ChatGPT

Facilitating Group Phase Synchronization through Shared Feedback

Introduction

In group meditation, education, and team-building contexts, people often seek a harmonious *"in sync"* state – a collective rhythm or mindset that enhances cohesion and performance. Modern neuroscience confirms that humans can literally synchronize their physiological and neural rhythms with others during social interaction [1] [2]. This report explores how shared visual or auditory feedback (for example, a rotating torus visualization or ambient soundscape) might actively *facilitate* such phase synchronization in groups. We review academic findings on interpersonal synchrony (brainwave and body rhythms aligning across people), survey technologies for multi-user biofeedback and "social neurofeedback," and propose design concepts that use shared feedback to encourage group "phase-locking." Key challenges and opportunities in implementing these multi-user feedback systems are also discussed.

The Science of Interpersonal Synchrony

Behavioral, Physiological, and Neural Synchronization

Humans have a natural propensity to sync their behavior and biology with others. Synchronized **movement** – such as walking in step or dancing in unison – builds trust, bonding, and cooperation [3]. For example, dancing in sync made participants feel closer emotionally than dancing out of sync, and people who chanted together rhythmically were later more cooperative [3]. Beyond behavior, **physiological** processes can align: when people drum together, their heart rates tend to synchronize; the heartbeats of therapists and clients or long-term partners can literally fall into step during good interaction; even breathing rates and skin conductance may line up among people who share an experience [1]. This mind-body mirroring underlies the sense of *connection* we feel in a group.

In the last two decades, neuroscience tools have enabled direct study of **inter-brain synchrony** – the alignment of brainwave patterns across individuals. Using hyperscanning (simultaneous recording of multiple brains), researchers have observed that people's brain signals can oscillate in unison during social engagement [2]. Multiple studies confirm that when individuals interact (e.g. making eye contact, conversing, making music), their brainwaves show significant synchronization at various frequencies [2]. On EEG readouts of two people in sync, the waveforms rise and fall together – sometimes even in mirror image, where one person's brainwave goes up as the other's goes down, a complementary form of synchrony [2]. Notably, merely exchanging a smile or gaze can spontaneously synchronize two brains. In one experiment, pairs of volunteers sitting face-to-face achieved *instantaneous* brainwave alignment the moment they made eye contact – with a shared smile boosting the synchrony even further [4]. Such findings underscore that social signals and shared attention can rapidly phase-lock neural activity across individuals.

This inter-brain coupling is not just a curiosity; it correlates with social outcomes. Higher brainwave synchrony in pairs and teams has been linked to greater rapport, empathy, and even better collective performance on tasks [5] [3]. For instance, speakers and listeners develop synchronized EEG oscillations during storytelling – their brains entrain to the same rhythms when a narrative is shared [6]. In educational settings, teacher-student brain synchrony has been associated with improved learning engagement, and in teamwork scenarios, teams with more synchronized brain activity tend to coordinate and perform better. Neuroscientists theorize that inter-brain synchrony reflects aligned attention and shared understanding ("on the same wavelength" both figuratively and literally), supporting communication and group cohesion.

However, emerging evidence also urges nuance. Synchronizing with others might carry a *trade-off* for one's internal rhythms. A recent hyperscanning study of paired breathing found that when two people deliberately synchronized their breathing, not only did their heartbeats sync up in-phase across individuals, but each person's heart and breath fell *out* of their usual phase alignment [7]. In other words, aligning to someone else's rhythm induced a *decoupling* between that person's own heart and respiratory cycles [7]. This suggests that interpersonal synchrony can come at the cost of altering one's internal physiological balance. Designers of group synchronization exercises should be mindful of such effects – for example, intense focus on matching a group rhythm might momentarily weaken one's self-regulatory rhythms. Further research is needed on the long-term effects, but this finding highlights that "phase locking" with others engages complex physiological dynamics.

Multi-User Neurophysiological Alignment

To actively encourage brain/body synchrony, researchers have begun developing **social neurofeedback** techniques. Traditional biofeedback trains an individual to adjust their autonomic signals (like heart rate or brainwaves) by watching or hearing real-time feedback from those signals. Social or multi-user neurofeedback extends this idea to *shared* signals: it provides a group with feedback derived from their *collective* physiological state or the *synchrony* between individuals [8]. The goal is to make otherwise invisible group dynamics tangible, so that users can *together* learn to achieve a desired collective state (e.g. calm, focus, or unity).

