Life Tree: Understanding the Design of Breathing Exercise Games

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ABSTRACT
Regular breathing exercises can be a beneficial part of leading a healthy life. Digital games may have the potential to help people practice breathing exercises in an engaging way, however designing breathing exercise games is not well understood. To contribute to such an understanding, we created *Life Tree* as the culmination of three prototypal breathing games. *Life Tree* is a virtual reality (VR) game in which a player controls the growth of a tree by practicing pursed-lip breathing. We selected VR head-mounted display technology because it allows players to focus and limit external distractions, which is beneficial for breathing exercises. 32 participants played *Life Tree* and analysis of the collected data identified four key themes: 1) Designing Breathing Feedback; 2) Increasing Self-Awareness of Breathing and Body; 3) Facilitating Focused Immersion; and, 4) Engagement with Breathing Hardware. We used these themes to articulate a set of breathing exercise game design strategies that future game designers may consider to develop engaging breathing exercise games.

Author Keywords
Breathing exercises; game design; virtual reality; wellbeing; mindfulness.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Breathing is a core activity of our everyday life and yet we are mostly unaware of it [26]. Breathing is one of the only conscious physical activities that directly affects our heart, therefore, we can successfully treat illnesses such as hypertension and arrhythmia by controlling our breathing [21]. Practicing breathing exercises is considered one of the most fundamental ways for the development of both physical and mental well-being. It can reduce stress and promote feelings of relaxation [14, 32, 37, 50]. The way we do our breathing affects our whole body [61]. In particular, practicing breathing exercises may help reduce breathing related disorders such as Attention Deficit Hyperactivity Disorder (ADHD), Chronic Obstructive Pulmonary Disease (COPD) and Asthma [14, 27, 28] while improving our quality of life [14]. Several researchers suggest that digital games can support the practice of breathing exercises to improve wellbeing of players [19, 26, 39, 53, 60]. Furthermore, Moraveji [3] says that, *"breathing is one of the only conscious things we have control of, and digital feedback could help understand our breathing pattern and alter it, if necessary."* These perceptions of breathing informed our core motivation to use the interactive nature of digital games [52] to help players practice breathing exercises such as pursed-lip breathing, in an engaging way.

The design of digital games using the breath of players as a control mechanism has emerged in recent years with works such as *Breath controlled amusement park rides*, *Breathalising games* and *Breathtaking Journey* [35, 41, 57]. These games seem to entertain players, however, they do not appear to help practice breathing exercises, which can also support the wellbeing of players. Also, while some preliminary game research exists (such as with *AirFlow*, *ChillFish* and *DEEP* [49, 55, 58]), in which researchers have developed games to support the practice of breathing exercises, this research does not specifically present strategies on how to design engaging breathing exercise games. Recent developments in mobile and ubiquitous computing hardware technology, such as with Breathing+ [38], Zephyr [24] and sensors in smartphones like the microphone [42] have made it possible for game designers to sense players' breathing. Accordingly, we see this as an opportunity to use breathing as a control mechanism.

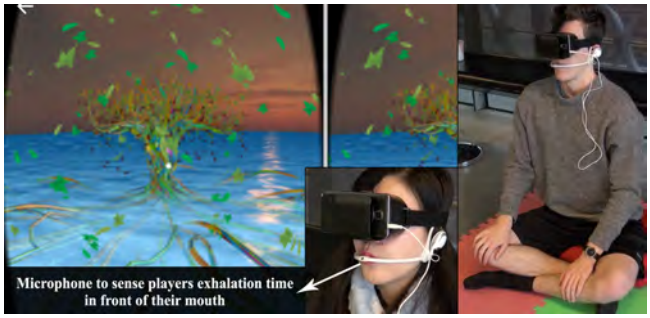

Figure 1. Players play the game wearing a breathing headset and a virtual reality head-mounted display.

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Our intention with this paper is to better understand the opportunities and challenges in designing games that help players practice breathing exercises and answer our research question: *How do we design engaging breathing exercise games?* In order to answer this question, we first discuss the relationship between breathing and body posture. We also discuss technologies available to measure breathing, and list previous research on breathing in various forms of interactive media. We then discuss the design of our three initial prototype games that led to the design of our final game, *Life Tree* (figure. 1), a VR game that helps players practice pursed-lip breathing. Further, we describe a user study carried out to understand subjective experiences of participants' playing *Life Tree* before presenting a thematic analysis of the data captured. This data informs four overarching themes that we use to articulate of set of design strategies that may act as a stepping stone for future designers interested in designing breathing exercise games.

BACKGROUND

In order to design engaging breathing exercise games, designers may want to make use of the following considerations from existing literature as per our knowledge on breathing and, interactive media that uses breathing as a control mechanism.

Breathing and Body Posture

Body posture has been shown to significantly affect the way we breathe [6, 40]. Hewitt [26] suggests that breathing exercises can be practiced using different body-postures. He suggests that sitting down cross-legged with the hands resting on our thighs gives us greater stability and has been used for thousands of years by Yogis [54] (a historic term for Yoga practitioners). As such, considering the right body posture may play an important role for the design of breathing exercise games.

Pursed-Lip Breathing

Pursed-Lip Breathing (PLB) [12] is performed by exhaling through tightly pressed lips (pursed lips) and inhaling through the nose with a closed mouth. Physicians, physical therapists, occupational therapists, and respiratory therapists teach this breathing technique to their patients to ease shortness of breath and to promote deep breathing [26]. In a study conducted to design personalised relaxation techniques involving breathing exercises for oncology patients, researchers asked patients to practice PLB and observed a significant decrease in their stress levels [43]. We have therefore chosen PLB as the breathing exercise technique players can practice while playing *Life Tree*.

