Designing Whispa: Supporting Awareness and Action Through Peripheral Interaction

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ABSTRACT

This study explores how interactive interventions can support user awareness and response to collective stress in small-group meeting settings. While traditional office tools enable task collaboration, they rarely support the emotional and social dynamics within teams. This research explores peripheral interaction as a possible means of supporting non-verbal engagement. A functional prototype was developed, which is an inflatable tabletop that responds to collective stress in small group meeting context, aiming to support self-reflection and group awareness without interrupting the meeting flow. A mixed-method experiment was conducted, involving repeated-measure STAI assessments and semi-structured interviews with 24 participants. Although the quantitative results did not show statistically significant differences, the qualitative analysis revealed rich patterns in how users noticed, interpreted, and responded to the prototype. Key themes include how users interpret interaction cues, adjust their attention and behavior, and engage in communication and group awareness. The study offers valuable insight into how peripheral interactive office table can support awareness to collective stress in collaborative contexts. It also explores how design elements promote engagement without disrupting task focus, and design balance between cognitive attention and action support.

Keywords

Collective stress; stress physicalization; social dynamics; small group meeting; workplace wellness; industrial design; flexible interactive interface; peripheral interaction

1. INTRODUCTION

Stress is a topic that is frequently discussed in the context of modern work life. Nowadays, many people spend a large part of their day working in offices, collaborating with others to solve problems and complete tasks. Although much existing research focuses on stress at the individual level, stress is often experienced collectively when people work in the same space, share responsibilities, and coordinate resources. As a result, workplace health and vitality are increasingly recognized as important topics.

Collective stress usually results from difficulties in adapting to organizational or social challenges, and can be eased through group-level coping strategies (Lansisalmi et al., 2000). It is not simply an aggregation of individual stress, but a collective phenomenon that impacts both individual workers and the broader workplace by reducing team performance, impairing decision-making, and weakening communication (Festinger, 1954).

However, research on solutions to collective stress across different office settings within the interaction design domain requires further exploration. Most current discussions around collective stress emerge from psychology and sociology. Study shows that in office environments, collective stress often arises from external pressures like organizational restructuring and high work demands, as well as internal dynamics such as a lack of recognition and reputational concerns within team (Lansisalmi et al., 2000). Research also indicates that, among coping strategies, collective problem-focused coping is more effective than individual or co-active efforts in reducing employees' perceived stress and improving the organizational stress climate (Rodríguez et al., 2019). As this highlights the importance of group-level strategies in stress management, there is an increasing demand to explore how interaction design can support these strategies. Systematic investigation into design solutions that facilitate collective coping could provide valuable insights for both researchers and practitioners.

When exploring solutions to collective stress in the workplace, it is important to consider the diversity of work contexts, as user needs and expectations can vary greatly. There are differences between open and more structured work environments, large and small work teams, and formal and informal workplace cultures. For example, in open and team-oriented office cultures, collective coping strategies tend to be more common and effective because these environments encourage communication, mutual support and collaborative problem solving (Lansisalmi et al., 2000). Collective stress also differs across organizational levels. Higher-level employees tend to experience pressure from decision-making and crisis situations, while lower-level staff are more affected by limited pay and advancement opportunities (Vagg et al., 2002). Therefore, context-specific strategies that respond to the different needs appear most promising. Another current challenge is the effective integration of interactive interventions into existing workflows. As people in offices usually focus primarily within their own work groups and consider topics unrelated to direct work tasks to be private, it can be difficult to use natural group dialogue to relieve stress. This adds complexity to potential interventions. Existing literature continues to emphasize the importance of team-building and improving individual communication skills as strategies for enhancing group performance(Smeltzer, 1987). As collective coping has been linked to increased group cohesion (Morris et al., 1976), investigating how these mechanisms can be meaningfully embedded into interactive design presents a promising and important area of study.

After exploring typical workplace scenarios and engaging with relevant user groups, meetings emerged as an area worth further exploration. As a structured and widely used group activity, workplace meetings often involve goal-related pressure, time limitations, and complex interpersonal dynamics. With core elements such as leading, engaging, and interacting (Allen & Lehmann-Willenbrock, 2023), meetings offer a relevant setting for exploring how collective stress emerges and is managed in group work. However, addressing collective stress within meetings is challenging. Stress indicators in meetings tend to be subtle and difficult to detect or respond to effectively. Participants usually prioritize achieving task objectives promptly, often overlooking or ignoring collective stress. This could create a vicious cycle, negatively affecting both the efficiency of meetings and the overall atmosphere of the group. Improving how collective stress is managed in meetings could lead to more focused participation, smoother collaboration, and a healthier team climate.

Due to the need for focused attention in meetings, peripheral interaction has become a key design consideration for this project. Peripheral interaction (Bakker et al., 2015) involves subtle, non-disruptive methods for conveying stress-related signals or feedback without disrupting ongoing activities. Compared to highly interfering approaches, peripheral interventions use environmental cues to gently support group awareness and regulation, nudging user behavior without explicitly forcing change or passively waiting for spontaneous realization.

This study presents an interactive meeting table with a soft, flexible interface that gradually shifts from subtle to more focused interactions, avoiding a fixed level of intervention. The design employs inflatable silicone surfaces to visualize collective stress and progressively raise users' awareness. It also encourages physical engagement with the table, promoting positive body language and gently prompting actions that support healthier group dynamics during meetings.

This study explores how interactive interventions can be used to encourage active responses to collective stress in meeting contexts, with the goal of improving group engagement and meeting efficiency. To address this main question, the research focuses on three sub-questions:

(1) In what ways can interactive elements, such as visual, physical, or behavioral cues, effectively prompt participants to respond?

(2) What forms of user actions are triggered by such interventions during meetings?

(3) How do interactive interventions compare to ambient displays in terms of their effectiveness in supporting group dynamics?

This project will provide insights into how interactive elements can facilitate effective user interaction, identify patterns in user responses and determine appropriate intervention levels in meeting contexts.

2. RELATED WORK

2.1 Measuring stress and collective stress

Individual stress is commonly measured through a combination of self-report questionnaires and physiological signals. Validated self-report forms such as the State-Trait Anxiety Inventory (STAI) (Spielberger et al., 2017) and the Perceived Stress Scale (PSS) (Lee, 2012) are widely used to assess how individuals perceive and experience stress over a recent period. In controlled environments, the Trier Social Stress Test (TSST) (Kudielka et al., n.d.) is a standard protocol used to induce acute psychosocial stress for experimental purposes.

