Exploring Collective Physiology Sharing as Social Cues to Support Engagement in Online Learning

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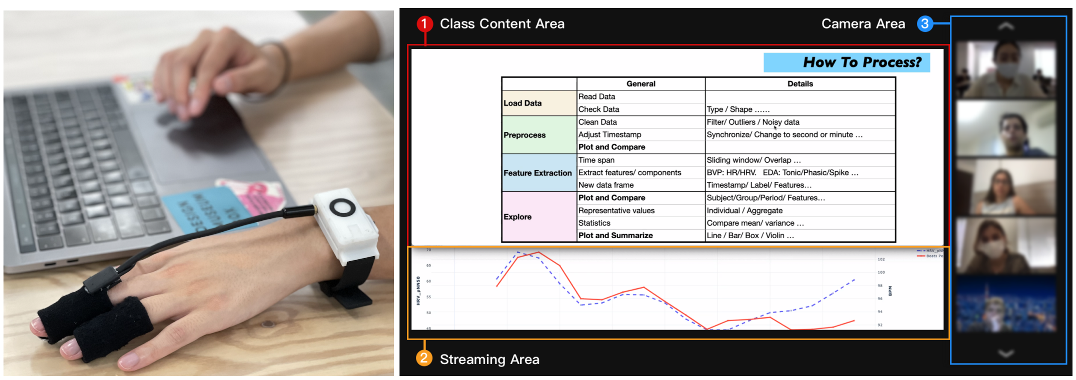

Figure 1: Streaming system used in the field study. Left is the device for streaming blood volume pressure (BVP) signal. Right is the interface consisted of class content area, streaming area, and camera area.The visualization in the streaming area was generated based on two features: (1) beats per minute (BPM) (2) the percentage of adjacent normal sinus beats' interbeat intervals that differ from each other by more than 50 ms (pNN50). The red and blue lines represented collective BPM and pNN50 respectively and both were calculated from rolling means of all data contributors every one minute.

ABSTRACT

Insufficient social cues between distributed learners in online learning could result in lack of engagement and social bonds. With the development of wearable sensing, sharing physiological data can be used to enhance mutual understanding and connectedness among sharers. Our work aims to explore the potential of sharing heart rate (HR) and heart rate variability (HRV) collected from distributed learners to enhance their online learning experiences. We implemented a physiological streaming system and conducted a field study with 11 learners in online classes. This paper describes the study and discusses our interview findings by contrasting the influence of visualized collective physiological data from viewpoints of data contributors and viewers. Our exploratory results suggest streaming collective HR and HRV from multiple distributed learners could be used in online classes to improve engagement and sense of community.

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CCS CONCEPTS

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

KEYWORDS

physiological sensing, online learning system,engagement, visualization

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1 BACKGROUND AND MOTIVATION

Lacking of engagement and sense of community has been identified challenging for distributed learners in online learning [8, 14, 17] due to insufficient socials cues [17]. Various approaches have been proposed to enhance social presence in online learning. For example, visualizing historical social comments from prior online peers to support learner engagements [9], or applying scenario-based interaction design to facilitate social interactions among distributed learners [16]. However, most research focused on mediating user-generated contents to engage distributed learners, which requires learners to actively spend extra efforts while attending the lecture. Different from these related works, our research aims to use physiological data as social cues to express distributed learners' implicit feedback during online learning.

Physiological signal such as electroencephalography (EEG) [4, 5, 10], galvanic skin response (GSR) [15], and heart rate (HR) [1, 12] can be a substitute for social cues to interpret others engagement and emotional situations. We selected HR and heart rate variability (HRV) as our key physiological data because HR is relatively intuitive to interpret and the streaming system is feasible to be set up in large scale even remotely. Slovak et al. proved HR feedback is a strong connectedness cue affecting interactions especially in remote scenarios [12]. There are also some practical applications in which HR and HRV sharing alleviated stress in remote collaborations [15] and augment social games [1]. Inspired by these works, our study aims to explore how sharing cardiovascular activities could influence distributed learners' engagement and sense of community. Our exploratory results show the feasibility of streaming collective HR and HRV measurements from distributed learners and the potential to enhance social bonds in online learning.

