HEALTHCARE SYSTEM FOCUSING ON EMOTIONAL ASPECTS USING AUGMENTED REALITY:

Re-Design of Breathing Control Application in Relaxation Service

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Abstract: We propose a new healthcare system that focuses on emotional aspects to cope with negative emotional health in daily life. Our healthcare system integrates augmented reality to display virtual objects in real environments and integrates Kinect, which allows users to freely interact with virtual objects. We also employ biological sensors to measure and detect user emotions and provide three services based on their expected emotions: relaxation, amusement and excitement services. We designed and implemented a small prototype for our relaxation service called a breathing control application. This application applies deep breathing techniques of stress management to supports users when they experience stress from society or work as well as other negative emotions. This application displays a virtual music box to assist them breathe deeply. Moreover, virtual objects and music can increase user relaxation and decrease their stress. This paper focuses on re-designing our breathing control application to improve its efficiency based on experiment results.

Key words: Healthcare, Emotion, Augmented Reality

1. Introduction

In recent years, the design and implementation of such ubiquitous, intelligent space and healthcare systems have become very popular in the field of human computer interaction and human robot interaction. Such systems automatically monitor both the environment and the humans in it to provide assistance and services to them. Several systems provide more support of the physical aspects of people at the expense of the emotional aspects. However, negative emotional health can lead to social or mental health problems.

In the last 45 years, worldwide suicide rates have increased by 60% [1]. According to suicide rates reported by the World Health Organization (WHO) [2], Japan ranks among the top-ten countries. One causes is such negative emotions as stress and anxiety, which are often caused by excessive studying and overwork. However, not all people can cope with such emotional pressures.

To cope with negative emotions in daily life and improve emotional states, we designed a new healthcare system that focuses on emotional aspects using augmented reality (AR). Our system provides services that allow users to interact with virtual objects in real environments to get different positive emotions and to reduce their negative emotions.

