Respire: a Breath Away from the Experience in Virtual Environment

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Abstract
Respire is a virtual environment presented on a head-mounted display with generative sound built upon our previous work *Pulse Breath Water*. The system follows the changes in user's breathing patterns upon which it generates changes in the audio and virtual environment. The piece is built upon mindfulness-based design principles with a focus on breath as a primary object of the user's attention, and employs various approaches to augmenting breathing in the virtual environment.

Author Keywords
Virtual Environment; Mindfulness; Interactive Art; Musical Agents

ACM Classification Keywords
H.5.1. [Information Interfaces and Presentation (e.g. HCI)]: Multimedia Information Systems – Artificial, Augmented, and Virtual Realities

Introduction
Respire brings together three components: a virtual environment (via head-mounted display: Oculus Rift/HTC Vive), embodied interaction (via a respiration sensor), and an intelligent musical agent to listen to breathing patterns and generate the sound with affective properties (figure 2).

Figure 1: The changes in sky color over time: top image shows sky at minute 1, last image is at minute 6

In *Respire*, a user journey starts from being immersed in a large body of water: an ocean. The ambiguous environment reacts to the user's breathing patterns and invites the user to create their experience by playful exploration of breathing patterns. Users, by becoming aware of their breath and their agency in the environment via breath, become co-creators of the experience. As time progresses and in respect to a variety of breathing patterns, the user is taken on the journey to different atmospheres and parts of the environment. The design principles we built *Respire* upon follow nuances of mindfulness-based designs, and ambiguity in design, and as such it encourages a user to re-connect with their breath and shift their attention inwards, towards bodily sensations of their breath while opening a space for reflection and exploration of self and the virtual environment.

The narrative of the experience of the virtual environment depends on the user's breathing and changes in their breathing patterns. The system captures the user's breathing frequencies via thoracic and abdominal breathing sensors, and does three things. First, the system determines the user's position in the environment: when the user breathes in, they rise in the VE, and then slowly sink (underwater) when breathing out, moving across the environment at a slow pace. Second, the system sends the breathing frequencies to the artificial musical agent that generates the audio in real-time by mapping the frequency of the user's breathing to the eventfulness of the audio. Affective computing in sound is implemented in the system design to allow the agent to estimate the affective qualities of generated sound and of the sounds in the memory of the agent. Affective audio accompanies the moody atmospheres of an impermanent and ever changing virtual environment that follows the journey of the user's breath. Finally, variety in breathing patterns trigger different elements in the VE, populating the VE as the time progresses. For instance, fast thoracic breathing will trigger unpredictability of the environment and the visual elements displayed will convey sense of unrest and tensed atmosphere. In contrast, slow thoracic coupled with slow abdominal breathing will stabilize the environment in the state of serenity and peaceful atmosphere.

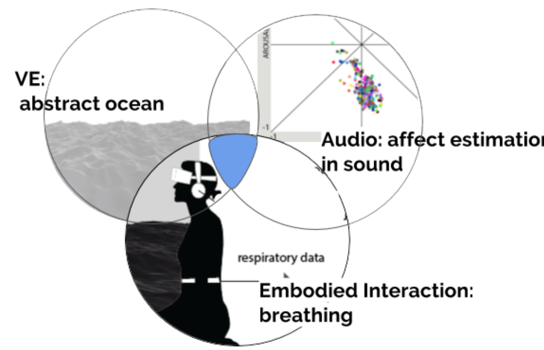

Figure 2: Respire's audio corpus in affect grid space.

Interaction Scenario

All the events in the environment are determined by the user's breathing patterns. Deep slow breathing triggers slower, more sustained movement on the up/down-axis, allowing users to observe, reflect, and position themselves in a particular part of the environment. Sustained breaths allow for staying in a specific place, while fast, strong breaths cause erratic movement. Mapping of a movement allows for interaction that is easy to understand: on the participant's inhale, the position of the participant rises in the environment, and on the exhale they sink, just like when submerged in water. As the time spent in the environment increases, the environment becomes more complex, with

