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Light Bird: An Animated Biofeedback Interface for Coherent Breathing

Abstract
Biofeedback-assisted breathing training is widely used in stress mitigation and relaxation exercise. It helps users to breathe coherently with the natural heart rate oscillation, which facilitates circulation and strengthens the capability of autonomic nervous system to adapt to stress. We present Light bird: a paper-crane shaped animated interface that presents biofeedback information and targeted breathing guidance in the same interface. We hypothesized that Light bird would improve the effectiveness and the experience of breathing training. We tested our hypotheses by comparing Light bird with a graphic interface during the 10-minute breathing training. While users gave higher subjective ratings for the experience on Light bird, their heart rate oscillation was not enhanced significantly. We discuss these results and future design insights for designing the interface of biofeedback technology in the context of coherent breathing training and stress mitigation.

Keywords
Biofeedback; coherent breathing; interface design; relaxation

1 Introduction
The competitive working environment in modern society is full of stressors, which put people at risk of several stress-related illnesses like heart disease, hypertension and strokes. As we already know, doing exercise, listening to music and watching a good movie all can help relieve excessive stress. Meanwhile, in recent years, biofeedback technology offers a new way for stress mitigation [1]. An increasing number of biofeedback-assisted devices and games have been developed for helping people to practice coherent breathing and achieve a better state of physical relaxation and mental calmness [2, 3].

Coherent breathing facilitates circulation and autonomic nervous system (ANS) balance, which could strengthen our bodies' capability to adapt to stress [4]. Several researchers had found a 0.1-Hz natural oscillation in heart rate which could be observed when people relax and breathe deeply [5]. This oscillation is the result of many nervous systems (i.e. the parasympathetic nervous system and the baroreflex system) and circulation system working together. Deep breathing could be a 'stimulus' causing heart rate to fluctuate and generate a low frequency rhythm at around 0.1 Hz. Especially when people breathe at the same rate of 0.1 Hz (around 6 circles per minute), the rhythm of breathing forms a 'harmonious' resonance with the heart rate oscillation, boosting 'relaxation responses' of autonomic nervous system. The 'relaxation responses' could balance the excessive 'stress responses' triggered by the external environment. The balance of autonomic nervous system will yield good psychological and physiological changes including mental and physical comfort, better performance, greater emotional stability, etc.

As Stephen Elliott described in a BMED Report [6] *"When we are breathing "coherently", the nervous system "relaxes", and when it does both body and mind follow".* During a coherent breathing exercise, people observe the oscillation of heart rate from a biofeedback device and learn to regulate their breathing. Usually, they need to slow down their breathing rate into a similar pace of the heart rate oscillation for improving heart rate variability. Heart rate variability (HRV) biofeedback is developed for guiding users to inhale and exhale at the 'right timing' (i.e. 'A' point breathes-in, 'B' point breathes-out in Fig.1).

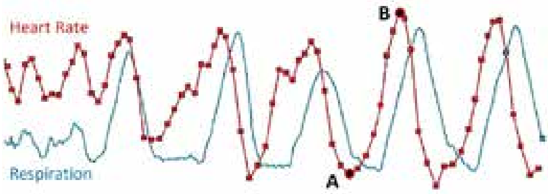


Fig. 1. The waveforms of heart rate and respiration during the transformation from normal breathing to coherent breathing [7]

