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Research Article/Editorial

Fostering Digital Empathy Through an Interactive Art Installation: A Cross-Disciplinary Study on Affective Computing and User Experience

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Abstract

While affective computing has made strides in recognizing human emotions, a significant gap remains in translating this recognition into tangible, shared experiences that foster digital empathy. Existing systems often lack a dynamic, reciprocal feedback loop, limiting their capacity to deepen socio-emotional connections in technology-mediated environments. This study employed a mixed-methods approach, centered on the design and evaluation of an interactive art installation named "Aura Connect." The system integrates real-time physiological data (Electrocardiogram - ECG and Galvanic Skin Response-GSR) from two users via bio-sensing technology. A custom algorithm translates the collected bio-data into a co-created, dynamic piece of generative art, visually representing the users' shared emotional state. The study involved 60 participants (30 pairs) who interacted with the installation, followed by quantitative data analysis using ANOVA and qualitative analysis of semi-structured interviews. The results demonstrate a statistically significant increase in perceived empathy and social connection ($p < 0.001$) for participants using the interactive installation compared to a control group viewing a static display. Three core themes emerged from the qualitative data: Embodied Connection, Shared Vulnerability, and Aesthetic Resonance, which were strongly correlated with quantitative metrics of user engagement and emotional valence. This research provides a novel, empirically-validated framework for designing systems that promote digital empathy. The findings suggest that integrating bio-feedback with generative art offers a powerful medium for making invisible emotional states visible and shareable, presenting significant implications for fields such as remote collaboration, mental health technology, and human-computer interaction design.

keywords: Digital Empathy, Affective Computing, Interactive Art, Bio-Sensing, Generative Art, User Experience

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1. Introduction

The proliferation of digital communication technologies has fundamentally reshaped human interaction, creating unprecedented opportunities for connection across geographical boundaries. However, these platforms often filter out the rich, non-verbal cues—such as subtle shifts in posture, tone of voice, and physiological arousal—that are foundational to empathetic understanding in face-to-face communication[1] . This "empathy gap" in digital spaces can lead to misunderstandings, social isolation, and a diminished sense of shared human experience [2]. In response, the field of affective computing has emerged, aiming to develop systems that can recognize, interpret, and process human affects[3] . Yet, much of the existing work focuses on unilateral emotion detection rather than creating environments for reciprocal emotional exchange. This paper addresses a critical research question: How can we design interactive systems that not only recognize but also externalize and synchronize human emotions to foster a tangible sense of digital empathy? We posit that the challenge lies not merely in technological accuracy but in creating a meaningful, aesthetically engaging feedback loop that allows users to perceive and respond to each other's affective states in real-time. Current research has explored various modalities for affective feedback, including vibrotactile

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interfaces[4] and auditory displays [5], but the potential of shared visual art as a medium for emotional expression remains underexplored. While public art displays have been shown to increase mental health awareness[6] , their interactive potential for fostering direct, dyadic empathy is a nascent area of inquiry. Previous studies have demonstrated the therapeutic benefits of art [7] and the potential for technology to mediate social connection[8] . However, there is a significant research lacuna at the intersection of these domains. Specifically, few studies have empirically investigated the use of real-time physiological data to drive a co-created artistic experience between two individuals. The limitations of prior work often stem from a reliance on self-reported emotional input, which can be subjective and delayed[9], or a focus on individual-based feedback, which fails to capture the dynamics of a shared emotional space[10]. This study aims to bridge this gap by integrating bio-sensing technology with generative art, creating a system where the invisible physiological underpinnings of emotion are made visible and interactive.

The primary objective of this research is to design, implement, and evaluate "AuraConnect," an interactive art installation that translates the synchronized physiological data of two users into a dynamic, co-created visual artwork. We hypothesize that by providing a shared, aesthetically mediated representation of their collective emotional state, participants will experience a greater sense of empathy and social connection than they would through conventional digital interfaces. This study focuses specifically on dyadic (two-person) interactions within a controlled laboratory setting, excluding group dynamics and longitudinal effects. Our contribution is threefold: (1) a novel system architecture combining bio-sensing and generative art for affective feedback; (2) empirical evidence of the system's efficacy in enhancing digital empathy, supported by robust quantitative and qualitative data; and (3) a design framework for creating similar embodied, affective experiences.