Breathing and Interactive Media

Breathing as a control mechanism has been put to creative uses: for navigating an immersive virtual world through the metaphor of diving [36]; and for enabling two-way communication [57]. Devices for measuring breathing have also entered the market, for example, the Sensawaft Breath Controlled Mouse [45], Breathing+ headset [38] and Spire [33]. Breathing as a control mechanism has been used in some game interfaces from simply blowing out candles on a digital screen, to the sensory deprivation game, *Deep Sea* [5]. *Deep Sea* is an audio only breathing first-person shooter game [5]. This game serves as an example of how breathing can be used as a novel control mechanism. *The Journey to Wild Divine* [7] is a study that investigates a biofeedback management tool to teach breathing techniques to children with Attention Deficit Hyperactivity Disorder (ADHD). Children played the game by manipulating their heart rate using breathing techniques taught in the game. This game indicated that a breathing game has the potential to produce positive developments for children with ADHD [2]. *ChillFish* [55] is another breathing game for children with ADHD to help them retain attention on practicing breathing exercises. The gameplay is based on an underwater 2D world, where the player's character collects as many starfishes as possible. This research suggests that doctors treating breathing disorders such as ADHD might want to use creative solutions such as games.

The incorporation of music in breathing is a widespread practice [22]. Researchers have used music as the central entity being controlled by breathing: *Sonic Cradle* [59] is a non-visual interactive system that promotes mindfulness using breathing to control the ambient music. This study suggests that meditative processes such as practicing breathing exercises could be enhanced by using certain kinds of music. *Breathing Light* and *Soma Carpet* are two applications by Somaesthetic designers [29]. Somaesthetics allows the design of interactions that subtly support directing users' attention inwards, towards their own body [29, 30]. *Breathing Light* consists of an enclosure made of fabric and string curtains that one crawls under, creating a room within a room, effectively shutting out the external world. Inside this enclosure, a breathing sensor controls an ambient light that will dim in cadence with the participant's breathing. *Soma Carpet* is a system that has the ability to direct the participant's attention by providing heat feedback to different parts of one's body while one follows the instructions of a pre-recorded breathing exercise lesson. Here, *Soma Carpet* draws attention to the importance of self-awareness of one's own body while breathing. Their research suggests that game designers may want to consider using subtle feedback: that is, feedback that does not disturb the breathing experience for users, such as the dimming of lights in *Breathing Light*. External stimuli such as heat in *Soma Carpet* might also help direct the users' attention towards their own body while practicing breathing exercises.

Marshall et al. [41] explored the potential of breathing as a control mechanism for *Bronco Ride*, an amusement park ride. They use breathing as a control mechanism in amusement park rides to: 1) encourage the rider to hold their breath; and, 2) use rapid breathing to power up the ride. Tennent et al. [57] explored the potential for breathing as a control mechanism in gaming. They developed five games using breathing as an exclusive, secondary and ambient control mechanism. In order to sense the breathing of players

they developed a custom gas mask and used it with gaming interfaces such as keyboard and mouse to control parts of the game. Using their research, we are better able to understand the challenges and opportunities in designing breathing exercise games.

Breathing and virtual reality

Davies [19] was one of the first to use breathing as a control mechanism with her project, *Osmose* [19]. *Osmose* is an immersive interactive virtual reality installation with a head-mounted display and real-time motion tracking based on breathing and balance. Players gently float in order to navigate through the different worlds within *Osmose*. Davies filled the virtual world of *Osmose* with simple particle systems. These particle systems were used as ambiguous representations of objects in the world of *Osmose* such as a water stream or birds. Importantly, Davies used this technique to help players feel centered to their physical bodies during immersion, in a way that is similar to the effect of practicing meditation.

DEEP is another VR game that has been developed to support children with anxiety disorders [58]. *DEEP's* main aim is to provide an immersive and relaxing experience with no explicit tasks or goals. The player's diaphragm expansions are recorded (using a variable resistor/stretch sensor) and used as feedback. A study of *DEEP* showed reduced levels of stress and anxiety in children. These findings confirm the potential of using VR technology in the design of breathing exercise games. *Breathtaking Journey* [35] is a Mixed-Reality (MR) game providing a first-person perspective of a refugee's journey. It has been developed to research the influence of multi-sensory experiences on presence, empathy and ultimately on attitude change. The aim of the game is to avoid detection by stopping your breath while the enemies are on the prowl. Players wear a custom-built mask having the ability to measure breathing in order to play the game.

In summary, breathing as a control mechanism has been used for entertainment in games, however, it has rarely been explored in the context of helping players practice breathing exercises. While we were inspired by the philosophical literature on breathing exercises [26], we also drew design tactics from existing work [41, 57] and used them in the design of *Life Tree*.

Hardware to Measure Breathing and Software

Digital games discussed in the previous sections such as *DEEP* and the *breath controlled amusement park ride* [41] have used custom-built strap devices to measure breathing. Devices like Zephyr [24] are readily available on the market to calculate aspects of breathing such as breathing rate, tidal volume, etc. These aspects can be easily sensed and considered by game designers as input. Exhalation is important for PLB [12] and Breathing+ is a headset specifically designed [38] to measure the exhalation time of players while practicing PLB. Breathing+ can be connected to the 3.5 mm headset jack of either your smart phone or desktop computer. The microphone in front of the player's mouth (fig. 1) helps calculate exhalation time. While this device can only calculate exhalation time, it is light and one of the most portable devices available. This is one reason why we chose this device to sense breathing in our games. In addition, research suggests that strapped measuring devices such as Zephyr were judged uncomfortable by participants [20]. We used Unity 3D (version 5.4.4) to develop our games and Maya (version 2016) to design and animate 3D objects in our games.

