



## **The Science Behind Spire**

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Continuous monitoring and feedback of biometric data is a powerful tool for clinical and subclinical health. It can lead to insights that would be otherwise impossible and behavioral cues that turn training into practice. Monitoring involves two components: (1) accurate, discreet, and comfortable sensing and (2) actionable feedback based on that data to facilitate the in-the-moment changes which drive outcomes over time.

Spire is a platform for psychotherapeutic modalities that collects, analyzes, and reports data to support mental and physical health interventions. The Spire stone is a clothing-worn device that accurately senses physical activity and biomarkers associated with cognitive/emotional state such as anxiety and focus. The stone feeds into the Spire app to track biomarker changes to provide visualizations, real-time notifications, and training.

What uniquely distinguishes Spire is that it is (1) comfortable enough to wear every day, all-day, (2) provides accurate readings given its location at the core of the body, (3) makes the data meaningful and actionable by employing the respiratory signal, and (4) presents feedback to go beyond physical health and exercise into cognitive/emotional health.

### *Neurophysiology and respiration*

The cluster of 175 neurons deep in the brainstem known as the pre-Bötzinger complex (“pacemaker for breathing”) link respiratory patterns to stress, concentration, and state of mind [25]. A similar group exists for heart rate but respiration exhibits more complexity that corresponds to different respiratory forms: breath-holding, sighing, gasping, laughing, and so on. Rather than solely monitoring oxygen-intake, these patterns reflect cognitive/emotional state, as indicated by how the pre-Bötzinger complex cluster reports to the locus coeruleus, the arousal center whose rhythmic behavior is correlated with that of breathing and has widespread influence on arousal, attention, and emotion [25] (see Figure 1).

Further differentiating respiration from other autonomic functions, it is under intricate voluntary control and thus the basis for the most effective self-regulatory interventions for blood pressure [7], heart rate variability [12, 13], pain management [15], and cognitive/emotional state [8]. In effect, respiration behaves as both tachometer, gas, and brake pedals for the nervous system.

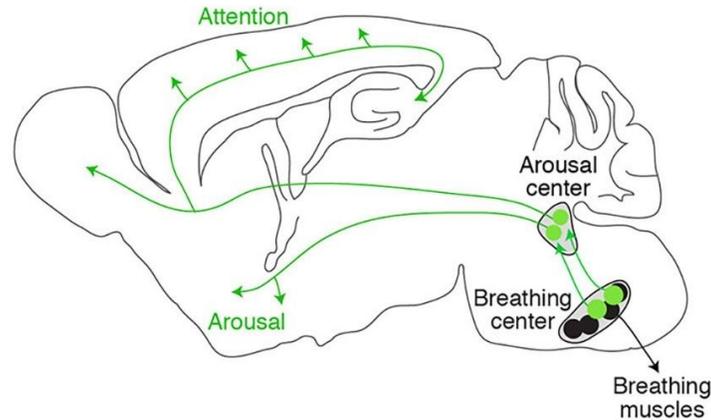


Figure 1: This diagram depicts the pathway (in green) that directly connects the brain's breathing center to the arousal center and the rest of the brain. (Credit: Krasnow lab, Stanford University)

### *Patterns of respiration*

Respiration patterns alone are sufficient to predict psychosocial stress when compared to other biosignals such as electrodermal activity (EDA) and heart rate variability (HRV) [16]. The respiratory signal offers many metrics such as minute ventilation, inhalation-exhalation ratio, and mean exhalation duration. Respiratory rate and stability are two of the most common metrics and provide the basis for Spire's algorithms.

There are no known specific universal respiratory thresholds that designate stress or relaxation. Rather, Spire first identifies a user's respiratory norms then identifies significant deviations. If a deviation is sustained for at least two consecutive minutes (a threshold empirically derived by simulating distributions of streaks across thousands of Spire users), Spire counts this as a respiratory "streak" in the app (see Figure 2). Thus, people vary in the number, variety, and pattern of streaks in their day according to how they carry themselves as they work and live.

States of relaxation lead to significantly slower respiratory rates (called 'calm' in Spire) [3, 8] while decreased respiratory stability distinguishes psychosocial stress or anticipatory anxiety ('tense') from sustained attention and arousal ('focus') [3, 19, 20]. The Spire app displays to the user a distribution of how much time was spent in each of these three states (calm, tense, and focus).

### *Clinical use*

Spire is a complement to clinical interventions that address emotion regulation, mindfulness, and self-awareness. These interventions include psychotherapy, mindfulness-based stress reduction (MBSR), cognitive-behavioral therapy (CBT) [1, 4, 17]. As such, Spire can and has been used for to help treat PTSD [17], depression and anxiety [1, 10, 23, 24], workplace stress [15], general well-being [1] as well as addressing the stress component of traditionally physical issues like hypertension [7] and chronic or acute pain [11, 15]. Sustained mindfulness training has been shown to lead to a slower resting respiration rate [22], a metric Spire displays on the Home screen of the app. A subset of the guided breathing practices included in the Spire app are based on clinical protocols published in the aforementioned studies.

STATE-OF-MIND FACT SHEET		
 Calm	 Tense	 Focus
6-12 breaths per minute*	18-24 breaths per minute*	16-20 breaths per minute*
slow, regular breathing	fast, erratic breathing	very consistent breathing

*\*Spire personalizes these numbers to you based on your baseline breath rate.*

Figure 2: Spire assesses the user's median respiratory rate and stability, identifies sustained deviations, then classifies those periods as "streaks".

Spire can also be effective for non-clinical chronic or acute stress emerging from high-pressure work and school environments, significant life transitions, non-clinical trauma, divorce, eating disorders, and even attention training. Health practitioners should use the Spire Professional Protocol with clients for tracking and influencing outcomes.

In summary, respiratory neurophysiology is at once well-practiced and understood yet a timely and relevant domain of scientific inquiry. Respiration both reflects and regulates cognitive/emotional state; this dual function makes it an ideal candidate for monitoring, tracking, and real-time feedback. These are the reasons behind Spire's emphasis on respiration as a biometric. The Spire device and app combines findings from both clinical and laboratory research to make the utility of respiration more broadly accessible. Spire R&D continues to innovate based on the discoveries made using the largest known dataset of daily-life respiratory data with a goal to make self-awareness and regulation inherent to mindfulness-, sleep-, and activity-based interventions more accessible to more people for both clinical and subclinical treatment.

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