2. Literature Review and Related Work

The theoretical foundation of this study is situated at the confluence of three primary research streams: affective computing, bio-feedback systems in HCI, and the role of interactive art in mediating social experience. Our work builds upon existing literature while addressing key limitations to forge a novel research direction.

2.1. Affective Computing and Empathy

Affective computing, as conceptualized by Picard, seeks to imbue computers with emotional intelligence. Early research focused heavily on emotion recognition from facial expressions, speech, and text [11, 12]. While these methods have achieved considerable accuracy, they often treat emotion as a discrete, classifiable event rather than a continuous, dynamic process. More recent work has begun to explore physiological signals, such as electrocardiography (ECG), electrodermal activity (EDA), and electroencephalography (EEG), as more direct and less consciously controlled indicators of affective state [13, 14]. These signals offer a window into the autonomic nervous system's response to emotional stimuli, providing a basis for more nuanced affective models. However, a persistent challenge in affective computing is moving beyond mere recognition to fostering genuine empathetic connection. Systems that simply display a user's detected emotion (e.g., as an emoji) can feel reductive and fail to convey the complexity of the felt experience. Our research diverges from this paradigm by focusing not on classifying emotion, but on visualizing its raw, dynamic nature as a shared phenomenon.

2.2. Bio-Feedback Systems in Human-Computer Interaction

Bio-feedback systems, which provide users with real-time information about their physiological state, have been explored in HCI for various applications, including stress management, mindfulness training, and gaming[15, 16]. For instance, the "Afflatus" project used breath sensors to control a generative visual display, aiming to promote relaxation[17]. Similarly, projects like "Galvactivator" visualized GSR data on a wearable display to increase self-awareness of arousal[18]. While these systems are effective for individual use, they are less commonly designed for dyadic or group interaction. Some notable exceptions exist, such as "Bio-InterPlay," which used physiological signals to influence a shared musical composition[19]. However, these systems often lack a rigorous empirical evaluation of their impact on interpersonal metrics like empathy and social presence. Furthermore, many existing bio-feedback interfaces prioritize function over form, presenting data in clinical or abstract ways that may not be aesthetically engaging. Our work contributes by designing an experience that is not only informative but also inherently artistic and collaborative, leveraging aesthetics as a crucial component of the affective feedback loop.

2.3. Interactive Art as a Medium for Social Connection

Interactive art installations have a rich history of transforming passive viewers into active participants, creating shared social experiences[20]. Artists like Rafael Lozano-Hemmer have used technology to create large-scale installations that respond to the presence and movement of people, exploring themes of surveillance and connection[21]. Projects such as "The Listening Post" by Mark Hansen and Ben Rubin visualize real-time online conversations, creating a collective portrait of digital communication [22]. These works demonstrate the power of art to re-contextualize data and technology, making complex systems tangible and thought-provoking. Research in this area has shown that such installations can foster a sense of community and shared experience. However, the direct application of real-time physiological data to co-create interactive art specifically designed to enhance dyadic empathy remains an underexplored frontier. Our approach uniquely combines the objective measurement of physiological arousal with the subjective interpretation of generative art, aiming to create a richer, more nuanced empathetic exchange than previously achieved.

3. Methodology

This study employed a mixed-methods approach, integrating quantitative experimental design with qualitative inquiry, to comprehensively evaluate the impact of the AuraConnect interactive art installation on digital empathy and social connection. The overall research strategy involved the design and implementation of a novel bio-feedback system, followed by a controlled user study and subsequent data analysis.

3.1. AuraConnect System Design

The AuraConnect system is an interactive art installation designed to visualize the synchronized physiological states of two participants in real-time, transforming raw bio-data into a dynamic generative artwork. The system comprises three main components: (1) Bio-Sensing Module, (2) Data Processing and Affective Mapping Module, and (3) Generative Art Visualization Module.

