Breathm: A Calm Device with Personalized Slow Breathing Guidance

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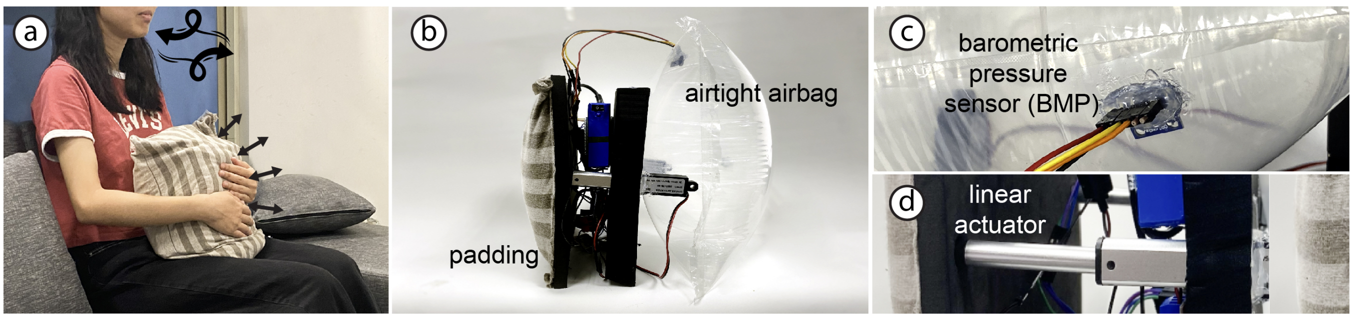

Figure 1: (a) *Breathm* is a device that mimics the user's breath and smoothly guides the user towards a calm pace. (b) Taken off the fabric sheet outside, the device consists of (c) a barometric pressure sensor (BMP) in an airtight airbag that senses the user's abdominal movement and (d) a linear actuated platform at the center surrounded with padding that expands and contracts to provide bloating sensation.

ABSTRACT

We present *Breathm*, a haptic feedback cushion designed to lead user into a state of relaxation. To achieve this, Breathm provides slow breathing guidance by expanding and contracting, mirroring the natural abdominal movements during inhalation and exhalation. Instead of providing a fixed target breathing rate, Breathm continuously monitors user's breathing and adjusts the target throughout the guidance process, ensuring a smooth transition from user's natural breathing rate to the intended slower pace. Through this design, Breathm facilitates user to calm their breath and relax. A user study is conducted to evaluate the impact of user's breath mirror period on the guidance design. Our results show that, within the same timeframe, participants achieve longer breath extension when this mirror period is incorporated.

CCS CONCEPTS

• **Human-centered computing** → **Interaction devices**.

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KEYWORDS

Calm interface, breathing guidance, respiration coaching, meditation

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1 INTRODUCTION

In today's fast-paced world, individuals lead busy lives, which often lead to the accumulation of stress. A common method of relieving stress is rhythmic breathing. Busch et al. [4] stated that a series of specific breathing techniques can relieve stress, anxiety, depression.

Since then, more research has been done to explore breathing guidance in therapies. For example, various studies used visual and audio breathing guidance to aid disease treatment [6, 12]. To enhance immersion, Soyka et al. [15] constructed an underwater virtual reality (VR) world to facilitate slower breathing.

The aforementioned breathing guidance can pose some challenges, as both audio and visual breathing guidance require awareness, making it difficult to fully rest or concentrate on other tasks. To address this issue, Breathe app on Apple Watch [9] integrated vibration to remind user of the timing for inhale and exhale. In another study, Paredes et al. [13] constructed a directional vibration device to guide breathing by tactile feedback perceived through user's back. Their study compared tactile and auditory modalities, with results noted that tactile feedback felt more natural and less distracting.

