Enhancing Social Connection in Shared Audiovisual Experiences via Collective Heartbeat Haptic Feedback

Andreia Valente
Empathic Computing Laboratory
The University of Auckland
Auckland, New Zealand

Juliana Marcelino
ITI / LARSyS
Instituto Superior Técnico
Universidade de Lisboa
Lisbon, Portugal

Mark Billinghurst
Empathic Computing Laboratory
The University of Auckland
Auckland, New Zealand

Augusto Esteves
ITI / LARSyS
Instituto Superior Técnico
Universidade de Lisboa
Lisbon, Portugal

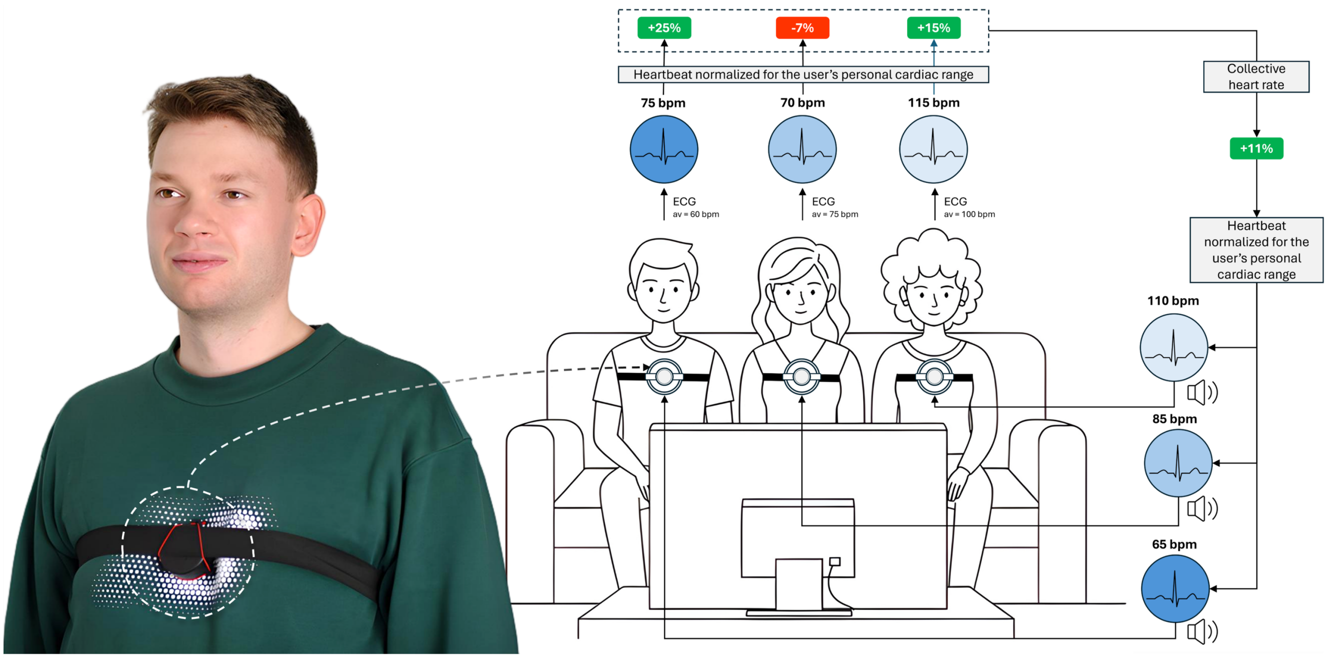

Figure 1: Left: Haptic audio transducer worn on the chest. Right: System architecture showing how individual heart rates are normalized, averaged into a collective heartbeat, and transmitted back to each participant through chest-worn transducers at personalized rates.

Abstract

Social live streaming services (SLSSs) connect millions of viewers across distance, yet fail to reproduce the togetherness of shared physical presence. We introduce collective haptic heartbeat biofeedback that transforms viewers' combined cardiac activity into chest-worn vibrations, creating ambient awareness of shared physiological participation. A controlled study with 36 participants in co-located triads demonstrated that this feedback significantly enhanced interpersonal closeness ($p = .007$). We discuss implications for deploying collective biofeedback in distributed streaming contexts where it can restore missing dimensions of togetherness.

