

CardioCommXR: Training Empathy Through Gamified Emotional Regulation

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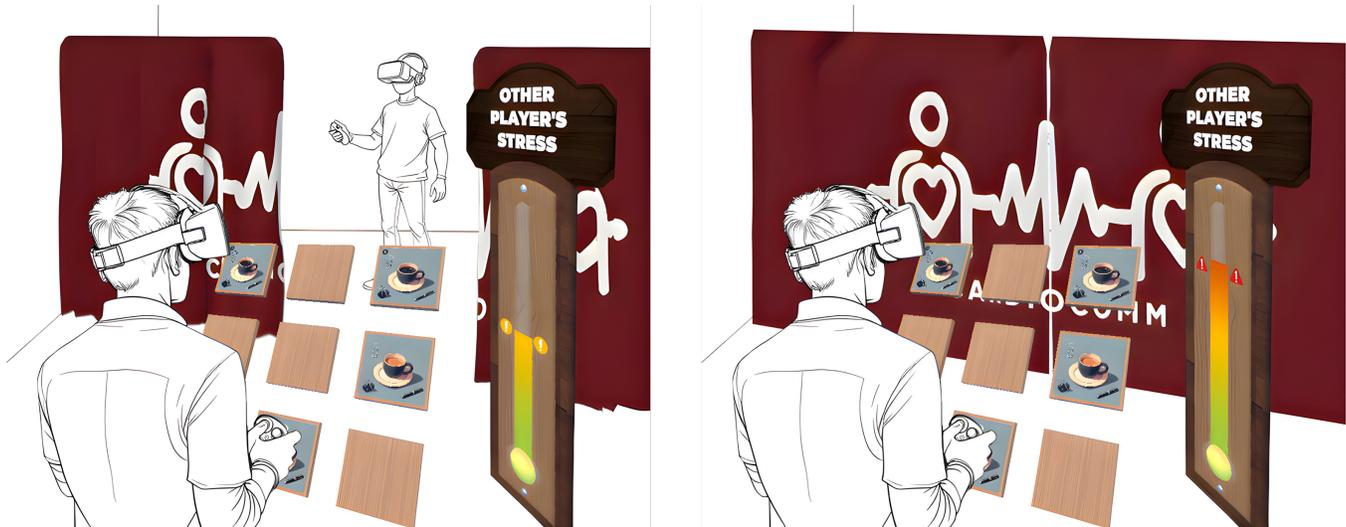


Figure 1: CardioCommXR's Mixed Reality interface with two states. Left: Players collaborate on a memory match game while monitoring partner's stress via virtual thermometer. Right: When partner's stress exceeds threshold (shown by elevated thermometer level), virtual curtain blocks communication until stress levels normalize.

ABSTRACT

Approaches to biofeedback-based empathy training often struggle to motivate participants to learn their partner's emotional cues. CardioComm is a Mixed-Reality collaborative game where communication is conditioned by players' cardiac activity. Players match images through verbal descriptions while monitoring their partner's stress via heart rate variability. When stress exceeds a threshold, visual and auditory communication is restricted between partners; creating consequences for poor interpersonal regulation. By making emotional awareness integral to gameplay success, CardioCommXR creates intrinsic motivation for learning emotional cues.

CCS CONCEPTS

• **Human-centered computing** → **Collaborative and social computing devices; Mixed / augmented reality.**

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CHI EA '25, April 26-May 1, 2025, Yokohama, Japan

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ACM ISBN 979-8-4007-1395-8/2025/04.

<https://doi.org/10.1145/3706599.3720319>

KEYWORDS

Physiological computing, empathy, biofeedback

ACM Reference Format:

Andreia Valente, and Mark Billingham. 2025. CardioCommXR: Training Empathy Through Gamified Emotional Regulation. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '25)*, April 26-May 1, 2025, Yokohama, Japan. ACM, New York, NY, USA, 4 pages. <https://doi.org/10.1145/3706599.3720319>

1 INTRODUCTION

In this research, we are developing a game that explores how biofeedback can be used to motivate players to learn about their partner's emotional state. Cognitive empathy is the ability to understand others' emotional states [1, 4]. It requires interpreting emotional cues across verbal, nonverbal, and paraverbal channels [20, 28], relying on attention to subtle signals within social contexts [13]. Developing cognitive empathy involves recognizing specific emotional markers, such as changes in voice pitch or facial expressions [15]. People with higher cognitive empathy show enhanced detection of emotional variations [11] and have a stronger foundation for adaptive social behavior and effective interpersonal regulation [5].

Barriers complicate the recognition of emotional cues, ranging from individual variation to cross-cultural differences [10]. Research shows an "in-group advantage" where people from different cultural backgrounds interpret emotions less accurately [17]. For instance, direct eye contact signaling engagement in Western cultures may be interpreted as confrontational in other cultures. The challenges in understanding emotions across different demographic backgrounds can reinforce social divides and promote stereotypes [8].