In addition to self-reports, physiological signals such as heart rate variability (HRV) and photoplethysmography (PPG) are often collected to monitor physical indicators of stress (Cho et al., 2019; Umair et al., 2021). These individual-level methods also serve as the basis for assessing collective stress, which typically involves aggregating physiological data from multiple users. Design such as smart cushions (Hoekstra et al., 2022), BallBounce (Nkem & Xue, 2023), a workplace biofeedback system, and AffectiveWall (Xue et al., 2019), a shared display of individual stress-related physiological data, have applied aggregated data to evaluate collective stress conditions.

There are also emerging technologies, including deep learning approaches, have been applied to detect stress states with reported accuracy as high as 92% in laboratory settings(Bromuri et al., 2020; Tervonen et al., 2020). However, the reliability of such systems in real-world environments remains a challenge due to contextual variability, noise, and individual differences (Abd-alrazaq et al., 2024). Still, these methods provide a theoretical and technical foundation for exploring stress-related interactions in applied settings.

2.2 Approaches and considerations for addressing collective stress in office settings

Within the HCI field, several approaches have been proposed to visualize and address collective stress in workplace environments. Many studies encourage group-based interactions and ambient visualizations to communicate stress levels and promote shared reflection. Beyond the earlier examples, PopStress (Bao et al., 2023) offers a playful approach by converting collective stress in office environments into the energy used to operate a popcorn machine, introducing a lighthearted and symbolic way of externalizing stress.

Other work focuses on adaptive environmental interventions. For instance, the concept of the "smart office" suggests that workspaces can co-evolve with employees by adjusting lighting, temperature, and other ambient factors to help reduce environmental stress (Awada et al., 2023). Artistic approaches have also been explored, such as VIT.IN, a dynamic wall painting that continuously reflects the collective stress levels of employees, aiming to increase awareness in a subtle and aesthetic manner (Stappers & Hu, 2024).

Together, these approaches reflect a growing interest in supporting group awareness, stress regulation, and healthier collaboration in shared office environments.

As the topic involves emotions and individuals' performance in everyday work contexts, ethical considerations are important. When discussing strategies related to collective stress, it is usually best to avoid presenting information that is specific related to individuals. Instead, the group is considered as a whole, with no personal emotional states disclosed. This principle also informs the approach adopted in the present design.

2.3 From implicit interaction, peripheral interaction, to focused interaction

Given that people need to stay focused on their work while still being able to respond to group dynamics and collective stress, the cost of attention and action becomes an important consideration in interaction design. Understanding how people engage with interaction requires recognizing different levels of attention and intention. Here, the concepts of implicit, peripheral, and focused interaction are introduced. The distinction between them lies mainly in the degree of user awareness and effort involved (Bakker & Niemantsverdriet, 2016). As interaction shifts from implicit to peripheral to focused, the cognitive load and engagement required from the user gradually increase. Applying these modes appropriately allows interactions to be integrated into everyday routines in a subtle and non-intrusive way.

To illustrate, focused interaction refers to deliberate and conscious engagement with a system, such as actively using a smartphone or interacting with a graphical interface, where the user's full attention is required(Bakker & Niemantsverdriet, 2016). Implicit interaction, by contrast, involves systems that sense and respond to user behavior without requiring active input or awareness (Bakker & Niemantsverdriet, 2016; Stampf et al., 2022). For instance, a smart thermostat that adjusts temperature based on routine and presence.

Peripheral interaction typically involves subtle engagement with physical objects or digitally augmented surfaces that remain at the edge of attention (Edge & Blackwell, 2016). In meeting contexts, peripheral interaction is a suitable choice for guiding users toward increased awareness and encouraging simple actions.

3. OVERALL DESIGN PROCESS

As this design research project is closely aligned with the previous design phase, it is essential to provide a comprehensive overview of the entire process and explain how each stage logically connects to the next. This section therefore provides a comprehensive overview of the entire design process. The work from the last semester is summarized, highlighting key methods, objectives and insights, while the current semester's explorations are discussed in more detail.

3.1 Understanding user needs and proposing initial design directions

To better understand user expectations in meeting scenarios and identify typical pain points, a workshop was developed within the context of a creative, collaborative session. This workshop explored requirements for managing collective stress and included an educational group work scenario. Participants were provided with multiple informational cards (Figure 1&2) to facilitate understanding of various information types relevant to specific situations and examples. These cards were designed to initiate discussions and encourage participants to consider solutions within an established interaction framework (Figure 3). The framework drew inspiration from an interaction design framework originally proposed by Vallgårda (2014), which illustrated three fundamental form elements of interaction design. The informational cards themselves were derived from established terminologies in interaction design and semantic categorization frameworks(Dassen & Bruns Alonso, 2017) and the Levels of Digital Twin Framework(Agrawal et al., 2023).