CHI EA '26, Barcelona, Spain

ACM ISBN 979-8-4007-2281-3/2026/04
https://doi.org/10.1145/3772363.3798307

CCS Concepts

• **Human-centered computing → Empirical studies in collaborative and social computing**; *Haptic devices.*

Keywords

Social haptics, affective computing, biofeedback, social presence, shared experience, physiology, emotional contagion

ACM Reference Format:
Andreia Valente, Juliana Marcelino, Mark Billinghurst, and Augusto Esteves. 2026. Enhancing Social Connection in Shared Audiovisual Experiences via Collective Heartbeat Haptic Feedback. In *Extended Abstracts of the 2026 CHI Conference on Human Factors in Computing Systems (CHI EA '26), April 13–17, 2026, Barcelona, Spain.* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3772363.3798307

1 Introduction

Social live streaming services (SLSSs) have become central for sharing experiences across distance [26]. Millions watch movies together, attend live-streamed concerts, and participate in shared online events, making SLSSs key social infrastructure for maintaining relationships and collectively enjoying media [14]. Their scale and everyday adoption underscore the importance of mediated shared experiences in contemporary social life.

Despite their growing prominence, SLSSs provide an incomplete sense of togetherness. Although they synchronize media consumption, social interaction is largely confined to text chat, symbolic actions, and platform mechanics [14, 16], missing key qualities of physical co-viewing: seeing physical reactions, collective energy, and shared emotional responses [17, 30]. Ergin et al. [5] characterizes this as "incomplete entertainment," where platforms favor individualized enjoyment over collective emotional expression. Virtual co-presence lacks the cognitive and social benefits of physical proximity [24]. In co-located settings, people naturally coordinate their physiological responses during shared emotional experiences [4, 21], which correlates with social bonding [10, 19]. SLSSs render these collective physiological dynamics imperceptible, creating a gap between being technically together and feeling emotionally connected. This motivates a design opportunity: **can technology make collective physiological participation perceptible?** Making such signals perceptible may externalize otherwise implicit synchrony, transforming it into an ambient cue of co-participation. Rather than merely mirroring physiological alignment, collective biofeedback can function as a social signal that reinforces awareness of shared emotional engagement during media consumption.

We address this opportunity through collective biofeedback. We developed a system that captures co-viewers' cardiac activity, computes a collective heartbeat, and delivers it via chest-worn haptic transducers. We evaluated the system with 36 participants watching emotional video clips in triads. The study was conducted in a controlled co-located setting as a first-step validation of the mechanism's intrinsic social value prior to deployment in distributed SLSS contexts. This design isolated the contribution of collective biofeedback while minimizing remote confounds such as latency, variable audiovisual quality, and interface asymmetries.

We found that collective haptic heartbeat feedback significantly increased perceived interpersonal closeness. This suggests that making collective physiological states perceptible can foster empathic connection beyond visual or verbal interaction. Unlike prior collective biofeedback systems that rely primarily on visual displays or explicit interaction, our approach investigates chest-based haptic aggregation as an ambient, non-visual channel for fostering shared emotional awareness during media consumption. This work provides preliminary evidence that collective physiological biofeedback enhances perceived togetherness in shared media experiences. We discuss design considerations for integrating physiological feedback into SLSSs, and areas for future research.

2 Related Work

Shared experiences foster social bonds through coordinated emotional and physiological responses. Prior work shows that collective moments produce physiological synchrony [4, 8], increased pain thresholds, and stronger group cohesion [4]. Emotional contagion operates through facial mimicry, synchronized movement, and overlapping neural activation [9, 31]. Physiological synchrony refers to the temporal coordination of autonomic responses such as heart rate and electrodermal activity [3, 21], and is associated with empathy and rapport during shared emotional experiences [10, 19, 20]. Social presence theory further suggests that connection depends on perceptible cues of co-participation [15], ranging from gaze, proximity, and timing to embodied signals such as movement and physiological alignment [18]. Technologies that render collective participation perceptible through ambient awareness can therefore foster genuine feelings of connection [27].

Existing biofeedback systems demonstrate the potential of technology to foster connection through shared physiological data. Individual systems support intimate breathing communication [7] and VR/MR environments visualizing heart rate or EEG for shared regulation [13, 23, 29]. Group systems such as CoEx [22], AffectiveWall [32], ClockViz [6], and Heart Sounds Bench [11] explore collective physiological feedback through visual, auditory, and haptic modalities. Prior work investigated sharing biodata during video viewing in remote and VR contexts [28]. However, these systems either address contexts beyond shared media viewing or use modalities that compete with media content for attention.

