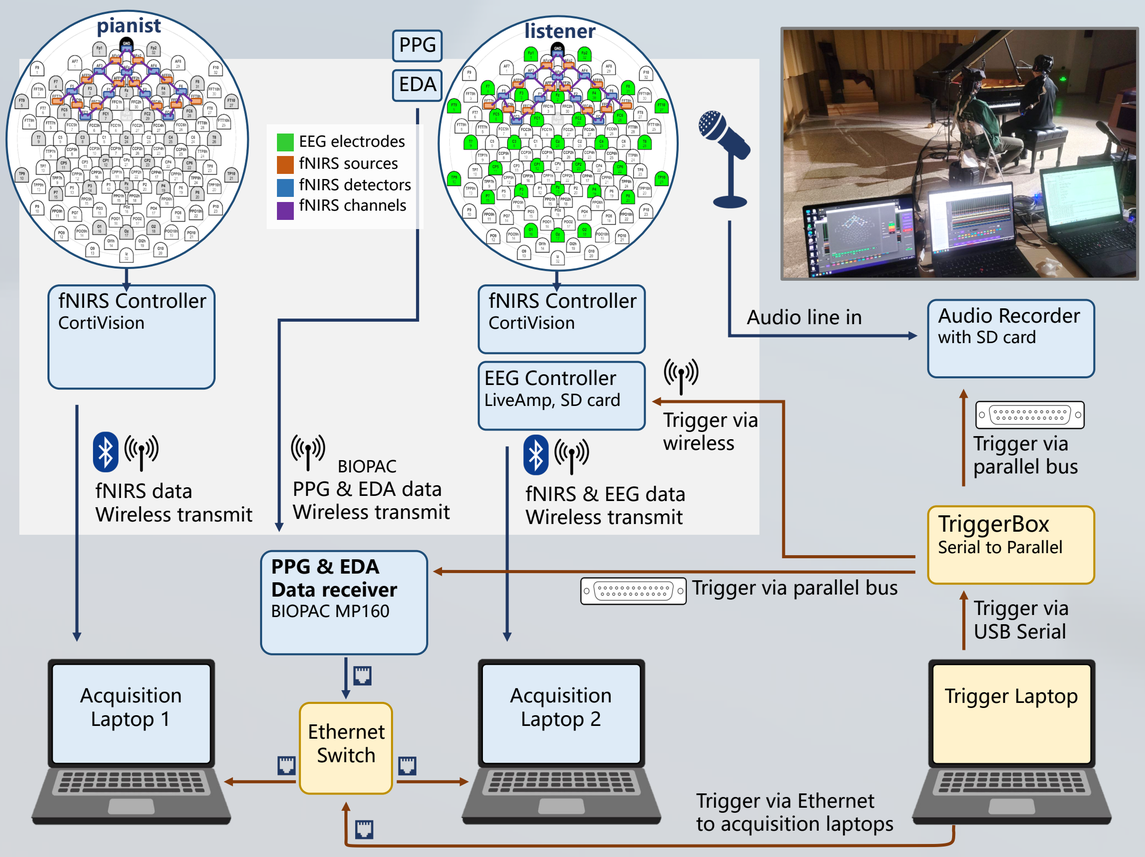
A paradigm was designed by pianist Mr. Kong Xiangdong to convey love to listeners through music, providing a valuable framework for studying the impact of music on human cognition and social interaction in real-life scenarios. The experimental paradigm is illustrated in the figure below.





The pianist and the listener sit together at the piano, side by side. In Stage 1, the pianist typically spends a few minutes building a connection with the listener by sharing life stories and learning about their background. The listener is then invited to select any two black keys and two white keys, regardless of their piano knowledge. After a one-minute break, Stage 2 begins, where the pianist creates a personalized musical portrait for the listener through improvisation, using the four notes chosen by the listener as the melodic foundation. After 5-8 minutes of performance, Stage 3 follows. Here, the pianist and the listener discuss their experiences and emotions, with some listeners moved to tears or embracing the pianist. Finally, the pianist invites the listener to listen to the playback together.

Experiment Setup



To enable natural-environment experiments, we developed a lightweight, wearable brain activity acquisition system, shown above. It integrates the CortiVision fNIRS, LiveAmp EEG, and BIOPAC for Photoplethysmogram (PPG) and Electrodermal Activity (EDA). The fNIRS (10 sources, 12 detectors, 26 channels) and EEG (32+2 electrodes) systems are combined into one cap, harnessing both technologies. All devices (highlighted top-left) are wearable, battery-powered, and wirelessly transmit data, allowing free movement within the hall. Two laptops receive, monitor, and store data, while a trigger laptop sends precise 1-second intervals. Trigger devices/flows are in orange; data acquisition in blue.

