Understanding How Group Workers Reflect on Organizational Stress with a Shared, Anonymous Heart Rate Variability Data Visualization

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Figure 1: In this paper, we understand how group workers reflect on their daily organization stress by deploying a shared, anonymous heart-rate variability data visualization for a week (5 days, 4 hours per day) with six groups of office workers in their workspace.

ABSTRACT

For a small group of office workers who share the same workspace and the task load, leveraging their social skills and awareness could further increase their mutual awareness of each other's work-related stress. This paper presents a case study of a one-week deployment of a shared, anonymous heart rate variability (HRV) data visualization system at six workplaces with 24 office workers, who were closely collaborated in four-person groups. We collected stress-related physiology data (i.e., heart-rate variability) from wearable sensors and anonymously visualized them on a shared display. Although the physiological data collection where noisy due to the practical constraints in the field settings, we found the participants still increasingly agreed with the systems and used the visualization as a reference for their subjective stress assessment. We also present and discuss how groups of office workers individually and socially reflect on their one-week experiences and then summarize takeaways for designing shared physiological data visualization systems for group stress management in the long term.

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CCS CONCEPTS

• **Human-centered computing** → *Information visualization.*

KEYWORDS

stress, workplace stress, stress visualization, personal informatics.

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1 INTRODUCTION

Nowadays, office workers often suffer from occupational stress that comes from various sources, such as job per se, role in the organization, relationship at work, organizational structure [7]. In a shared working space, social stressors (e.g., peer pressure) affect the interpersonal and intrapersonal emotional status, reduce job satisfaction, and cause high absenteeism and low productivity [2, 3]. Current computer-mediated interventions focus on providing stress-related physiological information (e.g., heart rate variability; HRV) as personal informatics (PI) [10] or as biofeedback systems [21] to individuals to stimulate self-reflection and to facilitate self-regulation [12, 15, 15]. They mainly use expressive and effective visualizations of physiological data as a means of communication to raise awareness and trigger further reflection and action. However, these data visualizations are often deployed on a personal display [13] rather than on a shared display, so the intervention mostly leveraged the user's personal awareness, motivation, and skills.

Leveraging the social skills and awareness of a small group of office workers, who share the same workspace and the task load, could further increase their mutual awareness of each other's work-related stress. Previous work [20] shows a shared, anonymous HRV data visualization can efficiently draw users' awareness and evoke objective reflections from the viewpoint of a group, but the investigation is limited as they only explored short-term reflection on the acute stressors applied to the users in an idealistic lab setting.

In this work, we extend the previous work by deploying a shared physiological data visualization over an extended period: one week (5 days, 4 hours per day) in a realistic field setting. We deployed an anonymous HRV data visualization with six groups of office workers to understand how they use such visualization to reflect their daily stressors with their everyday activity in each group. We extended the previous system [20] by providing wearable and wireless HRV and motion data collection and improving the visualizations for visualizing four hours of anonymized HRV data of multiple workers, as shown in Figure 1. We intentionally minimized the physiology data collection apparatus and process's obtrusiveness to let the workers freely do their work in their routine. Using the system as a vehicle, we invited these office workers to reflect on their subjective feelings, daily activities with their colleagues while keeping the anonymity.

In the first round of 5-day deployment with four users working in the same group, we found the data collection were reliable at the beginning yet occasionally corrupted due to the office workers' daily activities. However, the qualitative results surprisingly revealed that the users increasingly agreed with the system with time and more frequently engaged and used the data visualization to reference individual and social reflection with their colleagues. This finding triggered us to the same experimental condition with five more groups of office workers and then obtained similar observations that supported our initial findings. The participants reported that they were convinced because they recognized the system captured their absence and some daily stressful moments, which they can relate to what happened.

Since the system was *perceived* as reliable and elicited a fair amount of reflection, we used the participants' quotes to understand how they reflected on their subjective stress by using the qualitative content analysis approach [1]. We also summarized what the participants experienced in their individual and social reflections. They compared their subjective feelings with the visualization over time and shared their awareness and interventions through comparing with peers. Overall, although the data collection system was less reliable than the previous work [20] by nature in the field deployment, we still suggest future research to use shared, anonymized heart-rate variability visualization as a tool for facilitating the reflection of organizational stress in the field setting.

