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ClockViz: Designing Public Visualization for Coping with Collective Stress in Teamwork

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Abstract

The intervention solutions for coping with collective stress have been neglected in interaction design because of limited scalability of the physiological measuring methods. This paper focuses on exploring visual biofeedback design for collective stress in the context of teamwork. We design *ClockViz*, an augmented reality installation overlaid with static or dynamic projection to visualize three different extents of collective stress on a clock. Results of a 16-participant study show that *ClockViz* is useful to provide biofeedback data, change their internal status, and increase their mindfulness. Based on the results, we also discussed the potential solutions to collective stress sensing for designers to apply into their interactive design intervention.

Keywords: collective stress, biofeedback, visualization, design intervention, interaction design

1. Introduction

People often experience stress in the workplaces. Stress normally comes from internal stressors such as working environment, daily issues, and life changes or the external stressors such as interpersonal relationship and society. The impact of stress can be either positive or negative. Thus, stress can be categorized into eustress and distress [1], respectively. Eustress normally gives people motivation to deal with challenging routines, produces higher performance, and generates positive feelings, which can give people a sense of achievement during work. However, researchers also have found some evidence that stress can lead to illness emotionally and physiologically. Overloaded prolonged stress leads to illness like anxiety, depression,

anger, headache, insomnia, indigestion, or even worse. It lessens people's resistances to diseases [2]. Helping people to adapt to the changing levels of stress is a significant challenge for interaction designers to promote healthier working and lifestyles.

Several techniques can be used as tools for designing applications of stress management. Sharma et al. demonstrated some common techniques that include analyzing physical signals such as eye gaze, pupil diameter, voice characteristic, and face movement and physiological signals such as electroencephalography (EEG), blood volume pressure (BVP), heart rate variability (HRV), galvanic skin response (GSR), electromyography (EMG), etc. [3]. With these input signals, the information can be further visualized as several forms of biofeedback [4] to raise the awareness and therefore help them deal with the stress. However, these physiological measuring methods seem to be hardly scalable because the deployment cost is directly proportional to the subjects wearing the devices. Due to the limited scalability of measurements, the designs of biofeedback mechanisms are limited to the stress sources from individuals, instead of the collective and organizational ones.

In this work, we aim to explore the visual biofeedback design of collective stress and to treat a group of people as an entity. Collective stress, as a certain type of stress, represents the stressful feelings of members in a particular organization [5]. Like individual stress, collective stress could be caused by external stressors such as natural catastrophes, economic crises, and political collapses. Moreover, collective stress may also be affected by some internal stressors like conflict or propagation between individuals. It could lead to less productivity, poor performance, strained relationship, or members' burnout. Providing suitable visual biofeedback design of collective stress help the workers dealing with the stress may increase the performances and lead healthier ways of teamworking.

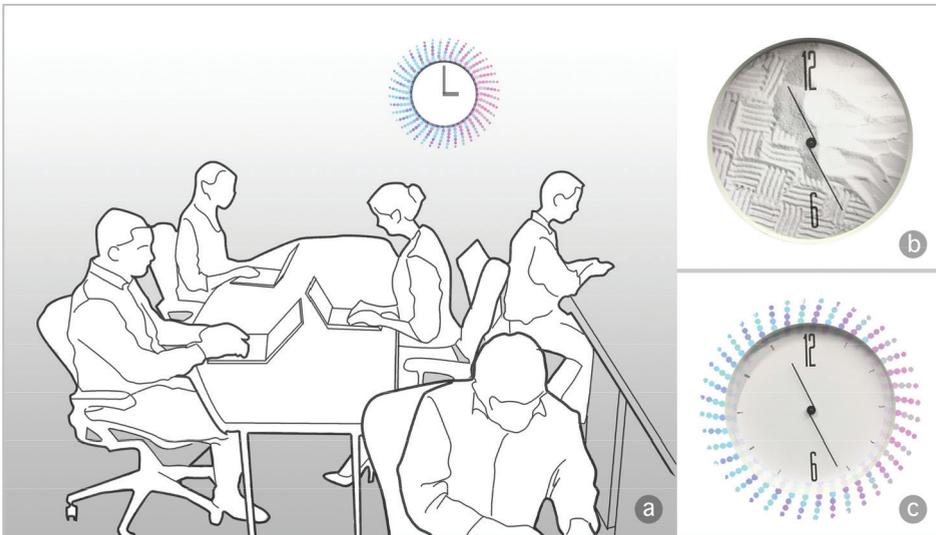


Figure 1. ClockViz. (a) Illustrations of application scenario, (b) static visualization, and (c) dynamic visualization.

