# Guided Breathing Lamp: An Interactive Real-Time Breathing-Sensing and Guidance System

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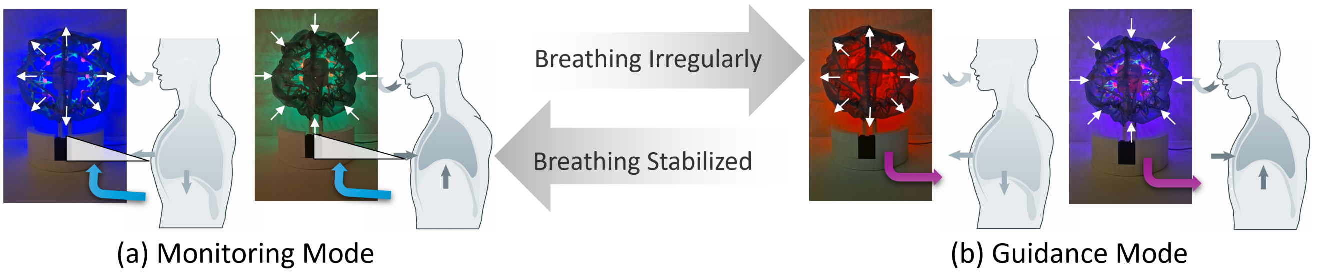


**Figure 1: Guided Breath Lamp visualizes inhalation and exhalation through expansion and color changes (a) The lamp mirrors the user's natural breathing in *Monitoring Mode.* (b) When irregular breathing is detected, the lamp enters to *Guidance Mode*, help stabilize the user's respiratory rhythm.**

## Abstract

We present the Guided Breathing Lamp, an interactive system that detects real-time breathing using mmWave radar and provides adaptive visual feedback through an expandable, color-changing physical display. The lamp operates in two modes: a Monitoring Mode that mirrors the user's natural inhalation and exhalation, and a Guidance Mode that activates when irregular breathing is detected, offering paced cues to help stabilize respiratory rhythm.

## 1 Introduction

Respiratory rate is one of the earliest and most sensitive indicators of physiological deterioration. Elevated rates—such as above 27 breaths per minute—have been shown to strongly predict cardiac arrest in hospitalized patients [2]. Unstable or high respiratory rates often signal cardiopulmonary stress, infection, or metabolic imbalance, and clinical guidelines recommend more frequent monitoring when a patient's rate exceeds 20 breaths per minute [1]. Commercial guided breathing lamps aim to support relaxation by encouraging slow, steady breathing patterns. However, existing products lack the ability to detect a user's real-time respiratory rate. Integrating sensing and feedback mechanisms would enable a system that not only guides breathing but also responds dynamically to unstable respiratory patterns—helping users restore a normal respiratory rate and promoting relaxation and physiological stability.

We present the Guided Breathing Lamp, an interactive system designed to sense, interpret, and support users' breathing patterns. The lamp detects real-time respiratory motion and visually represents inhalation and exhalation. When irregular breathing is detected, the lamp transitions into a guidance mode that provides paced cues to help the user follow a calming respiratory rhythm. Our goal is to promote everyday health sensing for mental well-being by enabling both passive monitoring and active stabilization of breathing.

## 2 System Overview

Guided Breathing Lamp operates in two modes: *Monitoring Mode* and *Guidance Mode*. In *Monitoring Mode* ( Fig. 1a), the lamp detects the user's real-time respiratory pattern and visually represents each inhale and exhale through gentle light changes. When the system identifies irregular or unstable breathing, it automatically transitions into Guidance Mode. In *Guidance Mode* (Fig. 1b), the lamp provides paced-breathing cues to help the user follow a steady, calming respiratory rhythm. Once the user's breathing stabilizes, the system seamlessly returns to *Monitoring Mode*. Each mode is indicated through distinct LED colors—red (inhale) and purple (exhale) for Guidance Mode, and blue (inhale) and green (exhale) for Monitoring Mode. These color displays allow users to intuitively recognize both the lamp's current mode and whether it is representing inhalation or exhalation at a glance.

## 3 Implementation

We implemented the Guided Breathing Lamp by integrating both a sensing pipeline and a physical display system into a single device. The sensing component uses mmWave radar to detect human presence and measure breathing rate by capturing subtle chest movements in real time. The display component expands, contracts, and changes color to visually mirror the breathing cycle and indicate system mode. Together, these components form an interactive lamp that responds dynamically to the user's respiratory state.