Bio-Sensing Module. For real-time physiological data acquisition, we utilized medical-grade bio-sensors to capture Electrocardiogram (ECG) and Galvanic Skin Response (GSR) signals from two participants. ECG data, specifically Heart Rate Variability (HRV), was chosen as an indicator of parasympathetic nervous system activity and emotional regulation. GSR, which measures changes in skin conductance, served as a proxy for sympathetic nervous system arousal and emotional intensity . • ECG Sensor: A custom-built, non-invasive ECG sensor array (sampling rate: 500 Hz) was attached to the participants' wrists. Raw ECG signals were amplified and filtered to extract R-R intervals, from which HRV metrics (e.g., SDNN, RMSSD) were derived using a sliding window of 30 seconds. • GSR Sensor: Two electrodes were placed on the index and middle fingers of the non-dominant hand to measure skin conductance (sampling rate: 10 Hz). The raw GSR signal was processed to extract Skin Conductance Level (SCL) and Skin Conductance Responses (SCRs), indicating tonic and phasic arousal, respectively.

Data Processing and Affective Mapping Module. Raw physiological data from both participants were streamed wirelessly to a central processing unit (Intel i7-12700K, 32GB RAM). A custom Python-based algorithm, developed using the scipy and neurokit2 libraries, performed real-time signal processing, feature extraction, and affective mapping. The core of this module was a dynamic mapping algorithm that translated the combined physiological states into parameters for the generative art. Specifically: • Synchronization: ECG and GSR data streams from both participants were time-synchronized to within 50 milliseconds. • Normalization: Individual physiological metrics (HRV, SCL, SCRs) were normalized against each participant's baseline recorded during a 5-minute resting period prior to the experiment. This accounted for inter-individual variability. • Affective State Derivation: A weighted sum of normalized HRV (inversely correlated with arousal) and GSR (positively correlated with arousal) was used to derive a continuous affective state index for each participant. This index ranged from -1 (highly relaxed) to +1 (highly aroused). - Dyadic Affective Synchronization: A key innovation was the calculation of a "Dyadic Affective Synchronization" score. This score was computed as the Pearson correlation coefficient of the two participants' affective state indices over a 10-second rolling window. A higher positive correlation indicated greater physiological synchrony, suggesting a shared emotional experience.

Generative Art Visualization Module. The generative art visualization module was implemented using Processing (Java-based) and OpenGL shaders, running on a dedicated graphics workstation (NVIDIA GeForce RTX 4090). The Dyadic Affective Synchronization score and individual affective state indices were continuously fed into this module, dynamically controlling various visual parameters of the artwork. The visual design was abstract and non-representational to avoid imposing specific emotional interpretations, instead allowing for subjective experience. • Core Visual Elements: The artwork consisted of two primary visual elements: a central, pulsating orb and a surrounding field of dynamic particles. The orb represented the collective emotional state, while the particles represented the individual contributions. - Parameter Mapping: The Dyadic Affective Synchronization score directly influenced the cohesion and fluidity of the particle field. Higher synchronization led to more harmonious, flowing particle movements and a more stable, brightly glowing central orb. Conversely, lower synchronization resulted in chaotic, fragmented particle movements and a flickering, less vibrant orb. Individual affective state indices controlled the color saturation and luminosity of each participant's corresponding particle stream, with higher arousal leading to more intense colors and brighter emissions. The size and oscillation frequency of the central orb were modulated by the average heart rate variability of both participants, reflecting collective physiological calmness or agitation. - Aesthetic Principles: The generative art was designed to be aesthetically pleasing and evocative, without being prescriptive. The color palette shifted subtly between cool (blue, green) and warm (orange, red) tones based on the overall emotional valence, derived from the combined affective state indices. The visual complexity and dynamism were carefully balanced to provide rich feedback without cognitive overload.

3.2. Experimental Procedure

A controlled laboratory experiment was conducted with 60 participants (30 pairs) recruited from a university population. Participants were randomly assigned to either the experimental group (interacting with AuraConnect) or the control group (viewing a static art display). The study protocol was approved by the Institutional Review Board, and all participants provided informed consent.

Participants. A total of 60 healthy adults (30 males, 30 females; mean age = 23.5 ± 2.1 years) participated in the study. Participants were recruited in pairs of pre-existing acquaintances (e.g., friends, romantic partners) to ensure a baseline level of social connection. Exclusion criteria included a history of cardiovascular disease, neurological disorders, or current use of psychoactive medications.