Our work extends this research by introducing collective haptic heartbeat feedback for shared viewing contexts. We investigate whether ambient awareness of shared physiological participation, conveyed through chest-worn haptic feedback, offers intrinsic value for social connection. By studying this in co-located settings, we examine whether collective biofeedback creates meaningful connections beyond simply compensating for absent information, with implications for distributed viewing contexts.

3 User Study

This study examines whether conveying a group's combined cardiac rhythm strengthens togetherness. The research question is: **can shared haptic heartbeat feedback enhance emotional connection during collective viewing?**

System Design. We developed a system that transmits a collective heartbeat through chest-worn haptic devices while subjects watched emotionally evocative video clips together. Each subject's heart rate was normalized relative to their baseline $\overline{HR_i}$, averaged across the group, and mapped back to personalized feedback:

$$N_i(t) = \frac{HR_i(t) - \overline{HR_i}}{\overline{HR_i}} \quad \text{(a)} \qquad N_{\text{collective}}(t) = \frac{1}{n}\sum_{i=1}^{n} N_i(t) \quad \text{(b)}$$

$$HR_{\text{feedback},i}(t) = \overline{HR_i} \times (1 + N_{\text{collective}}(t)) \qquad \text{(c)}$$

where (a) $HR_i(t)$ is subject i's instantaneous heart rate, (b) normalized values are averaged across the group, and (c) mapped back to personalized feedback. For example, baselines of 60, 75, and 100 BPM with normalized states of +25%, -7%, and +15% produce a collective mean of +11% and feedback rates of 65, 85, and 110 BPM.

Subjects and Procedure. We conducted a within-subjects experiment with 36 subjects (12 triads, 16 female, 20 male, ages 18-35) who were strangers. Subjects were seated approximately 2 meters from a large display and did not talk during viewing. Sessions began with a 5-minute baseline to measure resting heart rate ($\overline{HR_i}$) with electrocardiogram (ECG) sensors from BITalino, followed by individual calibration of vibration intensity. In each trial, two subjects received haptic feedback while one served as control with no vibration. The control role rotated across trials, and control subjects wore the same sensors and transducers but were not informed of their condition to avoid demand characteristics.

Subjects viewed six validated 2-3 minute film clips from the FilmStim database [25] evoking varying valence and arousal while their heart rate was monitored by ECG. After each clip, they rated their own and the group's valence and arousal using the Self-Assessment Manikin (SAM) [2], and interpersonal closeness using the Inclusion of Other in Self (IOS) scale [1]. Sessions took about 75 minutes.

We designed this study to assess whether collective biofeedback has intrinsic social value prior to addressing distributed implementation challenges. Participants were co-located with visual awareness of one another but instructed not to talk. This controlled design isolates engagement with feedback while minimizing distributed confounds such as latency, network variability, and device differences. By controlling these factors, we evaluate whether shared physiological awareness provides added value to the experience.

Physiological Measurement. Electrodermal activity (EDA) was recorded continuously at 1000 Hz using BITalino sensors attached to the non-dominant hand. Signals were low-pass filtered at 1 Hz and decomposed into tonic and phasic components using continuous decomposition analysis in NeuroKit 2.0. The tonic component, skin conductance level (SCL), reflects overall sympathetic arousal, whereas the phasic component, skin conductance response (SCR), captures moment-to-moment orienting and emotional reactivity. We used SCR frequency, defined as peaks per minute, as the primary measure of attentional engagement and emotional responsiveness, since SCL and SCR may vary independently.

4 Results

Social Connection. Haptic feedback significantly increased social connection. IOS scores were significantly higher in the feedback condition ($Z = 2.705$, $p = .007$), indicating stronger interpersonal closeness (Figure 2, left). Sixty-one percent of subjects reported feeling more connected when receiving heartbeat feedback. This effect occurred without measurable physiological synchronization or emotional intensity differences between conditions and despite participants having peripheral visual awareness of one another. Self-reported valence and arousal ratings, measured using the **Self-Assessment Manikin (SAM)**, did not differ significantly between the feedback and control conditions. This suggests that increased interpersonal closeness cannot be explained by differences in subjective emotional intensity.