In the next section, we describe the design of our three initial VR prototypes and present our learnings through a Formal Analysis of Gameplay (FAOG). FAOG is a method that provides an understanding of a game system by deriving design primitives, which are a combination of 1) Components, 2) Actions and, 3) Goals [9]. FAOG allows us to determine these design primitives by repeatedly playing our own games and writing in detail about them. We used this method to play test our prototype games repeatedly with five fellow researchers and heuristically evaluate the prototypes while noting the design primitives that worked well with breathing exercises. These learnings then informed the design of our final game, *Life Tree*.

DESIGNING INITIAL BREATHING EXERCISE GAMES

Our idea before developing *Life Tree* was to experiment with different ways to design engaging breathing feedback to support the practice of breathing exercises. We designed different kinds of breathing feedback in these three initial VR prototypes: 1) *Space Gaze*; 2) *Focus Tree;* and, 3) *Outlandish Whisper*. We refined these prototypes by playing them repeatedly with fellow researchers (fig. 3) who have expertise in game design and also with researchers conducting research on breathing applications (non-game ones). This informed the final design of *Life Tree*. Breathing exercises are best practiced in short intervals [26], therefore, all our games were designed to be played for 2-3 minutes.

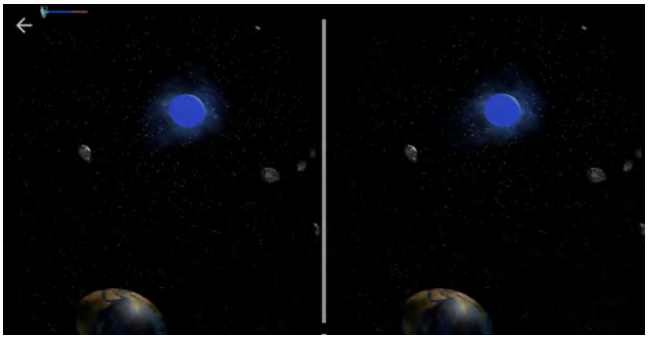

Figure 2. Blue oxygen that players collect to survive.

Prototype 1: Space Gaze

In *Space Gaze*, players practice PLB to move gently inside the virtual environment and collect oxygen (fig.2) in order to maintain the oxygen level in the atmosphere and survive in the game. To provide breathing feedback, we explored the slow movement of the player's viewpoint and, as the end goal we experimented with the survival mechanic [51].

Players see a blue shimmering light, i.e., the oxygen while wearing the HMD. The player's viewpoint moves upward in space on exhalation and moves down during inhalation to help players collect the oxygen. By conducting a FAOG, we concluded that the slow motion of the player's viewpoint in the virtual environment could help them focus on their breathing. However, it also appeared that the survival mechanism in the game could distract players from focusing on their breathing, making them anxious.

Prototype 2: Focus Tree

In Focus Tree, the viewpoint of players slowly revolves around an island while they practice PLB. On inhaling, clouds cover the island to block the view of players; and on exhaling, clouds get blown away allowing players to view the island (fig.3). Trees start growing on the island when the players exhale. The aim of the game is to grow as many trees as possible within the time limit. Rhythmic breathing leads to the growth of more trees on the island and non-rhythmic breathing leads to lesser growth. Conducting a FAOG suggested that participants liked the naturalistic game environment in the form of a green island, flowing water, trees growing and playing with the colours of the tree as a result of their breathing exercise. We observed that players enjoyed how the feedback with the growth of trees as a result of rhythmic breathing was embedded into the environment of the game. However, we found that showing the remaining game time caused stress to the players.

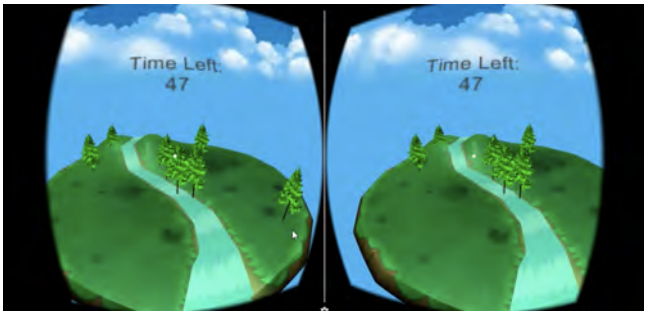

Figure 3. The clouds dissipate with every exhalation.

Prototype 3: Outlandish Whisper

In *Outlandish Whisper*, players dive into a world filled with ambiguous particles to practice PLB. We wanted to explore breathing feedback by allowing players to feel as if they are exhaling something out of their body and inhaling something into their body. When players inhale, they see that they are inhaling gold particles and when they exhale, they exhale red particles. The rationale for selecting these colours was that gold represents fresh oxygen and the red represents carbon dioxide. Further, blue particles were generated whenever the game detects that the players are breathing in rhythm. When participants were breathing non-rhythmically, a pre-recorded voice instructed participants to gently focus on their breathing again. We noted that players liked the responsiveness of the breathing feedback. It seemed that players liked the subtleness of rhythmic breathing feedback embedded into the environment. We noticed that players liked the pre-recorded voice instructions before the game started, as they believed this helped them understand the goal of the game. Players did not like the pre-recorded voice instructions being played during the game as it seemed to distract them from focusing on their breathing.

LIFE TREE: DESIGN AND DEVELOPMENT

Our aim with the design of *Life Tree* was to create an immersive and engaging way to practice PLB. We made the following design decisions using findings from our initial three prototypes and based on the literature on breathing. *Life Tree* is a VR game that helps players practice PLB. The environment of the game consists of a tree submerged in the middle of the water. The game lasts approximately two and a half minutes. Players wear the HMD along with the Breathing+ headset as shown in fig. 1.