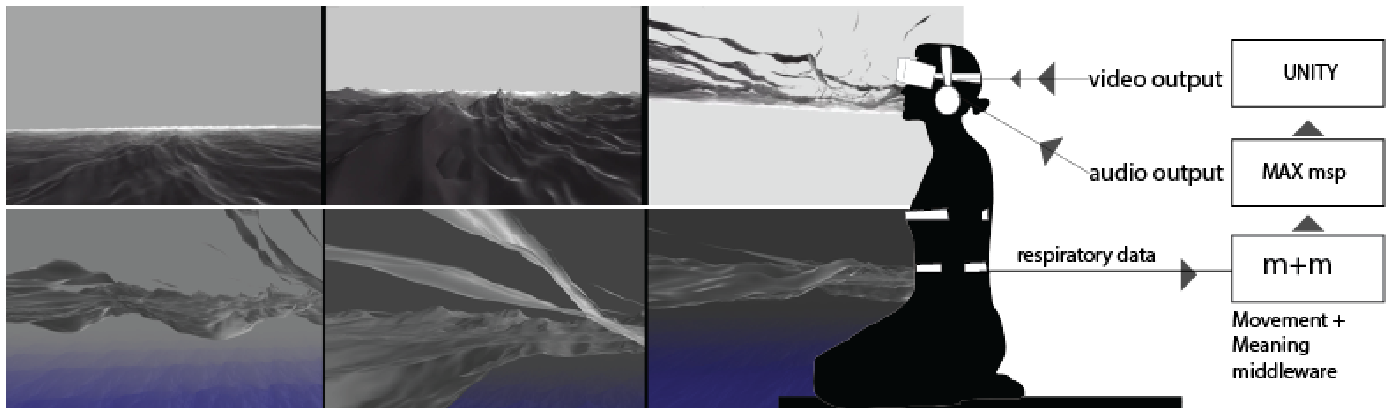

Figure 3: Respire: system design

visual components filling the space above and below the water. In our VE, the eventfulness of the audio is mapped to the appearance of the elements in the VE: for example, more eventful audio reflects in a more disturbed ocean surface and increased waves, or erratic movement of a flock of birds. The element that depicts the passage of time is the sky that changes the color from light gray to pitch black within a span of 6 minutes (see figure 1), however sustained slow breathing can slow this progression to up to 10 minutes.

System Description

The overall system outline is represented in Figure 3. One respiration sensor (Thought Technology) [2] attached to the user's abdominal area streams respiration data to M+M middleware [1] to a MAX patch [1].

[1]a visual programming framework for creative applications: https://cycling74.com/products/max

Virtual environment
The virtual environment consists of a number of elements that are triggered by changes in breathing patterns. A user is immersed in an environment that is abstract but still perceivable as a representation of a mass of water – ocean. The scene is split into 3 sections: above the water (high arousal), in the waves (neutral arousal), and under the surface (low arousal). Each of these three sections represent different affective qualities. Rapid breathing patterns reflect highly aroused states, positioning the user above the water level. Uneven, fluctuating breathing positions the user in the middle of the waves. Finally, slow paced, deep breathing positions the user under the water surface level with the aim to elicit relaxed, calm, feelings in the user. These 3 sections convey different atmospheres in regard to audio/visual elements. From a water surface that is stormy and an atmosphere that is moody during rapid breathing, to a calm underwater atmosphere that is surreal and ambient, breath

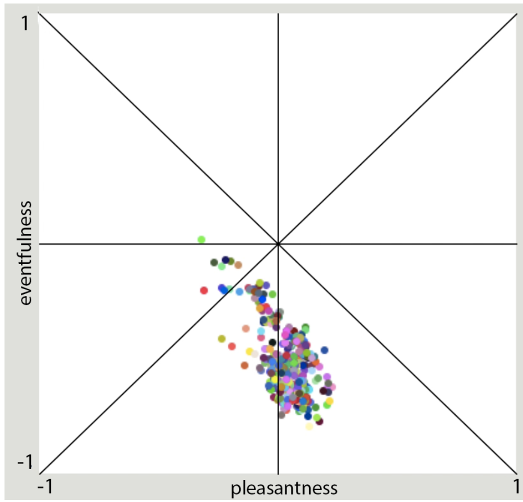

Figure 4: a segment of *Respire*'s audio corpus in affect grid space, centered around neutral pleasantness and low eventfulness.

is the key interaction that happens between a user and the environment. By changing the breathing frequencies and switching between chest and thoracic breathing, the user changes the scene, and then consequently, the scene might influence the user. This influence is anticipated by allowing the user to make a connection between their breathing and the elements they see in the environment (e.g., sustained, slow paced breathing "makes" the environment look very different).

Audio environment

The audio is generated by an autonomous agent that selects samples from the audio corpus according to the frequency of the user's breathing. All audio samples are tagged with different eventfulness and pleasantness properties using a state of the art music emotion recognition algorithm [4, 3]. The average affect values of each audio sample in *Respire*'s audio corpus are presented in the figure 4. We created the audio corpus by recording two, three, four, and five voice chords with quartile harmony on the piano. On that corpus we applied pitch shift and time stretch to produce more sounds around neutral valence and neutral to low arousal in the affective space. The user's abdominal breathing patterns are extracted using the wavelet transform of the breathing data and mapped to the highest and the lowest arousal (eventfulness) values in our audio corpus. Hence, we map the frequency of the user's breathing to the eventfulness of the audio. The overall affect of the audio is centered around neutral arousal with the aim of creating a particular audio aesthetic. Our goal was to lead our users towards relaxing states, by introducing audio low in arousal (in audio vocabulary of affect: eventfulness), and staying in neutral to the positive end of valence axis (pleasantness).

