AirFlow: Designing Immersive Breathing Training Games for COPD

Yongqiang Qin, Chris Vincent, Nadia Bianchi-Berthouze & Yuanchun Shi


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Yongqiang Qin 1,2
qinyq@tsinghua.edu.cn

Chris Vincent 2
c.vincent@ucl.ac.uk

Nadia Bianchi-Berthouze 2
nadia.berthouze@ucl.ac.uk

Yuanchun Shi 1,3
shiyc@tsinghua.edu.cn

1. Pervasive Computing Division, Tsinghua National Laboratory for Information Science and Technology, Department of Computer Science and Technology, Tsinghua University, Beijing 100084, China

2. UCL Interaction Centre
University College London
MPEB 6th Floor, UCL
Gower Street, London WC1E 6BT, UK

3. Department of Computer Technology, Qinghai University, Xining 810016, China

Abstract
Chronic Obstructive Pulmonary Disease (COPD) refers to a collection of lung diseases that result in breathing difficulties. In some cases, the symptoms of COPD can be reduced, by engaging in breathing exercises. Technology can support, and we are developing AirFlow, a suite of interactive computer games, to guide breathing exercises and promote learning. To establish requirements, we interviewed 20 people with COPD, in China, to understand their use of breathing exercises, and learn how technology might fit their lifestyle. The findings informed our design goals. We outline a prototype system, where respiration rate, waveform, and amplitude are captured and used to control a virtual environment. The system will guide users through breathing exercises, and provide training instructions, using a series of games. The immersive environment aims to support a fun and motivating experience, therefore underpinning user confidence.

Author Keywords
COPD; Immersive media; Life style change

ACM Classification Keywords
H.5.2. User Interfaces. Training, help, and documentation.
Introduction
In 2011, the WHO reported Chronic Obstructive Pulmonary Disease (COPD) as being the fourth leading cause of death in the world [12]. The disease causes an abnormal inflammatory response in the lungs, restricted airflow and shortness of breath [3] (e.g. Figure 1). Although damage to the lungs is defined as irreversible, the progression of COPD can be slowed, and the symptoms treated [3]. For example, clinicians can use medicine to open up the airways or assist breathing. Besides medication, maintaining a healthy lifestyle and practicing breathing exercises are important supplemental approaches to slow down or halt the progress of COPD [3].

As in the case of other chronic conditions, unfortunately, despite the contribution of breathing exercises, research has shown that not all people maintain regular exercises [5]. Limited exercise (e.g. only two or three times a week), may not be sufficient, as efficacy has been shown only on the basis of daily routine [8]. In this paper, we interviewed people with moderate COPD to explore why the lack of adherence happens.

After a literature survey and analysis of interview data, we formed an initial design for AirFlow, involving a suite of interactive computer games. The aim is to train moderate COPD sufferers to perform correct breathing exercises, whilst at the same time enjoying themselves. Respiration movements will be used as the game controller; the system will have the ability to detect movements relating to inhaling, exhaling, laughing and coughing, as different input parameters. The system will offer several modes or levels to provide a gradual increment in challenge, with the objective of raising confidence, whilst maintaining a daily routine.

Technology to support COPD
Several research groups have developed systems to support management of the condition. For example videoconferencing systems, that allow physiotherapists to deliver rehabilitation in the home, have been tested and found to be feasible and acceptable [11]. Mobile phone technologies have been used to train and monitor physical exercise programs. They support performance and quality, and can also be used in the home [10]. The long-term physical activity of people with COPD can be measured, using wearable sensors, and classification algorithms used to help monitor the status and development of the condition[4].

For breathing techniques, mCOPD, a mobile phone based lung function diagnosis tool, offers both diagnostic potential and treatment potential, by interfacing with games to make breathing exercises engaging [13]. Other similar prototypes have included the use of commercial controllers (WiiMote) to capture breathing rate and provide guidance to patients [7]. Whilst these studies shows that technology can be used to monitor breathing [7] and potentially support rehabilitation [12], however there have not being studies that focused on user engagement, and user need, for the domain in question.

