BreathCrunch and BellyBreath: Exploring EMS-based Breath Guidance and Enforcement for Meditation and Running

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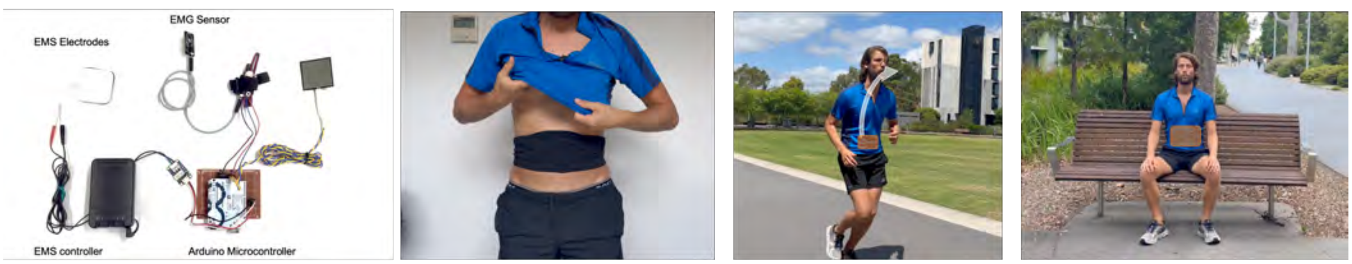

Figure 1: BreathCrunch and BellyBreath: EMS-based breath guidance and enforcement for running and meditation

Abstract

Breath has a fundamentally influence on our psychophysiological system. Deep exhalation is beneficial for both meditation and running. Many systems support breathing through visual or auditory guidance. In contrast, our work uses electrical muscle stimulation (EMS) to stimulate the abdominal muscles during the exhalation phase of the breath. We explored both a guided approach, in which the EMS functions as a passive guidance, and a force approach, in which EMS is used to force an exhalation. We present both implementations and reflect on using EMS for breathing as a form of human-computer integration.

CCS Concepts

• **Human-centered computing → Ubiquitous and mobile computing design and evaluation methods**; *Mobile devices*; • **Hardware** → *Bio-embedded electronics.*

Keywords

Electrical muscle stimulation, wearable devices, wearables, sports training, running, real-time assistance

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1 Introduction

Breathing is part of life, and breathing well is important. For thousands of years, yogic practices involved breath awareness and exercises to develop "prana," which in Sanskrit refers to both "breath" and "life force." Similarly, meditation, breathwork, and freediving all utilize specific breathing methods to enhance calmness, concentration, and performance. In this work we aim to support two breathing techniques. First, belly breathing in the context of meditation. Second, active exhales, in the context of physical exercise in the form of running.

Belly breathing (or diaphragmatic, or abdominal breathing) is a breathing technique in which deep slow breaths are taken through the nose into the lower abdominal area with a minimum movement

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of the chest. Practitioners lie on the back or with the face upward. One hand is placed on the chest and the other on the belly [28]. When practicing breathing techniques, individuals should ensure that the chest stays as still as possible while the abdomen presses against the hand, emphasizing the contraction of the diaphragm. Typically, practitioners of belly breathing inhale and exhale over a span of about six seconds each. Belly breathing is a core practice in meditation for those involved in yoga and traditional martial arts like tai chi. This breathing technique is known to have many positive physical and psychological effects. For example, deep belly breathing boosted antioxidant activity and lowered oxidative stress in athletes following physical exercise [18]. Furthermore it positively affects heart-rate variability (HRV) [32], and improved overall quality of life ratings, for example used by patients after bariatric surgery [1] or with asthma [27]. It can also improve sustained attention, affect and cortisol levels [17]. As such we see an opportunity to support this technique through interactive technology.

Breathing also has a profound effect on physical exercise. Breathing is closely associated with perceived effort [22], but also significantly affects psychological perception of running and its quality [10]. Breath not only adjusts to meet physiological demands, but can also be consciously controlled to enhance the running experience [8]. Various studies reported that coupling breath to steps reduces oxygen consumption, enhances running economy, and diminishes dyspnea (i.e., breathlessness) [2, 6, 11, 31]. Longer exhales cause improved HRV, ventilatory efficiency, and oxygen consumption (VO2) during incremental cycling [19]. Active exhales is a breathing technique, in which the athlete takes stronger, forced exhales in combination with a lower duty cycle [8]. The mountaineering community has long advocated a technique of active exhales, known as the "rescue breath" or "pressure breath," to help manage breathing difficulties at high altitudes [5]. Research revealed a delayed onset of fatigue, a reduction in heart rate, and an increase in time to exhaustion during a progressive cycling test. Furthermore, it was observed that peak CO_2 levels were delayed by 40% and the anaerobic threshold was postponed by 120 seconds. Since breath duty cycle remains notably consistent in the majority of healthy individuals during exercise [21], executing active exhales while running likely necessitates focus, guidance, and practice [8]. Hence, in this work we aim to explore this breathing technique by forcing exhales through EMS.