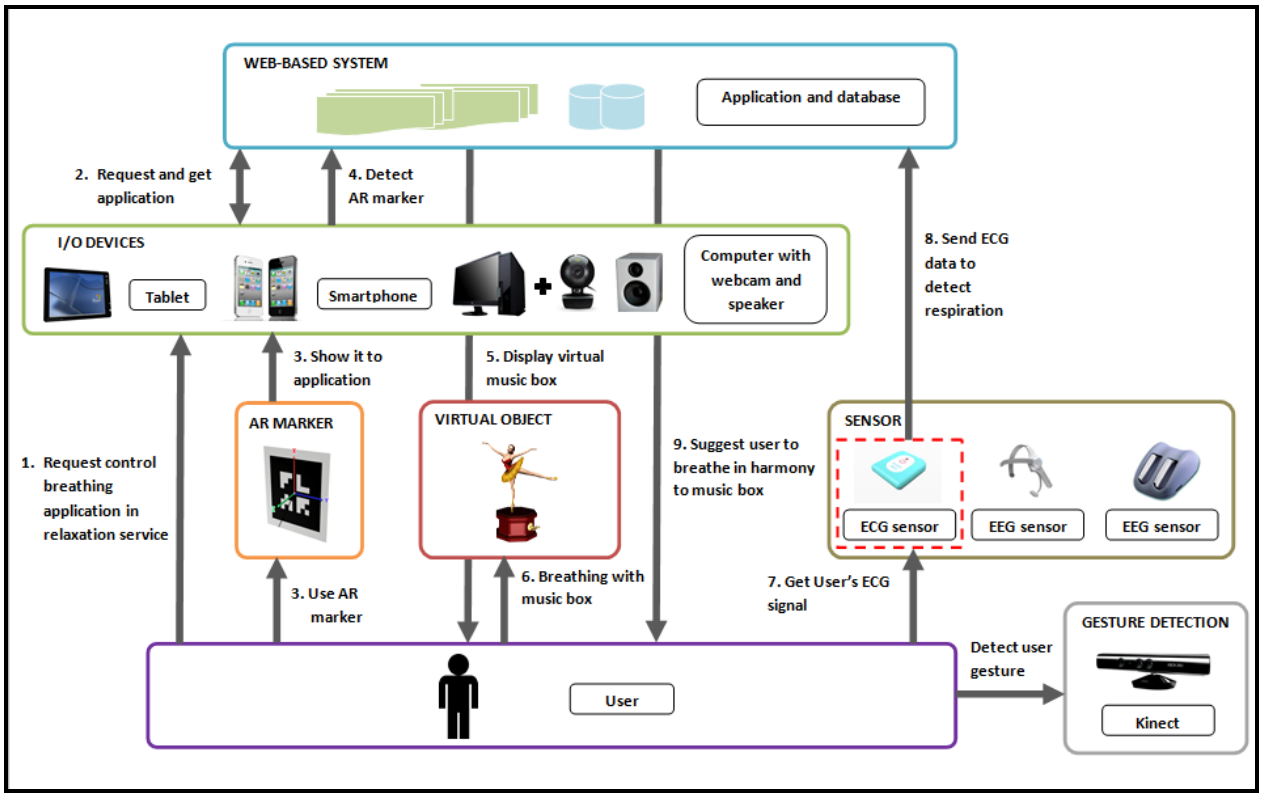


Figure.1 Workflow of breathing control application

2. Literature Review

Nakajima et al. developed a relax/refresh system that applies virtual reality technology [3]. Their system consists of a massage lounger, a head-mounted display (HMD), a standard VCR, and an interface circuit that controls the massage chair and generates stereographic images. This system provides visual, aural and physical simulations that promote the following three stages: encouraging sleep, sleep and refreshed.

- In the encouraging sleep stage, our system provides relaxing 2D images, music with body vibrations, and gentle massages.
- When the user falls asleep (sleeping stage), it dims the user's view, lowers the music, and stops the massages.
- When the user wakes up (refreshed stage), it provides refreshing 3D images, relatively loud music, and strong massages.

This system relaxes and refreshes users and reduces their stress. The researchers also experimentally measured electrocardiograms and calculated the activity level of sympathetic and parasympathetic nervous systems to indicate relaxed and refreshed states. Their subjects performed three specified VDT tasks. They performed one task for 40 minutes. After they finished performing one VDT task, they can continue to perform VDT task or take 10 minutes break using the VR relax/refresh system or sitting. Their results indicated that using the VR relax and refresh system provided effective relaxation and refreshed feeligns after using it.

Pioggia et al. proposed Interreality, which is a technology-based approach to assess and treat stress [4]. It is based on cognitive behavioral therapy (CBT) and provides a 3D virtual world to assist patients who are suffering from stress and stress-related disorders. It consists of the following three virtual islands:

- *The learning island* teaches patients how to relax and improve their stress management skills.
- *The community island* provides real-life examples to help patients gain self-awareness, reduce avoidance behaviors, and unrealistic thinking. Patients are encouraged to discuss and share their experiences.
- *The experience island* practices controlled exposure, emotional management, general decision making, and problem solving skills.

Interreality also applied bio and activity sensors to provide patient behaviors and health state to therapists with which they can monitor their patients. With this system, therapists can treat and assess their patients.

From our literature reviews, we believe that we can design a system to help users cope with negative emotions in daily life. We propose a new healthcare system design that detects user emotions and offers support when people are suffering from negative emotions to improve their emotional state.

3. Proposed Healthcare System Design

3.1 Overall System Design

We designed our scheme [5] as a web-based system that users can easily access by web browsers on personal computers, tablets, or smartphones (Figure 1). Sensors measure such biological signals as electroencephalography (EEG) and Electrocardiogram (ECG) to detect and analyze user emotions while they are using our system. When they are experiencing negative emotions, our system suggests that they take a break and provides services to improve their emotional health. After selecting a service, they can choose which application they would like. To process each application, users show an AR marker to the camera in order to display a virtual object that encourages such positive emotions as relaxation, enjoyment, amusement, or excitement. For some applications, they need to interact with virtual objects using Kinect, which detects gestures. We believe that interaction with virtual objects may decrease negative emotions.

3.2 Framework Design

The framework design [5] of our system is shown in Figure 2. This healthcare system consists of five parts: I/O devices, a detection module, an application module, emotional services and a web server.

- *I/O devices*: EEG, ECG, and GSR sensors, a personal computer, a webcam, a Kinect, a tablet, and a smartphone.
- *Detection module*: There are three applications. *Emotional detection* measures, locates and analyzes user emotions with biological sensors. *Gesture detection* identifies hand, leg, or finger gestures using Kinect. *Breathing detection* finds and measures user respiratory rates with an ECG sensor.
- *Application module:* There are four applications in this module. *The augmented reality application* detects and analyzes AR markers to display a related 3D virtual model and its components. *The breathing control application* uses deep breathing techniques to decrease user stress. *The notification application* suggests that users take a break by offering appropriate services related to their current emotions. While users access the healthcare system, *the report application* displays such biological information as heart rates and current emotional states using emoticons.
- *Web server:* Our design uses an internet information server as a web application server. We also created a database to collect the personal information of users and their emotion status logs based on biological signals.
- *Emotional services:* Based on user expected emotions, our system provides three services: relaxation, amusement, and excitement.