Videogames to support COPD
In healthcare, the use of videogames can increase compliance with rehabilitation and support the management of conditions. It can provide for a better experience (e.g. for balance disorders see [9]). It can provide clinical benefit, for example, the use of computer games to manage COPD can lead to positive short-term outcomes [1]. Although we expect that computer games can help people manage COPD [2], we
need to know what type of game will be effective and understand ways in which systems can engage users. This is because there is a mixed literature, as to the effectiveness of computer games to support healthcare. For example, in similar applications, where games have been used to support physiotherapy or occupational therapy, there is a lack of long term follow up trials, to show benefit [6]. The principles behind designing an effective game for rehabilitation, are likely to be different from those that provide games for more general purposes. Different people like different games, and some might not want to use games at all. Research is required to understand how best to design and deploy computer games to support healthcare. We therefore chose to adopt a games based approach, not only because it could improve or substitute for existing mechanisms of care, but because there are many unanswered questions about the best way forward. Part of this involves understanding the everyday lives of people with COPD, as per the following section.

**Interviews**

**Procedure**

We spent 2 weeks conducting interviews in a three-level grade-A hospital in Beijing. People with COPD were asked to participate in a 15-minute interview, concerning topics relating to breathing exercises and their daily life. Our participants included 20 people with moderate COPD (10 male) and their family members. The interview was an interactive process: interviewees were asked questions about breathing exercise, in addition to perspectives on COPD, their own quality-of-life, and suggestions for research. For privacy considerations, no video or audio were recorded during the interview, however the interviewer did take notes.

The breathing exercise questions included 1) whether the interviewee knew what breathing exercise was, and what it involved, 2) whether & why they thought breathing training was useful and 3) why they could not practice breathing exercises regularly. Questions concerning their quality-of-life included 1) how shortness of breath affected their daily life, 2) what they usually did in their spare time and 3) how they perceived the development of their disease. Although there various responses to the questions, we broadly grouped the feedback as per the results.

**Results**

**Breathing Exercise**

Every participant knew about breathing exercise (they had been told about it by their doctors), but only four of the participants (20%) had ever tried it out. Three main reasons of why participants had never tried the exercises (RNT) emerged (figure 2):

- **RNT1.** Don’t know how.
- **RNT2.** Don’t think it’s useful.
- **RNT3.** Reported reasons for having never tried the exercise.

Ten participants (50%) reported a lack of effect, relating to the breathing exercise, although eight of them had never tried it out. The two participants who tried breathing training several times reported no effects regarding their symptoms. The other two participants said it might be useful, but weren’t sure.
Breathing Exercises

Pursed-Lip Breathing: people inhale through their nose and exhale through their mouth two or three times. They exhale slower than they inhale. These breathing exercises can help change the pressure in the airways and prevent the small airways from collapsing.

Holding Breath and Coughing: people inhale deeply and slowly, hold the breath for 5 – 10 seconds and then cough while breathing out. These exercises help improve functional exercise capacity and tolerance.

Figure 5. The sensors are worn over clothes, on chest and abdomen. The ProComp Infiniti encoder is not illustrated in the figure.

Figure 6. Example waveform of captured respiration signal. The amplitudes are different according to different types of breathing.

RNT3. Other diseases.

Three participants reported other diseases as barriers to practice the exercises.

Four participants reported on reasons for not being able to maintain a daily exercise routine (RNR) (figure 3):

RNR1. Interrupted by daily chores

Three reported many daily interruptions that cause delays, or make them oblivious, or distracted from the need to do the exercise. Ten participants that had never tried the exercises also reported these issues.

RNR2. Embarrassment.

Two participants reported that if they had partners, they might be able to create a routine. Ten participants who had never tried the exercise also reported that partners would help them to learn and practice breathing training.


Ten participants reported that if they had partners, they might be able to create a routine. Ten participants that had never tried the exercises also reported these issues.

Everyday life

As shown in figure 4, during their spare time, the most common activities were watching TV (eighteen), taking care of grandchildren (eight of twelve did this), chatting with the community (ten) and online gaming (two). Fifteen subjects reported that they were not familiar with online gaming at all. When asking about their understanding of the development of COPD, all participants knew that the disease wouldn’t be cured, but only half of them (ten) had the desire to control the development of the disease. The others were holding the opinion “that’s it”. This is concerning, but by introducing self-management technology; the attitudes of this group could change, because they would be empowered to manage their own condition. This remains a topic for future research. All of them reported that they hoped that the doctors could know more about the disease in the future.

From Interview to Design

Based on the interview results, three main barriers to help control the development of COPD were identified:

C1. Lack of confidence in the effects of breathing exercises.