More recent studies introduced cushion-type devices mimicking abdominal breathing, designed as small cushion held inside the palm [11, 16] or laid under the palm [1, 17], and larger cushion that can be hugged [3, 7]. Studies using handheld device were shown to require user to spend time to learn the interaction, whilst no such feedback were reported for huggable device. Overall, these studies demonstrate that using tactile feedback for breathing guidance can be more intuitive, while showing similar effectiveness when compared to audio and visual guidance.

Subsequent research continues to develop and explore haptic feedback-guided breathing. Several studies incorporate external breath detection devices to measure breath frequency and provide data to help users understand their current breathing status [2, 5]. Notably, the detection data is rarely actively used as a reference for calculation of the assisted breathing guidance. In our work, we propose *Breathm*, a haptic feedback device integrating breath detection and guidance. With detection function, our cushion-shaped device can personalize breathing guidance by adjusting the guidance basing on the detected breathing rate, measured in breathing rate per minute (bpm). Through our user study, we explore various methods of personalizing guidance to identify the most effective approach for gradually influencing user's breathing to achieve a relaxation effect.

2 RELATED WORK

Among various guidance methods, most commonly seen approach provides a fixed frequency, requiring user to actively follow the predetermined pace. This method has been extensively implemented through visual [6], audio [12] and touch-based [2, 3, 7] modalities. Subsequent research builds upon this foundation, offering more effective guidance. In a study by Macik et al. [11], a haptic feedback device is proposed, to provide progressively slower breathing rate from 15 to 6 bpm, moving down to slower guidance after each 3 minutes. Another study by Lim et al. [10] integrated breath detection, providing personalized guidance curves by visually presenting the user's breathing and guidance rate. Integrating both progressive guidance with breath detection, *Breathe deep* [14] designed a visual guidance aiding user in understanding their current condition and extending each phase when target breath has yet to be achieved. A similar mechanism is observed in a commercial audio-guided breathing product *RESPeRATE* [8], designed to ensure user keeps pace with each progressively slower stage. *ViBreathe* [16] designed a handheld device and compared different guidance methods. This study showed that users prefer personalized guidance, as it provides a deeper and more engaging interaction with the guidance.

Throughout these studies, it is found that personalized and progressive guidance are mostly offered in the form of visual or audio guidance. To the best of our knowledge, while previous studies using huggable device have proven that tactile feedback can affect breathing [3, 7], there has been limited research on personalized and progressive guidance utilizing huggable device. We propose Breathm to fill this gap.

3 CONTRIBUTION

Taking inspiration from aforementioned studies, we address the research gap by developing *Breathm*. Breathm is a cushion-shaped device that can detect the user's condition and provide suitable guidance, gradually extending their breathing rate to a slower pace. Differing from most studies, detection component is integrated inside Breathm, eliminating the need for additional wearable equipment. This mechanism allows for more progressive and personalized breathing guidance design.

Users are not required to set a specific goal; instead, the device incrementally adjusts the breathing rate as long as the user follows the guidance effectively. Conversely, if user struggle to maintain the guidance, the device does not push for further extensions.

4 DEVICE DESIGN

Our breath guidance device is designed as a huggable cushion, integrating both breath detection and guidance components.

For breath detection, we use BMP280 (Barometric Pressure) sensor positioned within an airtight airbag, as shown in Figure 1c. This sensor measures the change of pressure inside the airbag to distinguish transition between inhalation and exhalation.

For guidance mechanism, we utilize two linear actuators to simulate the motion of abdominal breathing, replicating belly's outward and inward movement for inhaling and exhaling (Figure 1d). An L298N motor driver is added to control the speed and direction of the linear actuator, allowing a more accurate mirror of user's detected breathing rate.

The sketch of our device is depicted in Figure 1b. The linear actuators are oriented in a direction opposite to user's body, replicating the tactile sensation similar to when touching one's own belly during breathing (Figure 1a). The BMP280 sensor is positioned between user and cushion, detecting the pressure differentials resulting from the user's abdominal movements towards the cushion. To maintain the soft sensation of the cushion, we use EVA (Ethylene Vinyl Acetate) sheet as the base. Additional cushions are used to fill the empty area around the hardware.

