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Evaluating mobile apps for breathing training: The effectiveness of visualization

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ABSTRACT

Deep and slow breathing exercises can be an effective adjunct in the treatment of stress, anxiety, post-traumatic stress disorder, chronic pain and depression. Breathing techniques are traditionally learned in courses with trainers and/or with materials such as audio CDs for home practice. Recently, mobile apps have been proposed as novel breathing training tools, but to the best of our knowledge no research has focused on their evaluation so far. In this paper, we study three different designs for breathing training apps. The first employs audio instructions as in traditional training based on audio CDs, while the other two include visualizations of the breathing process, representative of those employed in current breathing training apps. We carry out a thorough analysis, focusing on users' physiological parameters as well as subjective perception. One visualization produces better results both objectively (measured deepness of breath) and subjectively (users' preferences and perceived effectiveness) than the more traditional audio-only design. This indicates that a visualization can contribute to the effectiveness of breathing training apps. We discuss which features could have allowed one visualization (but not the other) to obtain better results than traditional audio-only instructions.

1. Introduction

Deep and slow breathing, as well as more complex breathing exercises such as Yogic breathing, have been found to be an effective adjunct in the treatment of stress, anxiety, post-traumatic stress disorder (PTSD), chronic pain and depression (Brown & Gerbarg, 2005; Bush et al., 2012; Han, Stegen, De Valck, Clément, & Van de Woestijne, 1996), and in the achievement of relaxation (Grossman, Grossman, Schein, Zimlichman, & Gavish, 2001). These benefits can be explained by the fact that deep and slow breathing exercises contrast the effects of fast and shallow chest breathing, which is a common automatic habit, e.g., in patients with anxiety disorders (Hazlett-Stevens, 2008). In general, hyperventilation can lead to physical sensations resembling anxiety (Hazlett-Stevens, 2008) and symptoms typical of panic attacks (Conrad et al., 2007). Furthermore, several medical studies have reported that breathing exercises can also have positive effects on the circulatory system, by helping to lower blood pressure (Grossman et al., 2001; Joseph et al., 2005; Radaelli et al., 2004). Integrating breathing exercises with more general relaxation training can also ameliorate respiratory symptoms in patients with asthma (Holloway & West, 2007).

Breathing exercises are traditionally learned in courses with trainers, e.g., courses for pregnant women in preparation to labor, programs for dealing with medical conditions such as hypertension or stress-related disorders, stress management courses for different professions that encounter stressful situations in the field (e.g., soldiers, first responders, nurses, doctors, etc.). Moreover, deep and slow breathing is useful also for handling stress in personal situations such as school exams, job interviews, public speaking and various kinds of social interactions. Audio CDs are often used to support breathing practice at home. Recently, some authors (Elliott et al., 2004; Liu, Huang, & Wang, 2011; Mitchell, Coyle, O'Connor, Diamond, & Ward, 2010; Schein et al., 2001) have focused on specialized hardware to guide the trainee during breathing exercises. In general, these systems exploit wearable devices like elastic girth sensors to record users' breathing activity (e.g., Liu et al., 2011; Mitchell et al., 2010), sometimes combining them with other devices, e.g., a portable music player (Elliott et al., 2004; Schein et al., 2001). The goal of these systems is to provide real-time adaptation of the training to users' physiology. Unfortunately, specialized hardware may be costly and not always available when required, e.g., when stress strikes. Furthermore, the transition to applying the skills learned through exercises in everyday life remains a challenge (Morris & Guilak, 2009).

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Smartphones can be a novel opportunity to improve breathing training. They follow their users anywhere, so a breathing training app could be always available to support users at any moment. Moreover, the cost of a smartphone app is typically low, and it is relatively easy to find free apps. In general, smartphones are increasingly seen as a versatile m-health instrument for treatment and training, in medicine as well as psychology (Miller, 2012), and some authors predict that the mobile phone will emerge as the preferred personal coach for the 21st century (Morris & Guilak, 2009). A few mobile apps for breathing training have been proposed in the literature, e.g., in the Mobile Heart Health project (Morris & Guilak, 2009). Moreover, app stores such as Apple's App Store and Google Play Store are making available a growing number of mobile apps for breathing training, developed both by small enterprises (e.g., "Universal Breathing: Pranayama" (Saagara, 2011)) and organizations such as the US National Center for Telehealth and Technology (T2), a part of the US Military Health System (MHS). In particular, T2 has recently launched Tactical Breather (National Center for Telehealth & Technology, 2011a), a mobile app for repetitive breathing training. The goal of Tactical Breather is to help soldiers in gaining a better control of heart rate, emotions, concentration, and other physiological and psychological responses during stressful situations (National Center for Telehealth & Technology, 2011a).

Unfortunately, to the best of our knowledge, no research study has yet focused on the evaluation of mobile breathing training apps. In this paper, we study three different designs for such apps. The first employs audio instructions as in traditional training based on audio CDs. The other two include also visualizations of the breathing process, which are representative of approaches followed in current breathing training apps. We carry out a thorough analysis of participants' physiological parameters as well as their subjective perception and preferences.