Prior works have explored the support of breathing within HCI, through visuals (e.g., [24]), sounds (e.g., [34]), and haptics (e.g., [23]). In this work we explore the potential of electrical muscle stimulation (EMS) to support both breath guidance in a calm meditative setting through BellyBreath, and forced breath support in an active physical exercise situation through BreathCrunch.

2 Related Work

2.1 Haptic breathing interfaces

HCI has explored breathing guidance interfaces that rely on visuals or audio, such as meditation and breathing games [7, 13, 20, 24, 29, 30]. For example, Patibanda et al. [24] used a virtual reality game as a playful breathing interaction to guide meditation. Burr et al. [3] evaluated a playful breathing game to guide the breath of runners. Van Rheden et al. [34, 35] explored sonic guidance for runners to adhere to certain breathing rates. The haptic modality has been explored through tactile vibrations placed on various locations of the body. Yu et al. create a device to be covered with the palm of the hand to sense the vibration that provides breath guidance [36]. Paredes et al. explored vibrations in the car to guide slow breathing [23]. In the context of running, Valsted et al. [33] used vibrations on the wrist to guide a breathing pattern connected to the runner's stride. From these works, we learned that breath can be guided through more superficial tactile feedback such as vibrations. Haptics have also been explored through pneumatics. For example, pneumatics clipped on a cross-body strap to provide haptic feedback [4]. Jung et al. took a soma-design approach to explore breath awareness, control, and guidance through pneumatics [12]. More specifically, they explored deep pressure to limit the breath and rhythmically guide the breath. We learned that these types of on-torso systems are a more intimate approach is the use of the haptic modality to guide breathing. Taken together, we learned from previous works that breath can be guided (e.g., through vibrations) and enforced (through pneumatics). Extending on this work, we explore the guidance and enforcement of the breath through EMS.

2.2 EMS-based interfaces

EMS has found its way as an interface into Human-Computer Interaction (HCI) applications. Researchers have explored playful interactions in which part of the body is taken over by the computer [25]. Lopez et al. [14] introduced a mobile video game where an EMS signal is sent to the player's arm to increase the game's difficulty. In Impacto [15], the physical sensations of a virtual reality boxing game are simulated through EMS by creating arm movements similar to those in a real boxing match. Pfeiffer et al. [26] developed a prototype where users experienced the tactile sensations of the softness and hardness of virtual 3D objects on a computer. Lopes et al.'s Affordance++ [16] extended the concept of physical affordances to everyday objects, allowing them to "communicate" how they should be used. For example, a paint can may indicate to the user that it needs to be shaken before use.

In the context of sports, Hassan et al. [9] explored the use of EMS to induce forefoot striking in runners. Their system would activate electrodes on the calf muscle when a runner attempted to heel strike and the foot would rotate to a forefoot striking position. With our work, we extend the existing work by using EMS for breath stimulation. Additionally, we apply EMS both as a passive and enforced guidance, reflecting on the differences and potentials of both approaches.

3 BreathCrunch and BellyBreath Prototypes

In this section, we describe the design and technological aspects of the EMS breathing prototypes. Eventhough BreathCrunch and BellyBreath both are based on microprocessor controlled EMS system, each has its own context, technical implementation and character —as a Jackel and Hyde. As such we present them as two individual systems.

3.1 Prototype Configuration

To monitor the breath cycle we integrated a pressure sensitive resistor in a broad elastic band at the abdomen. With a simple moving