The overall eventfulness and pleasantness values of the audio environment are sent to the 3D game engine Unity 3D [2] along with respiration data via OSC messages. This data generates visual changes in the VE presented to the user via HMD. The user listens to the audio environment with circumaural noise-canceling headphones.

Creating the experience from a breath

The elements in the virtual environment are triggered by a combination of two values: 1. breathing frequencies from thoracic and abdominal sensors, and 2. eventfulness and pleasantness values from the audio environment. The combinations of 1. and 2. are depicted in figure 5. The figure shows the affect grid (similar to the grid in figure 4) and the visual environment is determined by the combination of the

[2] a game engine: https://unity3d.com/

aforementioned values. For instance, fast thoracic breathing causes the environment to switch to a moody, dark atmosphere, positioning the user in the upper left quadrant of the affect grid (high eventfulness, low pleasantness). By engaging in fast abdominal breathing, additional elements are added to the scene, such as a disturbed, wavy surface of the ocean. In contrast, slow thoracic and abdominal breathing will position a user on the surface of the ocean, letting them float gently on it, while the virtual environment slowly gets brighter and vivid in color. The color of the entire environment is determined by the audio values: pleasantness determines the color of the sky (low pleasantness = dark sky), whereas eventfulness determines how vivid the colors are (the more eventful the audio = brighter colors of the virtual environment).

Design Principles

Respire is built with the intention to help users reconnect with an embodied experience, often lost in our interaction with new and emerging technologies. To guide the user's attention inwards to the self, we focused on mindfulness based design and breathing as an object of the user's attention. The changes in *Respire* come directly from changes in breathing patterns, allowing the user to become aware of their breath and the agency they have in the environment. Designing to support breath awareness was our primary focus in interaction design. To support further reflection and self-exploration of breath, we present a user with an ambiguous environment. In our design, breathing is augmented through various audio and visual cues, out of which a narrative emerges through embodied interaction.

User Experience

In this piece, the musical agent listens to the user's breathing and takes the user on a journey through abstracted worlds with different affective qualities creating a user-

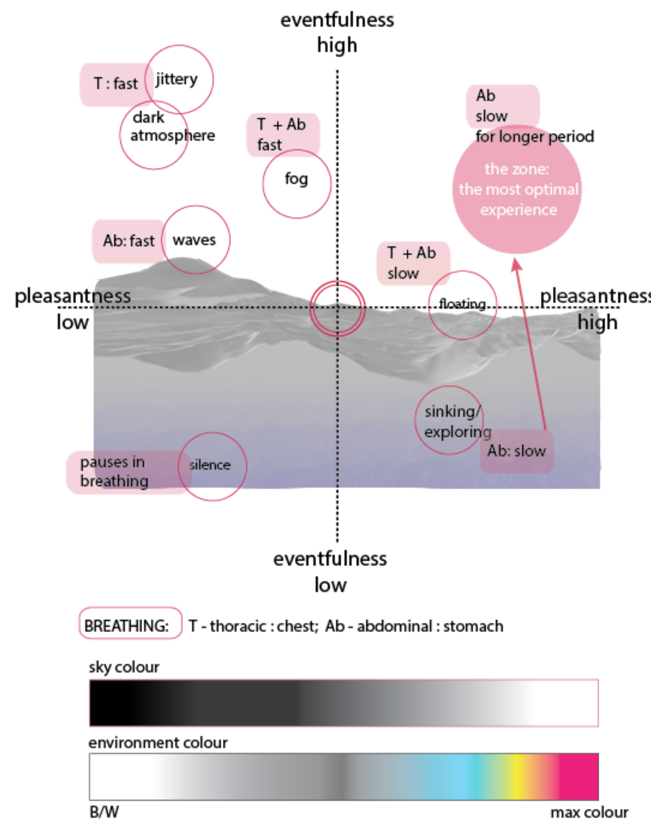

Figure 5: *Respire*'s audio corpus in affect grid space.

dependent narrative. From the calm to stormy oceans and ambiguous architectures that one is immersed in and that elicit curiosity; this is a journey within one's own breathing. The environment allows each audience member to create their alternate realities based on the interaction between two dynamic systems: the user and the system. This makes each journey unique, personal, and unrepeatable.

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