Catch Your Breath - musical biofeedback for breathing regulation

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Abstract

Catch Your Breath is an interactive audiovisual bio-feedback system adapted from a project designed to reduce respiratory irregularity in patients undergoing 4D CT scans for oncological diagnosis. The system is currently implemented and assessed as a potential means to reduce motion-induced distortion in CT images.

A museum installation based on the same principle was created in which an inexpensive wall-mounted web camera tracks an IR sensor embedded into a pendant worn by the user. The motion of the subjects breathing is tracked and interpreted as a real-time variable tempo adjustment to a stored musical file. The subject can then adjust his/her breathing to synchronize with a separate accompaniment line. When the breathing is regular and is at the desired tempo, the audible result sounds synchronous and harmonious. The accompaniment's tempo progresses and gradually decrease which causes the breathing to synchronize and slow down, thus increasing relaxation.

Keywords: sensor, music, auditory display.

1. Introduction

This project originated during a collaborative research effort with the department of Radiation Oncology at Stanford University, to develop auditory and visual biofeedback for patients who undergo a 4-dimensional computed tomography (4D-CT). 4D-CT, an integral tool in diagnosing lung cancer, suffers from imaging artifacts that arise from irregular breathing. By reducing the irregularity of breathing cycles, the imaging process gains a significant increase in efficacy. First we track the patient's breathing pattern through use of a camera and a reflective cube to optically scan the motion of the chest cavity during the imaging process (figure 1). After determining the period of patient's ideal breathing rate, we choose a musical accompaniment whose meter and harmonic rhythm matches it. While the patient is in the imager, his/her breathing is mapped to a musical melody created to adapt to the harmonic rhythm of the normalized breath. The patient is asked to breathe in such a way that the music sounds good. Preliminary tests suggest that this method is remarkably effective.

This method was adapted for an interactive installation for an exhibition at the Pasadena Museum of California Art. At the installation the user sits on a barstool and dons a pendant containing an IR sensor. A piece of music stored in MIDI format is randomly selected from a repertoire of Baroque and Classical music, which are at approximately standard breathing tempi. Each work is divided into one file containing the accompaniment (*leader*) and another containing the principle or salient melodic materials of the work (*follower*). The accompaniment is played at the set tempo and the melody is controlled by the users breathing pattern. In the version we bring to NIME, the tempo of the accompaniment is gradually decreased such that by the end of the mastery period, the user has synchronized with the accompaniment and should be breathing more regularly and slowly than at the start.

2. Background

Olson [3] defines applied biofeedback as

> ...a group of therapeutic procedures that utilizes electronic or electromechanical instruments to accurately measure, process, and feedback to person's information with reinforcing properties about their neuromuscular and autonomic activity, both normal and abnormal in the form of analogue or binary, auditory and/ or visual feedback signals. Best achieved with a competent biofeedback professional, the objectives are to help persons develop greater awareness and voluntary control over their physiological processes that are otherwise outside awareness and/or under less voluntary control, by first controlling the external signal, and then with internal psychophysiological cues.

The use of audiovisual biofeedback to monitor and to regulate breathing is not uncommon. A number of methods have been commercially available and at least one has been patented [1]. Breathing regulation through biofeedback has been shown to be effective in a wide range of situations, including stress reduction and AD/HD therapy [2]. The specific use of music to regulate breathing and induce relaxation is described in [4] and elsewhere. The effect of breathing control to manage hypertension has been widely studied (eg [5]).

3. Methods

3.1. Hardware

Catch Your Breath uses inexpensive, readily available materials. A webcam is shielded by unexposed, developed slide film that serves as an ambient light filter. The IR sensor is then the only visible light, allowing for direct motion tracking from a single source. The sensor is encased in a clear plastic box and affixed to a lanyard-style necklace. When worn by the subject, the casing naturally sits over the chest of the user with the sensor pointing directly at the camera. Tracking is performed along the X axis, as one inhales and exhales. A button embedded in the pendant changes between training and mastery modes and cycles through a pre-stored library of music. The CT scan implementation is complemented by visual feedback. The museum installation is designed to work effectively with or without the visual feedback. Reliance upon auditory feedback alone seems to be equally effective as a means of self-regulation.

3.2. Software

Software was written in Max/MSP with Jitter. Jitter tracks the IR sensor. Max then calculates the peaks and troughs associated with a breathing cycle. Every time the previous peak or trough is reached, a bang is sent out. The time between bangs is then calculated as a value in beats per minute. This is logarithmically scaled as a multiplier for the tempo of the MIDI files, such that 90BPM is a scale factor of 1.3 times the original. Two MIDI sequencers, each with real-time tempo variability, are synchronized by a millisecond clock that aligns the time when a tempo is altered.

In the visual feedback system, Jitter is used to create an animated visual representation of the *leader* and *follower* tempi using colored geometric objects that breathe along with the auditory feedback.

4. Implementation

The installation is set in a corner with a barstool facing a wall that is unadorned, except for a list of instructions. In the version with visual feedback, the barstool faces a flat-screen plasma display. The user sits on the stool, dons the sensor pendant and presses a switch to enter a training mode, to change from training to mastery mode, to change the music, or to reset the system. The museum installation version sets the tempo of the leader at a pre-determined rate. In the 4D-CT scanner implementation, the tempo of the *leader* is computed during a preliminary observation period in which an averaged and normalized breathing rate is determined.

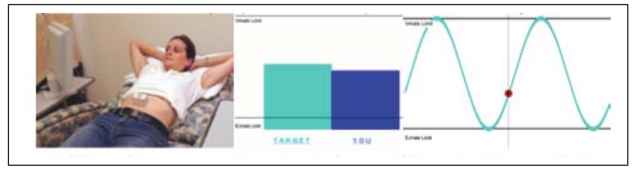

Figure 1. The sensor (placed above the patient's waist) in the 4D-CT scanner system with visual representations of the tracked breathing.

When the system starts, the music begins with one or more parts (often the chordal accompaniment, or bass-line) set at the *leader*, and the remaining parts (typically the melody) set at the *follower* tempo. By regulating breathing rate, the *leader* and *follower* can be made to synchronize with one another. Thus the sustained synchronization of all sounding parts of the music correspond with a desired regular rate of breathing.

5. Future work

We continue to fine-tune system responsiveness and expand upon the musical repertoire. Future work will include further study on using the system for relaxation. We are currently designing implementation on ubiquitous portable devices.

6. Acknowledgments

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