Therefore, we developed *ClockViz* (**Figure 1**), a projection-mapped clock to prove the concept. *ClockViz* visualizes collective stress information by visually augmenting to a clock that has been a public display in the working space, so workers in situ can easily perceive the collective stress information visually when they are working together. Regarding simplicity, we designed a static (**Figure 1b**) and a dynamic (**Figure 1c**) projection overlays to visualize three different extents of collective stress on a clock as an augmented reality installation. Initial user feedbacks were gathered from a sixteen-participant pilot testing, which was conducted to understand the effectiveness of the provided visualization under a pressure cooker. It showed that the participants not only agree that our system visualizes their mental states meaningfully but are also willing to provide constructive suggestions for the next iteration of customization.

The rest of the paper is organized as follows. First, we review the relevant literature. Then, we explain the design, the implementation, and the users' feedback obtained from a pilot study. Finally, future research directions are discussed and suggested with our conclusion.

2. Related work

Individual stress coping strategies had been framed in the domain of interaction design. These designs mostly correlated to other domains, such as stress measurement and social science. Hence, this section will explain stress-related work in the following three sections: social factors on stress management, stress measurements, and related solutions in interaction design.

2.1. Social factors of stress management

In the domain of social science, many factors can cause stress in the context of a collective, for instance, the changing of organizational structure, leadership style, and quality; the demands of tasks and roles; the communication within an organization; and so on [6]. A majority of the previous studies on collective stress coping methods are sociological resolutions like training, rewarding, and self-developing [6], and they have also been explored extensively in catastrophic psychology [7]. However, it is infrequently approached in empirical stress research in the context of organizations [8].

2.2. Stress measurement methods

Other than physical and physiological techniques noted above, stress can also be measured through scales or questionnaires. Famous methodology to scale stress includes PANAS scale [9], perceived stress scale [10], Hassles scale [11], etc. Limited scalable methods of collective stress narrow down the interactive design solutions. Mark et al. use multi-methods that include heart rate monitors, computer logging, daily survey, general questionnaire, and interviews to measure college students' stress. She proposed that the amount of multitasking is positively associated with stress [12]. This research is one step further toward helping people change their behavior to reduce stress. In this case, collective stress information can be objectively measured which provide future researchers a way to gain collective data. Unfortunately, no possible solutions of collective stress were brought up at the end. Moreover, stress status

can be created and adjusted through complete difficult tasks or challenging games, such as memory card game [13], domino game [14], soccer game [15], and first-person shooter game [16], which validity and practicability have been proven in the previous research [17].

2.3. Biofeedback for visual perception

The combination of stress measurement and interaction design has been well explored. Some artifacts had been designed to give biofeedback of individual's stress status and attempt to visualize personal biological parameters [18, 19], or do interventions [20–22] to mediate their stress through various methodologies. For instance, Van Rooij et al. [18] applied RSP data in their work, and Henriques et al. [19] offered BVP parameters. Beyond the visualization level, Yu et al. designed an auditory display providing HRV to help biofeedback training [20]. Bhandari et al. [21] also applied music biofeedback intervention to help users regulate their stress. Gaggioli et al. [22] verified that inter-reality could better manage psychological stress than traditional stress management training. Some of these studies involved solutions considering visual, auditory, and tactile perceptions of a human being. Since visual perception has less interruption and disturbance, it has been widely applied in biofeedback visualization. Thus, we will mainly discuss biofeedback for visual perception in this case. Various patterns or physical objects associated with natural patterns had been used in former studies [4, 23]. A 3D graphic serious game design on smartphone provides biofeedback and adjusts user's breath through animation, which is related to the real-time cardiac coherence level [4]. In other words, letting people acknowledge their biomedical signals with certain training exercises could help them relax. MoodLight [23] is a real-time interactive lighting system, which designed to promote even to lead biofeedback to users. Matthew et al. claimed that "promoting or leading feedback can be more helpful to make user relax than the real-time feedback" [23]. Those studies verified that present biometric information to individuals could provide a sense of control and possibly regulate themselves on their own in specific scenarios.

2.4. Summary

Our review shows that the discipline of interaction research and design has taken a great interest in stress-related topics in recent years. It has been well explored of interaction design artifacts to mediate individual stress. Nonetheless, researchers mostly use technical solutions for stress measurements on individual users instead of a group of users as an entity. Interaction designers design artifacts to deal with social issues and neglect collective stress because of practical limitations. Hence, this research focuses on seeking practical solutions for collective stress management in teamwork.