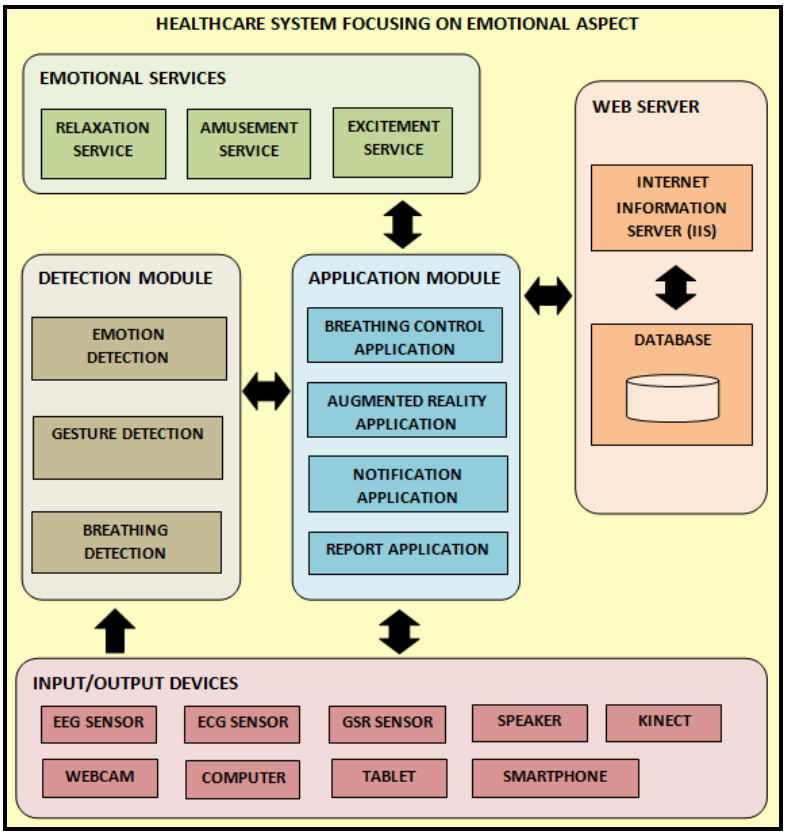


Figure.2 Framework design

4. Relaxation Service Design

We designed and implemented a breathing control application to support this service that is designed to relax users and decrease their stress, anxiety and anger.

4.1 Design of Breathing Control Application

This application, which increases user relaxation with deep breathing techniques of stress management [6], supports users when they experience stress from society and work, as well as other negative emotions. According to deep breathing techniques [6], visualizing or imaging relaxing objects or scenes while breathing deeply might improve user more relaxation. This application includes a virtual music box to assist such deep breathing. Virtual objects and music might improve users' relaxation quickly. This application's workflow is shown in Figure 1.

First, users can request this application from the relaxation service by a web browser on a tablet, a smartphone, or a personal computer. After that it sends requests to a web-based healthcare system. They can start using it by showing an AR marker to a camera. The application detects the AR marker and displays a virtual music box, which slowly turns and plays music. The users inhale and exhale in harmony to the turning of the music box to control their breathing. While they are controlling their breathing, the ECG sensor on their chest records their ECG signals to detect their respiration. If it isn't in harmony with the virtual music box, the application suggests that they breathe more slowly or quickly. The application continues to support users until they feel more relaxed.

Our breathing control application is shown in Figure 3. It has four main components:

- *Animation guide (a):* guides users how long they should inhale/exhale.

- *Application suggestion (b):* gives advice so that users breathe more deeply or shortly.
- *Music (c):* provides three types of classical music that users can choose using arrows
- *3D virtual music box (d):* slowly turns around.

Figure.3 Breathing control application

4.2. Implementation of Breathing Control Application

The breathing control application sends requests to the augmented reality application that detects AR markers to display a virtual music box with music and the breathing detection converts ECG signals to respiratory signals to detect inhalation and expiration.

- Augmented Reality Application [7]

Augmented Reality is a technology that combines such virtual world components as sound, 3D virtual objects, video, images and graphics to real world to produce a new environment. We implemented this application using FLARManager [8]. With this application, the breathing control application detects AR markers to render and display a virtual music box with music for users [9].