This paper's main contribution is the empirical understanding of how groups of office workers reflected on their organization stress with a shared HRV data visualization system. The extracted qualitative results contributed useful insights into future longitudinal studies.

2 DESIGNING SHARED, ANONYMOUS HRV DATA VISUALIZATION FOR ONE-WEEK FIELD STUDIES

The proposed system is designed based on the design guidelines of a previous stress-related physiological data visualization system, AffectiveWall [20]. In their experiments where the users experienced the induced acute stressors, AffectiveWall 1) provides valid photoplethysmography (PPG) HRV collection, 2) uses a simple yet legible mono-color round pattern for visualizing a collective of 5-min HRV data, and 3) supports a stress-free reflection through anonymity. The visualization successfully provokes group reflections on the HRV data visualization in a one-hour lab experiment. However, for a five-days, four hours per day deployment in the field, the system designs have to be extended.

Portable HRV and Motion Data Collection. Comparing to PPG sensors, ECG-based HRV sensing is more resilient to the wearers' body movements and the environmental light condition. Therefore, we use chest-mounted ECG (electrocardiogram) heart rate sensors, Aidlab[1], for unobtrusive HRV motion data collection. Aidlab provides an ECG-sensor that integrated wearable computer connected ECG sensor, an inertia measurement unit (IMU), and a Bluetooth Low Energy (BLE) module. Timestamped raw ECG and raw IMU data from the sensors were collected wirelessly by a client PC. So, we can inspect the quality of ECG data collection with the raw IMU data later. Then, the client PC processed the raw data and calculated the HRV using an algorithm based on template-matching beat extraction [17] and then send the HRV to a server PC for visualization via sockets over a WiFi network.

Visualizing Four Hours of Anonymous HRV Data. Instead of circular patterns [20], line charts can better represent information that

[1]https://www.aidlab.com

changes over time. However, the line chart might be too expressive, so that could induce excess stressful feelings. To increase visibility and avoid the stressful up-and-down expressions, we use the color of grass in its lifecycle as a more biophilic expression that could generate more positive feelings [9, 19], as shown in Figure 1. We map the low HRV (SDNN< 50ms; more stressful) to withering color (red, orange, and yellow) and high HRV (SDNN≥ 50ms; less stressful) to thriving colors (from light to saturated grass green), as suggested in [8]. The graph gradually updates every 5 minutes, so it stays static and ambient. Notably, when the system detected insufficient heartbeats (less than 30 beats/minute on average) within the 5 minutes, the system did not over-interpret the insufficient data and showed a gap instead. The gaps may also make the wearers aware of the problems and asked for help. The shared display shows the color bars on a calendar-like timeline to help the users associate the bars with their daily events. The color bars of multiple users were aligned to the timeline as rows to facilitate comparison, but the display does not show participants' identities. Each user knows their row, but they do not know other rows belong to whom.

3 FIELD STUDY

3.1 Method

Participants. We initially deploy the system in an office with 4 office workers for 5 days as a pilot. Afterward, we add another five groups of employees under the same settings. In total, 24 office workers (7 females, 17 males) aged from 26-49 ($M = 31.125, SD = 5.52$) were recruited from six different working groups. Five groups were employees from various research institutions, and one group worked for Information and communications technology services. Each group contained 4 employees required to be colleagues who work in the same office or are seated close to each other in a shared working space (Figure 1). One team leader also joined the user study.

Apparatus. Four Aidlab sensors were handed out to the office workers on Monday and took back on Friday. We used four Raspberry Pis in their office for receiving ECG and motion signals from each Aidlab sensor. An extra pressure sensor is added under each participant's seat, so the system can also annotate their leave. A laptop with a Linux system worked as a Client to receive data from the Raspberry Pis. A Server laptop is connected to a shared display in their office. Every device is connected to the same WiFi network for reliable data collection.