3. Design

3.1. Design considerations

According to the brief review, we assume that biofeedback visualization information of collective stress could help the team members better cope with their stress. The visualization should be "a tool that brings people together to address issues instead of isolates people as individuals" [24],

based on the practical theory of social design. Thus, providing a public display is more preferable than using personal displays of individual users. Our research question is could public biofeedback visualization have meaningful influences on participants during teamwork?

In the context of designing visualization of public display, three main considerations while forming the visualization design are the choice of expression, the correlations between collective stress status and corresponding expression, and the avoidance of interruption or distraction.

On the choice of expression, we try to change the environment as least as possible so that the workers can transfer their daily behaviors to the display we provide to them. By observing common working scenarios, we found out that most of the public working spaces have a clock on the wall, which is a public display of time, allowing us to design a nonintrusive installation by augmenting a clock. Regarding a clock as a display of time, time-related collective pressures are mostly suitable to be displayed on it. To further understand the correlations between collective stress status and corresponding expression, we conducted informal interviews with several student study groups in a university and summarize three common collective stress statuses in the teamwork with time:

1. Everyone in the team feels stressed. Before a deadline, everyone feels stressed from the time pressures. When the deadline is approaching, everyone is doing challenging tasks on their own. The team that suffers from even the stress level among all team members often leads to a stressful working atmosphere. In this case, the collective stress steadily changes with time.
2. Someone (s) feel stressed, someone(s) do not. This happens when there are dependencies between the divisions of labors (e.g., one has to wait for another one's response) and uneven divisions of labors (e.g., someone's task is beyond his or her capability, but someone's task is not or even too easy). The uneven stress would lead to unharmonious working atmosphere and even drive affection between team members (e.g., members argue or blame each other). So, the collective stress unsteadily changes with time.
3. Everyone in the team does not feel stressed. This happens when the deadline passes, and the next deadline is still far away, everyone in the team does not suffer from time pressures. In this case, stress condition is affected by the individual factor, and the collective stress visualization does not seem to be necessary.

On avoidance of interruption or distraction, the clock should stay ambient in the background, and the coworkers should notice the visualization only when they look at the clock for checking the time. Therefore, the visualization should avoid attention grabbers that may interfere with user's peripheral perception, such as salient movement, startle changes of colors, and intensities. Therefore, the visual augmentation should be designed either as static as possible or consists of consistent dynamic movements.

3.2. Designing ambient visualization of collective stress

Based on this principle, we proposed two proof-of-concept visualizations of collective stress: static and dynamic. Each expression contained three collective stress statuses that we discussed previously: (S1) everyone in the team feels stressed; (S2) someone(s) feel stressed, someone(s) do not; and (S0) everyone in the team does not feel stressed.



Figure 2. Static visualization. (a) Everyone in the team feels stressed. (b) Someone(s) feel stressed, someone(s) do not. (c) Everyone in the team does not feel stressed.

Static visualization (**Figure 2**) is an ambient intervention, which is inspired by Zen garden. The sand traces changed imperceptibly slowly within a glance, so it appears to be static. When everyone in the team feels stressed (**Figure 2a**), the entire clock is covered by dense patterns, showing the even pressure of every team member. When someone(s) feels stressed, but someone(s) does not (**Figure 2b**), the sand traces appear to be bipolar: half of the clock is covered by dense traces, but half of it is not. The ratio of the two parts also displays the uneven loadings of workers. When everyone in the team does not feel stressed (**Figure 2c**), the sand traces are slowly erased, so it appears to be peaceful. With these trace patterns of the sand, the design also attempts to evoke inner peace, calmness, and tranquility of people.

Dynamic visualization (**Figure 3**) is a dynamic intervention, which is inspired by water shows. The light pattern spins, dilates, and erodes in a stable speed, which is governed by several sine functions, to provide dynamic but peaceful representation when the users take a glance at the clock. When everyone in the team feels stressed (**Figure 3a**), a colorful spiral is displayed around the clock with dense, long traces, showing the even pressure of every team member. The length of trace changes with the time pressure. When someone(s) feels stressed, but someone(s) does not (**Figure 3b**), the density of spiral varies with time to display the uneven loadings of workers. The density of spiral also changes according to the unevenness of task loads. When everyone in the team does not feel stressed (**Figure 3c**), the length of trace reduced, so it appears like a peaceful, rotating color wheel. The design also attempts to use many positive metaphors such as the colors and shapes [25] to provide cheerful experiences.