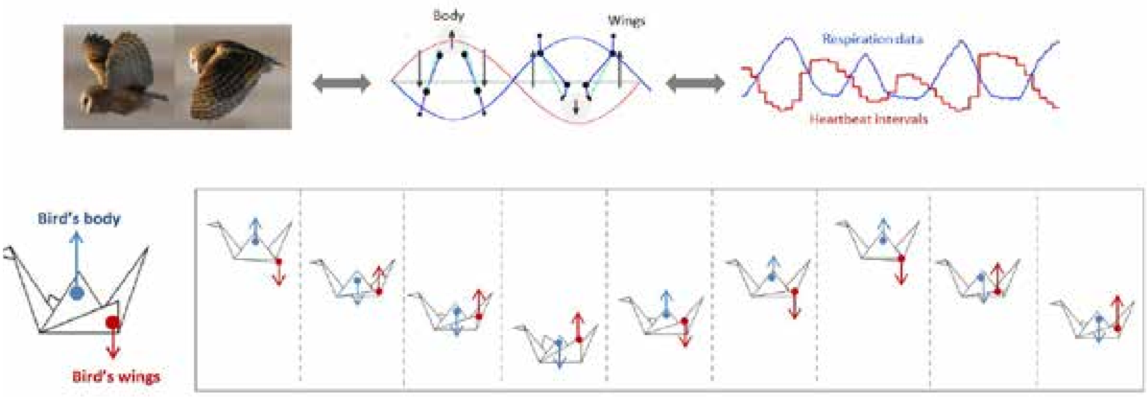
Unfortunately, most of biofeedback systems offer the average users a *'technical style'* or *'medical style'* interface, which seems too task-oriented to feel relax using it. As shown in Fig.1, according to specific visual cues displayed on the computer screen, users regulate their breathing to control the fluctuations of 'Red' heart rate line in synchronization with the 'Blue' respiration line. Despite high accuracy and fast responses, the graphic or numeric interfaces seem not suitable to be used in stress-coping or relaxation-inducing products due to decreasing motivation levels with time.

In this study, we present Light bird, a new animated interface of biofeedback breathing training application. Light bird is designed for physical relaxation and stress mitigation by guiding the users' breathing into a 0.1 Hz resonant frequency. The Light bird's body fluctuates up and down periodically at 0.1 Hz, providing the targeted breathing rate. The wings' movements are controlled by heart rate data, presenting the real-time heart rate oscillation. Thus, by regulating the bird's body and wings up-and-downs in a coordinated fashion, the user could acquire a better breathing pattern and achieve greater heart rate variability. We also present results from an experiment, in which the effectiveness and the experience of Light bird was evaluated.

2 Design Process

In this design, we aim to bring more enjoyments into a breathing training by add-ing new aesthetics and metaphors into the interface design. We believe that the field 'in between' pure art visualization and technical graphic display can benefit to both breathing training and relaxation. In addition to presenting biofeedback information (i.e. heartbeat intervals), we also want to visualize an important concept of 'coherent breathing'. Heart rate has an inbuilt oscillation around 0.1 Hz, when people breathe at a similar frequency, the oscillation will be enhanced. To present this coherence, we finally select a 'flying bird' as the 'carrier' of biofeedback; and the heart rate data and breathing guidance are mapped to its wings movements and body's up-and-downs respectively. During a bird's flight, its wings and body move in a coordinated fashion. This coordinated movement could properly present the coherence between our cardiac activities and breathing movements, as shown in Fig.2.

Fig. 2. The design process of the visualization of 'Light bird'



We visualize Light bird using an image of paper cranes, as shown in Fig.2. In Asian cultures, especially in Chinese and Japanese cultures, the paper crane (Thousand origami cranes) is thought to be a sign of long life, good luck and peace of mind. Here, we assume that the aesthetic of paper cranes could enhance the experience of interface and the light-weighted visual effects will make it looks easy to move and control. On the interface, Light bird moves up and down smoothly at the rate of 0.1 Hz, indicating a targeted breathing rate of 6 cycles per minute. The position of wings is controlled by heartbeats intervals, which are the inverse of heart rate. Light bird moving from the bottom up indicates an inhalation, in which the heart rate accelerates and heartbeat intervals decrease, presented with a moving-down wings. When the user achieves a state of coherent breathing, Light bird's flight becomes well-coordinated. Figure 3 shows our biofeedback system. Heartbeat data is measured by a pulse sensor placed on the left index finger. The pulse sensor is connected to an Arduino board as the unit for data acquisition. The program of Arduino processes the raw pulse signal into heartbeats intervals data, and then transmits the data to the PC through a USB serial port. The PC runs the visualization program mapping the acquired HRV data to the movements of Light bird.