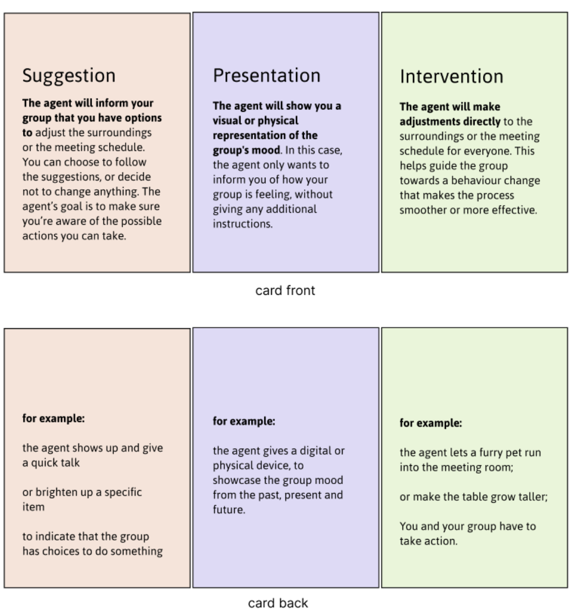

Figure 1 The category cards of information

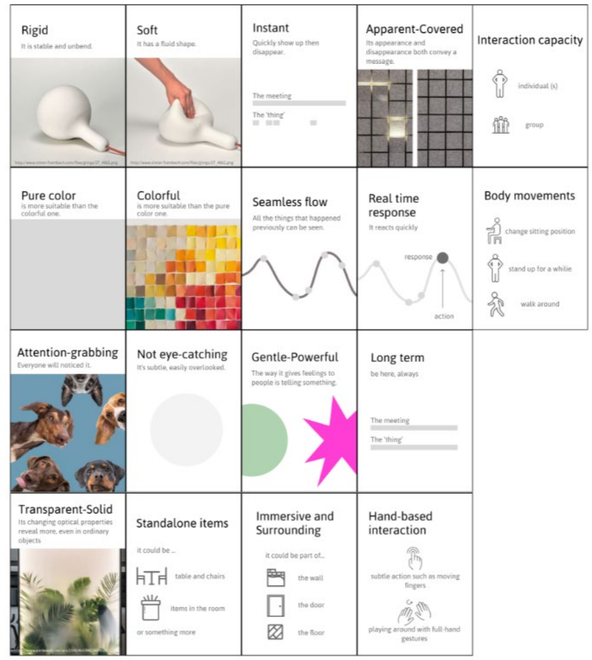

Figure 2 The design property cards

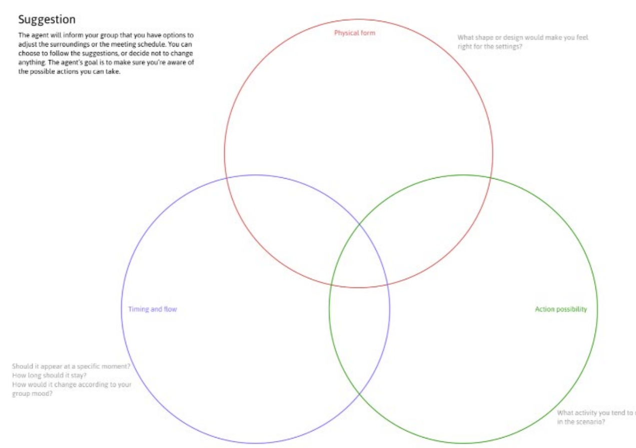

Figure 3 One of the three collaboration boards, suggestion edition

Three groups participated in the workshop, each consisting of three participants. This number was chosen to balance effective collaboration, observational needs for group dynamics, and practical considerations, representing the minimum viable size for meaningful group interaction within a meeting context. The workshop began with an introduction to the contextual scenario, after which each participant reviewed the cards, engaged with the scenario, and collaboratively identified and discussed the key elements desired in their envisioned designs. After the collaborative discussion, semi-structured interviews were conducted to gain deeper insights into participants' thoughts and expectations.

Insights from this workshop highlighted that users preferred clear and easily implementable information that could prompt immediate coping actions in real-time without disclosing personal thoughts directly. Participants favored subtle indications, hints, or even light-hearted jokes as effective cues. At the same time, they valued practical and actionable guidance on coping strategies more highly than updates about the current status. In terms of coping strategies, activities that promote positive group dynamics and those that are explicitly focused on relieving stress were identified as crucial. Participants particularly appreciated interventions that encouraged physical movement, such as walking or standing up. They recognised these as beneficial for managing stress and for promoting overall group engagement. When it came to problems and requirements, people said they found it hard to stay focused, especially when making decisions together. There was also uncertainty about how to interpret differences in group members' thoughts and feelings. Participants also emphasised the importance of establishing trust and psychological safety within the team, as well as expressing concerns about scheduling and managing time effectively during group interactions.

3.2 Initial prototype and preliminary validation

At this stage, a preliminary design concept was introduced. The prototype (Figure 5) was a table surface module with an inflatable silicone interlayer, which was designed to help users recognise collective stress and explore potential coping strategies. The general interaction process involved inflating the silicone layer to slightly raise the tabletop, indicating an increase in collective stress. If users chose not to interact, the tabletop continued to rise, subtly prompting participants to stand up.

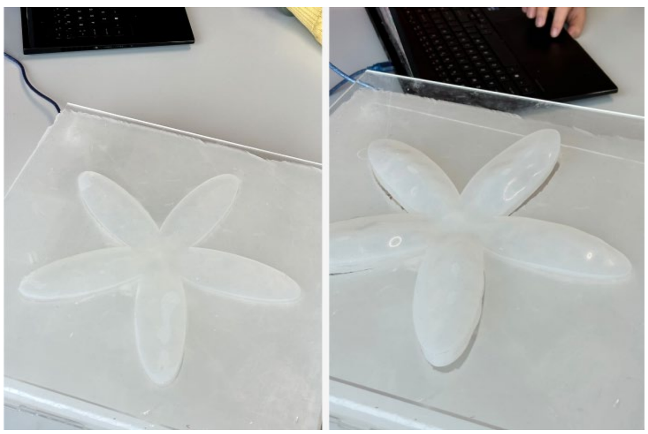

Figure 4 Comparison of the functional prototype. The left image shows the prototype in a deflated state, while the right image shows the prototype after inflation

Silicone was selected for implementation due to its high malleability, enabling the formation of specific chambers and shapes as needed, and superior durability compared to plastic air bladders. The initial prototype measured 40x40 cm and featured a tangible floral pattern as a visual cue.

To preliminarily validate and explore design constraints while collecting feedback, 9 participants were recruited for feedback sessions, divided into groups of 3. Each group was given a topic to discuss within a specific timeframe. During this time, the prototype was activated twice: first with slight tabletop elevation and then with a significant elevation suitable for standing meetings. Afterwards, the participants completed questionnaires and were interviewed.

The feedback results indicated positive attitudes towards the concept in general, noting its role in promoting reflection and providing stress relief through physical interaction. Participants also expressed favorable sentiments toward standing meetings. However, concerns about potential disruptions were also raised. Due to limitations in the prototype's size and functionality, the initial model was not yet suitable for formal studies. The detailed effects on social dynamics and user behaviour also required further exploration. In summary, the concept required further refinement and expert feedback for development.

3.3 Expert interviews and insight summary

To further refine the research direction and identify both opportunities and challenges within the current concept, interviews were conducted with three experts. The aim was to assess technological feasibility, explore core values, and understand the potential of the proposed interaction. The experts came from the fields of biomedical signal analysis, mental health, and data-enabled design. Here are the insight summary.