Overview of *Life Tree's* Gameplay

As the game begins, players see a colorless tree standing in the middle of a body of water. If players exhale at this point in time, they can see leaves being blown towards the tree. A pre-recorded voice instruction informs players to sit down cross-legged. As the players sit down, an animation of the tree getting submerged into the water is triggered in order to replicate their bodily action. This is achieved by using the input acceleration in the y-direction (if input.acceleration.y <= -1.1f). Once the players sit down, the game menu pops up. To start the game, players have to target (using head orientation) the reticle (VR pointer) on the start button and exhale continuously for three seconds. As a way to introduce visual breathing feedback before the game starts, players can see leaves being blown towards the menu button on exhalation while navigating the game. This action performed by the players starts the game which, in turn, triggers a sound of rhythmic breathing in the background that lasts for 30 seconds. Players can follow the rhythm by inhaling and exhaling for at least three seconds. In order to give them visual feedback, the trunk of the tree expands on inhalation and contracts on exhalation. The animation of the tree contracting is played until the maximum frame number is reached. If the players' exhalation time is lesser than the maximum frame number then it is played only until that particular time frame (if frame is "f", f <= f (max)). Similarly, when players inhale, the animation of the tree expanding is played till the minimum frame (f (min) <= f).

In order to visualise the exhalation of players, we use particle effects of leaves being blown towards the tree. The colour of the leaves changes to a bluish-green shade if the players breathe rhythmically, otherwise, it changes to a greenish-brown shade. If the time difference between two consecutive exhalations is less than two seconds and the current exhale time is longer than one second, it is considered as rhythmic breathing. Further, if the difference between two consecutive exhalations is more than three seconds then it is considered as non-rhythmic breathing. If the breathing of players is non-rhythmic then the system starts to blur the view of players in the game (It starts from value "0" and is increased by a value

of 0.03f for every update, i.e., 0 <= Blur Value <= 3. Similarly, on rhythmic breathing, the *Blur Value* is decreased by 0.03f). This is effective only 20 seconds after the game starts. The goal of the game is for players to make the tree as colourful as possible by breathing rhythmically and keeping the game in focus for as long as they can. In order to design *Life Tree,* we considered the following concepts: 1) Designing Focus; 2) Encouraging Players to Sit in a Cross-Legged Posture; 3) Designing for Self-Reflection and Awareness of Breathing; and, 4) Designing Audio.

Figure 4. The game encouraging a player into the right body posture to play the game.

Designing to Nurture Player's Focus on Breathing

Practitioners of breathing exercises benefit from being able to focus on their breathing [26]. We wanted to embed breathing feedback in the game environment in a similar way to that which had worked well with *Focus Tree* and *Outlandish Whisper*. Players liked the use of naturalistic visuals in *Focus Tree*, with the trees and leaves. We applied our learning from *Focus Tree* and designed naturalistic visuals for Life Tree. A tree is the only visual element in the game. We chose an illustration of a tree from the works of Apostolescu [4].

Designing to Encourage Right Body Posture

To encourage players to move into the right body posture to play *Life Tree*, we used a soothing pre-recorded female voice asking them to sit down in a cross-legged posture placing their hands on their thighs (fig.4). These are initial instructions to get players into the right position before the start of the actual gameplay. We used this as players liked the initial voice instructions in *Outlandish Whisper.*

Figure 5a shows the tree expanding when players inhale and 5b shows the tree contracting when players exhale.

Designing to Increase Awareness of Breathing and Body

Focusing on one's breathing leads to awareness of both breathing pattern, and body movement while practicing breathing exercises [26, 61]. We learned from *Outlandish Whisper* that players did not like the pre-recorded voice instructions during the game. As an approach to design breathing feedback for *Life Tree* we imagined the trunk of the tree in our game to be the lungs of the player's body. When a player inhales, the trunk of the tree expands and when the player exhales, the trunk of the tree contracts (fig 5. a & b).

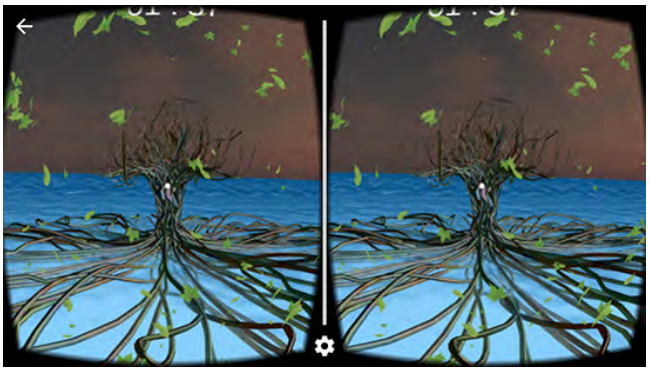

Figure 6. Lifeless tree when the game begins along with feedback of leaves on exhalation.

Furthermore, we used the tree's texture as breathing feedback. The tree looks lifeless and gray in colour at the beginning of the game. The tree is filled with colour exponentially as players practice PLB (fig.7). The saturation value of the tree increases slowly from 0 (black) to 1 (actual colour of the tree). The players add colour to the tree based on their breathing rhythm. We used leaves (fig. 6 & 7) as a way to help players visualise and understand that their exhale is recognised by the Breathing+ headset. Breathing is widely considered as a subconscious activity [44]. Therefore, in order to not distract them from focusing on their breathing, we slowly blurred the game's view as a subtle way to give feedback to players that they were not breathing in rhythm.

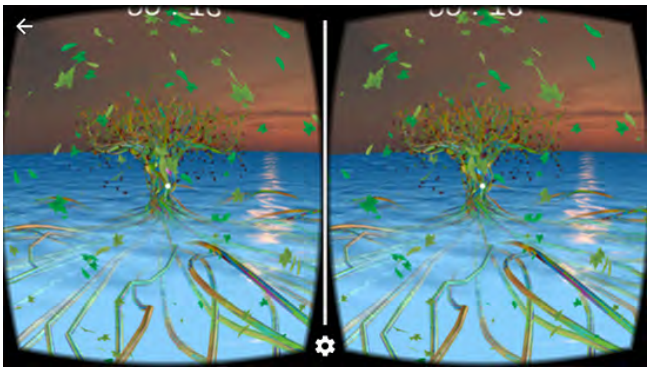

Figure 7. The full of life tree at the end of the game.