Procedures. As shown in Figure 2, we deployed the system for one week per group to observe how this system facilitates users' reflection and stress coping action based on both real-time and historical data within one week. Four colleagues from the same office were asked to wear the Aidlab sensor 4 hours a day (10:00-12:00, 13:00-15:00) during work for five days a week to collect ECG and motion signals to visualize. On Monday, the display was turned off as baseline setting and was turned on and showed the visualization from Tuesday to Friday. We choose Monday as a baseline because it is the least one that could be affected by the job-related task of the previous day. We paid each participant 30 Euro as compensation.

We introduced the experimental protocols to users in the daily introduction session. At the beginning of each day, the experimenter

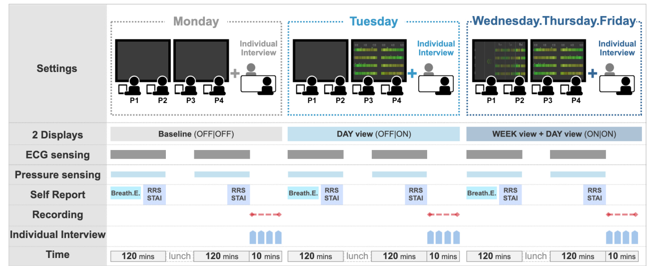


Figure 2: User study procedures.

introduced to every user: what data will be collected from them, how it can be a parameter to represent physiological stress, how deep breathing can make people relax, and what the stress visualization will look like. At the end of each morning and afternoon detection, each employee was asked to fill in the self-report stress questionnaires (RRS+STAI state) [16]. A self-report form was also handed out to record their breathing exercise by hand as a subsidiary recording tool. At the end of each day, a semi-structured individual interview was held and recorded.

3.2 Measurements and Data Analysis

All the interviews were audio-recorded and transcribed according to the qualitative content analysis approach [1]. Two coders (one author and one external) discussed the themes and consulted our analysis approach with an outside researcher whose expertise is qualitative data analysis. The quotes were clustered into two main categories: *individual reflections* and *social reflections*. *Individual reflections* refer to quotes comparing the individual user's subjective feelings with the visualization results (199 quotes). And *social reflections* refer to quotes comparing the individual user's stress status with others in the group (153 quotes).

4 RESULTS AND DISCUSSION

4.1 The First Week of Sensor Data Collection from the Field is Noisy

After conducting the study with the first group, we closely examined the 80 hours of ECG and motion sensor data collected from the 4 participants in five days. Despite that, the data collection was mostly successful initially, showing that the system was properly deployed. The unstable signal to noise ratio accompanying loss or missing beats were detected in the middle of the collection when the users were into their workflow. From the correlation between the ECG and motion sensor data, we identified the noises' causes mostly from the users' bodily movements. These occasionally missing/abnormal beats turned into unrealistic high HRV values that should have been processed with an advanced filter. Other events of a longer duration of missing beats occurred when the users left their seats (e.g., went to the toilet) or had a loosen sensor before they adjusted it. Although the experimenter noticed missing data and helped the participants reset the device properly, the display still showed these events as gaps on the timeline. After retrospected these data, we concluded that the quantitative data collected from the field is too noisy to be used to perform a rigorous subjective quantitative analysis, so we first moved to the qualitative results.

4.2 Users' Agreement to the System Increased with Time

Intriguingly, the qualitative findings showed that the users did perceive this system as a reliable system. Figure 3 shows our analysis of their quotes related to their agreement to the visualization. We clustered these quotes based on whether the users *agreed* or *disagreed* that the HRV visualization aligned with their subjective feelings, in both cases of stressed or not. Specifically, when a user made a statement addressing the comparisons between their subjective feelings and the visualization results, their quote was counted and categorized into one of the four quadrants:

- I: Both HRV visualization and subjective feeling are not stressed.
- II: The user feels stressed, but the visualization shows no stress.
- III: Both HRV visualization and subjective feeling are stressed.
- IV: The user feels relaxed, but the visualization shows stress.