From a technical viewpoint, it was found that current sensing technologies still lacked stability in final-stage testing. Experts noted that while physiological signals such as electrocardiography (ECG) and skin conductance level (SCL) can provide accurate stress-related data, their reliance on wearable or contact-based setups may disrupt natural behavior in meetings. If the final study aims to observe behavioral responses, less intrusive sensing approaches are recommended. However, alternatives such as table-embedded photoplethysmography (PPG) involve a trade-off in precision, and remote PPG remains highly sensitive to motion noise, especially during spontaneous user movements. Therefore, in the final testing phase, the system will prioritize user experience. Physiological sensing will be treated as a non-essential addition, while relevant technical details can be explained to participants to help them better understand the system and engage meaningfully with the prototype.

When it comes to data presentation, experts showed a preference for abstract and visually appealing patterns over direct or overly specific data visualisations such as heatmaps. Concrete numerical feedback could increase the cognitive load for users and would require the system to process and present multiple overlapping data layers, which would complicate the design unnecessarily. A more ambient visual presentation that is calm, organic and symbolically interpretable was considered better for supporting peripheral awareness without distraction.

As for interaction possiblities, the experts discussed the potential of adaptive systems that integrate naturally into meeting workflows. Suggestions included environmental responses (e.g., changes based on weather), multi-sensory elements such as music or light, and learning algorithms that reduce user effort. Such systems should balance responsiveness with subtlety to avoid disrupting attention and meeting flow.

Beyond these insights, an important topic emerged during the interviews: the balance between ambient displays and interactive interventions in meetings. Experts pointed out that while interactive systems may encourage more proactive responses, their impact on workflow and the nature of triggered user actions remains under-explored. Questions were raised about what types of actions are encouraged, how this affect productivity, and whether the interaction supports or disrupts the intended group processes. This perspective highlights the need for deeper investigation into how peripheral interaction can be designed to support, rather than distract from meeting tasks.

3.4 Positioning the design and research questions through theory

In this stage, the main goal was to deepen the research questions and to theoretically refine the design concept. This included incorporating new literature on peripheral interaction and reflecting on how the current design fits within related frameworks, thereby adding clarity to its underlying logic. Small adjustments were also

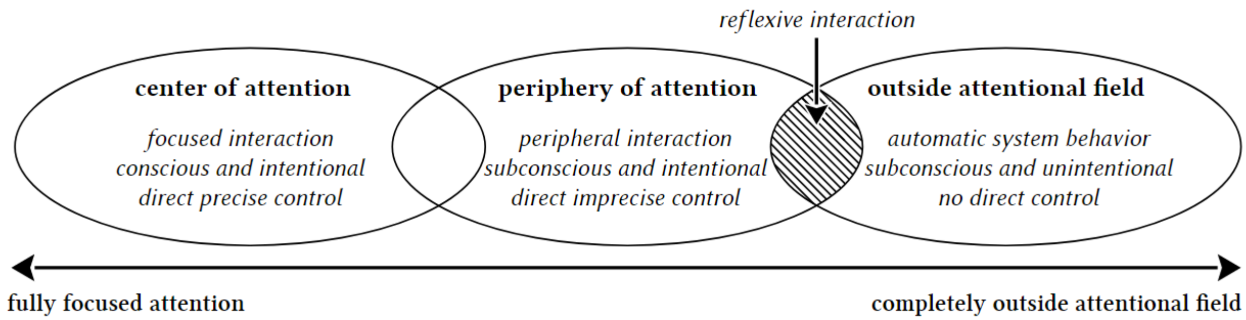

Figure 5 Illustration of the three types of interaction based on the user's involved level of attention by Bakker et al. (2016)

made to the interaction details, and the main research question was further developed into sub-questions.

To support this refinement, several theoretical concepts were introduced, including reflexive, peripheral and focused interaction. These concepts differ in terms of the complexity of the tasks they facilitate and the level of attention they demand. They also involve distinct modes of user engagement. In the context of this project, the meeting task remains the user's primary focus, meaning that any additional interaction must play a secondary role. Therefore, it is not desirable to require users to devote substantial attention to the interactive system.

At the same time, raising awareness of collective stress and encouraging users to take responsive action does require some level of engagement. The proposed design concept has a dynamic quality: it starts as a peripheral interaction that remains discreet and ambient under low-stress conditions. As collective stress levels increase, the interaction gradually shifts along the spectrum (Figure 6) toward focused interaction by demanding more attention and becoming more noticeable. However, it does so without fully crossing into focus interaction. This gradual shift increases the level of invitation in line with sensed collective stress, aiming to provide a more intuitive and comfortable user experience.

Building on this, the main research question was refined into three sub-questions, focusing respectively on the effectiveness of interactive elements, the forms of user actions triggered, and the comparison between peripheral and implicit interaction. A user test was conducted in the later on process to explore these refined questions.

3.5 Final Design Implementation

The prototype used in the final user test was a functional version of the interactive meeting table. The tabletop measured 70 × 70 cm to accommodate at least three users comfortably, with a total height of approximately 75 cm. The design featured an inflatable silicone interlayer that, when fully inflated, could raise the table surface by up to 4.5 cm. During the experiment, however, the inflation height was limited at this maximum value.

To ensure smooth and coordinated elevation of the tabletop, four micro actuators were installed beneath the silicone layer. These actuators simultaneously supported the top acrylic surface during inflation. However, synchronization issues occasionally occurred,