- Breathing Detection [7]

To detect heart rates and emotions, our healthcare system integrates ECG sensor because it is wearable and can send measured data over wireless networks. Our small sensor is also light-weight, convenient, and comfortable in daily life.

Breathing detection utilizes ECG sensor to converts and analyzes ECG signals to detect respiration signals using ECG signal processing (Figure 4). Our breathing detection is implemented based on a previous method [10] that derived respiratory signals from the estimation of R-wave amplitude modulation. After respiratory signals are produced, this application detects inhalation and expiration signals and calculates their time.

The breathing control application uses the result from this application to control inhalation and exhalation in harmony with the rotation of the virtual music box to increase relaxation based on stress management technique.

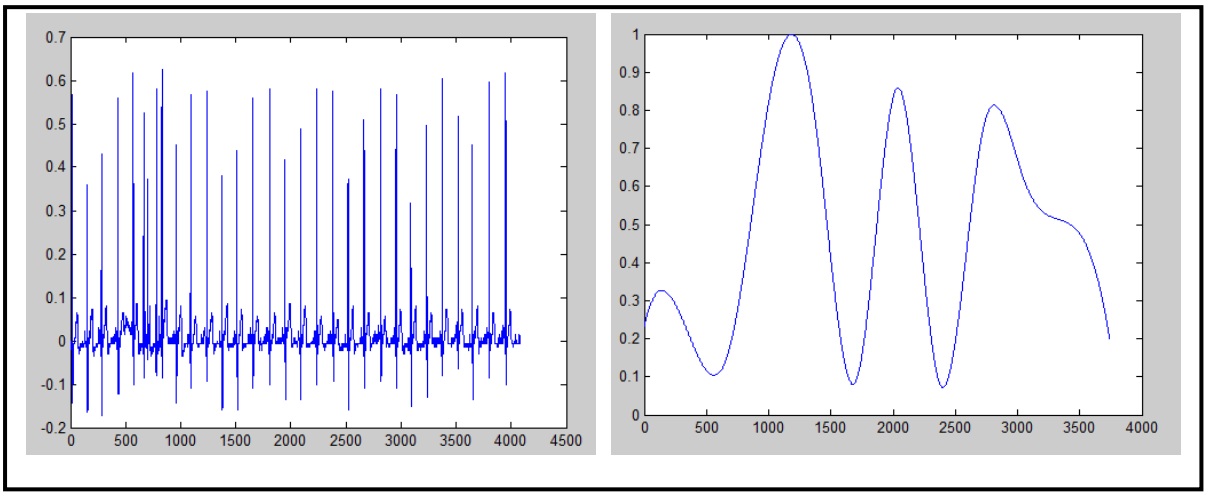


Figure.4 ECG (left) and respiration (right) signals

4.3 Experiment

After we designed and implemented the breathing control application, we performed an experiment with five young participants: four females and one male. Our experiment checked whether this application effectively decreased stress and evaluated the participant feelings when they used it. The methods to evaluate the application effectiveness and the participant feelings [11] are described below:

- Stress Measurement

We evaluated the effectiveness of the breathing control application by measuring each participant's stress by salivary amylase test [12-14] using a Cocoro Meter (Figure 5) which measures the salivary amylase [KU/L] from saliva and classifies it into stress levels.

Figure.5 Cocoro meter

- Evaluation of Participant feelings

We evaluated by questionnaires all the feelings of the participants when they used the breathing control application to decrease their stress. We designed the questionnaires with a 5-point Likert scale where five is the highest score (strongly agree) and one is lowest score (strongly disagree). The questionnaire questions are shown in Table 1.

Table 1. Questions to evaluate user feelings

#	Questions
1	While using this application, did you feel relaxed?
2	While using this application, did you feel comfortable?
3	While using this application, did you feel boring?
4	While using this application, did you feel sleepy?
5	While using this application, did you like it?

The following are the processes to perform this experiment [10]:

1. The participants performed salivary amylase tests to measure their current stress levels.
2. Then each participant performed a calculation exercise for 20 minutes to increase their stress.
3. After the stress increase period, the participants again performed salivary amylase tests.
4. Then they used our breathing control application for ten minutes. They breathed deeply, listened to the classical music, and watched the virtual music box slowly turn to decrease their stress and increase their relaxation. Every five minutes, the participant performed salivary amylase tests to check their stress levels.
5. Finally, they answered questionnaire to evaluate their feelings.