2 FIELD STUDY

We conducted a field study to investigate how distributed learners react to the streaming system that presents collective HR and HRV measurements in real time. Our system tracked Blood Volume Pulse (BVP) from self-built wrist-worn devices with an optical sensor placed on the fingertip referring to the set-up in previous work [2, 6, 13] (Fig. 1 (left)). The device sampled the BVP at 50Hz and streamed to our system server via User Datagram Protocol (UDP), which supported distributed learners to stream their data without location restrictions. We implemented glance-able line charts right below the presenter's slide content (Fig. 1 (right)) to avoid distracting learners from the class content. BPM was selected as an intuitive HR indicator of excitement and anxiety. While pNN50 was adopted as an established HRV feature to reflect relaxation and sustained attention [7, 11]. We briefly introduced the features we used in the beginning of the class.

The streaming session was embedded in a lecture series lasting about 40 minutes. 48 learners in total attended the online lecture over Zoom. The field study had ethic board approval from Keio University. 8 learners volunteered to stream and share their physiological data. After the streaming session, we organized interviews on 11 learners and 6 of them were data contributors while the others were viewers. During the interview, we asked participants about their perception and experience while viewing the streaming visual in the class, and to compare their experiences in class without the streaming event. We also asked participants to share their interpretations about the visuals including the meanings behind and sources of the data. We also questioned the learners who contributed streaming data about their personal feelings when wearing the device and sharing their physiological data to others.

We delivered surveys after the classes with and without the streaming visualization to quantify its impact on learners. Besides demographic questions, the survey asked questions about sense of community [14] and perceived psychological engagement [3] in 7-point Likert scales (1:Strongly Disagree, 7:Strongly Agree). 17 learners answered the survey after the class without seeing physiological data streaming, and 19 learners answered the survey after the class implemented with physiological data streaming. We notified students that joining the study was not compulsory and all of the answers would be kept confidential and not related to any type of grading.

3 RESULTS AND DISCUSSIONS

In this section, we summarized the themes emerged from the qualitative analysis and identified feedback from data contributors and viewers. We also report survey results to triangulate the interview findings.

All the participants reported they had the motivation to look at the streaming visual. Main reasons were the curiosity in others' reactions (*"I find it very interesting to see how people develop together."(C1)*) and the awareness of what's going on in the class *"Whether I intentionally looked the streaming was related to the instructor and the content of the course itself."(C3).*

In accordance with our concept design, participants reported increasing engagement and sense of community with the streaming system. As data contributors, they could involve in the class more actively (*"The change of the data visualization was like the more spontaneous reaction, what's happening in class [...] when the instructor was asking us something, then I was curious if it goes up because people feel involved and then they're like, oh, I need to act now."(C1)*), and feel more connected to other distributed learners by seeing the data visualization (*"Putting aside how accurate the visualization were or what it meant, I felt it really cool to see that we are somehow affecting this class and visuals. [...] I felt like I was part of a class and felt like there were people like in this class that there was a presence rather than me sitting alone in the room and whatever." (C2)*). Moreover, data contributors did not report privacy concerns with the sharing mostly because of the visual was shown in an aggregated manner and perceived anonymity (*" Because it feels like so many people's data and not my data alone. It's something more objective and doesn't feel violating." (C3)*).

Regarding viewers' experience, they mentioned it was a little hard to understand the system setup, such as how was the data recorded, integrated, and transformed. However, they were still interested in the trend and fluctuations of the streaming visualization (*"I can get a rough idea of what it is, but I don't understand what it is. But looking at the trend, I can feel the change." (V2)*). Viewers also mentioned the streaming visual enhanced their engagement and connection especially when most of the people turned off the cameras in the online class, which was a common practice of the class we studied (*"I could see the visuals like moving. So I can see that people are listening or people are actually there attending the class and will sort of indirectly causing me to feel like feel connected to the students." (V1)*).

Survey results also showed perceived psychological engagement was slightly higher in the streaming session (M = 3.99, SD = 0.38) than that without streaming (M = 3.73, SD = 0.4), with a marginal significant difference ($t[32]$= 1.95 , (.05<p<.10)). Although there was no significant difference of sense of community between two conditions ($t[33]$ = 0.92, *n.s.*, without streaming: M = 4.29, SD = 1.01; with streaming: M = 4.63, SD = 1.13). We will further explore in controlled lab settings to clarify the effect of streaming visualization on learners' perception of social bonds.

4 CONCLUSION AND FUTURE WORK

This field work presents the feasibility and potential of streaming collective HR and HRV remotely from multiple users in real time. Data contributors and viewers reported slightly different experience in terms of participation. However, both of their feedback indicates that sharing HR and HRV during the online class could serve as an extra channel to provide social cues for enhancing distributed learners' engagement and sense of community. In the future, we will further explore physiological, psychological, and behavior changes among distributed learners during the feedback loop triggered by visualizing shared physiological data.