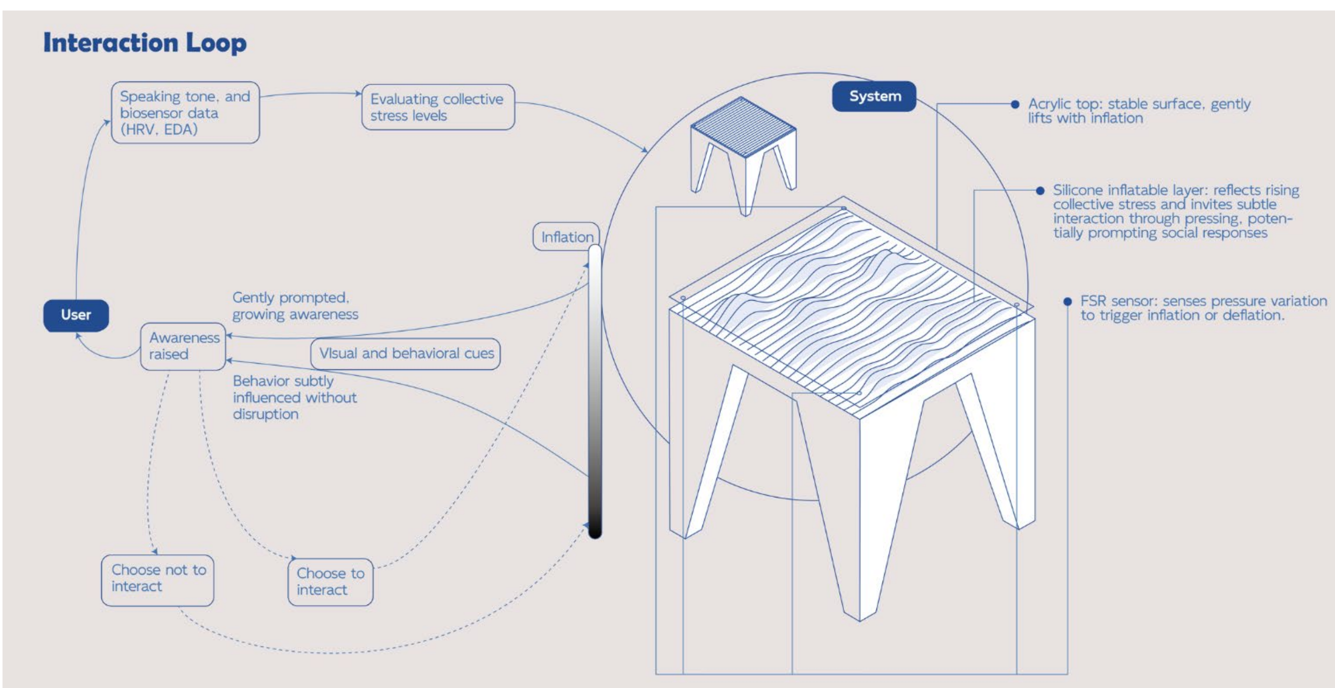

Figure 6 This loop illustrates how stress signals are sensed, reflected, and responded to through interaction.

sometimes causing a slight tilt in the table. This limitation was partially due to variations in the manufacturing quality of the actuators. To enable consistent forward and reverse control, the actuators were managed through an H-bridge driver connected to a 9V power source and an Arduino board.

Beneath the actuators, four force-sensitive resistor sensors were embedded. These sensors detected pressure applied to the table during user interaction and enabled the table to respond accordingly. In real-world usage, sensor readings can fluctuate due to normal user behavior and mechanical actuation. To ensure reliable operation during user testing, an additional remote control system was included, allowing manual triggering of inflation or deflation events as needed.

This prototype was designed specifically for small team meetings involving 3 to 5 participants, such as academic group discussions. These meetings are typically more formal than casual conversations but do not involve rigid hierarchies or high-stakes decision-making. Although the meetings have a clear task-oriented focus, participants are given more opportunity to engage in informal group dynamics and spontaneous interaction.

The interaction flow was as follows: the system was designed to evaluate the group's collective stress level. In theory, this could be determined through bio signal input, such as vocal tone or heart rate variability (HRV). The inflation behaviour of the silicone layer would vary based on different levels of collective stress. The visual and behavioural cues became more pronounced as stress levels increased: in the early stage of inflation, the cues remained subtle and were intended to attract user attention gradually. At higher stages of inflation, the cues became more visible, aiming to draw the user's attention and indicate the need for action, but without being abrupt or forceful.

This progressive feedback enabled users to stay focused on the task at hand, even under increased inflation. The cues were designed to remain on the edge of perception, making them visible but not attention-demanding, thereby preserving user autonomy. If users chose to respond, they could physically interact with the tabletop by pressing or tapping it, which would trigger deflation and return the table to a relaxed state. If they chose not to respond, the silicone layer continued to inflate. Due to the mechanical limits of the linear actuators, the tabletop would not rise any further, but the increasing tension in the silicone became more visually apparent. This served as a subtle signal, indicating a more critical level of collective stress and potentially prompting user action.

Figure 7 People in discussion, with the prototype functioning

4. EXPERIMENT

To address the research questions, a within-subject experimental design was used. Each group of participants experienced all experimental scenarios, allowing for direct comparison across different settings. Data was collected through self-reported questionnaires and semi-structured interviews. The experiment aimed to identify whether users' stress self-reports differed significantly across scenarios and to extract insights from interview transcripts using thematic analysis in relation to the research questions.

4.1 Participants

The experiment involved 8 groups, each comprising 3 participants, for a total of 24 individuals. All participants were aged between 23 and 30, and had prior experience of team-based work through professional employment or academic collaboration. The group size of 3 was chosen to simulate a typical small meeting context while facilitating effective communication.

4.2 Settings and Methods

All sessions were conducted in meeting rooms on the TU/e campus. The experiment included three distinct scenarios:

Control scenario: No visual or interactive feedback.

Scenario A – Ambient Display: Participants received non-interactive, ambient visual feedback through a wall-mounted display.

Scenario B – Interactive Intervention: Participants interacted with a prototype table with inflatable feedback responding to collective stress.

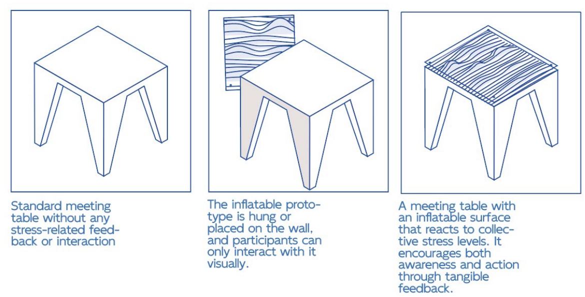

Figure 8 Three experimental conditions visualized from left to right: Control scenario, Scenario A, Scenario B

Each group experienced all three scenarios in randomized order to reduce sequencing effects and minimize learning bias.

A modified barter puzzle task was used as the stimuli task. Compared to standardized stress tests such as the TSST-G (Von Dawans et al., 2011), this task focused more on group coordination and distributed stress evenly among participants. It also allowed for better control over task difficulty and avoided issues related to physical changes. During each scenario, each participant was given a puzzle with missing pieces, which were distributed among the other team members. They had to complete the puzzle cooperatively within 20 minutes. Nine puzzle sets were prepared in total, with each participant receiving a unique set for each scenario to prevent repetition. This setup encouraged continuous communication, negotiation and decision-making, which aligned well with the collective stress context. The STAI (State-Trait Anxiety Inventory) form was used to measure participants' perceived stress before and after each scenario.