4.4 Result and Discussion

We performed our experiment to evaluate two aspects: effectiveness aspect by measuring stress and user feeling aspect by questionnaire. The results of the stress measurement and questionnaire [11] are shown below.

- Stress measurement result

From the measured salivary amylase results of all participants, an increase in the measured data indicates that the participants became more stressed. If the measured data decreased, the participants became more relaxed. This experiment only evaluates an application that can relax users and decrease their stress. Table 2 indicates the number of participants, whose stress increased, decreased or didn't change after performing calculation exercise and using our breathing control application for five and ten minutes.

Table 2. Analysis result of effectiveness aspect

	Stress increased	Stress decreased	No change
After calculation exercises	3	1	1
After using breathing control application for five minutes	0	4	1
After using breathing control application for ten minutes	0	5	0

- Questionnaire results

After we got the experiment data, we analyzed it using statistic method to determine how users felt when they experienced our breathing control application to decrease stress and increase relaxation. We used t-test to determine our experiment data are significantly different from population mean (**μ = 3**).

Table 3. Analysis Result of Questionnaire

Question	Mean	S.D.	t	P-Value
#1	3.0	1.0	.000	1.000
#2	3.4	1.14	.784	.477
#3	3.4	1.14	.784	.477
#4	3.4	1.81	.492	.648
#5	3.2	0.44	1.000	.374

*: P<0.05

Even though no questions are significant, we obtained tendencies of the participant feelings when they used our application. They felt more comfortable, bored, sleepy and relaxed. Moreover, we also got the following useful comments from participants:

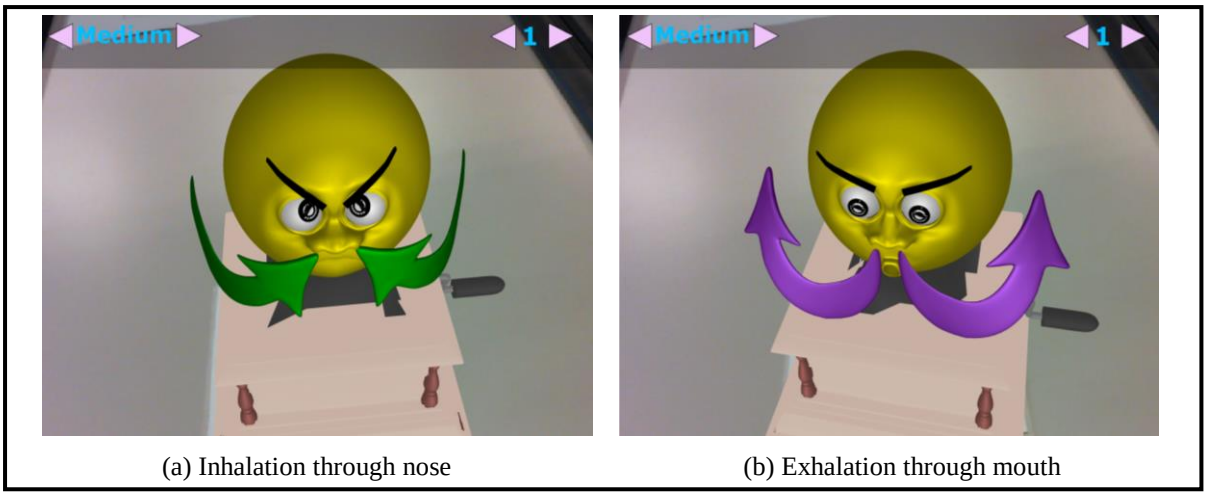
- It needs more different kinds of music.
- The 3D virtual music does not look very realistic.
- There are too many components to focus on with different interface positions. The participants prefer to concentrate on only one position.

From this experimental result and all participant comments, we re-designed our breathing control application, as described in section 5.

5. Re-Design of Breathing Control Application

Based on our experimental results and participant comments, we improved the following issues.

- Many users only focused on the animation guide and the application suggestions. They focused less on the 3D virtual music box. So we changed the animation guide process. We re-created it into a virtual object and combined it with 3D virtual music box called a training model (Figure 6), which is only displayed for two a half minutes. After that, the different kind of virtual music box is displayed.