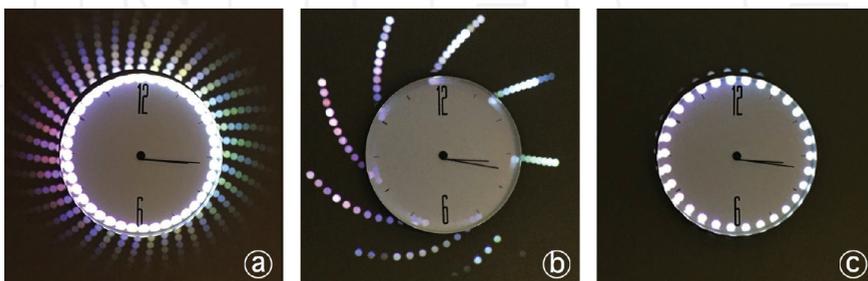


Figure 3. Dynamic visualization. (a) Everyone in the team feels stressed. (b) Someone(s) feel stressed, someone(s) do not. (c) Everyone in the team does not feel stressed.

4. Pilot study

To understand the effectiveness of our design, a pilot study was conducted to understand the users' behaviors and responses to the provided visualization in teamwork under time pressure.

4.1. Participant and apparatus

Sixteen participants (seven males, nine females) were recruited and divided into two groups: eight for the static visualization and another eight for the dynamic visualization. For each visualization, the eight participants were further evenly divided into two teams. The study is conducted in a meeting room where a projection-mapped clock was installed on the wall. As shown in **Figure 4**, the visualization of the projection is controlled by a computer.

4.2. Task and stimuli

Domino game is chosen as a pressure cooker because of the following three reasons. First, domino is a game that participants from various cultural backgrounds are familiar with, introducing immediate walk-up-and-use system to our study. Second, domino games not only require but also encourage teamwork. Third, the difficulty of domino games is easily adjustable based on the complexity of construction. By assigning different domino challenges to a team by asking them to complete it within a given period, we can test our system and obtain initial feedback with this pressure cooker.

Each team was asked to finish each of the three tasks in 5 minutes. The tasks are designed in different difficulties. The first task is to collaborate with each other and make a 2D pattern that can be knocked down in one push. This refers to an easy task that associated with low-stress status. The second task is to collaborate with each other and make a 3D round tower,



Figure 4. Experimental apparatus.

as shown in **Figure 4**. This refers to a relatively stressful task for everyone in the team. In the third task, we divide the team into two groups: one group is asked to build a 3D tower, and another group is asked to build a 2D pattern in the middle of the 3D tower. This refers to two uneven and mutual-dependent stressful tasks performed by each of the two groups in the team.

The transitions of visualization are human controlled. The stress visualization of all the tasks started from the stressless visualization (S0). In Task 1, we keep the same visualization until the end. In Task 2, we switch the visualization from S0 to the even stress visualization (S1) after 1–1.5 minutes the task started without noticing the participants. Similarly, in Task 3, the visualization was switched unconsciously from S0 to the uneven stress visualization (S2) after 1–1.5 minutes the task started. The stages of visualization quietly and gradually transit without disturbing the participants. After all the three tasks were performed, an interview is conducted to gather feedback from all participants.

4.3. User feedback

Static visualization: The static visualization brought peaceful feelings to most participants, and they reported that it has less interruption of their ongoing work. Half of the participants (4/8) mentioned that they like the feeling of the static pattern and it won't disturb their ongoing work. Comments from participants like "It looks nice. I like the natural feeling of irregular patterns than a digital one." "The thing I like more is it's different that I saw before. It's new, the material." "I can't imagine how comes up with this idea, the sand, the appearance looked more attractive." One participant (P1) commented "There's a lot of directions and lines, must indicate stress, is it?" "There's a lot of patterns over there so it's stress, but the flat one likes empty, so very peaceful." "This means half of us stressed and half are not stressed." "Right now it's all stressed!" One (P7) also mentioned "I realize this scene is much easier for me to understand the stress status." Most participants (6/8) described the influences of the static pattern to their internal activities. "I feel the flat pattern made me more relaxed compared with the striped one. Because it feels like some kind of scratches." "It has kinds of regulation, it reminds me meditation, like the Zen garden." Most participants (6/8) claimed that they can hardly associate the stress status with the static pattern without clarifying the announcement in the beginning. Since we intend to apply positive metaphors to visualize something negative in life, it is necessary to declare the initial intention of the expression in advance. Otherwise, the expressions will be too abstract to be accepted by the audiences. Overall, the feedback shows that the static visualization could help people adjust their inner peace through public display as a mean of visual intervention. The correlation between the visualization and the stress needs to be improved since most of them claimed that they did not feel connected to the visualization in the first place.