Table 1 Study Procedure Overview

Phase	Pre-test	Three scenarios experienced in a randomized order		Post-task
Activity	Baseline stress questionnaire (STAI)	STAI	Relaxation	Interview

RESULTS

4.3 Quantitative analysis

Prior to formal analysis, Shapiro-Wilk normality tests were performed on the difference scores between all scenario pairs to assess the suitability of parametric methods. Results showed no significant deviation from normality across all pairwise comparisons (all $p > 0.3$), suggesting that the assumptions for parametric analysis were met. Based on this, a Repeated Measures ANOVA was conducted to test whether there was a significant overall effect of scenario on STAI scores. This method accounts for individual differences by analyzing repeated measurements from the same participants across scenarios. The analysis revealed a significant effect of scenario: $F(3, 69) = 5.236$, $p = 0.0026$, indicating that anxiety levels varied across the experimental scenarios.

To support the robustness of the findings, a Friedman test was conducted as a non-parametric alternative. The result ($\chi^2(3) = 7.174$, $p = 0.067$) did not meet the conventional significance threshold, but showed a trend similar to the main analysis. In order to further explore specific differences, paired-sample t-tests were carried out with Bonferroni correction. The raw p-values suggested that Scenario 2 and Scenario 3 might lead to higher stress compared to the Baseline condition (Baseline vs. Scenario 2: $p = 0.021$; Baseline vs. Scenario 3: $p = 0.018$). However, after correction for multiple comparisons (adjusted $p = 0.126$ and 0.106, respectively), these differences were no longer statistically significant. All other condition comparisons also showed no significant differences, with some adjusted p-values higher than 1.000.

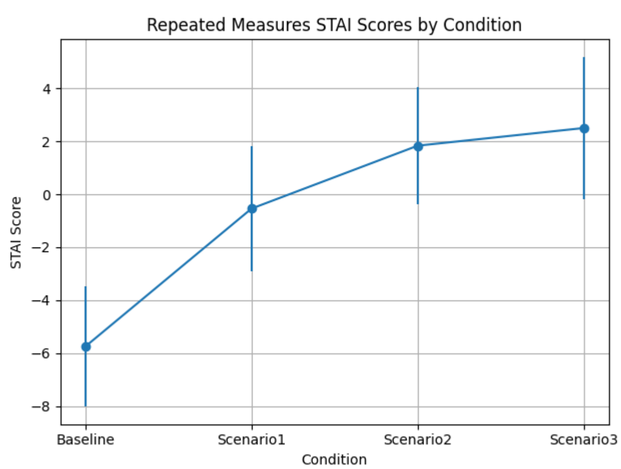

Figure 9 Repeated measures STAI by condition

A visual review of the average STAI scores across all scenarios (Figure 10) reveals a general upward trend from the Baseline to the later conditions. The error bars in the graph show the standard error of the mean (SEM). The overlapping error ranges and the absence of statistically significant results indicate that these changes should be interpreted with caution..

All analyses were conducted using Python, with the aid of libraries such as pandas, scipy, statsmodels, and matplotlib for data processing and visualization.

Table 2 Paired t-test results of STAI scores between conditions (Bonferroni corrected)

Comparison	t	Meanp_raw	p_adj
Baseline vs Scenario1	-1.676125	0.107256	0.643537
Baseline vs Scenario2	-2.476507	0.021056	0.126333
Baseline vs Scenario3	-2.557838	0.01759	0.105537
Scenario1 vs Scenario2	-1.029871	0.31378	1
Scenario1 vs Scenario3	-1.008528	0.323694	1
Scenario2 vs Scenario3	-0.261731	0.795858	1

4.4 Qualitative analysis

Although the quantitative data did not yield statistically significant results, the qualitative findings provided valuable insights that helped address the research questions. Through interviews, participants reflected more deeply on their experiences, actions, and thoughts during the sessions. Thematic analysis of the interviews aimed to identify and summarize the underlying patterns in these reflections, revealing meaningful perspectives on how participants perceived and responded to the interventions.

4.4.1 Users' emotional interpretations

Before addressing the core research questions, it is essential to learn how users interpreted the intended meaning of the prototype's behavior. This provides a foundation for understanding users' experiences in later themes. In the interviews, most participants perceived the tabletop's inflation and slight elevation as a reminder of an existing issue. Many used humorous metaphors, suggesting a generally positive and accepting attitude toward the intervention. Comments include:

> *"I felt like I had a cat that would come and bother you at your most painful moments."— Group 8*

> *"It might give me the feeling that it's counting down. Hurry up and finish the puzzle. If you don't, I'll explode."— Group 5*

> *"This is like a few people sitting around with their computers open, and someone spills a cup of coffee in the middle."— Group 6*

Some participants described the inflation effect in bodily or sensory terms, often referencing breathing or tension. This indicates that the intended metaphorical message was conveyed and interpreted. Comments include:

> *"It reminded me of a feeling of suffocation."— Group 6*

> *"It was the feeling of holding your breath, maybe the lungs were inflated or something."— Group 3*

In addition, a few participants reflected on how they interpreted the inflation not necessarily based on their own stress, but as a cue relating to the group's state. Comments include:

"I didn't think it might misjudge me. Maybe I just thought I wasn't anxious, but actually I was. It also might be a bit of a reminder to all of us."— Group 4.

4.4.2 Design Qualities That Support awareness and Engagement

Inflated form triggers an urge to press or release under stress. Just as participants compared the silicone inflation to the feeling of pressure in the lungs, the inflation seemed to naturally invite pressing either out of curiosity or as a stress-relief instinct. Comments include:

"When I'm under a lot of stress, I just want to pop it. Well, that's what I think is human instinct and should be good."— Group 5

"People like to squeeze soft things, or things like nail clippers. It's because it gives people a sense of immediate control. They feel that since the thing is soft, when they squeeze it, they get immediate feedback."— Group 6

The inflation's motion and sensory associations made it a hybrid of visual and behavioral cue, suggesting the emotional expressiveness of dynamic forms.