Designing Audio to Enhance the Cognitive Experience of Practicing Breathing Exercises

Based on player feedback from *Focus Tree* and *Outlandish Whisper*, we avoided pre-recorded voice instructions in the background. In *Life Tree*, players listen to a rhythmic inhalation and exhalation sound at the start of the game to understand how to perform the breathing exercise. The sound

lasts for 30 seconds before fading out. We believe the ambiguous breathing sound might help players understand the kind of breathing exercise they have to perform in the game without disturbing the focus on their breathing. Furthermore, we used instrumental music of an Indian instrument called "Veena" as the background score for the game. A study by Clayton [16] suggests the Veena's music has been used to enhance the effect of practicing Yoga, which involves the practice of breathing exercises in various body postures.

USER STUDY AND DATA ANALYSIS

Ethical approval was obtained to conduct our research with 32 participants. Prior to the start of the game session, we briefed participants about PLB and *Life Tree*. Participants were free to play the game multiple times. Post the game session, all 32 participants (16 males and 16 female) answered questions in the Game Experience Questionnaire (GEQ) [31, 47] and were subsequently interviewed. The GEQ questions were measured on a 7-point Likert Scale with answers ranging from "Strongly Agree" to "Strongly Disagree". The average age of the participants was 25, with a standard deviation of three years. In the interviews, participants answered questions regarding their experience playing *Life Tree*, their feeling after the game session, PLB, situations in which they would like to play the game and follow-up questions based on their answers. Participants were video and audio recorded while playing the game and while they were being interviewed.

Interviews were transcribed. A question and its answer by a participant were put together and considered as one unit of data. In total, there were 642 units of data included in the analysis. An inductive thematic analysis was then conducted on the data [11]. This method was deemed appropriate, as the design of breathing exercise games is an emerging and crudely understood topic, for which limited relevant theory currently exists. Two researchers independently read all units of the data three times, and each researcher initially identified every data unit with a category code. These independent codes given by the two researchers were discussed and refined separately until agreement was reached on a total of 25 codes. The coding categories were then examined and cross-referenced with the data and further analysed for overarching themes that affected player experience, which were again reviewed by both researchers.

THEMES DESCRIBING PLAYER EXPERIENCE

Overall, participants liked playing *Life Tree*. They reported that *"the game was very fascinating and de-cluttering"*. They also thought of it as a novel experience. P17, a female participant said, *"It is really good. I feel surprised about that game because I have not experienced such a kind of game before. It really felt special for me"*.

We now unpack the player experience further by articulating four overarching themes: 1) Designing Breathing Feedback; 2) Increasing Self-Awareness of Breathing and Body; 3) Facilitating Focused Immersion; and, 4) Engagement with Breathing Hardware.

Theme 1: Designing Breathing Feedback

This theme describes participants' discussion of the breathing feedback design in *Life Tree*. 174 of the total 642 units of data were described by this theme, which consists of two category codes: 1) *Non-interruptive breathing feedback during gameplay* (mentioned in 106 units); and, 2) *Initial breathing guidance after starting the game* (mentioned in 68 units).

Non-interruptive breathing feedback during gameplay

Participants discussed the non-interruptive nature of the breathing feedback, i.e., the way in which feedback kept them informed about their breathing while ensuring they did not lose attention on their breathing rhythm. This seems to resonate with the high score of 5.78 (SD = 0.89) for the parameter *Flow* measured using the GEQ. *Flow* refers to the mental state of operation in which players performing actions in a game are fully immersed in a feeling of energised focus, full involvement, and enjoying the actions they are performing in the game [15, 17]. All the 32 participants liked the feedback with green leaves that they saw on exhalation. P3 said, *"I liked the visual representation of the breathing in the form of leaves. It showed me how I was exhaling, how hard I was exhaling and whether I was exhaling or not"*. Participant P1, when asked about the one thing she would like to keep in the game, said, *"Just that sense of reassurance you get with the feedback using leaves; that you are doing it right and not in your face about it."*

Ten participants said that they did not see the game getting blurred as they were breathing in the desired rhythm throughout the game. Seventeen out of the remaining 22 participants liked how the game informed and nudged them in a subtle way when they went out of rhythm, by blurring the view of the game. Participant P17 said, when asked about the one thing he wanted to keep in the game, *"The blurry part of the game. It helps me understand if I am breathing rhythmically or not in a way that does not distract me from my breathing"*. We noted that participants enjoyed seeing the tree become colourful over the course of the game. Participant P4 said, *"It felt like I was giving life to the tree because I saw colours creeping into it and it also helped me understand that I was breathing rhythmically"*.

We embedded the breathing feedback into the tree trunk, i.e., the environment of the game, to help players become self-aware of their own breathing. This design feature appeared to help achieve self-awareness of breathing. P27 said, *"The tree changes its form based on my exhale and inhale. This helped me become aware of my own breathing"*. While participants became self-aware of their own breathing with the help of this feature, 10 participants also perceived this as imitation of their own breathing and enjoyed the tree imitating their breathing pattern. These participants also suggested that this imitation encouraged them to breathe rhythmically. Participant P32 said, *"The breathing of the tree*

was imitating my breathing pattern. I felt that there was someone else breathing along with the tree. It was kind of prompting me to breathe rhythmically". We observed that 22 participants liked our design choice with embedding classical Indian music as the background. These participants felt the music helped them calm their nerves and relax. P3 said, *"The kind of music that was playing along with the game was very fascinating as it made me feel relaxed and calmed my nerves"*.