Physiological Responses. EDA analysis found that haptic feedback modulated sympathetic responses during negative high-arousal content (fear-inducing clips). Subjects showed significantly fewer EDA peaks in the feedback condition ($Z = -2.199$, $p = .028$), suggesting reduced physiological arousal (Figure 2, right). However, they did not report lower subjective arousal ratings for these clips, indicating reduced sympathetic activation occurred without diminished engagement. Other physiological measures and self-report ratings showed no significant differences between conditions.

User Experience. Post-experiment questionnaires supported these findings (Figure 3). Subjects rated the heartbeat feedback as comfortable and engaging, with 72% finding it pleasant and 75% enjoying watching videos with it. The system achieved high ratings for non-intrusiveness without distracting from viewing. While explicit empathy and synchrony ratings were moderate, qualitative comments indicated subjects valued the subtle sense of shared presence: *"You have the idea of someone feeling exactly the same as you, your senses experiencing the same as another person. That connected with me a bit more"* (S7) and *"I felt connected knowing it was the average of everyone's heartbeats"* (S19).

5 Discussion

5.1 Emotional Co-Regulation Through Collective Biofeedback

The reduction in EDA during negative high-arousal content reveals an unexpected regulatory effect. Subjects showed reduced sympathetic arousal during fear-inducing clips when receiving haptic feedback, yet maintained subjective engagement. This suggests that awareness of sharing an emotional experience may provide subtle regulatory influence, dampening physiological stress responses while preserving attention and interest. The collective heartbeat may serve as a reminder that others are experiencing the same content, reducing feelings of isolation during emotionally challenging moments. Future work should explore whether this regulatory effect scales to longer-form content and if it varies based on individual differences in interoceptive sensitivity or social anxiety.

5.2 Ambient Awareness Creates Connection Without Synchrony

Our findings show that collective haptic heartbeat feedback enhanced connection without measurable physiological synchrony and despite peripheral visual awareness, challenging assumptions that social bonding requires bodily alignment. Subjects felt closer because they shared a collective heartbeat, suggesting awareness of collective participation can be as powerful as actual coordination. Importantly, they did not dismiss the feedback as redundant with visual cues. Sixty-one percent reported feeling more connected, and qualitative comments indicated they valued this signal as distinct from direct observation. This suggests collective biofeedback

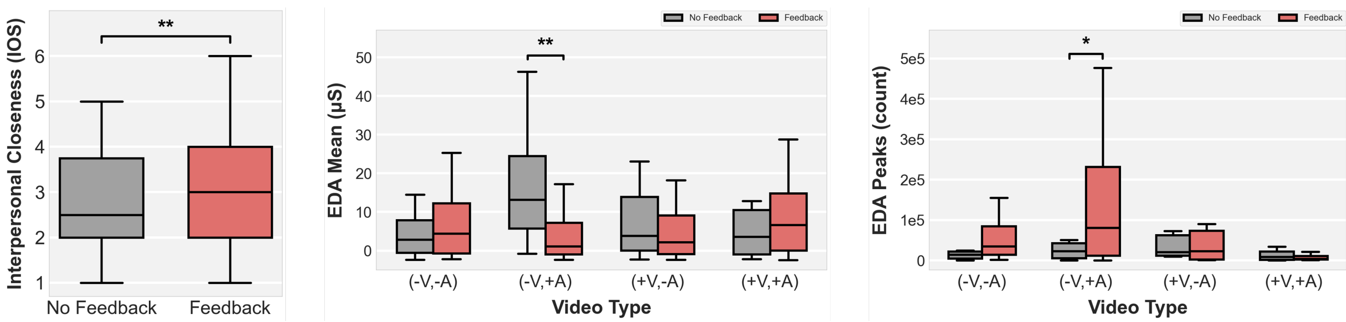

Figure 2: Left panel shows Inclusion of Other in Self (IOS) scores comparing no feedback vs. feedback conditions. Right panel displays EDA peaks (count) across four video types: negative high arousal (-V,+A), positive high arousal (+V,+A), negative low arousal (-V,-A), and positive low arousal (+V,-A) (* denotes p<.05, ** denotes p<.01).