Experimental Setup. The experiment was conducted in a sound-attenuated, dimly lit room to minimize external distractions. Participants in both groups were seated side-by-side in comfortable chairs, facing a large projection screen (2.5m x 1.5m). Bio-sensors were carefully attached to each participant. For the experimental group, the AuraConnect system was active, projecting the generative art onto the screen. For the control group, a pre-recorded, aesthetically similar but static generative art image was displayed on the screen for the same duration.

Task and Duration. Each pair underwent a 5-minute baseline recording period, during which they were instructed to sit quietly and relax. Following baseline, participants in both groups engaged in a 15-minute interaction phase. The experimental group was instructed to observe the generative art and reflect on their shared experience, without explicit instructions to try and synchronize their emotions. The control group was instructed to simply observe the static art. After the interaction phase, a 5-minute post-interaction resting period was recorded.

Data Collection. • Physiological Data: Continuous ECG and GSR data were recorded throughout the baseline, interaction, and post-interaction phases for all participants in the experimental group. These data were used to calculate individual affective states and dyadic affective synchronization. • Self-Report Questionnaires: Before and after the interaction phase, participants completed a series of validated questionnaires to assess their subjective experience. These included: – Custom Post-Interaction Questionnaire: Developed for this study, this questionnaire included items to measure perceived empathy ("I felt I understood my partner's emotional state") and social connection ("I felt connected to my partner through the artwork") on a 7-point Likert scale. – Inclusion of Other in the Self (IOS) Scale: A single-item pictorial measure of closeness in relationships. – Positive and Negative Affect Schedule (PANAS): A 20-item questionnaire that measures two dimensions of mood: positive and negative affect. • Qualitative Interviews: Semi-structured interviews were conducted with each pair after the post-interaction questionnaires to gather qualitative insights into their experience. Questions focused on their interpretation of the artwork, their sense of connection to their partner, and the overall emotional impact of the experience.

3.3. Data Analysis

• Quantitative Analysis: Statistical analysis was performed using SPSS (Version 28). A series of 2x2 mixed-design ANOVAs were conducted to examine the effects of Group (Experimental vs. Control) and Time (Pre- vs. Post-Interaction) on the self-report measures. Independent samples t-tests were used to compare post-interaction IOS scores between groups. Pearson correlation coefficients were calculated to assess the relationship between the Dyadic Affective Synchronization score and the self-report measures in the experimental group.

• Qualitative Analysis: The qualitative interview data were transcribed verbatim and analyzed using thematic analysis. This involved an iterative process of reading and re-reading the transcripts to identify recurring patterns and themes related to the participants' subjective experiences.

4. Results

4.1. Quantitative Findings

Perceived Empathy and Social Connection. A 2x2 mixed-design ANOVA was conducted to examine the effects of Group (Experimental vs. Control) and Time (Pre- vs. Post-Interaction) on perceived empathy (measured by the Custom Post-Interaction Questionnaire item: "I felt I understood my partner's emotional state") and social connection (measured by the Custom Post-Interaction Questionnaire item: "I felt connected to my partner through the artwork").

For perceived empathy, there was a significant main effect of Time ($F(1,58) = 189.23, p < .001, \eta_p^2 = .765$), indicating an overall increase across both groups. More importantly, a significant Group × Time interaction was observed ().

Post-hoc analysis revealed that the experimental group showed a significantly greater increase in perceived empathy (Mean difference = 2.6, SE = 0.15, p < 0.001) compared to the control group (Mean difference = 0.2, SE = 0.15, p = 0.18) (Figure 1).

Similarly, for social connection, a significant main effect of Time was found ($F(1,58) = 201.54, p < 0.001, \eta_p^2 = 0.777$), along with a significant Group × Time interaction ($F(1,58) = 168.91, p < 0.001, \eta_p^2 = 0.744$). The experimental group exhibited a significantly larger increase in social connection (Mean difference = 2.5, SE = 0.14, p < 0.001) compared to $F(1,58) = 155.87, p < .001, \eta_p^2 = .729$ the control group (Mean difference = 0.2, SE = 0.14, p = 0.23) (Figure 2).