Experiment 2 Dual-Musician and Audience Neuroimaging during Live Duet Performance

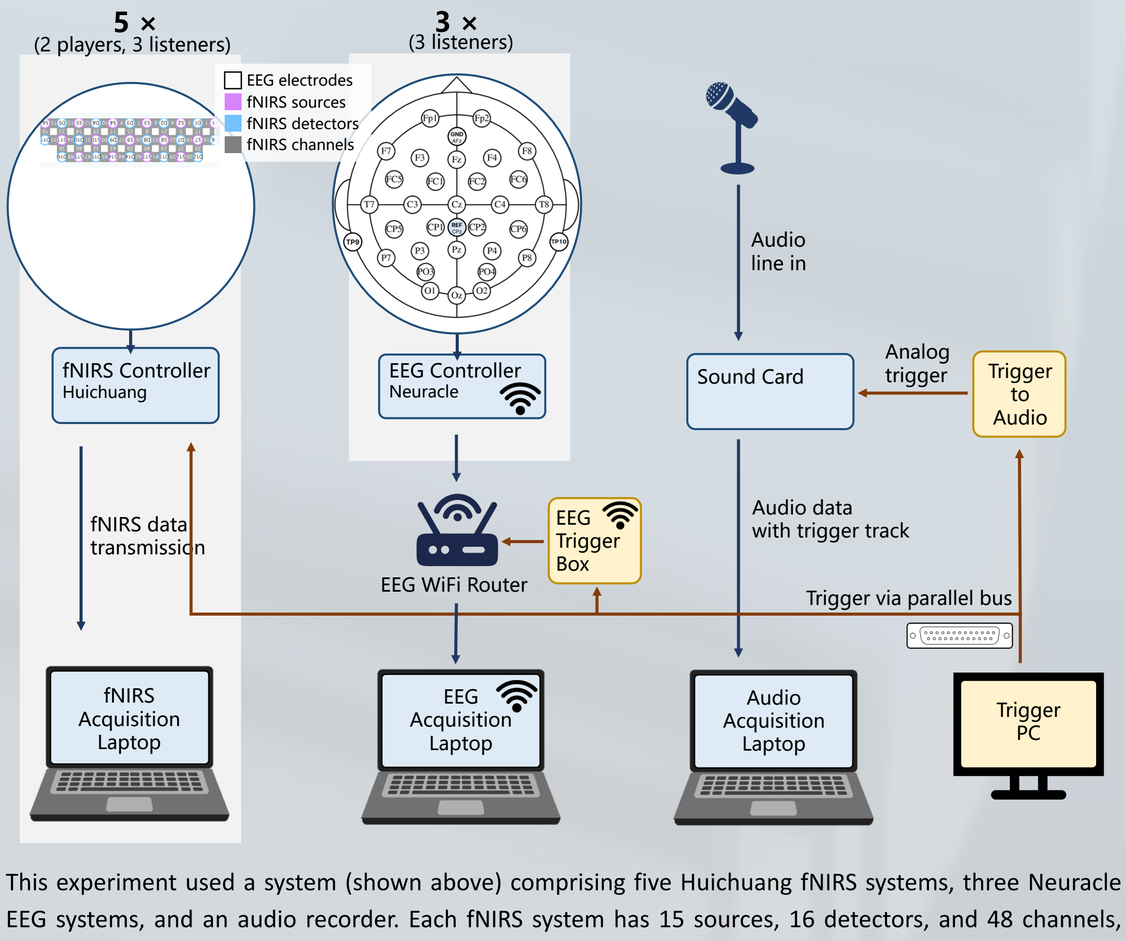
In Experiment 2, brain responses were recorded using two fNIRS systems from both a pianist and a cellist as they were performing a duet on stage. Simultaneously, the brain activity of six audience members was recorded—3 using portable EEG systems and 3 using fNIRS systems — all synchronized with the recording of the musicians.

A mini concert featuring a pianist and cellist duet was held at Tsinghua University. A photo of the two performers with six audience members is shown below. The audience consisted of university students, around 22 years old, who share a love for music.

This concert featured a captivating selection of six classical masterpieces, highlighting the emotive power of works by Beethoven, Saint-Saëns, Dvořák, Popper, Morricone, and Puccini, as shown below.

1. Ludwig van Beethoven
   7 Variationen über das Thema "Bei Männern, welche Liebe fühlen"
   from the opera *Die Zauberflöte* by W. A. Mozart
2. Camille Saint-Saëns
   The Swan
3. Antonín Dvořák
   "Goin' Home"
   from *Symphony No. 9* (*From the New World*)
4. David Popper
   Polonaise de Concert, Op. 14
5. Ennio Morricone
   Cinema Paradiso
6. Giacomo Puccini
   Nessun Dorma

Experiment Setup



This experiment used a system (shown above) comprising five Huichuang fNIRS systems, three Neuracle EEG systems, and an audio recorder. Each fNIRS system has 15 sources, 16 detectors, and 48 channels, while each EEG system has 32+2 electrodes. A Wi-Fi router synchronized data across the EEG systems and trigger signals, enabling data reception on a single acquisition laptop. A trigger PC sent triggers every second via the parallel port. Trigger devices and data flows are marked in orange, while data acquisition devices and flows are in blue.

Results Brain Activities during Performance of *Goin' Home* in Experiment 2

Visualization and evaluation of brain activity data during Experiment 2 with the music piece *Goin' Home*. The top section displays the frequency spectrum and waveform of the recorded music piece, with the full track accessible via the QR code on this poster. The heat maps illustrate the spatial distribution of cerebral activation over time, as captured by fNIRS for the cellist, pianist, and three listeners. The HbO concentrations across 48 channels were plotted at 30-second intervals, with each subplot is oriented with the head direction facing upward.

These experiments demonstrate the feasibility of simultaneously studying neural responses in both performers and listeners during music creation and perception in a natural, dynamic setting. By bridging the gap between lab-based and real-world music research, we aim to deepen our understanding of music's impact on human cognition and social interaction.

view media

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