4.1 Breath Detection Evaluation

We compare our breath detection with waist-belt breath detection. Our device has a calibration period, in which it is getting used to the pressure differences from user's hand pressure and pressure from belly. Our device might have slight delay, but it doesn't affect our detection of the transition between inhale and exhale.

5 BREATH GUIDANCE

We designed a pattern integrating user's breath mirroring and predetermined progressive guidance (Figure 2 pattern 1, Appendix A). The pattern consists of three primary phases: adjustment, mirror, and guidance.

Adjustment phase: During this initial phase, the cushion remains idle as it differentiates between pressure caused by abdominal movement and pressure from the user's hand on the cushion.

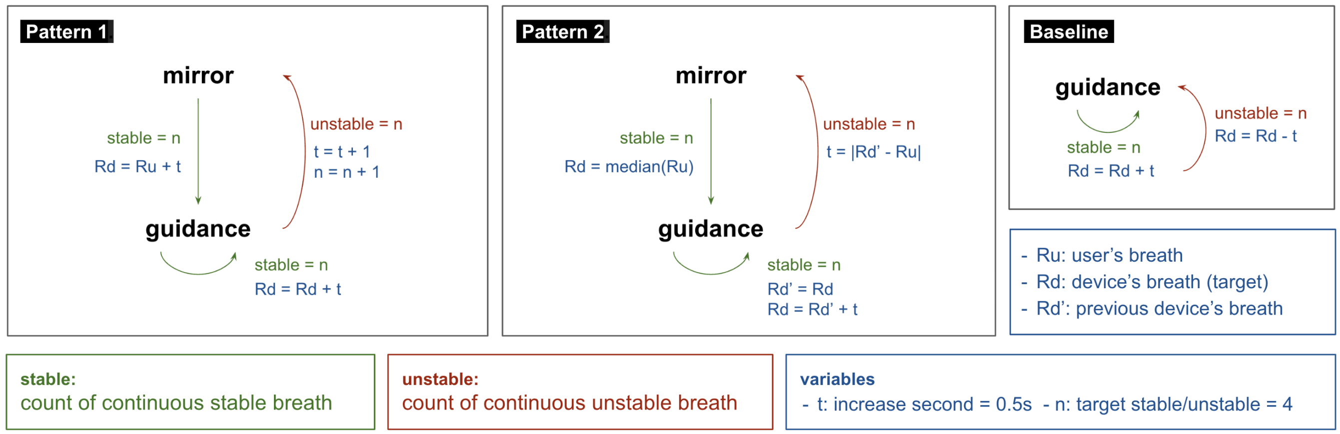

Figure 2: Breath pattern design

Mirror phase: As more consistent pressure changes are detected, the device progresses to the mirror phase, where the system directly translates the user's breathing into corresponding movements of the cushion.

Guidance phase: After user's breath stabilizes, the device advances into guidance phase, repeating a calculated target breath based on user's breathing data. If successful compliance with the pattern is detected, the target breath is increased; otherwise, it returns to the mirror process, providing user with time to control their breath. In this way, the system cycles between the mirror phase and the guidance phase.

A preliminary study with 12 participants (4 male, 8 female) between 23 and 28 years old (M = 25, SD = 1.88) was conducted to evaluate this pattern design.

All participants understood the device mimicked their breathing rate, indicating successful breath detection and mirroring. While most participants noted a slowing down of their breath, 4 participants found the guidance to closely resemble their own breath, making it less distinctive. This phenomenon may be due to excessive mirroring duration, which might hinder users from progressing to the guidance phase if they struggle to stabilize their breath.

Based on this preliminary result, we create a pattern with shorter mirror phase, in which the median value of user's breathing rate is used to calculate target breathing rate (Figure 2 pattern 2, Appendix B).