Soft texture enhances user comfort and engagement. The soft silicone layer played a clear role in inviting interaction. Participants were able to touch the inflated surface either directly or through the acrylic tabletop, and nearly all comments reflected a preference for its tactile qualities. Comments include:

"I've been poking it since I got here."— Group 2

"I like the feel of this thing since it's soft and flexible."— Group 3

Some participants also expressed concerns that the silicone might be too inviting, making it difficult to ignore even when stress was low. Comments include:

"When I'm not stressed, I like to press this too."— Group 6

Physical separation limits perception and engagement. A transparent acrylic panel was placed over the silicone layer to provide a stable work surface. However, this design decision unintentionally limited users' perception and emotional engagement. Participants felt the panel dulled the tactile feedback and made the inflation less visible. Comments include:

"I've noticed it. Well, but I think it's also this glass panel that makes me feel, well, a sense of distance. Yes, subconsciously I feel that no matter how much it bulges, it won't bulge much, or it won't go beyond this range. So the change doesn't seem that obvious or noticeable to me. If there were no board, I might be more sensitive to whether it bulges or not."— Group 5

"I like the feel. Well, but mainly when you cover it with acrylic, it's lost."— Group 4

Table movement is relatively more noticeable. Due to the actuator's limited speed control, the tabletop's upward motion was relatively abrupt. This made the movement a much more noticeable and impactful cue than intended. Three participants described how the table's elevation caught their attention or disrupted their focus. Comments include:

"Mainly more obvious when the desktop is raised."— Group 5

"I also found the lifting part a bit distracting. Like when we were really focused on the puzzle, and it suddenly rose up—it kind of threw me off."— Group 1

Noise immediately captures attention. Noise from the actuators was unavoidable in the prototype and turned out to be more disruptive than the physical movement. At least 7 participants said the noise interfered with either their concentration or decision-making. This highlights the importance of sound reduction in future designs. Comments include:

"For me, the raising and lowering parts were the most noticeable. I didn't really notice the inflation part. Especially the lifting—it made a loud noise and startled me."— Group 2

"I think sound is more impactful than vision. It can really interrupt my work."— Group 1

Disruptiveness depends on attentional state. In addition to design-related factors, many participants pointed to their own focus level as a key factor in whether they noticed or responded to cues. This varied by personality, task role, and momentary attention state. Some ignored cues completely, while others became aware. Comments include:

"I didn't notice it, but I was too focused on playing the puzzle, so I didn't do the interaction."— Group 2

"I was zoning out, so I noticed it. I think I'm the kind of person who's easily distracted. People like that may be more likely to notice these things."— Group 3

"I don't think this will affect me. It's not because I wasn't concentrating—but because it's not that intrusive. I noticed it, so it doesn't matter to me. But I don't think it has much impact."— Group 5.

Discomfort forces attention. Some participants described discomfort caused by various elements such as noise, the emotional tension of others, or slightly intrusive interactions. These weren't framed entirely negatively. Rather, discomfort was seen as something that forced awareness either of the prototype itself or of others in the group. Comments include:

"If there's some interaction with me, it will force me to, whether it's notice him or engage with him, to pull myself away from the anxious things and deal with a new thing first."— Group 3

"Yes, so for me, I only pay attention to something when I feel uncomfortable. For example, I only notice a sound when it makes me feel uncomfortable."— Group 1

Shared contribution through collective interaction. The prototype enabled collective interaction and, in doing so, created a sense of shared participation. This seemed to enhance users' sense of belonging and engagement within the group. Comments include:

"But I actually think your idea is really good because most of these interactive installations are more personal. What you've done is, on the one hand, as you said, the pressure, and on the other hand, you've made the issue more communal. Everyone contributes their own interaction to the overall response. You have something touchable and interactive that everyone can participate in, and everyone's participation counts." — Group 4

4.4.3 Triggered user responses

Triggering self-reflection and a shift in work or social engagement. Participants' responses revealed two contrasting types of attentional shifts: some described being overly focused on their own thoughts and needing a reminder to pay more attention to their team members, while others reported being mentally disengaged and welcomed the interaction as a nudge back into the task. Overall, most participants felt that the system encouraged them to reflect on something they had previously overlooked, which is often related to group stress, their own engagement, or the group's work state. Comments include:

> *"Well, when I'm collaborating with others, for example, when we're discussing something, but I have an idea, I'll follow my idea and start thinking on my own. Well, then I probably don't care what my peers are saying, but this is actually a very unhealthy state for group discussion. So, for example, if someone notices that the device has changed, or if the device attracts me, some changes may interrupt my behavior of following my own train of thought."— Group 3*

> *"I tend to zone out when doing things I don't like or am not good at. Sometimes I do zone out, and it reminds me."— Group 3*

> *"I think it's good. If it's in a meeting, it can be used as a trigger to make people aware of this state and then adjust it, OK, or pay attention to it."— Group 5*

Triggering peer observation to reflect on collective stress. Another theme that emerged was that some participants became more observant of their teammates in order to evaluate collective stress. This is subtly different from the previous theme, which focused on internal realisation. Here, the system appeared to prompt behavioural change by encouraging users to observe others. In this way, the abstract inflation patterns triggered not only individual interpretation, but also prompted participants to observe how others were reacting. Comments include:

> *"It'll distract you, and then you'll start to focus on someone else. Before that, I had a little anxiety myself. I didn't really notice it, and I didn't really pay attention to the emotions of the people around me."— Group 8*

> *Participants also noted a ripple effect, where one person's action (such as pressing the tabletop) would prompt others to do the same. Comments include:*

> *"Then I see that he just presses this down, and I feel that he really wants to return to the original workflow. This is why I feel tend to interact."— Group 5*

Prompt for communication and social interaction. In meeting contexts, teams sometimes fall into silence, drift off-topic, or hesitate to introduce new discussion points. The prototype seemed to help address these challenges by offering a subtle way to break the ice. At least 6 participants said the interaction positively influenced group discussion, either by sparking conversation or by easing the tension. Comments include:

> *"When a group discussion gets stuck somewhere, there is often a moment of silence because no one wants to admit that the atmosphere has become a bit tense. If you point out this matter very straightforwardly, you're the one who's a bit negative. This thing can slightly neutralize that."— Group 2*

> *"There is one point—that is, when we respond, it provides us with a communicating possibility. It gives us a point where we can collectively discuss."— Group 7*

> *"We'd start joking about things. Like during the second round with the hand puzzle, I'd just complain about how hard it was."— Group 1*

Body movement or languages triggered by physical elements. Although the prototype was initially designed with one clear response action, pressing the surface, through which participants naturally explored a variety of body-based expressions. These observations may support future efforts to expand the system's interactive inclusivity. Comments include:

> *"I was a little afraid of breaking it, so I pressed it gently."— Group 4*

> *"I think the main advantage of this table is that if you're in a meeting, usually you just have verbal and, um, facial or visual interactions. And this button gives you an extra way to express yourself. For example, if we are in a meeting and you suddenly notice that I press this button, we may still be talking about the content of the meeting verbally, but you notice this action of mine, which may express an attitude of mine—that I hope to ease the atmosphere, but I don't need to say it out loud."— Group 5*