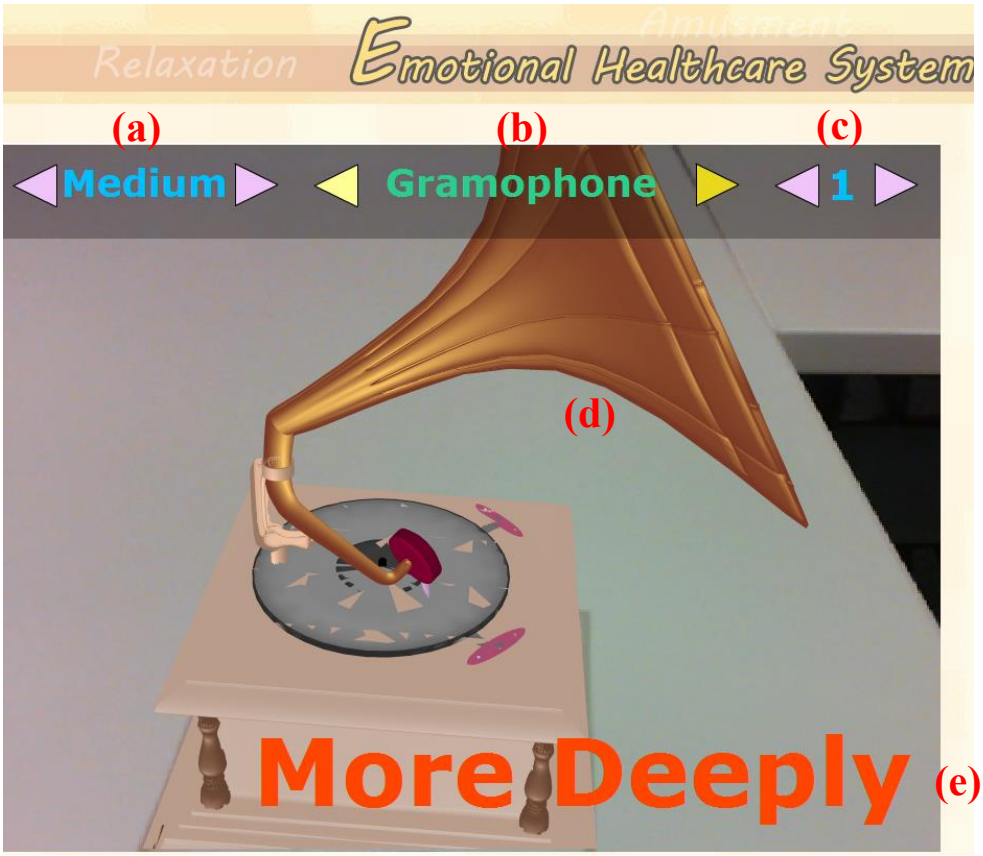
(a) Inhalation through nose (b) Exhalation through mouth

Figure.6 Training model

- The application suggestion informs users every 20 seconds to breathe more deeply or shortly. We changed its display position on the virtual music box to allow users to increase their concentration on the slow turning of virtual music box.
- We changed the deep breathing manner. Users need to slowly inhale through their nose for 3-5 seconds and slowly exhale through their mouth for 3-5 seconds [15].
- Since the users felt tired when they breathe by following the animation guide, we changed it to display only two and a half minutes to guide the length of their breathing.
- Since the users felt bored because there is only classical music, we provided many different kinds of music.

Our improvements of breathing control application are shown in Figure 7. It now has the following five main components.

- *The breathing speed (a):* provides five speeds for deep breathing: slowest (breath rate is 5 seconds), slow (breath rate is 4.5 seconds), medium (breath rate is 4 seconds.), fast (breath rate is 3.5 seconds), fastest (breath rate is 3 seconds).
- *The virtual model (b):* provides three different kinds of music boxes: Emoticon, Gramophone [9] and Castle [16].
- *The music (c):* provides classical, jazz and pop music which users can choose by using arrows.
- *The 3D virtual music box (d):* slowly rotates.
- *The application suggestion (e):* gives advice about breathing more deeply or quickly.



6. Conclusion and Future Works

We proposed a new healthcare system that focuses on emotional aspects to support the daily lives of students and working people and provide three services: relaxation, amusement and excitement. We designed its overall system and framework. For a relaxation service, we also designed, implemented and evaluated a breathing control application that applies a virtual music box and breathing detection to control users while they breathe to increase relaxation and decrease stress based on the deep breathing techniques of stress management. Since our experimental result identified many issues to improve the effectiveness of our application and user feelings, we re-designed the breathing control application. In summary, our system employs such applications as augmented reality, emotional detection and respiratory detection with biological sensors. Future work includes the design, implementation and evaluation of emotion detection, amusement and excitement services.

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