6 USER STUDY

We conducted a user study to evaluate the various design of the mirror phase. A total of 20 participants (9 male, 11 female; 6 with breathing exercise experience) between 21 and 42 years old (M = 23, SD = 4.67), external to pilot study, were recruited as participants through open recruitment. The study is carried out in a quiet environment, participant is seated on a straight chair and provided with noise-canceling headphones to minimize environmental noise. Each session of the user study lasted approximately 30 minutes.

Every participant experiences the 2 different patterns designed and baseline (Figure 2 baseline, Appendix C), with randomized sequence, each lasting for 5 minutes with short rest in between. Users are not given specific instructions on how to use the device, they are asked to interact with it based on their perception.

After experiencing each pattern, participants complete a self-designed questionnaire with 5-point Likert scale (1: strongly disagree, 5: strongly agree), which included following questions:

(1) Do you feel guided by the pattern?
(2) Do you notice a slowing down of your breath?
(3) Do you feel relaxed?

Following the user study, a semi-structured interview was conducted to gather more insights into their experience with the cushion.

7 RESULT & DISCUSSION

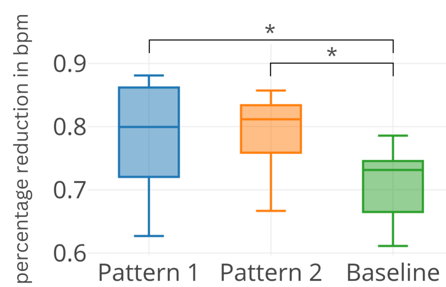

Figure 3: Boxplot illustrating the difference of percentage reduction in participants' bpm between patterns (* indicates pairwise significant difference)

We calculate the percentage reduction in participants' bpm, as shown in Figure 3. Through Freidman test, the difference between percentage of breath decrease between patterns are found to be statistically significant (Friedman chi squared = 16.88, df = 2, $p < 0.001$). Pairwise comparison is then applied, which revealed significant differences between each of pattern 1 and pattern 2 with baseline.

However, no significant difference is found between pattern 1 and pattern 2.

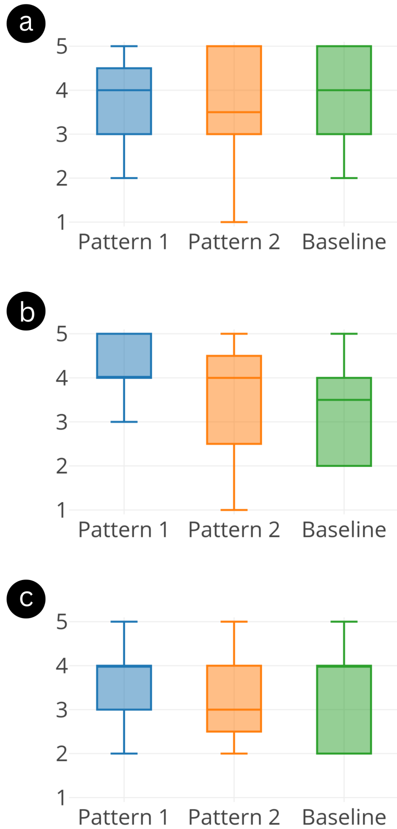

Figure 4: Boxplots illustrating participants' answer to (a) Do you feel guided by pattern? (b) Do you notice a slowing down of your breath? (c) Do you feel relaxed?

From an objective standpoint, a guidance with longer mirror phase can better slow the breathing rate. This is also proven through questionnaire results, where in pattern 1, participants feel the most breath slowing effect (Figure 4b; $\bar{x}$ = 4.15, M = 4, SD = 0.76) and relaxed (Figure 4c; $\bar{x}$ = 3.6, M = 4, SD = 0.83). However, all participants stated that their breathing was affected by the provided guidance without significant differences (Figure 4a).