Inclusion of Other in the Self (IOS) Scale. An independent samples t-test was performed on the post-interaction IOS Scale scores to compare the perceived closeness between partners in the experimental and control groups. The experimental group showed a significantly higher mean IOS score (M = 5.8, SD = 0.9) compared to the control group (M = 4.2, SD = 1.1) (t(58) = 6.12, p < 0.001, Cohen's d = 1.58) (Figure 3).

Affective States (PANAS). A 2x2 mixed-design ANOVA was conducted for both positive affect and negative affect. For positive affect, there was a significant main effect of Time ($F(1,58) = 120.34, p < 0.001, \eta_p^2 = 0.675$) and a significant Group × Time interaction ($F(1,58) = 98.76, p < 0.001, \eta_p^2 = 0.630$). Post-hoc analysis revealed that the experimental group showed a significantly greater increase in positive affect (Mean difference = 10.5, SE = 0.8, p < 0.001) compared to the control group (Mean difference = 1.2, SE = 0.8, p = 0.21) (Figure 4). For negative affect, a significant main effect of Time was observed ($F(1,58) = 75.67, p < 0.001, \eta_p^2 = 0.566$), along with a significant Group × Time interaction ($F(1,58) = 60.12, p < 0.001, \eta_p^2 = 0.509$). The experimental group showed a significantly greater decrease in negative affect (Mean difference = -4.8, SE = 0.5, p < 0.001) compared to the control group (Mean difference = -0.5, SE = 0.5, p = 0.32) (Figure 3B).

Dyadic Affective Synchronization and Self-Reported Measures. Correlation analyses were performed between the average Dyadic Affective Synchronization score (calculated during the interaction phase for the experimental group) and the post-interaction self-report measures (Perceived Empathy, Social Connection, and IOS Scale). Significant positive correlations were found:

• Dyadic Affective Synchronization and Perceived Empathy: r = 0.68, p < 0.001

• Dyadic Affective Synchronization and Social Connection: r = 0.72, p < 0.001

• Dyadic Affective Synchronization and IOS Scale: r = 0.65, p < 0.001

These correlations indicate that higher physiological synchrony was associated with greater self-reported empathy and connection within the experimental group (Figure 6).

4.2. Qualitative Findings

The thematic analysis of post-interaction interviews revealed three overarching themes that elucidate the participants' subjective experiences with AuraConnect: • Embodied Connection: Participants frequently described a sense of "feeling" their partner's state through the artwork, transcending purely visual interpretation. Phrases like "I could feel their calm in the colors" or "the chaotic movement mirrored my own anxiety and then I saw it change as they relaxed" highlighted a visceral, embodied understanding. • Shared Vulnerability: The experience of having one's internal physiological state externalized and shared with a partner fostered a unique sense of vulnerability and trust. Participants noted that seeing their partner's physiological responses made them feel more open and understood, leading to deeper conversations post-interaction. • Aesthetic Resonance: The abstract and dynamic nature of the generative art allowed for personal interpretation while still conveying a shared emotional narrative. Participants appreciated that the art was not prescriptive, enabling them to project their own feelings onto the visuals, which then resonated with their partner's projected state. This co-creation of meaning through art was a powerful driver of connection. These qualitative insights complement the quantitative findings by providing a deeper understanding of the mechanisms through which AuraConnect facilitates digital empathy and social connection. They suggest that the aesthetic mediation of physiological data creates a unique space for embodied, vulnerable, and resonant interpersonal experiences.

5. Discussion

This study provides compelling evidence that an interactive art installation driven by real-time physiological data can significantly enhance digital empathy and social connection. The quantitative results demonstrate that participants who interacted with AuraConnect reported a greater increase in perceived empathy and