One pioneering example is **interpersonal EEG neurofeedback**. *Chen et al.* (2021) exposed pairs of people to real-time feedback of their **inter-brain EEG synchrony** during face-to-face interaction [9]. Remarkably, they found that this feedback – essentially showing two people when their brainwaves were "in sync" – could increase their feeling of connectedness [9]. Building on this, the authors developed **Hybrid Harmony**, an open-source multi-person Brain-Computer Interface that records brain signals from multiple users and computes measures of synchrony on the fly [8]. The system feeds back those synchrony levels as shared audiovisual displays, effectively turning *hyperscanning* (multi-brain recording) into *hyperfeedback* (multi-brain training). In tests with 236 participant pairs, the inter-brain synchrony metrics produced by this system correlated strongly with social closeness and certain personality traits of the pairs [10]. This suggests that the feedback reflected meaningful social dynamics, and it raises the possibility that *training* groups to attain higher synchrony could enhance empathy or cooperation [8].

Physiological (non-EEG) synchrony feedback has likewise been explored. Breathing is a prime candidate, as it's easily self-regulated and contagious. A 2025 study by *Konvalinka et al.* asked pairs to synchronize their breathing with each other via visual biofeedback, and found that doing so reliably brought their heart rhythms into sync as well [11]. This demonstrates that a simple shared visual cue (like a breathing pacer displaying each other's breaths) can induce measurable physiological coupling between people. Heart rate is another accessible signal: groups tend to synchronize heart rhythms when experiencing the same stimuli or emotions, and intentional techniques like *paced breathing* can drive heart rate variability (HRV) into a coherent pattern across individuals. These mechanisms form the basis of many group relaxation or meditation practices (e.g. everyone breathing together to a count).

In summary, a growing body of research shows that when people attend to common stimuli or to each other, their internal rhythms can align. Moreover, giving people *real-time feedback* about those rhythms – especially shared or comparative feedback – enables them to deliberately tune themselves towards synchrony. This lays the scientific groundwork for interactive systems that foster group phase synchronization as a means to improve social connection, collective calm, or teamwork efficiency.

Technologies for Group Biofeedback and Social Neurofeedback

Multi-user biofeedback systems have evolved from both academic research and artistic experimentation. Table 1 summarizes representative examples of platforms (academic, artistic, and commercial) that enable real-time shared feedback based on group physiology or brain activity:

System / Project (Year)	**Modality**	**Feedback Medium**	**Purpose / Outcome**
Hybrid Harmony (Chen et al., 2021) [8] [12]	EEG hyperscanning (2+ users)	Visual: avatars & distance, light; Audio: modulated music	Research tool for *inter-brain neurofeedback*. Calculates EEG synchrony (phase locking, coherence, etc.) between people and feeds it back in real time. For example, higher synchrony makes two on-screen avatar heads move closer together, and produces more pleasant, consonant musical chords, whereas low synchrony leads to dissonant sound [13]. Used in an interactive art installation "Mutual Wave Machine" to let pairs *see* and *hear* when their brainwaves literally align [14] [12]. Aimed at enhancing interpersonal connectedness and studying social interaction.

System / Project (Year)	**Modality**	**Feedback Medium**	**Purpose / Outcome**
“Pulse” Installation (Jevbratt et al., 2006) [15] [16]	Heart rate (group)	Audio: rhythmic beats; Visual: abstract patterns	An early *collective biofeedback* art project intending to **synchronize participants’ heartbeats** [15]. Each person’s pulse (BPM) was measured and fed into a shared soundscape. The system played a drum-like tone at the *average* heart rate of the group, effectively creating a group heartbeat sound [16]. Participants would subconsciously adjust their own heart rhythms toward the common beat. Overlaid heart rhythms also generated moiré-like visual patterns, revealing when individual heart rates converged. *Pulse* provided an immersive experience of “forming one body” via synchronized hearts.
Heartsync (Basilashvili, 2024) [17] [18]	Heart rate (group)	Audio: ambient soundscape; Visual: floor projection	A recent interactive art installation that uses heart rate sensors and generative media to **unite a group’s heart rhythms**. Participants sit together and are guided through breathing exercises to slow their pulses, while listening to calming soundscapes [17]. As they relax and their heartbeats begin to align, their individual rhythms “merge and intertwine” into shared visual patterns projected on the floor [18]. The synchronized heart visuals and sounds symbolize deep human connection and oneness. *Heartsync* demonstrates a design where group biofeedback is used for a communal, empathetic experience.