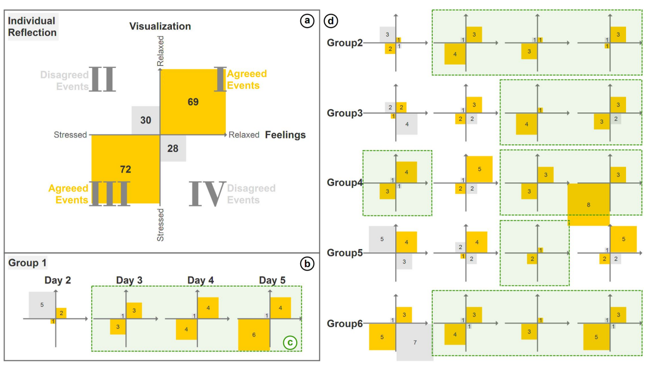


Figure 3: Users' agreement to the system. (a) Individual reflections related to comparisons between subjective feelings with the visualization fall into the four quadrants. (b) The frequency of agreed and disagreed events clustered from Group 1. (c) The days with the agreement frequency 75% higher than the disagreement frequency. (d) The frequency of events for the rest five groups.

In the first group, the ratio of *agreed* is 77.1% (27 out of 35), and *disagreed* is 22.9% (8 out of 35) among five days. More events appeared on Day5 than the other working days because extra 30-minutes questions were asked during the exit interview on Day5. On Day 3 and 5, the quotes of *agreed* are ≥ 75% among the total quotes that day. Participants showed disagreements on Day 2, the first day they saw the visualization, because the participants were expecting obvious changes (i.e., see some yellow or orange color) on the visualization at the beginning. For example, G1P1 (Group 1, Participant 1) reported, *"Sometimes I feel very stressed, but the visualization is quite green. It looked different than what I expected. (G1P1)"* Similarly, G1P2 claimed the visualization did not change much when he felt some stress near lunchtime, whereas the visualization only changed a bit within the green area. Nonetheless, on Day 3, G1P1 changed his attitudes and claimed the visualization reflect something interesting. He was watching football at that time, and his team lost the game made him upset. It surprised him that the visualization captured that moment. However, P2 still not agreed because he sensed himself stressed by the workload, but the visualization showed differently. On Day 4, G1P2 made connections with his patterns and his activities. He mentioned that he observed a gap caused by his absence. On Day 5, G1P4 showed an orange pattern for a while, which induced a group discussion. G1P4 was busy preparing some mental-demanding work while her stress showed up red. She thought the system is accurate and believed in it.

Among all the six groups, the ratio of *agreed* (70.9%) is 2.43 times higher than *disagreed* (29.1%). Like Group 1, we also found the other five groups showed an increased agreement from day 3. Figure 3d highlighted the days when *agreed* is ≥ 75% of the total, which are considered that the group of four participants generally agreed on the visualization. We interpret this finding as that the users who used the visualization calibrated their subjective feelings and the expectation of systems with time.

We further analyze the daily events to understand what were the drivers of change. The participants in Group 1 and Group 4 perceived the visualization changes aligned with the changes of tasks at hand. For example, *"It's accurate, I noticed it's related to the intensity of my current task. I noticed the change, I paid some attention in the background, and I would do something when I got time"(G1P4D5)*[2]*). "It must be mood-related. I felt good because I received some exciting news this morning, I was in a very good mood, and I saw a red bar. I think it senses my excitement as well"(G4P3D5). "I usually make a phone call to my home in the afternoon. Sometimes when I check the time, I'm stressed because I need to finish all the tasks at hand before they go to bed. And my bar was getting yellow at this period. After I finished the call and went back, it went back to green"(G4P2D5).* Group 5 has relatively fewer quotes on Day 4 than the other days because the system detected no specific event on that day (no one got stressed); also, one of the group members had to work outside of the building, which made the reflection material even less.