While 22 participants felt imaginative while playing the game, only eight participants could describe this imaginative feeling caused while playing *Life Tree*. Participant P12 said, *"It was interesting as I was enjoying the seasons in the game. I felt like I was in spring season then later I felt I was in autumn because what I was seeing made me feel very creative and imaginative."* We use the word, 'imaginative' as the colours changing in the tree due to their rhythmic breathing were never meant to be perceived as change in seasons. However, it looked like the combination of the features helped users become imaginative and creative with their thoughts. We believe this is the reason why *Sensory and Imaginative Immersion* got a relatively high score, i.e., 4.85 (SD = 1.09) on the Likert Scale.

Initial breathing guidance after starting the game

Twenty-five participants liked the sound of rhythmic breathing at the beginning of the game. Twenty participants had prior experience of using breathing exercise applications like the Headspace app [25, 48] and indicated that the initial sound of rhythmic breathing was enough to understand that they had to breathe rhythmically to play the game. We designed a breathing poster to recruit our participants who were interesting in breathing exercises. This is the reason why we had a large number of participants with prior experience with breathing exercises. Participant P7 said, *"I like the sound of the breathing that comes initially. It helped me understand that I had to breathe like the rhythmic sound being played or at least breathe rhythmically.* Seven participants liked the idea of the ambiguous breathing sound at the beginning, however, they had difficulty understanding its purpose. This is reflected by the average score of 3.88 (SD = 1.3) for the parameter *Competence* measured with the help of the GEQ. Competence is the ability to perform a particular task in a game [52] and, in this case, it is the practice of pursed-lip rhythmic breathing . Participant P26 said, *"The bit that I disliked was the breathing sound at the beginning as I did not know if I was supposed to follow that pattern or not"*. Seven of these 10 participants suggested adding a tutorial mode at the beginning of the game. Participants P3 and P11 said, *"It was a little hard to understand the game at the beginning. A little bit more instructions, maybe a guided tutorial mode would be really good to go with"*.

Theme 2: Increasing Self-Awareness of Breathing and Body

This theme describes how *Life Tree* helped participants become aware of their breathing and body. Ninety-three of the total 642 units of data were described by this theme, which consists of three category codes: 1) *Awareness of body movement* (19 units); 2) *Mindful practice of breathing exercises* (44 units); and, 3) *Feeling after the game session* (28 units).

Awareness of body movement

29 participants commented on how *Life Tree* made them more aware of their breathing and body movement while playing. Participant P9 said, *"I was able to feel my own breathing. I was also able to experience my whole body move and I could hear my heart beat as well"*. When participants were asked about what facilitated this self-awareness, they said that the synchronisation between their breathing pattern and breathing feedback in the game pushed them to concentrate and continue breathing rhythmically. P7 said, *"It made my body feel good while I exerted pressure on my diaphragm and lungs. It was also nice to see the game's response towards my breathing"*.

Mindful practice of breathing exercises

Eighteen participants discussed how the blurring of the game's view on breathing non-rhythmically nudged them to become mindful about their breathing and pushed them to breathe rhythmically. P23 said, *"I felt that I was not doing it right and that is why the tree was not in focus. To get back into rhythm I had to become more aware of my abdomen expanding and contracting to get it into a rhythm"*. As described by Bergomi et al. [8] the process of becoming self-aware of one's own feelings and inner sensations is referred to as *awareness towards inner experiences*, one of the factors that helps an individual become mindful. Eight participants even compared the experience of playing *Life Tree* to applications they use in general to practice mindfulness, which involves the practice of breathing exercises such as the Headspace app [25]. These participants suggested that the breathing feedback in *Life Tree* helped them become aware, and in turn, more mindful of, their breathing. P9 said, *"I felt more aware of my breathing while playing Life Tree than while using the application I generally use, i.e., Headspace [25]. I guess it is because of the more interactive nature of this game where you visualise your breathing."*

Feeling after the game session

Twenty-six participants discussed how they felt good after playing the game. Eight participants spoke about how they felt exhausted in a good way. For example, P10 said, *"I feel a little exhausted after playing the game but I feel that this is good exhaustion"*. This reflects on the relatively high score of 3.93 (SD = 1.07) for the parameter *Tiredness* measured using the GEQ. Twenty-one participants spoke about becoming calmer and feeling good about themselves after the game session. P29 said, *"After I finished playing the game I feel quite good and happier than I was before playing the game"*. We thought that this good post-game feeling was a result of the virtual environment that helped players concentrate on their own breathing and the soothing music. P16 said, *"I feel very peaceful and relaxed after playing the*

game because of the immersive environment and music". P3 mentioned how the music made him calmer and said*, "The kind of music that was playing along with the game was very fascinating as it made me feel relaxed and calmed my nerves"*. This discussion reflects the high score of 4.86 (SD = 1.4) for the parameter *Positive Experience* measured using the GEQ.

Theme 3: Facilitating Focused Immersion

This theme describes how *Life Tree* helped participants experience focused immersion. Focused immersion is referred to as a state of mind experienced by players while doing an activity in which they feel that the time flies [1]. One hundred and fifty-seven units of the total 642 units of data were characterised by this theme, consisting of two category codes: 1) *Immersiveness leading to flow* (99 units); and, 2) *Breathing as the focal point* (58 units).

Immersiveness leading to flow

Participants suggested that the repetitive nature of the task, i.e., breathing rhythmically, was one reason why they felt it to be an immersive experience. Participant P4 said, *"It was an easy repetitive thing to do and once I got the hang of it, I did not really need to consciously think about it as I was totally immersed while enjoying the responsiveness of the feedback I got with my breathing"*. This suggests that the rhythmic breathing activity in the game, synchronised with the responsiveness of the breathing feedback, might create an immersive experience for participants. While 30 participants thought of rhythmic breathing as an easy repetitive action, 16 participants found it to be challenging, as they still had to focus on their breathing to ensure it was rhythmic. P8 said, *"It was quite fun to see the leaves being blown towards the tree and then challenging myself to focus more on my breath to breathe rhythmically"*. These descriptions by the participants reflect nicely the score of 3.91 (SD = 0.72) for the parameter of *Challenge* measured using the GEQ.