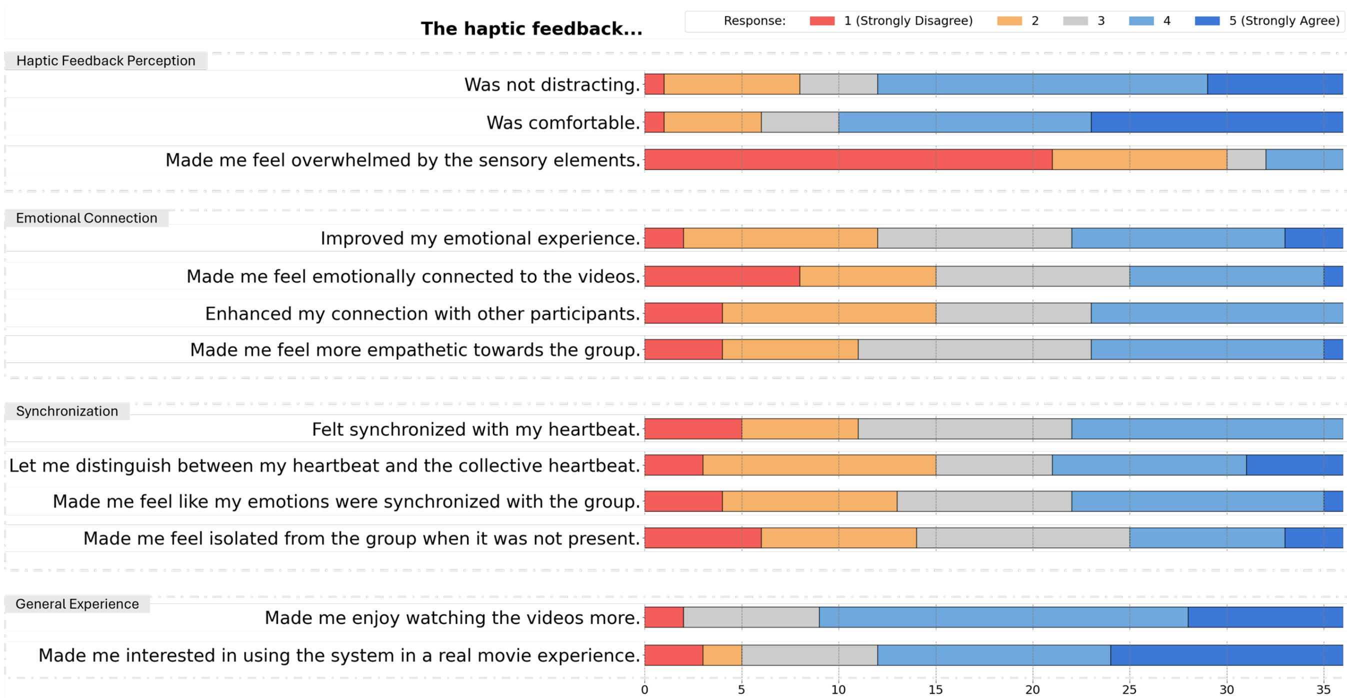

Figure 3: Post-experiment questionnaire results on experiences with our collective haptic heartbeat system. Responses used a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree) grouped into: Haptic Feedback Perception (comfort, distraction, sensory overload), Emotional Connection (emotional experience, connection to videos and others, empathy), Synchronization (self and group synchronization, heartbeat distinguishability, isolation when absent), and General Experience (enjoyment, future interest).

provides intrinsic value by conveying aggregated physiological information that complements rather than substitutes for traditional co-presence cues, with this value likely amplified in distributed contexts where visual cues are absent.

Although evaluated in co-located triads, these findings inform SLSS design by demonstrating that collective physiological awareness has relational value even when traditional co-presence cues are available. This positions the present study as a foundational validation of the mechanism before testing it in distributed streaming contexts, where such cues are reduced or absent.

These findings establish that people value collective biofeedback as a meaningful signal of shared experience, providing critical understanding before investing in distributed implementation: real-time physiological streaming across networks, synchronization despite variable latency, and consistent delivery across heterogeneous devices. Our results suggest this investment is worthwhile.

If collective biofeedback creates a connection when visual cues are available, it should prove more valuable in SLSSs where there is an absence of co-presence information. From a design perspective, SLSSs should focus on making shared participation perceptible rather than enforcing synchronization. The haptic feedback served as an ambient signal of togetherness, operating below conscious attention while influencing closeness. This differs from existing collective biofeedback systems [11, 22, 32] that visualize group data, requiring attention that may compete with primary tasks. Haptic feedback offers a non-visual channel conveying collective states without disrupting focus on shared content.