> *"Sometimes when you're doing something, you're sitting on a swivel chair, right? And sometimes this chair might be, um, spinning, which is actually similar to that."— Group 6*

4.4.4 From Passive Awareness to Active Engagement

Users construct meaning through interaction. Users also actively constructed meaning through their interactions. Some participants said they used the inflatable interface to communicate intentions or shift attention within the team. This suggests that interaction prompted users to reflect not only on how the system worked, but also on what kind of message they themselves were conveying, which is something not mentioned by users in the ambient display scenario. Comments include:

> *"For example, I think if it senses our stress, and it can sense where the stress mainly comes from, she can use shape changing to draw people's attention to this area."— Group 8*

> *"I'm doing something with the table. Yeah, yeah, I can feel this—like, some movement here. So I would think, that's what happened and what it means. And how, like, what you did made it change."— Group 1*

Higher interactivity welcomed in collaborative settings

Most participants expressed a clear preference for the more interactive prototype. Some emphasized that collective stress and group atmosphere were important but ignored, while others believed that interaction, not just visual cues, was the core mechanism for helping people engage. Comments include:

> *"The one with interaction is better. Why? If there's no interaction, he's just moving on his own, and we can completely ignore it."— Group 3*

> *"I don't think visualization alone is very useful for people at work."— Group 7*

Low user engagement with off-desk passive cues

In meeting contexts, participants' attention is often focused on documents, screens, or the current speaker. This made it difficult for participants to notice cues located outside their immediate area of focus. Many said they did not look at the ambient display at all during the session. Comments include:

> *"I think the desktop version is more intuitive, right? More intuitively, when you're doing something, you may not notice something at a certain distance from you, but if it's on your desk, you'll feel it very clearly—because it's where you're concentrating."— Group 5*

> *"When you're really focused on something—especially if it's placed off to the side—it's hard to notice."— Group 1*

Ambient displays suit observers more than active collaborators

Ambient displays that similar with the one used in this study were not perceived as useless in meetings, but rather as more appropriate for certain roles. Participants suggested that such displays might suit observers in large meetings and for those responsible for facilitation or coordination as more than active contributors. Comments include:

> *"It's suitable for group leaders or secretaries in big companies. There's a special person who posts something and then others can check it out. They can, for example, notice things and then go and give out fruits or drinks and stuff like that."— Group 6*

5. LIMITATIONS

This section summarizes the key limitations encountered in both the prototype development and experimental process, and discusses possible directions for future design iterations and application scenarios.

5.1 Limitations of the experiment

The lack of statistical significance in the quantitative results may be attributed to incomplete variable control. Conditions such as testing time and minor contextual differences between the three experimental scenarios may have affected the results. Furthermore, G*Power calculations suggested that at least 27 participants would be needed for sufficient statistical power, while the current sample size fell slightly short. These factors may help explain the less consistent visual patterns and the absence of significant differences in measured self-report data.

5.2 Limitation for prototype design and future directions

At both the technical and user experience levels, the most critical issue raised was the disruption caused by mechanical noise. Participant feedback indicated that the actuator and inflation noise significantly interfered with users' perception and meeting flow. Potential solutions include using high-pressure air reservoirs to reduce pump noise, adopting silent motors or optimizing the actuator transmission structure to minimize sound during the tabletop's vertical movement, and synchronizing the inflation speed of the silicone surface with the table's elevation.

In terms of material implementation, the current inflatable silicone layer presented several challenges, including its relatively heavy weight, inconsistent inflation due to uneven channel width, high production costs and the fact that it partially melts or becomes damp where it contacts MDF boards at temperatures above 20°C. TPU was also tested as an alternative material, but it was found to be too thin and prone to shifting, which caused localised deformation during inflation. One possible improvement would be to adjust the silicone curing composition, for example by adding a platinum-based curing accelerator, to improve stability while reducing the overall material thickness. Although manual fabrication poses challenges for these refinements, industrial-scale production may provide more consistent results.5.2 Design refinement and scenario expansion.

Based on user interviews, the defined usage context, which is a relatively informal small group meeting, proved to align well with participant expectations and needs. However, a key question is whether the design approach is suitable for other settings. Feedback indicated that the prototype might be less suitable for large or highly formal office meetings, where structured interaction and limited flexibility leave little room for tangible engagement. However, some participants expressed interest in applying the prototype in home environments or for personal creative work, highlighting its potential for playful use outside traditional office settings.

Participants also suggested refinements to the current physical structure. The acrylic cover was reported to hinder the visibility and interpretation of the inflation. In future iterations, this layer could be removed and the inflatable surface directly embedded into the tabletop. The visual pattern would remain soft and organic, while distinct hard-surfaced zones (e.g., MDF sections) would be reserved for placing work materials. To support diverse work styles, a modular structure could be introduced.

Additionally, users hoped for more diverse interaction modes beyond pressing and deflating—suggesting more lively or human-like surface behavior, such as different inflation rhythms triggered by leaning or resting on the table.

6. CONCLUSION

In this project, an interactive flexible tabletop was developed to enhance awareness of collective stress and encourage team-based responses in meeting settings. The results indicate that peripheral interactive interventions can serve as a gentle and effective method for helping users recognize and respond to collective stress in small team meetings. Although the quantitative data did not reveal statistically significant differences in perceived stress across scenarios, qualitative findings provided rich insight into how users perceived and interacted with the prototype. Participants interpreted the cues in diverse ways, reflected on both their own and others' states, and adjusted their behavior accordingly, such as supporting social connection and communication within the group. This suggests that even minimal interactive elements can support both individual reflection and collective awareness, and may promote constructive group behavior in collaborative settings.

The findings offer several implications for future design: the value of shared physical interaction in fostering group cohesion; the importance of clarity in visual and behavioral signaling; and the potential role of mild discomfort or disruption in prompting attention and action. Furthermore, the study highlights the importance of balancing visibility and subtlety when designing interactions for environments where task focus and emotional sensitivity must coexist. Future work also should explore more diverse interaction types and iterate on the physical design. While the current approach may not generalize to more formal or large-scale meeting contexts, such as hybrid or corporate settings, alternative methods for enhancing awareness and collective responsiveness should be explored. This research contribute a more nuanced understanding of how peripheral interaction design can support the awareness of collective stress and social dynamics of collaboration.

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