Prior research has explored biofeedback systems [25] that translate physiological signals into interpretable communication cues. This can facilitate a real-time understanding of communication impact while helping users recognize connections between physical reactions and emotional states. However, the implementation of these systems faces significant motivational barriers. Users may struggle to maintain consistent engagement with the tools because the development of emotional understanding skills requires sustained practice over time, and the benefits - such as improved relationships - typically emerge gradually [26]. Without clear reward structures or immediate feedback showing progress, participants might not invest sufficient effort in developing their interpersonal skills [12, 21].

2 RELATED WORK

In this section, we review previous research on biofeedback for Interpersonal Emotional Regulation (IER).

Prior research shows biofeedback systems support IER interactions through real-time physiological sensing. Early workplace systems like BioCrystal enabled colleagues to view emotional states via ambient displays [22], while MoodLight created awareness through shared physiological state lighting [27].

Recent systems explored shared biofeedback's impact on IER. For example, ExoPranayama supported group yoga regulation through breathing patterns [18], SpotlessMind enabled co-regulation via shared neurofeedback [9], and EmoEcho allowed participants to experience emotional states through interactive visualizations [19]. HeartLink broadcast biosignals between athletes and spectators [3], while BreathingFrame enabled non-verbal communication through respiration data [16].

Extended Reality (XR) provides advantages for biosignal sharing through immersive environments and spatial visualizations [7]. Studies show shared physiological data in XR enhances social presence - Dey et al. found increased physiological synchrony when users saw each other's heart rates [6]. Empathic AuRea [26] used electrocardiogram (ECG) visualizations to improve collaborative performance. Research on VR-based shared biofeedback demonstrated enhanced empathy through neurofeedback [14] and effectively evoked physiological synchrony between users [23].

While existing biofeedback systems provide tools for sensing emotional states, they lack intrinsic motivation for users to actually learn and respond to these cues. These systems assume that simply making physiological data available will naturally lead to increased empathy - an assumption that often fails in practice. CardioCommXR addresses this gap by integrating emotional awareness directly into gameplay success: players can only progress by actively learning to recognize and respond to their partner's emotional patterns.

Rather than treating emotional understanding as an optional overlay, our system creates genuine consequences and rewards tied to interpersonal emotional regulation skills, ensuring players are inherently motivated to develop deeper emotional awareness of their partners.

3 GAME DESIGN

This section describes CardioCommXR's three main components: (1) the Mixed Reality (MR) Setup, (2) the collaborative Memory Match gameplay, and (3) the physiological feedback system that influences player communication through stress monitoring.

3.1 Setup

CardioCommXR is a MR game that blends virtual elements with the physical environment through the Meta Quest 3 video passthrough head-mounted display. Players wear Virtual Reality (VR) headsets but remain aware of their surroundings, allowing them to see and communicate naturally with their co-located teammate. The game features its own sound effects, but players can easily talk outside of the game's audio.

3.2 Memory Match Game

CardioCommXR transforms the classic Memory Match game into a unique collaborative experience. Two players work together using speech to match corresponding images across two separate decks. Player One selects and describes an image from their deck, while Player Two must identify its match in their own deck based on the verbal description.

Like the traditional Memory Match game, both players need to remember the locations of previously revealed cards. If Player Two selects the correct match, both cards remain face-up, and Player One continues their turn. If Player Two selects an incorrect match, both cards are turned face-down, and Player Two becomes the describer, who will select and describe a new tile for Player One to match. Teams have 8 minutes to successfully match all 9 pairs of images to win the game. If time runs out before all matches are made, the team loses.

3.2.1 Images. Each game round randomly draws 1 set of 9 images from a collection of 40 image sets. An example of a set can be seen in Figure 2. Every set contains 9 variations of a base image generated using Deep AI Image Generator¹, each with intentionally subtle differences. These variations are meant to challenge players to communicate as precisely as possible to identify the correct matches based on specific details.

3.2.2 Motivation. Rather than establishing a hierarchical teaching relationship, the game promotes equal partnership through reciprocal communication. Both players alternate between describing and identifying images and must engage in iterative dialogue to establish a shared understanding of the images' spatial arrangement and visual details.

¹DeepAI Image Generator: <https://deepai.org/machine-learning-model/text2img>



Figure 2: Example of an image set used in the Memory Match game. Each set contains nine variations of a base image (in this case, a coffee cup) with subtle differences in details like cup position, steam patterns, and background elements, requiring precise verbal descriptions from players to identify correct matches.

