# Interpersonal Resonance: Developing Interpersonal Biofeedback for the Promotion of Empathy and Social Entrainment

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**Abstract.** We propose an interpersonal biofeedback technology which uses music-like stimuli to convey a user's physiological information to another observer. It is argued that this interpersonal biofeedback may facilitate empathy and interpersonal entrainment. We argue that music is an optimal carrier for biofeedback because it naturally regulates psychophysiology, is cross-modally associated with emotion, and can be attended to peripherally. We propose a research study to investigate the effects of interpersonal biofeedback on emotional mindreading.

**Keywords:** Interpersonal Synchrony · Biofeedback · Empathy · Entrainment

## 1 Intro

How do humans understand each other? Undoubtedly, this process requires a great deal of unconscious expression and processing of nonverbal cues: people unconsciously express emotions through actions and expressions , and mirror and entrain with others to establish shared psychophysical context [1]. They also attend to these nonverbal cues use them to make cognitive inferences about others' mental states [2]. These two processes together contribute to empathy, the ability to generate an understanding of the meaning and intent behind another person's actions. What if technology could facilitate this process in computer-mediated interaction? In this paper we outline the development of an interpersonal biofeedback system designed to facilitate mental inference between users. We explore theoretical and practical concerns in the development of such an technology, and propose applications in psychological research.

## 2 Designing Interpersonal Biofeedback

Traditionally, biofeedback involves presenting a user with data about their own biological processes. Biofeedback training helps users better understand, predict, or control those processes. However, little research has been done on exposing users to an-

other person's biosignals, which is our primary concern. A single study serves as evidence to the plausibility of this approach. Researchers showed that listening to another person's heartbeat while conversing has been shown to produce feelings of intimacy similar to eye contact [3]. We hypothesize that an interpersonal biofeedback technology may be able promote empathy through two distinct but compatible mechanisms of action: 1) by facilitating psychophysiological entrainment between the user and the target (entrainment approach), and 2) by providing users with relevant information for making mental inference (social information-processing approach). In this paper, we propose an interpersonal biofeedback technology where users are given perceptual access to another person's nonverbal signals as quasi-musical auditory stimuli. In order to maximize the effectiveness of the biofeedback intervention, the system will be designed to optimize both possible mechanisms of action. Each foregrounds different considerations which inform the major decisions in the design of a biofeedback system: appropriate selection of signals to encode (the message), and the method of encoding (the medium).

### 2.1 Interpersonal synchrony

People tend to unconsciously mirror, and fall into rhythms with other people, especially when performing similar tasks. Interpersonal synchrony researchers have studied emergent synchrony in pairs and groups of interacting participants. Researchers have found that overt motor behaviour such as rocking [4], tapping [5], speaking [6], and posturing [7] entrain between interacting participants. These synchronization processes have implications for social cognition. When pairs and groups of interacting people become entrained, they may find each other easier to understand and cooperate with. Indeed, researchers have found that induced or incidental motoric entrainment has positive effects on affiliation [8], empathy [9], cooperation [10], and altruism [11, 12]. Deficits in the ability to entrain with a partner have been implicated in social disorders such as Autism Spectrum Disorder [13].

More covert or difficult-to-perceive phenomena such as breathing [14], heart rate [15], skin conductance [16], and EEG activity [17] also show entrainment effects. But the causal role of these entrainment processes is not known. These covert synchrony processes have proven more difficult to study due to the difficulty of directly manipulating physiological or neurological synchrony. Thus research on covert interpersonal synchrony has been limited to correlational and observational study. So while researchers have been able show that entrainment correlates with feelings of intimacy [18], they have not been able to manipulate physiological synchrony directly in order to attribute to it a causal role in social cognition. Fortunately, many of the processes which show entrainment effects between people also show entrainment effects to repetitive environmental stimuli. The physiological rhythms of heart rate [19, 20], breathing [21], brainwaves [22], and motoric behaviour (e.g. dancing, foot tapping) [23] all show entrainment to both social and repetitive sensory stimuli (stimuli such as flashing lights, repetitive sounds (including music) and tactile sensations [24]). This suggests that an interpersonal biofeedback system which represents these biorhythms as entrainment-ready repetitive stimuli may allow us experimentally manipulate physiological synchrony, and consequently allow us to explore physiological synchrony's causal role in social cognition.

### 2.2 Social Information Processing

Given access to informative cues about another person's mental state, users should be be able to improve their ability to make mental inferences, regardless of whether they experience physiological synchrony with the target. Learning and conditioning research shows that organisms readily learn and use 1) stable, 2) informative, and 3) relevant stimulus pairings [25] in problem-solving contexts. Accordingly, for users to make effective use of the interpersonal biofeedback system, this research suggests that encoded cues should 1) reliably and 2) informatively covary with mental states, and should be 3) non-redundant, and this difficult to perceive under normal circumstances. Cues such as facial expressions, vocal prosody, and body language covary with mental states [26–28] (indeed they likely serve a communicative function [29]). But, while informative, these overt expressions of emotion are so easy to perceive in normal circumstances that biofeedback information about them would be redundant. In contrast, physiological signals like heartbeat, breathing, skin conductance also covary with mental states [30], but these are difficult to perceive under normal circumstances. They are therefore good candidates for inclusion in the biofeedback system.