C2. Little knowledge of how to do breathing exercises.

C3. An inability to make breathing exercises routine.

We realized that providing therapy at home is important for people with COPD, however during the design of technology we need to address these barriers. We proposed the following design goals:

G1. Support breathing training through the use of computer games. (RNT1) (RNR1-3)

G2. Provide positive feedback especially when people feel silly or suffer poor performance. (RNR3)

G3. Support long-term performance records. (RNT2)

G4. Provide deep engagement, to attract more attention from other activities such as watch TV. (RNR1)

G5. Support online competitions, across a wider COPD community. (RNT2)

AirFlow

System Design

In seeking to develop a prototype system, we used Commercial Off-The-Shelf (COTS) components to establish a proof of principle, and understand what type of inputs could be used to control the games. A full
system has yet to be built. When people breathe, their chest and abdomen expand and contract accordingly. Measuring the corresponding circumstances can capture people’s respiration movements. To do this, we used a non-invasive sensor and encoder set from Thought Technology Ltd (http://tinyurl.com/q5ueyhf). Sensors were worn over clothes (Figure 5). The sensors were connected to an encoder box (we choose ProComp Infiniti encoder), which was connected to a laptop PC, running Windows 7. The captured data was available via an API, in real-time at 256 Hz, which provided enough resolution to capture the aspects of the respiration signal that we required (Figure 6).

Respiration Signals
Players will be required to wear the sensors and breathe as normal to calibrate the controllers. The amplitude of normal breath is used as baseline to normalize the other kinds of respiration signals, e.g. deep breathing, coughing and laughing (see figure 7). The normalized amplitude and duration of inhale and exhale phases are used as the game controller’s input. We expect the players to be seated to avoid noisy input from body movements.

Breathing Exercise
Breathing exercises can help individuals with COPD to take deeper breaths and reduce shortness of breath [4]. The two main types of breathing exercises listed in the literature [5] (left hand box) guided the design of the gaming elements of AirFlow. The better they perform, the higher the score they get.

Computer Games
AirFlow is a set of computer games. In our prototype, we have three games:

The Balloon Game: The balloon game is designed to train the player to do Pursed-Lip Breathing. During the game, the player inhales to make the balloon inflate and then exhales to blow a flabellum, thus lifting a bucket from a well. Only when the exhale speed is two or three times slower than the inhale speed, does the bucket get lifted to the highest point. The water from the bucket is used to irrigate flowers. The flowers bloom when they get an appropriate amount of water. This can only be achieved when the players exercise everyday, or the flower will become withered.

The Eating Game: The eating game aims to train players to breathe rhythmically. During the game, rhythm is provided. If the player’s breath matches the rhythm, the character eats more. The character is only satisfied when he gets the right food, everyday. This can only be achieved when the players exercise everyday, or the character will become weak.

The Penguin Game: The penguin game is an Angry Birds like game, which uses a players inhale to stretch the slingshot. They then need to hold their breath to get the best launch angle and cough to shoot the penguin. Players can make penguins fly a long way by inhaling as deeply as they can, holding their breath (for a period), and then coughing as quickly as possible. Only limited numbers of penguins are allowed to fly on a given day; and a set number of penguins must fly or the number of available penguin for the next day will be decreased.

Social Ranking: To avoid loneliness, as well as provide opportunities for communication, a social ranking mechanism is proposed. In order to avoid negative impacts through comparison with other more successful
players (their COPD condition might be different). AirFlow only display the players’ scores that have similar respiratory volume in normal breathing.

**Discussion and Future Work**

Although the above remains a work in progress, it provides the basis for a more involved development and testing process, focusing on the needs and everyday experiences of COPD sufferers. The contribution is, and will be, to actively engage the community we seek to support, during the design of technology. This helps us move from current technology focused studies (e.g. solving the problem of detecting respiration), to ones that help us fit technology to purpose. Potential limitations could include the efficacy of the breathing exercises, as they may not work for the spectrum of COPD sufferers. To address this, we are planning a long term, formal development and evaluation process. We are also planning to widen the range of observational techniques used (e.g. diary studies, observational studies, conceptual modeling). We want to make use of best practice in games research, to provide an immersive experience, and one that optimizes the quality and benefit of the exercises, as well as supporting learning and adherence.

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