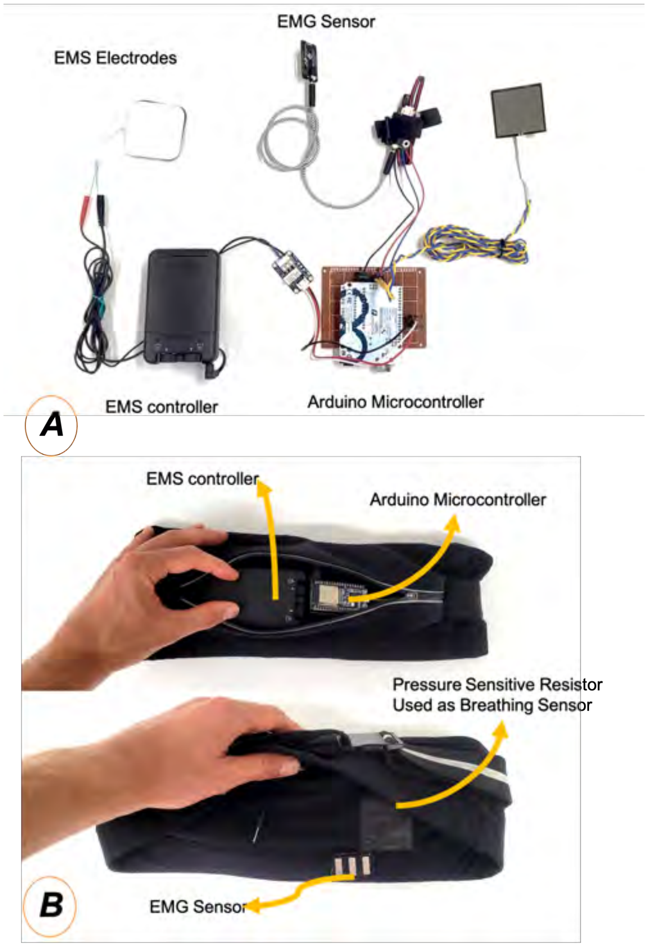

Figure 2: BreathCrunch and BellyBreath technology implementation. Left all components of the systems (EMG sensor only used in BreathCrunch). Right: the implementation in the band worn around the abdomen

average filter we are able to get a clear breath sample allowing us to distinguish the flow reversals in the breath cycle. The system utilizes a combination of electrical muscle stimulation (EMS) and electromyography (EMG) to enhance abdominal sensations (for BellyBreath) and contractions (for BreathCrunch) (Figure 4). The EMS actuator contains two EMS pads (4cm x 4cm) that are strategically placed to stimulate the rectus abdominis, one of the primary muscles involved in abdominal movements. For BreathCrunch specifically, an EMG sensor detects and measures the contraction of the rectus abdominis muscle. This real-time feedback allows for the monitoring of muscle activation and sensing the engagement of the abs needed to create a forced exhale.

3.2 BellyBreath: Design of the Belly Breathing Meditation Interaction

In this interaction BellyBreath supports the meditation approach of belly breathing (Figure 3). The core idea of this breathing technique is to perform and maintain slow breaths to calm down and activate the parasympathetic nervous system. BreatheMe analyses the current breathing state and nudges the user to breathe out deeper. When in the exhalation phase of the breath, the EMS is activated at a subtle intensity, and will last a bit longer than the last breath, inviting the user to maintain the exhalation for this period of time. This process will repeat until the user has reached about 30% increase in breath cycle time.

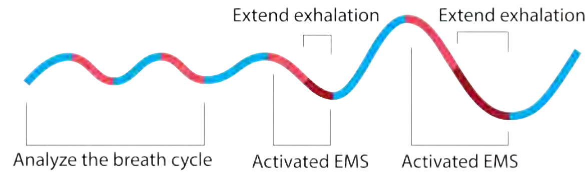

Figure 3: Diagram of BellyBreath interaction: The system analyzes the natural breath cycle and determines the exhalation time. During the next exhalations the EMS is activated, extending the original exhalation time, nudging the user to extend their exhalation.

3.3 BreathCrunch: Design of the Active Exhalation Interaction

In this interaction our EMS technology supports the breathing technique of "active exhales" [8] to be applied in the context of running. The core idea of this breathing technique is to extend the normal exhalation, performing an active forceful squeeze to press out any remaining air in the lungs. To perform an active exhale, the runner needs to actively engage the abs. When BreathCrunch does not sense the muscle activation during the exhalation phase, it will apply EMS to the abs to press out the extra air from the lungs (Figure 5).

The technical setup is as follows. BreathCrunch analyses the current breathing state to calibrate the system, determining a 'normal' breath. After the calibration the system starts with the breath enforcement program through EMS. When the EMG does not sense the engagement of the abs during the exhalation phase, the EMS will be activated. When the EMG detects the muscle activation prior to the calibrated breath, the EMS is not activated.