When users' subjective perceptions aligned with the system's feedback, they were more willing to engage further and interpret their data. For example, the system captured a participant's emotional event. Then, she expressed her interpretations of the visualization in the interview: *"I'm very surprised it can catch my exciting moment, the change with my heart. I guess I get the point. It doesn't exactly represent stress all the time. It reflects the mood"(G4P3D5).* Nonetheless, if the system provides unmatched data with users' expectations, it would destroy users' trust in the system. For example, one participant (G6P4D2) claimed he was a relaxed person by nature, and all his colleagues expect he must be the most relaxed person of all. However, he turned out to be the most stressed one. Therefore, he claimed he does not believe the data provided: *"I think I should be P2 (the greenest one in this group). It doesn't match my feelings. I don't know whether the data has deviation."* Another example from Group 2, P1 claimed she had a few episodes on Day 5 because of some chaos she couldn't handle at work, *"...not burnout, but at*

[2] Group1-Participant4-Day5

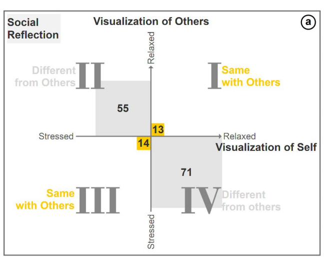
least I had some bad emotions come and go. But the visualization stays green. That does not match."

4.3 Social Reflections: Group Workers Compared with Peers and Shared the Stress-Coping Strategies

Office workers not only compared their subjective feelings with their own physiological signal visualization but also compared with each other in light of the visualization. Following the same approach in individual reflections, we cluster the quotes of *social reflections* into four quadrants as shown in Figure 4a.

- I: The visualization shows both the user and their peers are not stressed.
- II: The visualization shows the user is stressed, but their peers are not.
- III: The visualization shows both the user and their peers are stressed.
- IV: The visualization shows the user is not stressed, but their peers are.

The quotes were then categories into two categories: *Same with others* (I and III) and *different from others* (II and IV). The daily quote amounts of the two categories were compared in Figure 4b, in which we highlighted days that the participants ≥ 75% agreed with the system (Figure 3b-d) with at least 3 quotes in total.



(b)

	Day2		Day3		Day4		Day5	
	same	diff	same	diff	same	diff	same	diff (c)
G1	2	3	1	1	2	1	3	16
G2	0	5	0	0	0	1	3	8
G3	0	7	0	1	1	2	1	11
G4	1	6	0	1	1	2	3	10
G5	1	7	0	4	0	1	2	18
G6	0	6	0	2	0	0	4	13

Figure 4: (a) Social-reflections related to comparisons of personal stress with peers. (b) The table of frequency on the "same events" and the "different events" along four days of use. (c) The days that users agreed with the system (Fig 3c), meanwhile, the daily-based response events are higher than 3.

More discussions were found when users realized the differences with peers than under the same status. The quotes of *Different from others* (82.4%) are 4.67 times more than *same with others* (17.6%), which indicated that users made more comparison statements about their differences when someone shows stressed performance on the visualization. When the visualization showed someone is getting stressed with a bar of continuous yellow or orange, office workers made quotes on *Social-reflections* 10.77 times higher than nobody showed up stressed. For instance, *"I did not realize that mine gets red until my colleague asked me"(G1P4D5). "I was a bit worried that I had no yellow at all, everyone else has somewhat yellow parts, only me was all green"(G3P2D2). "Compared with other colleagues, I am the most stable green one"(G5P1D2). "The whole afternoon shows yellow, more yellow than each of them"(G6P1D3).* These findings showed office workers also use the physiological data visualization from peers as a reference to understand self through comparisons, especially when there is a difference or someone is stressed. Participants shared their awareness of each other's stress and stress management methods with people within the group. People co-interpret the visualization through discussions during small breaks throughout the day. For example, after every member in Group 4 has self-disclosed their identity, they interpret the visualization together during the breaks. For instance, *"Before it happened, the four of us discussed what we saw was the three of us appeared to be in the same shade of green, but only his bar had some fluctuations. We discussed possible reasons for that"(G3P2D4).* They discussed the possible reasons for their stress, *"We found everyone's stress is different because of the differences in stressors through our conversation today, and it's not necessarily from work only"(G3P2D2).* And participants propose new ways of coping with the stress together, *"If your colleagues know that they will try to help you to get over it"(G5P3D5); "We can release the stress through taking group breaks and making jokes together if we know we are stressed"(G6P1D5).*