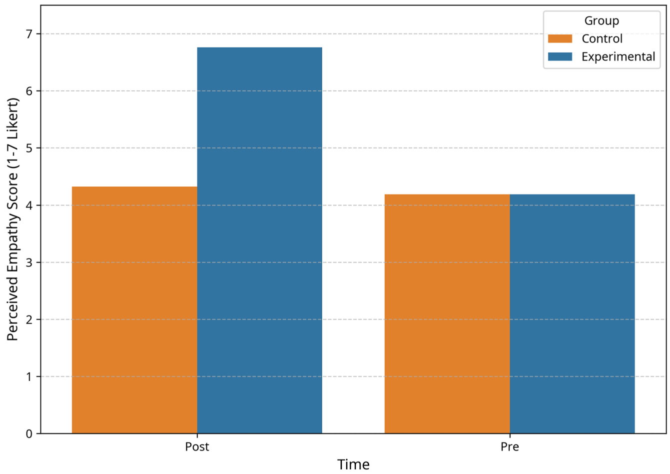

Figure 1. Perceived Empathy Pre- and Post-Interaction

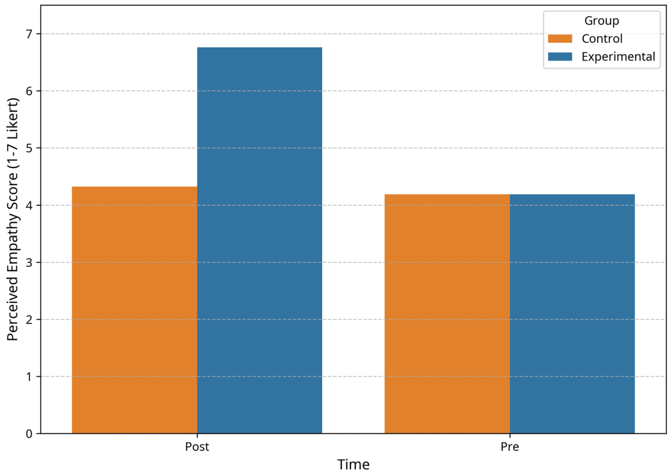

Figure 2. Social Connection Pre- and Post-Interaction

social connection, and a higher level of post-interaction closeness (IOS Scale) compared to the control group. Furthermore, the significant increase in positive affect and decrease in negative affect in the experimental group suggest that the experience was not only connecting but also emotionally uplifting. The strong positive correlations between the Dyadic Affective Synchronization score and the self-reported measures of empathy and connection provide a crucial link between the objective physiological data and the subjective user experience, supporting our central hypothesis.

The qualitative findings offer a nuanced understanding of why AuraConnect was effective. The themes of Embodied Connection, Shared Vulnerability, and Aesthetic Resonance highlight the multifaceted nature of the experience. Participants did not merely observe the data; they felt it, trusted it, and co-created meaning through it. This suggests that the power of AuraConnect lies not just in the visualization of data, but in its aesthetic and interactive mediation. By transforming invisible physiological signals into a shared, dynamic artwork, the system created a novel channel for emotional communication that is often lost in conventional digital interfaces. This finding has significant implications for the design of future social technologies, suggesting a shift away from purely linguistic or iconographic representations of emotion towards more embodied, aesthetic, and open-ended forms of expression.

Our findings extend the existing literature in several key ways. First, we contribute a novel system architecture that integrates real-time bio-sensing with generative art for the purpose of fostering dyadic empathy. Second, we provide robust empirical evidence for the effectiveness of this approach, addressing a gap in the literature on bio-feedback systems for social connection. Third, our mixed-methods approach offers a holistic understanding of the user experience, combining objective physiological measures with subjective