The paper is organized as follows. Section 2 briefly reviews the various apps for breathing training, while Section 3 provides additional motivations for our research. In Section 4, we describe the three designs considered in the present study. Then, Sections 5 and 6 illustrate in detail the experiment and its results, Section 7 discusses the results, while Section 8 presents conclusions and future work.

2. Related work

Visualization plays an important role in many kinds of medical applications (Chittaro, 2001) and is increasingly employed in mobile devices to make the information provided by their applications easier to understand (Chittaro, 2006). While some breathing training apps rely on audio-only instructions (as in the traditional approach based on audio CDs), more innovative apps are attempting to enrich audio instructions with interactive visualizations. Some of these apps share a common approach (called *circle-based visualization* in the following): they display a circle (or a sphere) that expands and contracts, which might suggest the expansion and contraction of human lungs during the breathing activity. For example, Morris et al. (Morris & Guilak, 2009; Morris et al., 2010) animate a simple blue circle to encourage deliberate and slower breathing (Morris et al., 2010). To better highlight the different phases of breathing, Tactical Breather (National Center for Telehealth & Technology, 2011a) also changes the color of the circle. During the inhalation phase, the circle is green and grows in size; in the hold phase (during which users must hold their breath), the circle turns yellow and its size remains constant; in the exhalation phase, the circle turns red and shrinks until it reaches its minimum size, which is marked by a light black circle in the center of the screen. During each phase, voice instructions first pronounce the name of the phase ("Inhale", "Hold" or "Exhale"), then count from 2 to 4 to give users an indication of the progress and duration of the phase. The phase and the pronounced number are also displayed as text on the screen. ColorBREATH (3CUBEs, 2012) substitutes the solid color circle with an iridescent bubble. ECNA-Breath (ECNA LAB, 2011) employs a green sphere that expands and contracts, but it allows users to adjust the maximum size of the sphere before starting the exercise to better fit it with their actual breathing depth. Breathing Zone (2011) employs a multicolor geometric shape similar to a lotus flower instead of a circle. Two different sounds, that can be chosen among various tones (e.g., two guitar chords), announce the beginning of the inhalation and exhalation phases.

Some apps follow a different approach (called *wave-based visualization* in the following), employing a wave-like line to show the optimal respiratory cycle. For example, Vital-EQ Respiroguide (Landelijk Centrum Stressmanagement, 2009) shows the breathing pattern as a sine wave that advances over time during the exercise. A yellow circle, locked on the curve and at the center of the screen, moves upwards and downwards following the wave to guide the user through the inhalation and exhalation phases. A wave-like line is also employed in Paced Breathing (IQPuzz, 2013): in this app, the wave represents a single respiratory cycle and does not move. During the exercise, a white circle follows the line to indicate the current position in the respiratory cycle. A tone with increasing or decreasing pitch is employed as an audio hint to indicate inhalation and exhalation respectively. The shape of the wave in terms of the length of breathing phases, but not their amplitude, is customizable by the user.

Two apps, "Universal Breathing: Pranayama" (Saagara, 2011) and TotalAwake (TotalAwake, 2012), have tried pie charts instead of waves. Pie sectors represent the different breathing phases and during a respiratory cycle, the chart is gradually filled with color to guide users through the different phases. Breathe2Relax (National Center for Telehealth & Technology, 2011b) employs a cylinder shape which fills up and empties out to indicate when to inhale and exhale. De Stress (Designit, 2009) employs instead animated arrows, which move towards or away from the screen to visually represent the inhalation and exhalation phases. The arrows move with decreasing speed during the exercise to help users gradually slow down their breathing frequency.

Finally, three apps resort to visualizations of the human body. "Universal Breathing: Pranayama" and Paced Breathing display a realistic 3D model of a human in the so-called "Burmese" posture, animated to represent the expansions and contractions of chest and abdomen during the exercise. A small blue arrow indicates the air coming in and out through the nose of the human. MyCalmBeat (MyBrainSolutions, 2012) introduces a silhouette of a human chest that encloses two 3D lungs. An animation shows when to inhale or exhale: a tone indicates the start of the inhalation phase; the 3D lungs expand and get gradually filled with oxygen, represented by a blue shade. When the lungs are full, a tone indicates the start of the exhalation phase, and the animation is reproduced in reverse order.

3. Motivations and goals

The lack of studies of the effects of mobile breathing training apps on users does not allow one to make substantiated claims about the effectiveness of the above described approaches. On one side, visualizations may offer easier to understand instructions and help trainees in reaching the optimal breathing pattern. On the other side, they could possibly distract users' attention from respiratory interoception which is important in controlling breath, and be detrimental to reaching slow and deep breathing. Their effects on breathing must thus be studied and contrasted with the