4 Demonstration

Through the demonstration of our system visitors will be able to experience its effect on their breathing. Visitors will be able to get a hands-on experience in which the EMS strength is adjusted to the comfort level of the individual. Two systems will be available for a smooth transitioning between visitors that would like the demo. One will allow participants to experience BreathCrunch, the other BellyBreath. Additionally, for spectators, a screen will be displaying the sensor readings and EMS activation, allowing for a third person experience of the demo. Overall, the demonstration will highlight the system's potential to enhance breathing performance through guided muscle activation and real-time feedback.

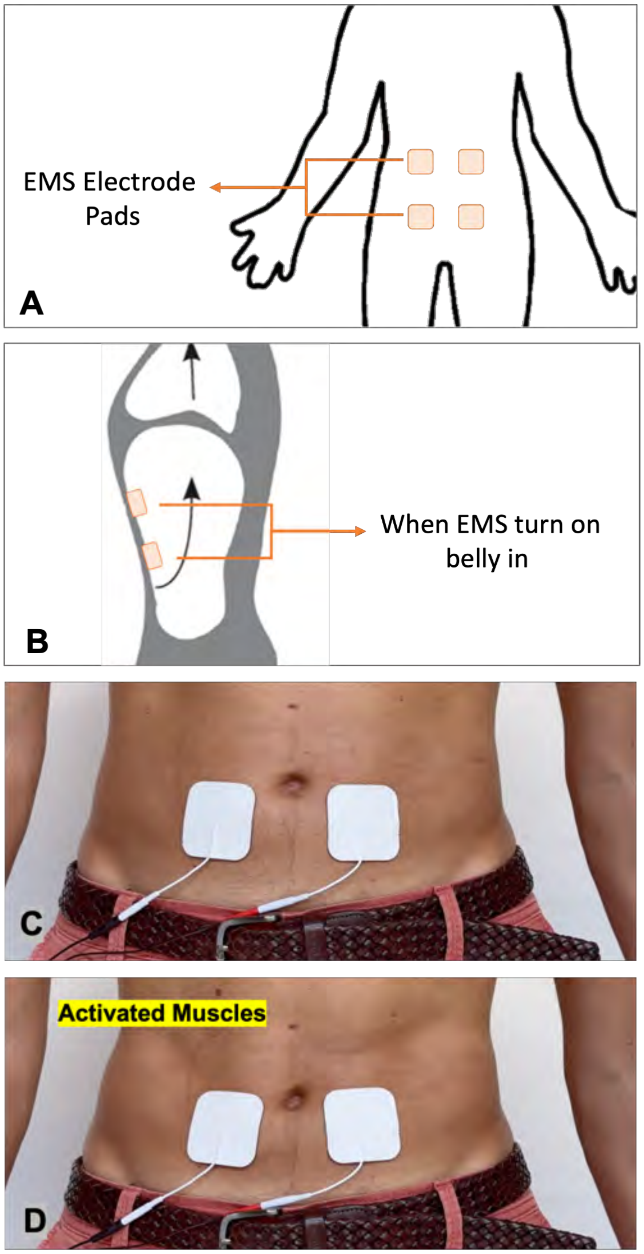

Figure 4: The EMS mechanics of BreathCrunch. A: EMS actuator and EMG sensor position, and B: through the EMS the muscle contracts and forces air to flow out, C: EMG not activated; muscles are relaxed, D: EMG activated, the muscles are activated and press out air from the lungs.

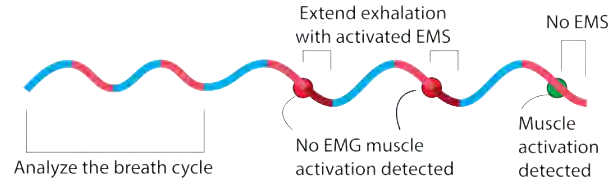

Figure 5: Diagram of BreathCrunch interaction: The system analyzes the natural breath cycle and determines the exhalation time. When the EMG does not sense the engagement of the abs during the exhalation phase, the EMS will be activated.

5 Conclusions and Future Work

In this paper, we presented BreathCrunch and BellyBreath, two interactive EMS systems to support breathing techniques. BreathCrunch forces active exhale to extend the normal exhalation in a physical exercise situation, while BellyBreath supports breath guidance to maintain slow breaths in a calm meditative setting. These systems assist people with the exhalation phase of breath through EMS. Using EMS for breath guidance has great potential, not only for meditation, but as well as for sports such as running and cycling. In next steps we aim to evaluate the systems in a formal experiment and explore how the dynamics of meditation and running over time might influence the behaviour of the systems.

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