Breathing as the focal point

Twenty-four participants said that they were able to focus on their breathing while playing *Life Tree*. Participant P17 said, *"I tried to practice breathing exercises with my partner but it is difficult to not let my mind wander. So, one thing I particularly liked about it was it gave me something to focus on. I can usually wait for a while and listen to my breathing, but I over think a lot anyway and this was cool about the game, because at least for the time I was playing the game, I was looking at the tree and focusing on it and the environment and did not think a lot about other things"*. This strengthens our belief that a simplistic visual design allows participants to focus on their breathing while giving them enough breathing feedback to understand and alter their breathing pattern, if necessary. Further, the use of a HMD also appeared to help participants feel focused while playing the game, as 20 participants spoke about how immersive an experience *Life Tree* was for them. For example, participant P26 said, *"I was really engrossed in the game and I was not really thinking of anything else"*. As participants started to get the hang of what they had to do in the game, they appeared to experience being in a state of flow, which is an altered sense of time [15, 18, 56]. P32 said, *"Two and a half minutes playing the game; I did not even realise. It felt like 20 seconds or something. I felt the time fly by when I was playing the game"*.

Theme 4: Engagement with Breathing Hardware

This theme describes the participants' engagement with technology used to sense breathing in *Life Tree*. Eighty-three of the total 642 units were characterised by this theme, consisting of two category codes: 1) *Awareness of breathing with hardware* (66 units); and, 2) *Ease of using the breathing hardware* (17 units).

Awareness of breathing with hardware

Twelve participants mentioned that apart from the breathing feedback, the headset also helped them become more aware of their breathing as they were able to hear their own breathing sound reverberating through the microphone in front of them. P2 said, *"I could also feel the sound of my breath through the mouthpiece as well. I could hear the air through the hole in front of mouth. This helped me understand if I was breathing correctly into the headset or not"*. This tells us that the physical design of the sensor could additionally help players receive breathing feedback, at least on exhalation.

Ease of using the breathing hardware

Participants adjusted their headset to ensure that the microphone was close enough to their mouth. However, participants could not adjust the width of the headset (i.e., loosen the headset to fit the size of their face) and seven of them discussed how uncomfortable wearing the headset felt. P24 said, *"I was really not comfortable wearing the headset as my head is a little too wide"*. Furthermore, the microphone only had a small hole in front of their mouth and they had to aim and blow into the hole to register their exhalation. P8 said, *"I sometimes had to exhale quite hard and sometimes had to aim into the microphone for it to register my breathing"*. Participants also suggested that due to this uncomfortable feeling, they had to adjust their headset a few times while playing the game and in consequence lost their focus on breathing. P14 said, *"I was enjoying the visuals and the breathing feedback but then suddenly I had to adjust my breathing headset over my ear and this disturbed by rhythm and focus"*.

STRATEGIES TO DESIGN BREATHING EXERCISE GAMES

In addition to the four themes discussed above, which might be particularly useful as descriptive tools for researchers, we now present a set of prescriptive strategies to serve as guiding tools for game designers interested in creating engaging breathing exercise games. These strategies are based on the reported experience of our participants as well as our craft knowledge that comes from designing three prototype games and *Life Tree*. We reference this discussion

back to each of the themes in order to showcase how these strategies could help future designers design engaging breathing exercise game experiences.

1. Consider Using Subtle Onboarding to Help Players Engage with the Breathing Exercises

Our results with *Initial breathing guidance after starting the game* under "Theme 1: Designing Breathing Feedback" suggest that participants enjoyed and understood how to play *Life Tree.* Results suggest that experienced players understood and liked the subtle use of the sound of rhythmic breathing in the background and recognised that it helped them understand the breathing pattern they had to follow to play the game. However, inexperienced players valued pre-recorded voice instructions to help understand the breathing pattern they had to follow in the game. On the whole, participants liked the subtleness of feedback and they also suggested that it helped them understand the actions in the game without disturbing their focus on breathing. Consequently, we suggest designers to consider what we call "subtle onboarding", as previously suggested by Zichermann [62], by which we mean informing players regarding the breathing pattern they have to perform in the game. Based on our results, we extend the notion of "subtle onboarding" to the design of breathing exercise games and recommend designers consider the use of subtle audio feedback that allows players to understand the breathing pattern they have to perform in the game while sustaining their focus on breathing.

2. Consider Using Non-Interruptive Breathing Feedback to Support Self-Awareness of Breathing During Gameplay

Our results with *Non-interruptive breathing feedback during gameplay* under "Theme 1: Designing Breathing Feedback" indicate that players can profit when designers develop an immersive and non-interruptive environment for breathing exercise games. Participants suggested that the synchronous breathing feedback with the tree, together with the leaves getting blown onto the tree, helped with the overall experience of *Life Tree's* immersive nature. They also suggested that the non-interruptive nature of the breathing feedback helped them become self-aware of their breathing and become immersed in the practice of breathing exercises. As previously suggested by Chen [15], an immersive environment can be created by designing feedback that does not distract players from the task that they are doing. Further, Bouvier et al. [10] suggest that an immersive environment can heighten the self-awareness of players while playing games. Based on our results, we recommend that designers consider creating what we call *Non-interruptive breathing feedback during gameplay*, which means designing breathing feedback that does not distract players from their breathing during gameplay to create an immersive game environment while nourishing and amplifying the player's self-awareness of their breathing pattern. In order to achieve this, designers might want to consider using visuals effects such as particles that sync with the theme of the game; for example, the use of leaves to provide breathing feedback in *Life Tree.*

3. Consider Using the Objects in the Game Environment to Provide Imitative Breathing Feedback

Results with *Initial breathing guidance after starting the game* under "Theme 1: Designing Breathing Feedback*"* suggest that players might like it more when the objects in the game environment are used to provide breathing feedback. For example, participants liked how the tree was giving them feedback about their breathing pattern by expanding and contracting its trunk on inhalation and exhalation. They also suggested that this helped them enhance their feeling of immersion while practicing breathing exercises; at least for the time they were playing the game. Therefore, we extend the notion of breathing feedback to the design of breathing exercise games and propose to designers that they use the objects in the environment of the game to provide what we call "imitative breathing feedback", i.e., breathing feedback designed in a way which allows players to feel as if the objects in the game are imitating their breathing pattern in a playful way.