5.3 Design Implications for Social Live Streaming Services

Participants valued the unobtrusive haptic feedback, describing it as present yet non-distracting. This suggests several design considerations for SLSSs: modality matters, as haptics provide somatic connection without competing for attention; personalization matters, as normalized feedback feels natural; and ambiguity may be beneficial, as precise interpretation may be unnecessary if the signal conveys shared experience. These principles can guide future work exploring physiological signals, such as breathing or movement, as ambient indicators of collective engagement in distributed viewing. Our approach emphasizes subtle integration with the shared experience to help restore co-presence across distance [12].

6 Limitations and Future Work

Despite these promising findings, several limitations remain. Short clips may not capture the sustained narrative engagement of full-length content, as one participant noted: *"lacks some of the emotion of a whole film"* (S1). Although the laboratory setting with stranger groups provided a conservative test, validation in real SLSS contexts is needed, where familiar groups view content at home without visual co-presence cues. Such naturalistic conditions may increase receptivity to subtle haptic feedback. Only 61% of participants reported feeling more connected, indicating meaningful individual variation. Some found the feedback confusing when it diverged from their own heart rate (S15). Future work should examine predictive factors such as interoceptive accuracy or baseline social connectedness. Finally, the effects observed reflect a single short-term session, and persistence with repeated use remains unknown. Thus, this study serves as an initial validation of collective biofeedback rather than a direct test of distributed SLSS deployment. By isolating shared physiological awareness under controlled conditions, we establish a foundation for future remote implementation.

Having established that people value collective haptic feedback as a meaningful signal of shared experience, the critical next step is distributed implementation addressing technical challenges we deliberately avoided: maintaining real-time physiological synchronization despite network latency and ensuring consistent quality across devices. Understanding how collective biofeedback performs under these constraints and without visual co-presence cues will validate whether the observed value translates to contexts where such feedback is most needed. Additional future research directions include extending to larger groups and longer content for ecological validity, investigating individual differences to explain variation in responsiveness, exploring alternative modalities like seat vibrations or wrist-worn devices (S15, S36), and examining therapeutic applications (S30) in remote clinical settings.

7 Conclusion

This study introduced a collective haptic heartbeat system to enhance connection during shared viewing. Haptic feedback increased perceived closeness without measurable physiological synchrony and despite peripheral visual awareness, demonstrating that ambient awareness of collective participation has intrinsic value for social bonding. EDA showed collective biofeedback modulated sympathetic arousal during intense content while preserving engagement. Subjects found the system comfortable and unobtrusive, indicating haptic feedback can strengthen connection without disrupting attention. By demonstrating collective biofeedback creates meaningful connection even with traditional co-presence cues, these findings establish a foundation for SLSSs where such feedback addresses a genuine need. Future work should validate these effects in distributed contexts and investigate individual differences.

Acknowledgments

This work was funded by Fundação para a Ciência e a Tecnologia (projects 10.54499/LA/P/0083/2020, UID/50009/2025).

References

[1] Arthur Aron, Elaine N. Aron, and Danny Smollan. 1992. Inclusion of Other in the Self Scale and the structure of interpersonal closeness. *Journal of Personality and Social Psychology* 63, 4 (1992), 596–612. https://doi.org/10.1037/0022-3514.63.4.596

[2] Margaret M. Bradley and Peter J. Lang. 1994. Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry* 25, 1 (1994), 49–59. https://doi.org/10.1016/0005-7916(94)90063-9

[3] E. Delaherche, M. Chetouani, A. Mahdhaoui, C. Saint-Georges, S. Viaux, and D. Cohen. 2012. Interpersonal Synchrony: A Survey of Evaluation Methods across Disciplines. *IEEE Transactions on Affective Computing* 3, 3 (July–September 2012), 349–365. https://doi.org/10.1109/T-AFFC.2012.12

[4] R. I. M. Dunbar, Ben Teasdale, Jackie Thompson, Felix Budelmann, Sophie Duncan, Evert van Emde Boas, and Laurie Maguire. 2016. Emotional Arousal When Watching Drama Increases Pain Threshold and Social Bonding. *Royal Society Open Science* 3, 9 (September 2016), 160288. https://doi.org/10.1098/rsos.160288

[5] Pınar Ergin. 2023. Are video streaming services offering incomplete entertainment? *Media, Culture & Society* 46, 2 (dec 2023), 414–424. https://doi.org/10.1177/01634437231216443