4.4 Overall User Experiences

We also asked how users' experiencing this visualization during the exit interview. We asked the questions individually (e.g., Was the information clear to catch from the visualization? Was it interrupt your work? What were your opinions on anonymity? What were your opinions on the design?). We transcribed and analyzed their answers from all the six groups of office workers. The results indicate that the visualization information was easy to perceive, clear to understand, and was not interrupting in general. All participants reported that the color design matched their intuitions, and the information was easy to catch. "*It's very easy to understand, I mean, there are quite a lot of things use this, red is bad, and green is good" (G5P1D5).* "*Green is always good, if you go far away from green, like yellow, to red, almost everywhere, it's not a good sign [...] for me it was clear" (G6P3D5).*

22 (out of 24) participants reported the visualization was not interrupting their work. 2 (out of 24) claimed that they could not stop watching the changes in the beginning, and it was to some extent distracting. For example, *"All morning I was watching very often to the bar, keep me sharp that how I was on my mind and how stressed I was or not. I kept watching" (G5P1D2).* 21 (out of 24) participants reported that they were engaged to take actions to manage stress from the visualization. 2 (out of 24) participants claimed their performance was so well; otherwise, they would be engaged in doing something if their bar showed up red. 1 (out of 24) participant (G6P4) was not engaged in doing anything because he did not believe the delivered information. 22 (out of 24) participants reported they do not mind sharing personal identity with their colleagues. A majority of them expressed they are willing to share because of the closeness or familiarity with peers.

We found various attitudes on sharing. Some group wants the system with all group members' names on the visualization. For example, all members from Group 5 would love to see their names on the visualization, including the team leader G5P2: *"From a team leader position, I actually do prefer seeing that because you can see which colleague might not able to cope with stress and you could* *probably help them, prevent them from getting more stressed or making mistakes. I can always do something when this situation comes up. See which colleagues might not be able to continue on, which ones might be tired"(G5P2D5).* Some group doesn't care whether the system is anonymous because they had a relatively open and close relationship with their colleagues. For example, *"If I share this with strangers, I would prefer it to be anonymized because I would rather worry others see my stress and treat me as a patient. But I have already worked with my colleagues for more than four years, and we already familiar with each other, so it's no problem to share with them"(G3P1D5).* One group (Group 4) holds different opinions as they are the only group that followed and kept the anonymity rules till the end of the study. One participant in that group claimed he is new there and feels awkward to share with colleagues. He thinks of stress as something private: *"Luckily, we do not have that much stress made people want to talk and guess. I think anonymity can protect those who don't want to share. If it's not anonymous, it will bring more stress"(G4P1D5).* And his colleague added she followed the rules of not sharing with others: *"Till the end, nobody knows who I am, and I only know P4 because he went away for a long time and expose himself. I didn't say a thing (to expose him)"(G4P3D5).* But not all the members in that group feel the same about anonymity. For instance, G4P2 and G4P4 talked with each other and exposed themselves: *"I was eager to know why they feel stressed, even though I may not be able to help"(G4P2D5).*

5 DISCUSSION

Reflection as Dialogues with the System and the Peers. Stress is a subjective feeling. Physiological data such as HRV are considered as stress indicators rather than a basis for a clinical diagnosis. The users should use the HRV data visualization system as a reminder to reflect their feelings with their experiences instead of taking the HRV visualization as a stress meter. Designers should encourage users to observe the differences between physiological data and their subjective feelings to make sense of the two's differences. In a group, the users can further learn from their peers' ways of interpretation and their preconceived impressions (e.g., my colleagues think I'm a relaxed person). It aligned with Höök et al.'s concept of *Affective loop experiences*, which describes experiences "where it is not possible to separate the intellectual from sensual experiences, nor to single out what is my individual experience from the overall experience arising in dialogue with a friend or in dialogue with a system" [5].