Further insights were gained through post-study interview. Participants who favored pattern 1 mentioned that they found the guidance very similar to their natural breathing rate while still allowing them to perceive the extension, making it intuitive and relaxing to follow. Meanwhile most participants didn't prefer pattern 2 as the frequent changes in the guidance made it challenging to follow. This frequent change between mirror and guidance phases may be attributed to the shorter mirror period, which led to confusion. For the baseline pattern, participants appreciated the stable guidance frequency but found it challenging to relate it to their own breath, leading to moments when the guidance felt too fast.

In conclusion, our study indicates pattern 1 offers greater benefits for slow breathing guidance design. Rather than extensively tailoring guidance to individual user conditions, fixed variables and functions are employed to maximize breath extension. This hybrid approach strikes a balance between user interaction and fixed guidance, potentially enhancing the effectiveness of slow breathing training.

8 LIMITATION

With our current device design, the optimal position for detecting user's breath is when the user is seated upright. This positioning allows the cushion to maintain maximum contact with the user's belly, enhancing sensitivity. Additional considerations for device design should be explored to ensure comfortable and effective usage.

9 CONCLUSION

We introduce *Breathm*, a haptic feedback cushion device to guide breathing, aiming to facilitate relaxation. Our main contribution is the design of mirror pattern that can most effectively slow users breathing. To evaluate the efficacy of the device design, a preliminary study and user study are conducted with 12 and 20 participants respectively. Result shows that a hybrid design of mirror with predetermined gradual decrease can provide longest extension of breath. The overall feedback from participants is positive, suggesting the potential of the cushion in promoting relaxation.

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A PATTERN 1

Pattern 1: Hybrid mirror with fixed gradual decrease

```
incrementValue ← 0.5
targetStable ← 4
targetUnstable ← 4
state ← mirror
while true do
    userBreath ← read user breath
    if state is mirror then
        device replicates userBreath
        totalStable ← count continuous stable userBreath
        if totalStable is targetStable then
            state ← guidance
            targetBreath ← userBreath + incrementValue
        end if
    else if state is guidance then
        device replicates targetBreath
        totalStable ← count userBreath = targetBreath
        totalUnstable ← count userBreath != targetBreath
        if totalStable is targetStable then
            targetBreath ← targetBreath + incrementValue
        else if totalUnstable is targetUnstable then
            totalStable ← totalStable + 1
            totalUnstable ← totalUnstable + 1
            state ← mirror
        end if
    end if
end while
```

B PATTERN 2

Pattern 2: Median mirror phase

```
userBreaths[] ← []
incrementValue ← 0.5
targetStable ← 4
targetUnstable ← 4
state ← mirror
while true do
    userBreath ← read user breath
    append userBreath to userBreaths
    if state is mirror then
        device replicates userBreath
        if length of userBreaths[] is targetStable then
            state ← guidance
            targetBreath ← Med(userBreaths)
            userBreaths ← []
        end if
    else if state is guidance then
        device replicates targetBreath
        totalStable ← count userBreath = targetBreath
        totalUnstable ← count userBreath != targetBreath
        if totalStable is targetStable then
            prevTargetBreath ← targetBreath
            targetBreath ← targetBreath + incrementValue
        else if totalUnstable is targetUnstable then
            incrementValue ← Med(userBreaths) − prevTargetBreath
            state ← mirror
            userBreaths ← []
        end if
    end if
end while
```

C BASELINE

Baseline: Guidance-only

```
targetBreath ← 4
incrementValue ← 0.5
targetStable ← 4
targetUnstable ← 4
state ← guidance
while true do
    userBreath ← read user breath
    device replicates targetBreath
    totalStable ← count userBreath = targetBreath
    totalUnstable ← count userBreath != targetBreath
    if totalStable is targetStable then
        targetBreath ← targetBreath + incrementValue
    else if totalUnstable is targetUnstable then
        if targetBreath > 4 then
            targetBreath ← targetBreath − incrementValue
        end if
    end if
end while
```