### 2.3 Interim Summary

Both interpersonal synchrony research and the social-information processing approach suggest that making physiological signals perceptually available to users may improve empathy. In addition to the content of the biofeedback system, it is important to consider the medium (i.e. the encoding scheme) used to present the data to the user. We propose using quasi-musical auditory stimuli to convey this information.

### 2.4 Musical Auditory Biofeedback

Music is an ideal carrier for interpersonal biofeedback data. It is one of the most researched targets for environmental entrainment of both motor action and biorhythms [31], and it automatically regulates psychophysiology [32]. Thus, music shows promise as an entrainment-ready stimulus for facilitating interpersonal synchrony.

Humans have highly sophisticated musical-cognitive abilities, and can process and entrain to many layers of complex sensation. Hence, use of musical/auditory signaling will allow for the simultaneous encoding of multiple channels of biofeedback data, into a stimulus which is easily discriminable, and readily parsed. More generally, auditory stimuli will not take up attention or space in the visual domain, ensuring that focal tasks requiring visual attention will be minimally hindered by the use of biofeedback.

Finally, music seems to have an intuitive relationship to the communication of mental states. People speak cross-culturally about the emotions or mental states conveyed by music [33], and musical biofeedback has demonstrated efficacy as a carrier for biofeedback information in individuals [34]. Music is therefore an intuitive choice for representing psychophysical states in interpersonal biofeedback. Researchers have

also found that certain musical parameters are cross-modally congruent with patterns of motion of on-screen objects and certain emotional states [35]. We can make use of these pairings in designing our biofeedback technology to ensure that the stimulus decoding is as intuitive as possible.

## 3 Proposed Biofeedback System

We propose an interpersonal biofeedback technology which conveys a user's physiological information to another observer in the form of quasi-musical stimuli. It is hypothesized that by increasing users' perceptual access to relevant physiological signals in another person, we will be able to enhance their ability to discern the other person's mental state. This technology will take advantage of two potentially independent, but mutually compatible processes in empathy. First, if the encoded physiological signals are indicative of the user's mental state, then learning & conditioning research suggests that an observer will be able to learn to use the biofeedback signal to make correct mental inferences. Second, interpersonal synchrony research suggests that the increased perceptual access will facilitate entrainment of physiological processes between the pairs of users, and that this entrainment will facilitate correct mental inference. We hypothesize that increasing perceptual access to physiological processes such as breathing, heart rate, and skin conductance will promote correct inferences through one or both of these processes. We will then be able to test if degree of entrainment predicts accuracy of mental inference judgements.

## 4 Research Utility

### 4.1 Current Research

Our current research is making use of the biofeedback system as follows:

Phase 1: Participants' psychophysiology (breathing, heart-rate & skin conductance) is recorded while they view a series of emotional video clips. This is similar to manipulations by Davis et al. [36, 37]). All participants are video recorded throughout. After each emotional video clip, participants log their emotional experience using a questionnaire and journal.

Phase 2: New participants watch all the emotional video clips shown to participants in phase 1. They are then shown video recordings of participants from phase 1. These video recordings show the target (with no sound) watching one of the emotional video clips. The content on the screen is hidden from view, however, so phase-2 participants cannot tell directly which clip the participant in the recording is being shown. Some participants hear the target's biofeedback through headphones, others receive none or sham (biofeedback from a different target). Phase-2 participants' physiology is recorded throughout. After watching each video recording, participants report on the emotions experienced by the subject in the video, and try to guess which video the subject was watching. We then examine 1) if hearing biofeedback from the target improves the accuracy of emotional judgements, 2) if participants show patterns of

physiological synchrony with the target (and/or with the sham biofeedback), and 3) if such synchrony improves performance on emotional empathy.

Two important limitations of this research are as follows: 1) Effective use of the interpersonal biofeedback system might require extended training which is not included in this research paradigm, 2) interesting effects of the system might be found in contexts where two people use the system simultaneously. In this situation, the mutual entrainment and interpersonal dynamics of experiencing a real interaction partner's biorhythms may more effectively engage social-cognitive processes and intuitive learning of the encoding system. Future research should investigate these exciting prospects.

## 5 Conclusion

Due to the limitations of previous research on covert interpersonal synchrony, researchers have not been able to assess the causal role of covert synchrony in social-cognitive processes such as empathy and trust. Although behavioural research has supported the hypothesis that embodied simulation of another person aids in empathy and promotes intimacy, the covert synchrony research has not been able to follow suit. Skepticism about the causal role of covert synchrony in producing these effects is warranted, as there are no clear mechanism for people to synchronize their biorhythms. The approach outlined here provides a means for clarifying this dispute. If the entrainment intervention is effective in manipulating interpersonal synchrony, then researchers will be able to examine the effects of covert synchrony much more directly. If successful manipulations of synchrony show social-cognitive effects on empathy/empathy, then this will be strong support for the causal role of covert synchrony in social cognition. On the contrary, if increases in covert synchrony are not associated with these effects, it would support a more cognitive theory of empathy which ascribes greater importance to attention to social cues and mental inference. Each of these results would be valuable. Significant or null findings resulting from this research could inform the direction of future social-cognitive theory and research programs. Whether the primary mechanism is entrainment, or attention to social cues, the interpersonal biofeedback methodology developed here may contribute to the development of interventions and technologies for enhancing social cognition in broader contexts.

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