System / Project (Year)	**Modality**	**Feedback Medium**	**Purpose / Outcome**
Global Coherence App (HeartMath Institute, 2015) [19]	Heart rate variability (HRV) via sensor or phone camera (mass participation)	Visual: coherence score dashboards (mobile/ online)	A commercial platform aimed at achieving global group **heart coherence**. Individuals use personal HRV sensors (ear clips or smartwatches) and the app computes their heart rhythm coherence (a measure of smooth, sine-wave-like heart rate patterns). Uniquely, users can join groups or "rooms" in the app to see a *collective coherence score* updated in real time [19]. For example, a meditation group can watch their group's coherence level rise as everyone breathes calmly together. The Global Coherence Initiative uses this system to connect thousands of people in synchronized meditations, under the premise that aligned heart energy can have positive social effects. It's an example of a **commercial multi-user biofeedback** tool for enhancing collective emotional state.
Multi-user Meditation with Muse/ Emotiv (2020s)	EEG (consumer headsets)	Audio: shared sound cues; Visual: group metrics (prototype apps)	While devices like *Muse 2* and *Emotiv Insight* are primarily single-user neurofeedback headsets, they have been used in group settings. Muse's meditation app, for instance, can aggregate data from several users (e.g. in group meditation classes) to display a *group calm score*. Experimental apps have linked multiple Emotiv EEGs to generate shared metrics like "team focus." These systems remain emerging, but they indicate a trend toward **group neurofeedback for wellness and teamwork**. For example, a team-building exercise might have all members wear EEG headbands and attempt to collectively lower their average stress level, with soothing sounds playing only when the group's brain signals indicate a relaxed state.

Table 1: Examples of multi-user biofeedback and social neurofeedback systems, spanning research, art, and commercial domains.

These examples illustrate the diverse approaches to shared neurophysiological feedback: from academic EEG-based systems that quantify subtle brain synchrony, to artistic installations that use simple heart/ breath rhythms to create a feeling of unity, to consumer tools enabling groups to practice coherence and mindfulness together. A common thread is the *real-time* nature of the feedback – participants immediately see or hear changes in the collective state – and the goal of guiding the group toward a beneficial synchronized pattern (be it coherent heart rhythms or synchronized brainwaves).

Notably, the **feedback modalities** are often visual and auditory, chosen for intuitiveness and impact. Visual metaphors like merging avatar heads, overlapping wave patterns, or unified glowing shapes help users *perceive* the abstract concept of synchrony [14] [20]. Auditory feedback is powerful for rhythm: a shared beat or evolving musical harmony can directly entrain participants' timing [21] [13]. Many systems combine modalities for a richer experience (e.g. synchronized light and sound). The design challenge is to represent group synchrony in a way that is *both* accurate (reflecting the actual physiology) and *actionable* (users intuit how to respond to improve synchrony). The projects above have tried various creative mappings – distance between graphics, brightness, drum tempo, musical consonance – to close the feedback loop between the group's internal rhythms and the external sensory world.

Design Concepts for Shared "Phase-Lock" Feedback

Envisioning future applications, one intriguing concept is to use a **rotating torus visualization** coupled with ambient sound to encourage group phase synchronization. A torus (doughnut shape) is topologically well-suited to represent cyclical, periodic processes – it loops around seamlessly, echoing how brainwaves, breath, or heart rhythms cycle continuously [22]. Researchers have even proposed a "space-time torus" model to visualize complex brain oscillations, because the torus's continuous circular form naturally depicts rhythmic patterns and phase relationships [22]. Building on this idea, a multi-user system could render a dynamic torus whose stability or rotation is governed by the *group's collective rhythms*.

For example, imagine a virtual torus floating at the center of a meditation circle (either on a shared screen/ AR display, or in each user's VR headset view). The torus might gently rotate in sync with the dominant brainwave frequency or breathing rate of the group. If all participants are *in phase* – breathing together or producing brainwaves at the same frequency with consistent phase relationships – the torus remains stable, symmetric, and smoothly rotating. However, if someone falls out of sync (their phase deviates), the torus could start to wobble, its rotation could slow or become uneven, or its surface pattern might become erratic. This provides immediate visual feedback: the group will literally see the torus *destabilize* when they are not aligned, and conversely see it *harmonize* when they re-align their rhythms. The torus could also change color or brightness to indicate the degree of phase synchrony (e.g. glowing uniformly when coherence is high, and fragmenting into multiple colors when each person is "on their own rhythm").