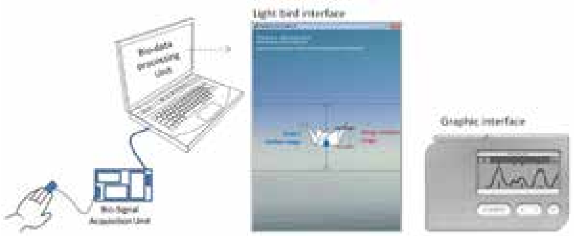


Fig. 3. Light bird interface in our biofeedback system and the graphic interface of Stresseraser

3 Evaluation

An experiment was conducted to evaluate Light bird from two aspects: 1. the effectiveness of breathing training; 2. the interface experience. We hypothesized that Light bird would improve the effectiveness and user experience of breathing training.

3.1 Experiment design

We designed a within-subjects experiment with 20 participants. All participants completed two 10-minute breathing trainings with different interfaces. The independent variable is the type of interface and dependent variables are users' heart rate variability and subjective rates on the interface's experience. We used the Light bird from section 2 and a commercial Stresseraser having a graphic interface for the control condition. *Stresseraser*[1] is a commercially marketed biofeedback device designed to enhance heart rate variability. The graphic interface of *Stresseraser* is shown in Fig 3.

3.2 Measurement

The aim of coherent breathing training is to improve heart rate variability (HRV). Therefore, to gain qualitative data about the training effects, subjects' heart rate variability data was measured during both pre-training resting period and two breathing tests. We calculated SDNN (standard deviation of heartbeats intervals) as the index of HRV. Regarding interface experience, we used *AttrakDiff*[2] questionnaire to collect the users' subjective rates on the experience of the interface.

3.3 Participants

20 volunteers (11 females and 9 males, age range: 25 to 35) participated in the study. All participants gave the written informed consent and provided the permission for publication of photographs with a scientific and educational purpose.

3.4 Procedure

On arrival at the laboratory, the participants were instructed how to use the biofeedback program. Then, we fitted the participant with the pulse sensor and instructed them to breathe deeply with eyes closed. This pre-training resting period lasted 10 minutes. Next, the participants performed two 10-minute breathing training tests in a random order and they were given a 10-minute break between two tests to relax. After each test, participants completed an online *AttrakDiff* questionnaire.

3.5 Qualitative results

The results of *AttrakDiff* questionnaire show that the overall scores of both interfaces are located in center area neutral (see Fig. 4). In terms of pragmatic quality (PQ), which describes the usability of an interface, the Light bird is rated higher than the graphic interface. The hedonic quality (HQ) dimension indicates to