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REFERENCES

[1] Jérémy Frey. 2016. Remote heart rate sensing and projection to renew traditional board games and foster social interactions. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. 1865–1871.

[2] Zhuoqi Fu, Jiawen Han, Dingding Zheng, Moe Sugawa, Taichi Furukawa, Chernyshov George, Hynds Danny, Padovani Marcelo, Marky Karola, Kouta Minamizawa, et al. 2021. Boiling Mind-A Dataset of Physiological Signals during an Exploratory Dance Performance. In *Augmented Humans Conference 2021*. 301–303.

[3] Chad Harms and Frank Biocca. 2004. Internal consistency and reliability of the networked minds measure of social presence. (2004).

[4] Mariam Hassib, Mohamed Khamis, Susanne Friedl, Stefan Schneegass, and Florian Alt. 2017. Brainatwork: Logging cognitive engagement and tasks in the workplace using electroencephalography. In *Proceedings of the 16th international conference on mobile and ubiquitous multimedia*. 305–310.

[5] Mariam Hassib, Stefan Schneegass, Philipp Eiglsperger, Niels Henze, Albrecht Schmidt, and Florian Alt. 2017. EngageMeter: A system for implicit audience engagement sensing using electroencephalography. In *Proceedings of the 2017 Chi conference on human factors in computing systems*. 5114–5119.

[6] Yan He, Dingding Zheng, George. Chernyshov, Ragnar. Thomsen, Jiawen. Han, Danny Hynds, Yun Suen. Pai, Kai. Kunze, and Kouta. Minamizawa. 2021. Frisson Waves: Sharing Frisson to Create Collective Empathetic Experiences for Music Performances. In *2021 IEEE World Haptics Conference (WHC)*. 591–591. https://doi.org/10.1109/WHC49131.2021.9517258

[7] Jacob B Holzman and David J Bridgett. 2017. Heart rate variability indices as bio-markers of top-down self-regulatory mechanisms: A meta-analytic review. *Neuroscience & biobehavioral reviews* 74 (2017), 233–255.

[8] René F Kizilcec, Chris Piech, and Emily Schneider. 2013. Deconstructing disengagement: analyzing learner subpopulations in massive open online courses. In *Proceedings of the third international conference on learning analytics and knowledge*. 170–179.

[9] Meng-Yun Liao, Ching-Ying Sung, Hao-Chuan Wang, Wen-Chieh Lin, and Fu-Yin Cherng. 2019. Embodying historical learners' messages as learning companions in a VR classroom. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–6.

[10] Fannie Liu, Laura Dabbish, and Geoff Kaufman. 2017. Can biosignals be expressive? how visualizations affect impression formation from shared brain activity. *Proceedings of the ACM on Human-Computer Interaction* 1, CSCW (2017), 1–21.

[11] Fred Shaffer and James P Ginsberg. 2017. An overview of heart rate variability metrics and norms. *Frontiers in public health* 5 (2017), 258.

[12] Petr Slovák, Joris Janssen, and Geraldine Fitzpatrick. 2012. Understanding heart rate sharing: towards unpacking physiosocial space. In *Proceedings of the SIGCHI conference on human factors in computing systems*. 859–868.

[13] Moe Sugawa, Taichi Furukawa, George Chernyshov, Danny Hynds, Jiawen Han, Marcelo Padovani, Dingding Zheng, Karola Marky, Kai Kunze, and Kouta Minamizawa. 2021. Boiling Mind: Amplifying the Audience-Performer Connection through Sonification and Visualization of Heart and Electrodermal Activities. In *Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction*. 1–10.

[14] Na Sun, Mary Beth Rosson, and John M Carroll. 2018. Where is community among online learners? Identity, efficacy and personal ties. In *Proceedings of the 2018 chi conference on human factors in computing systems*. 1–13.

[15] Chiew Seng Sean Tan, Johannes Schöning, Kris Luyten, and Karin Coninx. 2014. Investigating the effects of using biofeedback as visual stress indicator during video-mediated collaboration. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 71–80.

[16] Saijing Zheng, Mary Beth Rosson, Patrick C Shih, and John M Carroll. 2015. Designing MOOCs as interactive places for collaborative learning. In *Proceedings of the Second (2015) ACM Conference on Learning@ Scale*. 343–346.

[17] Saijing Zheng, Mary Beth Rosson, Patrick C Shih, and John M Carroll. 2015. Understanding student motivation, behaviors and perceptions in MOOCs. In *Proceedings of the 18th ACM conference on computer supported cooperative work & social computing*. 1882–1895.