[6] Loe Feijs, Mengru Xue, and Rong-Hao Liang. 2017. ClockViz: Designing Public Visualization for Coping with Collective Stress in Teamwork. In *Proceedings of the Conference on Design and Semantics of Form and Movement - Sense and Sensitivity, DeSForM 2017*. IntechOpen, Rijeka, 13 pages. https://doi.org/10.5772/intechopen.71220

[7] Jérémy Frey, May Grabli, Ronit Slyper, and Jessica R. Cauchard. 2018. Breeze: Sharing Biofeedback through Wearable Technologies. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3173574.3174219

[8] Julian Hanich. 2010. Collective Viewing. The Cinema and Affective Audience Interrelations. *Passions in Context. International Journal for the History and Theory of Emotions* 1, 1 (2010), 240 pages.

[9] Carolina Herrando and Efthymios Constantinides. 2021. Emotional Contagion: A Brief Overview and Future Directions. *Frontiers in Psychology* 12 (2021), Article 712606. https://doi.org/10.3389/fpsyg.2021.712606

[10] Michael J. Hove and Jane L. Risen. 2009. It's All in the Timing: Interpersonal Synchrony Increases Affiliation. *Social Cognition* 27, 6 (2009), 949–960. https://doi.org/10.1521/soco.2009.27.6.949

[11] Noura Howell, Greg Niemeyer, and Kimiko Ryokai. 2019. Life-Affirming Biosensing in Public: Sounding Heartbeats on a Red Bench. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland UK) *(CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–16. https://doi.org/10.1145/3290605.3300910

[12] James Hutson. 2023. Shared Cinematic Experience and Emerging Technologies: Integrating Mixed-Reality Components for the Future of Cinema. *Arts & Communication* 1, 2 (2023), 0683. https://doi.org/10.36922/ac.0683

[13] A. Jing, M. Frederick, M. Sewell, A. Karlson, B. Simpson, and M. Smith. 2023. How Visualising Emotions Affects Interpersonal Trust and Task Collaboration in a Shared Virtual Space. In *2023 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*. IEEE, Sydney, Australia, 849–858. https://doi.org/10.1109/ISMAR59233.2023.00100

[14] Han Soo Kim and Minjung Kim. 2020. Viewing sports online together? Psychological consequences on social live streaming service usage. *Sport Management Review* 23, 5 (nov 2020), 869–882. https://doi.org/10.1016/j.smr.2019.12.007

[15] Karel Kreijns, Kate Xu, and Joshua Weidlich. 2022. Social Presence: Conceptualization and Measurement. *Educational Psychology Review* 34, 1 (mar 2022), 139–170. https://doi.org/10.1007/s10648-021-09623-8

[16] Quan Long and Alec C. Tefertiller. 2020. China's New Mania for Live Streaming: Gender Differences in Motives and Uses of Social Live Streaming Services. *International Journal of Human-Computer Interaction* 36, 14 (aug 2020), 1314–1324. https://doi.org/10.1080/10447318.2020.1746060

[17] Anna Macaranas, Gina Venolia, Kori Inkpen, and John Tang. 2013. Sharing Experiences over Video: Watching Video Programs together at a Distance. In *Human-Computer Interaction – INTERACT 2013*, Paula Kotzé, Gary Marsden, Gitte Lindgaard, Janet Wesson, and Marco Winckler (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 73–90. https://doi.org/10.1007/978-3-642-40498-6_5

[18] Giulia Magni, Luana Amadini Genovese, Giuseppe Riva, and Claudia Repetto. 2025. Embodied metaphors and interpersonal synchrony in the digital age: the case of remote working. *Frontiers in Psychology* 16 (2025), 1–7. https://doi.org/10.3389/fpsyg.2025.1648733

[19] Analia Marzoratti and Tanya M. Evans. 2022. Measurement of Interpersonal Physiological Synchrony in Dyads: A Review of Timing Parameters Used in the Literature. *Cognitive, Affective, & Behavioral Neuroscience* 22, 6 (December 2022), 1215–1230. https://doi.org/10.3758/s13415-022-01011-1

[20] B. Moharana, C. Keighrey, and N. Murray. 2023. Physiological Synchrony in a Collaborative Virtual Reality Task. In *2023 15th International Conference on Quality of Multimedia Experience (QoMEX)*. IEEE, Ghent, Belgium, 288–293. https://doi.org/10.1109/QoMEX58391.2023.10178661