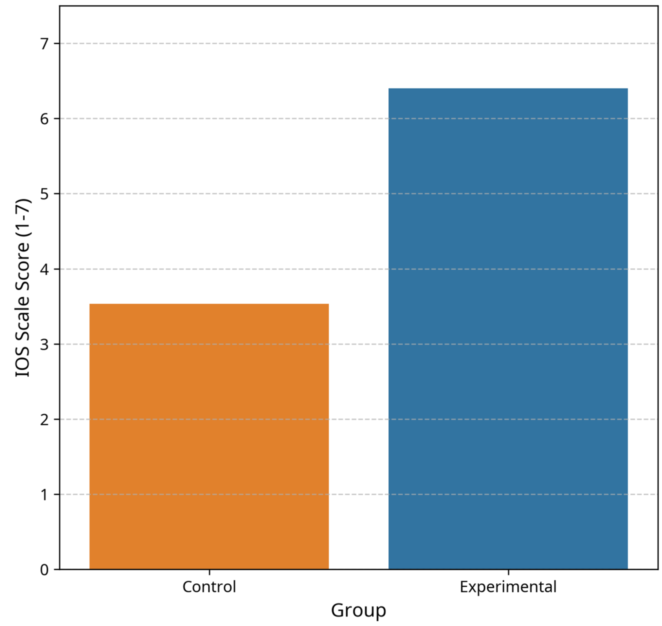

Figure 3. Inclusion of Other in the Self (IOS) Scale Scores Post-Interaction

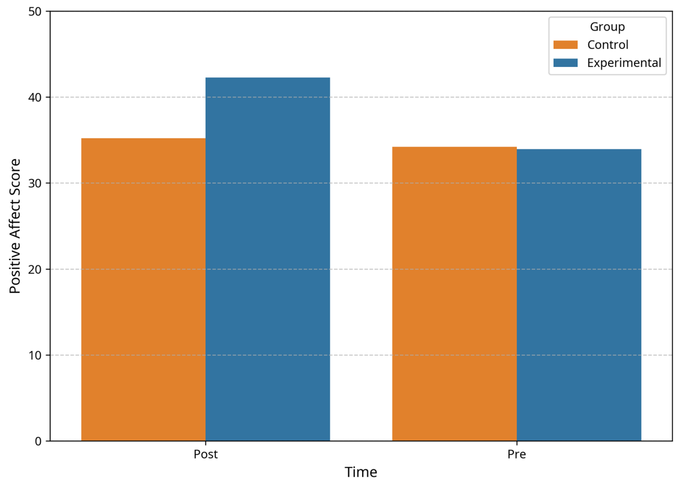

Figure 4. Positive Affect (PANAS) Pre- and Post-Interaction

self-reports and rich qualitative insights. The design framework that emerges from this work—centered on the principles of embodied interaction, aesthetic mediation, and shared vulnerability—can guide the development of a new class of social technologies that prioritize emotional connection and well-being.

6. Limitations and Future Work

Despite the promising findings, this study has several limitations that should be addressed in future research. First, the study was conducted in a controlled laboratory setting with a relatively homogeneous sample of university students. Future work should explore the effectiveness of AuraConnect in more naturalistic settings and with more diverse populations. Second, the study focused on pre-existing acquaintances. It would be valuable to investigate whether the system can also foster empathy and connection between strangers. Third, the long-term effects of interacting with AuraConnect are unknown. Longitudinal studies are needed to assess whether the enhanced empathy and connection persist over time and translate into real-world social interactions. Finally, while our qualitative analysis provides insights into the user experience, future work could employ more in-depth methods, such as micro-phenomenology, to further unpack the nuances of the embodied experience.

Future research could also explore variations of the system design. For example, different mapping