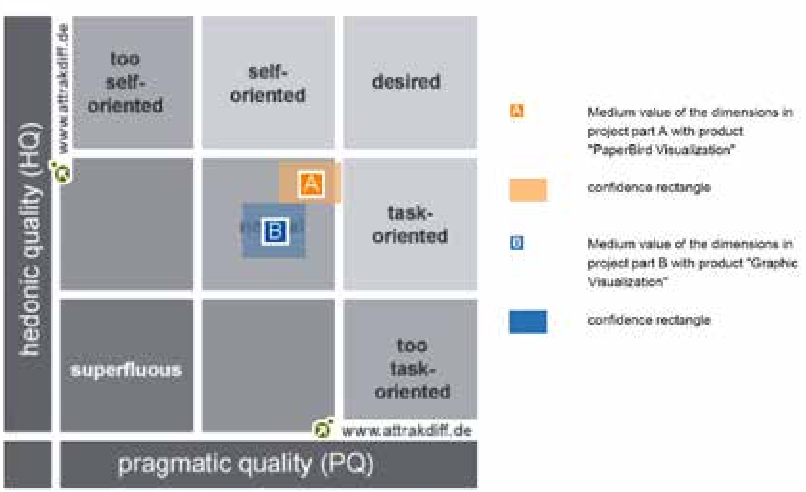


Fig. 4. Results of AttrakDiff questionnaire

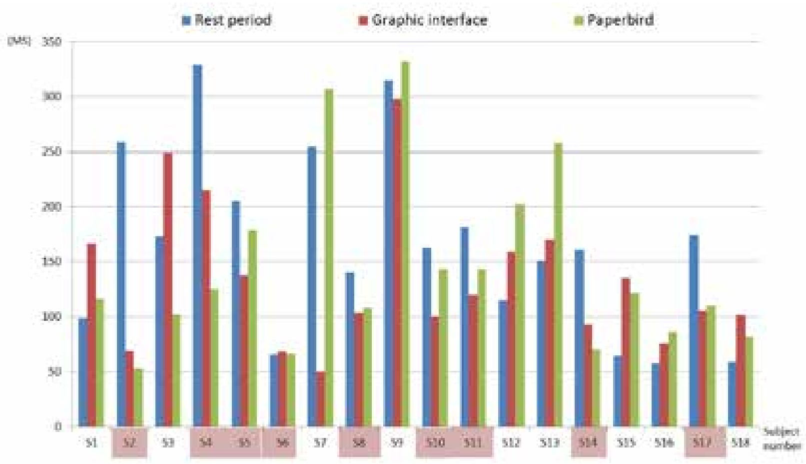


Fig. 5. Results of heart rate variability

what extent the interface can support those needs in terms of novel, interesting, and stimulating functions, contents and interaction. The Light bird also shows a higher HQ than graphic interface. The higher HQ of Light bird can possibly be explained by its visual design; several participants commented: *"it looks simple and elegant"*. However, in both dimensions PQ and HQ, both interfaces only reach the average level, which means there is room for improvement.

3.6 Quantitative results

For each participant, heart rate variability during the pre-test period and two breathing tests were calculated in terms of *SDNN*, which means the standard deviation of heartbeats intervals. Heartbeats data was missing from two participants because of technical problems. In Fig. 5, *SDNN* values do not show a significant increase on the whole after the breathing trainings. On the contrary, for nearly half of participants, the *SDNN* decrease after both trainings, these subjects' number is marked as red in the figure. The rest participants show an increased SDNN value after either or both of breathing trainings.

4 Discussion

The results of AttrakDiff questionnaire suggest that Light bird a higher hedonic quality. More than 80% participants thought it was interesting to transform the breathing training task into the control of bird's movement. Most participants emphasized that the Light bird was easy to understand and more interesting to use in the first several minutes of training during which they were getting familiar with the interface. Therefore, we think an animated interface like Light bird might help a new user get comfortable with biofeedback techniques in the initial stage of training. But for a longterm use, the biggest challenge of visual interface for breathing training might still be an increasing feeling of boredom and decreasing motivation level with time.

Before the experiment, we assumed that Light bird would help to improve the effectiveness of breathing training, which might be reflected by an improved HRV. Although the results were quite different from what we assumed, we still obtained many valuable insights for future design. One possible explanation for the decreased SDNN might be increased mental workload and psychological stress caused by the unfamiliarity with new technologies (i.e. new biofeedback concept, new interface and new training method etc.). This explains why nearly half of participants showed best relaxation effect during the self-relaxation period without any biofeedback. We think regarding biofeedback training, no matter in design of system, device or interface; it would still be challenging but interesting to investigate how to lower the learning effort of biofeedback in early use but also keep it fun and enjoyable for long term use.

5 Conclusion

In this study, an animated visualization Light bird was designed to present heart rate variability and breathing guidance in a biofeedback breathing training. We try to bring new aesthetics and right metaphors into the interface design. We described the design process of Light bird and results of the evaluation. The results show that Light bird received higher subjective rates on the user experience of interface. But there was no significant improvement of HRV being observed after breathing trainings with biofeedback. We think it is still a big challenge to design a proper form of biofeedback which can deliver feedback information adequately and clearly, but also promote relaxation experience effectively. For future research, we will develop a complete close-loop biofeedback system by integrating a respiratory sensor into the system to replace the fixed breathing guidance with the real-time personal respiration data. This will possibly contribute to the effects of training.

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[1]Stresseraser: http://www.stresseraser.nu/

[2]AttrakDiff: http://attrakdiff.de/index-en.html