Sharing is Caring. Although this research was limited by the nature of subjective interpretation and the imperfect data collection, they did not stop the participants from interpreting the HRV data visualization. Conversely, the participants increasingly agreed with this communication medium and engaged in discussion with their peers. One possible reason is that one can hardly evaluate the accuracy of the system's objective feedback by heart, as one is often not so sure about one's subjective feeling. The way how the users agreed with the system may consist of confirmation bias. Still, those willing to share and co-reflect with others feeling also benefited from others' awareness and caring. As a result, they got more peer supports than those who don't trust the system and refused to interpret.

Data Transparency. Although the physiological sensing system was perceived as sufficiently reliable to be used as a reflection tool, designers should still strive to provide accurate physiological measurements in the field. Nonetheless, noises and errors are almost inevitable because the experiment is lost control in field settings. As suggested by Luis et al. [6], designers should provide users with two forms of transparency: data acquisition transparency and data uncertainty transparency to ground the users' expectations. In our current system, data acquisition transparency is embodied as the gaps of missing data in the bars, which let the users believe that the data collection did work. However, our system could improve the data uncertainty transparency by showing how reliable the HRV data is in real-time rather than marking high-HRV motion artifacts as no-stress. With higher transparency, the users can understand what kinds of errors could be in the data and to what extent they can trust the data [6].

Peer Comparisons. More users realize the interpersonal differences through comparisons. It implied that emphasizing the interpersonal comparisons in visualization design might engage social sensemaking among peers. However, the comparison is a double-edged sword that implies both benefits and risks and thereby needs to be carefully designed for [18]. On the one hand, peer comparison can sometimes be stressful and burdensome, for example, if one is left behind. On the other hand, implying the overall performance of a team can motivate the members to achieve more. Fairness is the basis of comparison. To avoid comparing apples and oranges, the system is the most applicable for users with similar conditions, such as people from the same hierarchy or who share similar stressors. For example, in the context of mobility-impairment users' activity tracking, participants show a great desire to compare with peers with similar mobility impairments to discover new possibilities in rehabilitation [11]. When the situation is relatively comparable, the comparisons in shared experiences would be meaningful.

Future Work. Based on our results, future work can explore how to customize anonymity of sharing, such as allowing the individuals for self-identity disclosure in a subgroup because people have different preferences of sharing their stress. Future work can examine how participant closeness (e.g., how long they know each other, level of familiarity, or subjective closeness of relationship [4]) would affect the stress sharing experiences and how closeness could complement our research in users' privacy concerns. Future work can generalize this HRV visualization for other contexts, such as group sleep tracking [14], to understand the potential socio-technical issues in new applications.

6 CONCLUSION

We have presented an empirical study of how groups of office workers reflected on their organization stress with a shared HRV data visualization system in the field. The extracted qualitative results showed the group of users took the deployed HRV data visualization system as a vehicle to share their awareness and intervention with their peers. The one-week deployment indicates that the presented system was able to engage its users to make meaningful reflections related to the stressful moments they have in their daily activities. The results have extended from previous works by showing the applicability of shared anonymous HRV data in the field and contributed valuable insights into future longitudinal studies.

REFERENCES

[1] Alan Bryman. 2016. *Social research methods*. Oxford university press.

[2] Cary L Cooper and Judi Marshall. 1976. Occupational sources of stress: A review of the literature relating to coronary heart disease and mental ill health. *Journal of occupational psychology* 49, 1 (1976), 11–28.

[3] Caitlin Finney, Erene Stergiopoulos, Jennifer Hensel, Sarah Bonato, and Carolyn S Dewa. 2013. Organizational stressors associated with job stress and burnout in correctional officers: a systematic review. *BMC public health* 13, 1 (2013), 1–13.

[4] Simon Gächter, Chris Starmer, and Fabio Tufano. 2015. Measuring the closeness of relationships: a comprehensive evaluation of the'Inclusion of the Other in the Self'scale. *PloS one* 10, 6 (2015), e0129478.