Coupled with the visual, an **ambient sound environment** would reinforce the feedback. Building on prior sonification approaches, one design is to use musical harmony as an analog for synchrony. For instance, each person's brainwave or heartbeat could be mapped to a tone in a chord. When the group is in sync, the tones align into a harmonious chord (or a pleasing resonant drone). If they fall out of sync, the chord becomes dissonant or beats (pulsates) unpleasantly. *Chen et al.* demonstrated a version of this: in their Hybrid Harmony system they modulated the volume of musical pitches so that *greater* inter-brain connectivity yielded stable, pleasant chords, whereas lower synchrony produced tension and dissonance [13]. Expanding that concept, a group phase-lock system could play a continuous ambient track (like a drone or a bell sound) whose timbre depends on synchrony – perhaps a smooth, steady tone when everyone is aligned, versus a fluctuating or harsh noise when alignment breaks. Another layer could be rhythmic audio cues: a shared binaural beat or drum that all users hear and try to match with their breathing or mental focus, effectively acting as an external pacer to pull them into phase with each other.

Overall, the design philosophy is to create a **closed-loop**: the group's physiological signals drive a unifying audio-visual *environment*, and in turn that environment guides the individuals toward the desired state. The rotating torus is a metaphor for the *collective* rhythm – when it "locks" into a smooth rotation, the group knows they have achieved phase-lock. The ambient sound provides both motivation (rewarding harmony) and an intuitive cue for timing (a beat to align with). Users don't have to look at each other or consciously calculate their synchrony; they simply tune into the shared sensory cues. Over time, they may internalize the group rhythm, entering a state of mutual entrainment almost like musicians jamming in sync.

Such designs could be applied in various settings. In **mindfulness and meditation groups**, a shared visual like the torus could serve as a focal point for attention, while the biofeedback ensures everyone's mind-body slows into coherence together. In **educational settings**, a classroom could use a simplified version (e.g. a collective breathing orb on screen that only floats steadily when the whole class slows their breath) to calm students and build group focus. For **team-building or therapy**, these tools might cultivate empathy – participants learn to adjust their own rhythm not just for themselves but for the collective good (e.g. a family in therapy visually *sees* their emotional rhythms syncing as they practice breathing exercises together). Even in remote settings, networked apps could use shared ambient audio and synchronized visuals (via personal sensors) to give dispersed teams a sense of physiological togetherness – an antidote to the disconnection often felt in telepresence.

Challenges and Opportunities

Implementing multi-user phase synchronization feedback involves technical and human-factor challenges, but also offers rich opportunities for innovation:

- **Data Integration and Latency:** Combining signals from multiple users in real time is non-trivial. EEG signals in particular are noisy and require filtering, artifact removal, and perhaps cloud computation to extract synchrony metrics. Ensuring that feedback is delivered with minimal lag is crucial – if the torus or sound reacts seconds too late, users may struggle to link their actions to outcomes. Recent advances in wireless wearables and software like Lab Streaming Layer (LSL) can help synchronize data streams with millisecond accuracy [23]. Still, a robust system must handle dropouts (e.g. one person's sensor temporarily failing) gracefully, perhaps by smoothing or imputing the group signal.

- **Measurement of "Group Phase":** Defining a single measure of synchrony for a group (more than two people) is complex. Do we average all pairwise phase-lock values? Do we align everyone to a common reference? Different metrics (phase locking value, coherence, cross-correlation, etc.) might yield different notions of synchrony [24] [25]. There is an opportunity for research to determine which synchrony metrics best correspond to subjective feelings of unity or to desired outcomes like creativity and calmness [26] [27]. The system might even allow dynamic switching of metrics: for example, encouraging in-phase *breathing* vs. in-phase *alpha waves* might be two different modes, each useful in different contexts (relaxation vs. focused collaboration). Designers must also decide how to weight individual contributions – e.g. if one person is very out of sync, does the whole group feedback deteriorate, or can the system down-weight outliers to maintain a rewarding experience? Finding the right balance ensures the feedback neither unfairly punishes the group for one person's difficulty nor masks genuine lack of cohesion.

- **User Perception and Agency:** A critical human factor is how users perceive and respond to the feedback. If the feedback is too abstract or confusing (e.g. a complex torus pattern with no clear meaning), participants might ignore it or feel frustrated. Simplicity and intuitiveness are key: users should quickly grasp that "when we do *X* (breathe slower, clear the mind, connect with others) the environment becomes calmer and more unified." There is also a risk of *performance anxiety* – if people feel pressured to "get it right" to stabilize the torus, it could paradoxically increase stress and hinder synchrony. Gentle, game-like elements (e.g. treating it as a collective challenge rather than a test) and careful facilitation can mitigate this. On the flip side, success can be self-reinforcing: achieving a synchronized state often *feels* good – users report a sense of "flow" or social bonding when it clicks [3]. The feedback can capitalize on that intrinsic reward (e.g. the pleasant music when in sync [12]) to positively reinforce the group. Designing for a **positive feedback loop** (literally and figuratively) is a major opportunity – once users get a taste of the harmonious state, they may become more adept at returning to it even without the system, potentially improving group dynamics in everyday life.