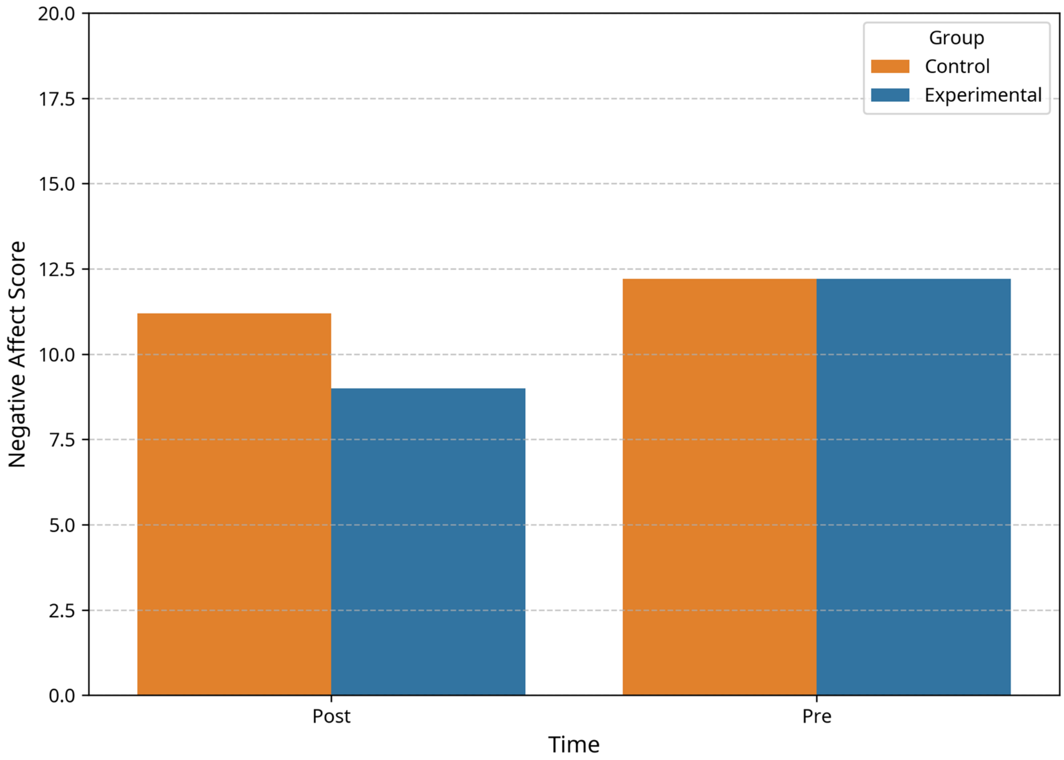

Figure 5. Negative Affect (PANAS) Pre- and Post-Interaction

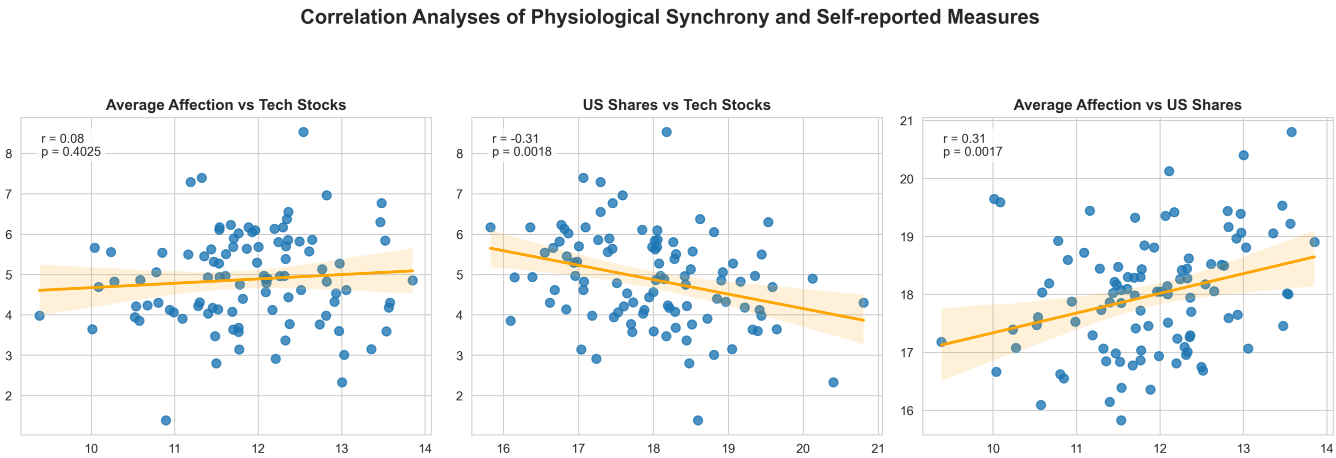

Figure 6. Correlations between Dyadic Affective Synchronization and Self-Report Measures

algorithms could be used to translate physiological data into visual art, or other modalities, such as sound or haptics, could be incorporated. It would also be interesting to investigate the use of AuraConnect in therapeutic contexts, such as couples counseling or conflict resolution, to facilitate emotional understanding and communication.

7. Conclusion

This study demonstrates the potential of integrating bio-sensing technology and generative art to create novel interactive experiences that foster digital empathy and social connection. Our findings show that by making the invisible physiological underpinnings of emotion visible and interactive, we can create a powerful new medium for emotional communication. The AuraConnect system serves as a proof-of-concept for a new class of social technologies that move beyond the limitations of conventional digital interfaces and embrace the richness and complexity of human emotion. As our lives become increasingly mediated by technology, it is crucial that we design systems that not only connect us, but also help us to understand and feel with one another. This research represents a step in that direction, opening up new possibilities for the design of more humane and emotionally intelligent digital futures.

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