[5] Kristina Höök, Anna Ståhl, Petra Sundström, and Jarmo Laaksolaahti. 2008. Interactional empowerment. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 647–656.

[6] Luis G Jaimes, Tylar Murray, and Andrew Raij. 2013. Increasing trust in personal informatics tools. In *International Conference of Design, User Experience, and Usability*. Springer, 520–529.

[7] Todd D Jick and Roy Payne. 1980. Stress at work. *Exchange: The Organizational Behavior Teaching Journal* 5, 3 (1980), 50–56.

[8] Robert E Kleiger, J Philip Miller, J Thomas Bigger Jr, and Arthur J Moss. 1987. Decreased heart rate variability and its association with increased mortality after acute myocardial infarction. *The American journal of cardiology* 59, 4 (1987), 256–262.

[9] Erin Largo-Wight, W William Chen, Virginia Dodd, and Robert Weiler. 2011. Healthy workplaces: The effects of nature contact at work on employee stress and health. *Public Health Reports* 126, 1_suppl (2011), 124–130.

[10] Ian Li, Anind Dey, and Jodi Forlizzi. 2010. A stage-based model of personal informatics systems. In *Proceedings of the SIGCHI conference on human factors in computing systems*. 557–566.

[11] Meethu Malu and Leah Findlater. 2017. Sharing automatically tracked activity data: implications for therapists and people with mobility impairments. In *Proceedings of the 11th EAI International Conference on Pervasive Computing Technologies for Healthcare*. 136–145.

[12] Daniel McDuff, Amy Karlson, Ashish Kapoor, Asta Roseway, and Mary Czerwinski. 2012. AffectAura: an intelligent system for emotional memory. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 849–858.

[13] Neema Moraveji, Athman Adiseshan, and Takehiro Hagiwara. 2012. Breathtray: augmenting respiration self-regulation without cognitive deficit. In *CHI'12 Extended Abstracts on Human Factors in Computing Systems*. 2405–2410.

[14] Laura Pina, Sang-Wha Sien, Clarissa Song, Teresa M Ward, James Fogarty, Sean A Munson, and Julie A Kientz. 2020. DreamCatcher: Exploring how parents and school-age children can track and review sleep information together. *Proceedings of the ACM on Human-computer Interaction* 4, CSCW1 (2020), 1–25.

[15] Pedro Sanches, Kristina Höök, Elsa Vaara, Claus Weymann, Markus Bylund, Pedro Ferreira, Nathalie Peira, and Marie Sjölinder. 2010. Mind the body!: designing a mobile stress management application encouraging personal reflection. In *Proceedings of the 8th ACM conference on designing interactive systems*. ACM, 47–56.

[16] Charles D Spielberger, Fernando Gonzalez-Reigosa, Angel Martinez-Urrutia, Luiz FS Natalicio, and Diana S Natalicio. 2017. The state-trait anxiety inventory. *Revista Interamericana de Psicologia/Interamerican Journal of Psychology* 5, 3 & 4 (2017).

[17] Salomon Tetelepta. 2018. Exploring Heart Rate Variability using Python. https://blog.orikami.nl/exploring-heart-rate-variability-using-python-483a7037c64d.

[18] Nina Valkanova, Sergi Jorda, Martin Tomitsch, and Andrew Vande Moere. 2013. Reveal-it! The impact of a social visualization projection on public awareness and discourse. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 3461–3470.

[19] Edward O Wilson. 1984. Biophilia. Massachusetts.

[20] Mengru Xue, Rong-Hao Liang, Bin Yu, Mathias Funk, Jun Hu, and Loe Feijs. 2019. AffectiveWall: Designing Collective Stress-Related Physiological Data Visualization for Reflection. *IEEE Access* 7 (2019), 131289–131303.

[21] Bin Yu, Mathias Funk, Jun Hu, Qi Wang, and Loe Feijs. 2018. Biofeedback for everyday stress management: a systematic review. *Frontiers in ICT* 5 (2018), 23.