3.3 Physiological Processing

Both players wear Polar H10 chest straps [24] monitoring cardiac activity. The device collects ECG data at 1000 Hz to analyze heart rate variability (HRV), in particular, Root Mean Square of the Successive Differences (RMSSD). HRV measures variations between heartbeats (RR intervals) and has an inverse relationship with stress levels - higher HRV indicates lower arousal, while lower HRV suggests higher arousal [2]. The game processes data using a sliding window that updates every second with ECG readings.

The MR environment includes a virtual thermometer providing players with real-time feedback on their partner's stress level. The virtual thermometer reflects stress levels by rank normalizing the partner's recent heart rate variability. It compares the variability of RR-intervals against all HRV measurements within the 3-minute window, ranking them from lowest to highest to determine stress level.

When the stress level of a player remains above the 75th percentile for 5 seconds, the game implements communication barriers: a virtual curtain blocks players' view of each other, and underwater sounds in headsets impede verbal communication. While tile selection remains possible, players must resort to guessing without clear communication. These barriers dissolve after both players maintain stress levels below the 75th percentile for 8 seconds.

3.3.1 Motivation. The stress-level thermometer provides real-time physiological feedback, allowing players to observe how their communication choices—whether it's speaking pace, reassurance techniques, detailed explanations, or error recovery—directly affect their partner's stress response. This insight enables them to adjust their communication style to help keep their partner calm and focused. The game's communication barriers are designed as a critical time penalty mechanism that can severely compromise the team's ability to complete the game within the time limit. When these barriers activate, players must shift their focus inward, taking personal responsibility for managing their own stress levels for the benefit of the team's performance.

Success requires players to prevent these communication barriers by monitoring their partner's stress levels. As players progress through multiple rounds, they must actively develop and implement calming strategies, whether through supportive communication or adjusting their approach to help their partner's stress stay within bounds. This makes stress regulation an essential component of the game's strategy, alongside the core matching mechanics.

4 CRITICAL REFLECTION

This section highlights three game design reflections: (1) facilitating authentic social-emotional learning, (2) integrating stress awareness into strategic gameplay, and (3) managing emotional transparency in biofeedback systems.

4.1 Realistic Social-Emotional Learning

CardioCommXR creates a unique environment for social-emotional learning by mirroring real-world collaborative scenarios where emotional states significantly impact team performance. Unlike games that focus solely on task completion, this design forces players to actively engage with the emotional dimension of teamwork. They must learn to balance their focus between the primary task (matching images) and the emotional state of their partnership, much like in professional environments where maintaining composure and supporting colleagues' emotional well-being is as crucial as completing the assigned work.

This design also provides a structured environment for developing explicit emotional communication skills. When players can see their partner's stress levels, they must learn to address emotional states professionally. This creates opportunities to practice different approaches to emotional support, from direct verbal acknowledgment to subtle adjustments in communication style. Such practice is valuable because many people find it challenging to discuss emotional states in professional settings, despite their impact on collaborative work.

4.2 Added Strategic Complexity

The display of stress levels adds a strategic layer to CardioCommXR that goes beyond the core matching mechanics. Players must constantly make tactical decisions about whether to prioritize speed versus accuracy in their descriptions, when to offer reassurance versus focusing on task completion and how to balance their own stress management with supporting their partner. This creates interesting decision points: a player might need to choose between quickly describing an image while their partner's stress is low, or taking time to compose a more precise description at the risk of stress building. When players notice their partner's stress rising, they must decide whether to acknowledge it directly or maintain their current approach to avoid drawing attention to it. These multiple layers of consideration transform what could be a simple matching game into an exercise in human interaction and emotional intelligence.

4.3 Forced Emotional Transparency in Biofeedback Systems

CardioCommXR's real-time physiological feedback creates complex interpersonal dynamics not present in typical collaborative environments. The system's transparency about players' stress levels introduces a layer of vulnerability that could amplify stress responses. The impact manifests in two connected ways: players may experience elevated stress due to the transparency of their emotional state to their teammate, while this stress is amplified by their knowledge that their anxiety can actively undermine the team's success.

While the inherent vulnerability of two-way interpersonal biofeedback systems cannot be eliminated, in the future we could shift the biofeedback design toward collective stress visualization. Instead of displaying individual stress levels, the system could present an aggregate measure of team stress. This would encourage both self-regulation and partner support as players work together to manage their combined stress levels without the added pressure of knowing their individual impact on the team's state.

5 CONCLUSIONS AND FUTURE WORK

CardioCommXR demonstrates an innovative approach to combining physiological awareness with collaborative gameplay. By integrating real-time biofeedback into a Memory Match game, we create opportunities for developing interpersonal communication and emotional regulation skills. The exposure of individual stress levels introduces inherent vulnerability, but it enables meaningful social-emotional learning and adds strategic depth through complex decision-making about communication timing, stress management, and partner support. Future work should explore alternative visualization approaches, such as collective stress measures, and investigate how different levels of interpersonal familiarity affect player responses to physiological sharing.

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