- **Adaptability and Personalization:** Groups are not homogeneous. Different contexts may demand different synchronization targets. For instance, in a brainstorming session, perhaps *moderate* arousal and synchrony is ideal (too much calm could dampen creativity), whereas in a meditation retreat, deep low-frequency synchrony is the goal. The system could adapt the feedback parameters (target frequency, threshold for "locked" state) to the situation. Furthermore, individuals have unique baseline rhythms – one person's resting heart rate or preferred breathing tempo might be higher than another's. Rigidly forcing everyone to one frequency could alienate some members. A more adaptive strategy is to gradually guide the group toward convergence, or find a middle ground. **Personalization** features (like each user's data is normalized or the visual encodes individual contributions subtly) might help everyone feel included. There's an opportunity for AI-assisted tuning: algorithms could detect which participant is struggling to sync and perhaps alter the feedback to gently bring them along (for example, slightly emphasize that person's rhythm in the sound mix so others adjust to them). Ensuring the system is inclusive and adaptive will improve its efficacy across different group compositions and objectives.

- **Ethical and Privacy Considerations:** Biosignals can be sensitive data. A group feedback tool inherently shares some personal physiological information with others (even if abstracted). Participants must consent and feel safe – for instance, someone may not want others to know that *their* heart is racing or *their* mind wandered (as inferred from the feedback). Designers should buffer individual privacy by focusing feedback on the aggregate or the synchrony, rather than exposing raw signals of any one person. Fortunately, many synchrony metrics are relational and do not single out individuals. Still, transparency about what data is used and how is important. Another ethical aspect is avoiding *enforced* conformity – the aim is to offer a voluntary pathway to synchrony, not coerce individuals to "merge" at all costs. Users should be able to opt out or take a break without feeling they are letting the group down. Managed well, the technology can foster a spirit of cooperative engagement rather than pressure to assimilate.

Despite these challenges, the **opportunities** are exciting. Group phase-lock feedback could unlock new levels of *collective coherence* in various domains. Teams that regularly "tune" their brainwaves together might enter a state of enhanced mutual understanding, potentially shortening the time needed to reach consensus or coordinate actions. Therapeutic groups (from anxiety support classes to corporate mindfulness programs) might find that shared biofeedback accelerates trust and emotional resonance among participants. Educators could incorporate brief synchrony exercises at the start of classes to prime students for better social and cognitive engagement (some studies suggest that inter-brain synchrony between students predicts greater class cooperation and learning [28] [29]). On a more experimental edge, artists and performers could use these systems to include the *audience's* physiology as part of an artwork or concert – for example, a music performance that changes tempo based on how synchronized the crowd's heartbeats become, truly making the audience part of the instrument.

Finally, these technologies invite us to explore fundamental questions in social neuroscience: *causality*. Thus far, we know synchrony correlates with connection, but tools like hyperfeedback allow us to test if inducing synchrony *causes* greater empathy or cooperation [27] [30]. Early hints, like the Hybrid Harmony results, are promising – they indicate that feedback-driven synchrony is at least reflecting important social variables (e.g. low empathy individuals showed lower neurofeedback synchrony) [31] [32]. By iterating on design and research together, we could discover optimal "group brain tunes" for different outcomes (e.g. a pattern of alpha wave synchrony that maximizes creativity, or a breathing rhythm that maximizes collective calm).

Conclusion

Shared visuals and ambient sounds offer a powerful medium to facilitate **phase synchronization** in groups. From the gentle alignment of heartbeats in an art installation to the high-tech coupling of brain oscillations in a lab, we are learning to guide the ephemeral experience of *being in sync* into a reproducible, trainable phenomenon. A rotating torus that steadies only when minds and bodies unite, or a musical harmony that blossoms as a group finds its rhythm – these are no longer sci-fi metaphors but feasible design strategies grounded in emerging science. Implementing such systems will require careful attention to technical detail and human psychology, but the reward is compelling: deeper empathy, improved cooperation, and perhaps new collective mental states that we have only begun to tap into. The convergence of hyperscanning research, wearable sensors, and creative feedback design is opening the door for *social neurotechnology* that not only measures group synchrony, but actively *cultivates* it for the benefit of meditation circles, classrooms, teams, and communities. The age-old wisdom that "we are all connected" may soon be experienced not just spiritually but physiologically – with glowing toruses and harmonious soundscapes to light the way towards collective coherence.

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