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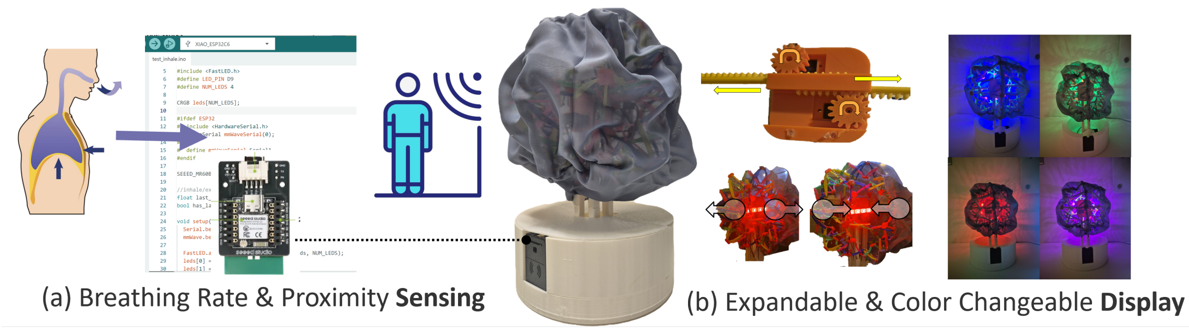


**Figure 2: We implemented the system using (a) the mmWave radar that detects user presence and measures breathing rate through chest movement, and (b) built an expandable, color-changeable display driven by a gear-and-rack mechanism with diffused LEDs that visualize breathing state and lamp mode.**

### 3.1 Sensing

In order to measure breathing rate, we used a wireless mmWave radar sensor capable of detecting small chest movements using planar patch antennas. We also implemented proximity sensing so the lamp can automatically detect human presence and manage power efficiently, as shown in Fig.2a.

*Breathing Rate Sensing:* We used the XIAO 60GHz mmWave Human Breathing MR60BHA2 sensor, which operates as a frequency modulated continuous wave (FMCW) radar. It emits frequency-modulated chirps and measures changes in the returned signal to compute chest displacement. The sensor detects chest movements in the 4-12 mm range with approximately 5 mm resolution and is paired with an ESP32-C6 and MIMO patch antennas. We read phase signals from the radar, compute changes in breath phase between samples, and detect peaks and troughs to mark each breathing cycle. Using timestamps of detected peaks over a 30-second window, the system estimates breaths per minute (BPM) and compares the user's rate to typical ranges.

*Proximity Sensing:* The lamp automatically powers on when a user approaches and turns off when the user leaves. Based on our experiments, we set a presence-detection threshold of 5. Each time the device wakes, the ESP32 enters a three-second Presence Detection Window, during which it collects raw sensor activity and computes an activity sum. If this value falls below the threshold, the system determines that no user is present and immediately returns to deep sleep, disabling the LED and motor to conserve power. If the activity exceeds the threshold, the system enters Active Mode, enabling real-time breathing tracking. Each valid breathing event updates a timestamp marking the most recent detected activity. When no breathing is detected for a defined timeout period, the system concludes that the user has left the sensing area and transitions back into deep sleep.

### 3.2 Display

Our display design focuses on creating a lamp that is both physically expandable and capable of changing color, as shown in Fig.2b. *Expandable Display:* To make the lamp expandable, we used a gear-and-rack to generate linear motion. A servo motor rotates the gear, which then moves the rack forward and backward linearly. Then we attached the end of the rack to a part of an expandable breathing ball, so that as the rack moves forward, the ball expands, and as the rack moves backward, the ball shrinks. Through this, we can precisely control the size of the lamp by adjusting the rotation of the servo motor. For the outer cover, we laser-cut a semi-transparent fabric and carefully glued it along each joint, so it maintains stable coverage even as the lamp changes shape.

*Color Changeable Display:* In order to indicate both lamp mode and breathing state, the lamp changes its color. We mounted an LED strip that will face opposite of the users, creating a soft glow instead of direct glare. The entire structure is covered with a transparent fabric that can softly diffuse the emitted light.

## 4 Demonstration

In the demo, participants experience real-time respiratory sensing and interactive feedback. We expect that the Guided Breathing Lamp can help users reduce stress by encouraging steady, regulated breathing. Participants will interact with the Guided Breathing Lamp through four straightforward steps. .**Step 1: Activate the lamp** The lamp is placed on a table, and participants sit down in front of it. Once the lamp detects human presence, it automatically activates, and the LED lights turn on. **Step 2: Monitor breathing.** The lamp begins in *Monitoring Mode*, where it expands and changes color in sync with the participant's natural breathing pattern. **Step 3: Trigger mode change by breathing irregularly.** Participants may breathe normally and then intentionally introduce irregular breathing. When irregularity is detected, the lamp transitions into *Guidance Mode*. **Step 4: Follow the breathing guidance:** In *Guidance Mode*, participants follow the paced-breathing cues provided by the lamp. After several cycles of guided breathing, the lamp automatically returns to *Monitoring Mode*, allowing participants to repeat the experience starting from Step 2.

## References

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[2] J. F. Fieselmann, M. S. Hendryx, C. M. Helms, and D. S. Wakefield. 1993. Respiratory rate predicts cardiopulmonary arrest for internal medicine patients. *Journal of General Internal Medicine* 8 (1993), 354–360.