4. Consider Using a Minimalist Approach to Designing Naturalistic Visuals to Help Players Focus on their Breathing

Players need to focus on their breathing while practicing breathing exercises [26]. Further, breathing exercises should help players to relax and calm their minds [2, 3]. Our results from "Theme 2: Self-Awareness of Breathing and Body" and "Theme 3: Facilitating Focused Immersion", suggest that players enjoyed the simplistic visuals in *Life Tree*. We noted that this simplistic visual design in the game helped them focus better on their breathing pattern as it created less focal points. Players also suggested that they liked how naturalistic the visuals were in *Life Tree* and how this helped foster relaxation and calm their minds. "naturalistic" here refers to natural objects such as the tree, leaves and water in the game. As previously suggested by Carroll et al. [13], following "The Minimalist Approach", defined as, *"designing for focus by showing things that matter the most for effective learning and performance,* helps foster focus in the minds of the players. Based on our results, we extend this notion of "The Minimalist Approach" to breathing exercise games and recommend designers consider the following approaches to help players focus on their breathing:

- Designers may consider designing minimal focal points in the game to help nurture focus in the minds of players while playing breathing exercise games.
- Designers may consider designing minimal naturalistic visuals in their game environment to help players relax and be calm while playing breathing exercise games.

5. Consider the Intimate Placement of Breathing Hardware and how it can Affect Breathing Performance

Players being comfortable with the technology worn when playing games is an important factor to consider [23]. Our results with "Theme 4: Engagement with Breathing

Hardware", suggest that hardware used to sense breathing in the game needs to be comfortable and consider that everyone's body is different. Our results suggest that participants lost their attention on their breathing briefly a few times due to irritation caused by the obstructive nature of the hardware design. Furthermore, participants suggested that the breathing hardware was unable to capture their breathing a few times while playing *Life Tree*. Therefore, these factors might have resulted in their loss of focus on their breathing. Gemperle et al. [23] define wearability as *"the interaction between the human body and the wearable object*". They suggest 13 guidelines for wearability such as considering unobtrusive placement, considering size variation, considering comfortable attachments, considering the sensory interaction and more. We extend this notion of wearability to consider the following approaches to designing breathing hardware that support the design of breathing exercise games:

- Design for adjustability; for example, by using lightweight straps that can be extended to fit either on the waist or around the head, and provide easy adjustment of the breathing hardware
- Breathing hardware should have high fidelity to ensure that every breath is sensed accurately. We suggest breathing hardware designers consider using sensors that cover a larger area of the mouth and nose to increase sensing accuracy, which will, in turn increase focus of players on their breathing.
- Since breathing is a bodily activity, a full body clothing system could also be designed in order to measure parameters of breathing such as breathing rate, tidal volume etc. This form of hardware design to measure breathing could increase the factor of wearability by making use of the standardised sizing systems set by the clothing industry.

6. Consider Designing Breathing Hardware that Helps Players Hear their Own Breathing

This strategy suggests how self-awareness of breathing can be increased with the choice of sensors used in the design of hardware. Our results with "Theme 4: Engagement with Breathing Hardware", suggest that participants liked to hear their own breathing sounds and that hardware used to measure breathing in the game can increase self-awareness of the player's breathing. As indicated by Gemperle et al. [23], sensory interaction includes both active and passive interaction and this is a valuable feature for any wearable device. *Active* refers to the primary function of the wearable and *passive* refers to the additional function perceived by the users. According to these researchers, it is important to be sensitive of how players interact with a wearable, especially something that is placed on the human body. We acknowledge this and extend this notion to the design of hardware that detects breathing by recommending hardware designers use sensors that capture the sounds of the player's breathing and replay the amplified sound back to the players in real-time. This can assist a player become aware of his or her own breathing pattern while playing the game.

LIMITATIONS AND FUTURE WORK

Our research contributes both to the theory and practice of game design by evaluating player experience using four themes and the six breathing exercise game design strategies. However, we have not tested the strategies with other designers. It is also unclear if participants would like to use *Life Tree* repeatedly or if the breathing technique led to their improved well-being. We also acknowledge that the current work cannot claim to show that a breathing game is superior to regular breathing exercises with respect to the user motivation or potential health benefits. However, it would be interesting for longitudinal studies to explore such questions. On a similar note, the design guidelines are largely based on qualitative data. Thus, it would be relevant for future work to empirically validate the proposed guidelines.

CONCLUSION

Our research may provide useful insights for designers who are interested in designing breathing exercise games that are engaging and enjoyable to play. Furthermore, in the future, we hope our research will help pulmonologists look at creative ways to treat breathing related problems such as Attention Deficit Hyperactivity Disorder (ADHD), Chronic Obstructive Pulmonary Disease (COPD) and, the 235 million children who suffer from Asthma [34]. Our research could also be used by meditation practitioners to support the practice of mindfulness.

In conclusion, game designers can explore the design of breathing exercise games to help people learn proper breathing techniques in an engaging way. Breathing related disorders such as COPD could rise to become the third most common illness in the world by 2020 [46]. Game designers could help improve the lives of millions of such individuals and nudge them towards leading a healthy life by designing engaging breathing exercise games.

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