Dynamic visualization: People hold split opinions about the dynamic visualization. Part of them claimed that they like dynamic feedback, and they felt that it looks like real-time heart rate, while there are participants who also brought up that the quick changing shapes distract their attention in some way. Many participants (5/8) mentioned that the dynamic pattern

looks like a symbol of time pressure. One participant (P3) commented that “Now it’s like somebody is telling you that you need to hurry up.” One participant (P4) claimed that it symbolizes the group heart rate “Is it the group’s biomedical signal? It reminds me of heart rate.” Some participants (2/8) stated that stress information is useful to themselves to better cope with it because it is unnoticeable. For example, one (P1) commented that “Stress is very unconscious, it’s hard to aware of my feeling that I’m under stress, but when I think about it, I can control myself and try to manage it.” On the contrary, like (P5) claimed that offering collective stress information will bring more stress. For instance, participant (P8) said “I would be more stressed if I see other people is under stress. Stress display might makes me anxious, that I should be stressed as the same.” In summary, the dynamic stress visualization could easily get people’s attention and accessible to provide stress information. One thing that needs to be designed carefully is to what extent the dynamic expression may produce disturbance to people.

4.4. Summary

The reactions and feedback gathered from the participants suggest the pros and cons of the two visualizations. Static visualization drives a peaceful and calmness status that attempt to balance users’ inner peace, but it could be easily neglected. Dynamic visualization is more noticeable, but, meanwhile, it might produce unwanted interruption and disturbance. Constructive suggestions such as customization were also brought up. Some participants (4/16) mentioned that they expect to see the correlation between their individual stress statuses from the collective stress information. Alternative expressions in the visualization and different modalities of biofeedback as well as more applications of this visualization were also suggested in the interview.

5. Discussion

The visualization mentioned herein can be provided based on the data collected from the calendar or schedule of a team with proper synchronization between the installation and the global time. However, to tailor the visual experiences as a more proactive and adaptive design intervention for teamwork, additional sensor data should be considered to give the feedback in better accuracy and responsiveness. We herein discuss the possible sensing extensions regarding reliability and scalability.

Regarding reliability, intrusive ways to sense organizational stress through HRV and EEG could be relatively stable and reliable indicators of stress. However, their original form appears to be not very practical in the context of teamwork, because everyone has to put on the device while working, and the device’s form factors may negatively affect their working performances. Therefore, future research can consider developing wearable HRV and EEG devices in better forms, making them comfortable and even fashionable to be worn in daily lives and the workspaces to facilitating data collections.

Regarding scalability, nonintrusive sensing methods such as using cameras and computer vision techniques track the emotion of multiple workers by tracking their motion and facial expressions as stress indicators. A possible way to embed sensors is to use accessories that people need inevitably in their daily lives, such as designing biosensors as smart things (e.g., pillow, mirror), to minimize intrusions and distractions. The advantages are that multiple users can be tracked using a single device and the users require no instruments on their body. However, the downsides are that the users are constrained by the sensing range and it may raise privacy concerns. Hence, the physical form and the data collection mechanisms of the stress collectors should be carefully considered and designed.

Another scalable solution is to design social interaction platform for workers to report their stress situations and give suggestions to their peers easily. For example, when the atmosphere is getting uncomfortable, workers can quickly share their feelings through a platform, and the visualization will be pushed to the potential stressors' personal devices. In this case, no extra hardware deployment and maintenance costs are required because human beings can be considered as sensors of collective stress. This solution can also be considered in the immersive AR or VR applications because the visualization can be provided to the users' wearable displays.

6. Conclusion and future work

This work presents *ClockViz*, an augmented reality installation applying static or dynamic projection overlays, which are designed to reflect collective stress through providing biofeedback visually. Both of the proposed static and dynamic visualizations can be applied in the environment as an ambient installation that expresses the collective stress information visually. The results of a pilot study with sixteen participants suggest that the visual information of collective stress status does have meaningful influences on participants. We also have discussed the sensing solutions, which may extend the proposed techniques toward more proactive and adaptive applications for interactive design interventions for coping with collective stress with time. Future work can consider investigating how the public visualization affects people's internal or external behaviors and how personalization and customization could be conducted in the next iterations. According to our literature review, there are no interactive interventions or empirical solutions in the context of collective stress. Hence, we believe that this research shed a light on a new direction that needs to be noticed and emphasized in the future research.

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