[21] Richard V. Palumbo, Marisa E. Marraccini, Lisa L. Weyandt, Oliver Wilder-Smith, Heather A. McGee, Siwei Liu, and Matthew S. Goodwin. 2017. Interpersonal Autonomic Physiology: A Systematic Review of the Literature. *Personality and Social Psychology Review* 21, 2 (May 2017), 99–141. https://doi.org/10.1177/1088868316628405

[22] Arttu Perttula, Pauliina Tuomi, Marko Suominen, Antti Koivisto, and Jari Multisilta. 2010. Users as Sensors: Creating Shared Experiences in Co-Creational Spaces by Collective Heart Rate. In *Proceedings of the 14th International Academic MindTrek Conference: Envisioning Future Media Environments* (Tampere, Finland) *(MindTrek '10)*. Association for Computing Machinery, New York, NY, USA, 41–48. https://doi.org/10.1145/1930488.1930497

[23] M. Salminen, S. Järvelä, A. Ruonala, V. J. Harjunen, J. Hamari, G. Jacucci, and N. Ravaja. 2022. Evoking Physiological Synchrony and Empathy Using Social VR With Biofeedback. *IEEE Transactions on Affective Computing* 13, 2 (2022), 746–755. https://doi.org/10.1109/TAFFC.2019.2958657

[24] Pietro Sarasso, Irene Ronga, Elena Del Fante, Paolo Barbieri, Irene Lozzi, Nicola Rosaia, Alessandro Cicerale, Marco Neppi-Modona, and Katiuscia Sacco. 2022. Physical but not virtual presence of others potentiates implicit and explicit learning. *Scientific Reports* 12, 1 (dec 2022), 21205. https://doi.org/10.1038/s41598-022-25273-4

[25] Alexandre Schaefer, Frédéric Nils, Xavier Sanchez, and Pierre Philippot. 2010. Assessing the effectiveness of a large database of emotion-eliciting films: A new tool for emotion researchers. *Cognition and Emotion* 24, 7 (2010), 1153–1172. https://doi.org/10.1080/02699930903274322

[26] Katrin Scheibe, Kaja J. Fietkiewicz, and Wolfgang G. Stock. 2016. Information Behavior on Social Live Streaming Services. *Journal of Information Science Theory and Practice* 4, 2 (jun 2016), 6–20. https://doi.org/10.1633/JISTaP.2016.4.2.1

[27] Ekaterina R. Stepanova, John Desnoyers-Stewart, Kristina Höök, and Bernhard E. Riecke. 2022. Strategies for Fostering a Genuine Feeling of Connection in Technologically Mediated Systems. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 139, 26 pages. https://doi.org/10.1145/3491102.3517580

[28] Chiew Seng Sean Tan, Kris Luyten, Jan Van Den Bergh, Johannes Schöning, and Karin Coninx. 2014. The Role of Physiological Cues during Remote Collaboration. *Presence: Teleoperators and Virtual Environments* 23, 1 (feb 2014), 90–107. https://doi.org/10.1162/PRES_a_00168

[29] Andreia Valente and Mark Billinghurst. 2025. CardioCommXR: Training Empathy Through Gamified Emotional Regulation. In *Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '25)*. Association for Computing Machinery, New York, NY, USA, Article 886, 4 pages. https://doi.org/10.1145/3706599.3720319

[30] Jelle van Dijk. 2022. Zooming in on embodied social sensemaking: Mapping the design space in the context of videoconferencing. In *Proceedings of the Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Daejeon, Republic of Korea) *(TEI '22)*. ACM, New York, NY, USA, Article 18, 10 pages. https://doi.org/10.1145/3490149.3501324

[31] Dan Wang, Changhong Liu, and Wenfeng Chen. 2024. The Role of Self-Representation in Emotional Contagion. *Frontiers in Human Neuroscience* 18 (2024), 8 pages. https://doi.org/10.3389/fnhum.2024.1361368

[32] M. Xue, R.-H. Liang, B. Yu, M. Funk, J. Hu, and L. Feijs. 2019. AffectiveWall: Designing Collective Stress-Related Physiological Data Visualization for Reflection. *IEEE Access* 7 (2019), 131289–131303. https://doi.org/10.1109/ACCESS.2019.2940866