Adaptive Biofeedback for Mind-Body Practices

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Abstract

Mind-body practices are widely used to reduce feelings of tension and effects of stress. With biofeedback, users receive information (feedback) about their body (bio), which facilitates mind and body interactions. Biofeedback process is a highly individual experience in the way the users respond to the feedback and use it to regulate their thoughts and physiology. This research explores a novel adaptive biofeedback system for mind-body practices. The proposed biofeedback system could adapt its feedback source, information load and interface modality based on the user's physiological states, achieved performance and interaction. The adaptive biofeedback system is currently being developed and a longitudinal evaluation will be conducted in the future.

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Author Keywords

Biofeedback; Adaptive interface; Mind-body practices

ACM Classification Keywords

H.5.2. Information interfaces and presentation: User Interfaces –Theory and methods

Research Situation

I am a third year PhD student in the Dept. of Industrial Design at Eindhoven University of Technology (TU/e, the Netherlands). I started my PhD in September 2013 and anticipate completing my thesis in summer 2017. I would identify myself as an engineer with a biomedical background and also an interaction designer. As a biomedical engineer, I build biofeedback software to process the measured bio-signals and extract the interested bio-data that would be fed back to the users. As an interaction designer, I explore novel information displays and interaction methods to enhance the users' self-awareness and facilitate self-regulation on psycho-physiological processes in mind-body practices, such as

biofeedback, breathing exercise and meditation. My research topic is on adaptive multi-modal user interfaces with a particular focus on biofeedback systems in the context of stress reduction and relaxation. The aim of my research is to develop an adaptive biofeedback model, apply it in a biofeedback system to explore the effect of the adaption of feedback source, information load and interface modality on the effectiveness of training and user experience for mind-body practice.

Context and Motivation

Mind-body practices are a large and diverse group of techniques that are based on the knowledge of mind and body interactions. They can be used to reduce the feeling of tension and effect of stress, and to enhance the physiological and psychological well being of an individual [1]. In recent years, biofeedback is increasingly accepted by ordinary families and goes into people's daily life. It serves as a "Bio-Mirror", which allows users to "visualize" bodily activities in their brain/mind. During a mind-body practice, the biofeedback device measures bio-signals from the body and displays them on a monitor, providing the status of one's own autonomic nervous system function. The biofeedback helps the users improve awareness of internal physiological functions, enhance the mind and body interactions and finally improve the skills of aligning the physiology towards a healthy direction.

Biofeedback users are different in the way they perceive, experience and respond to the feedback, for example how long does it take for a user to understand and follow the feedback or how easy it is to get bored of the feedback in the practice. Moreover, we found that biofeedback users also show different preferences on feedback modalities in different contexts [4, 10, 11, 12]. To date, research on adaptation of interface for biofeedback system is limited. To the best of our knowledge, biofeedback modality personalization and adaptive biofeedback system are areas that have not yet been studied extensively. The different ways in which different users perceive and utilize the feedback lead to the need for more personalized interaction with biofeedback systems. An adaptive biofeedback system that adapt its feedback source, information load and interface modality in response to user's physiological status, achieved performance, and practice time offers an opportunity to personalize the way people utilize biofeedback, which might improve effectiveness of biofeedback self-training and also enhance users' relaxing experience in mind-body practices.

Background and Related Work

In order to facilitate the perceptualization of biofeedback among non-specialists users, the feedback has also been presented in various audio-visual forms, such as animations [2], games [3], sound [4] and immersive environment [5]. But among these biofeedback systems, only a very small body of work has looked at the adaptation of the interface and feedback strategy. Adaptive User Interfaces (AUIs) are interfaces that are able to adapt to a specific user, provide feedback about the user's knowledge and predict the user's future behavior, such as goals, preferences and actions [6]. The adaptation does not only depend on the user, it can also depend on the context of use and the task to be performed. Over the years researchers have mainly proposed adaptive systems in different contexts for various applications, such as Interactive Voice Response (IVR) systems [7] and in-car communication system [8]. For a self-

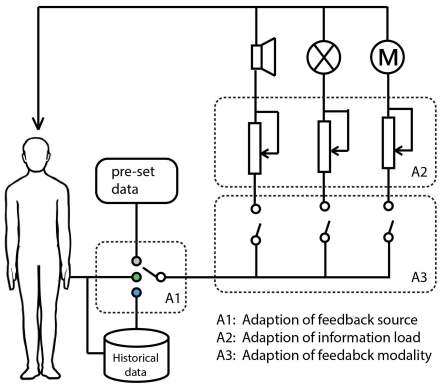

Figure 1: Adaptive Biofeedback Model

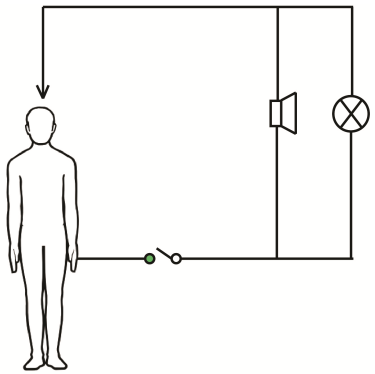

Figure 2: Classical Biofeedback diagram

training/learning system, Wulf [9] found that, in a motor learning process, adaptive feedback shows advantages in the adaptation to the learner's needs, in the promotion of deeper information processing, and in the involvement of the learner in the learning process, resulting in an increased motivation and learning effect.

Research Questions

In this study, I propose an adaptive biofeedback theoretical model and develop the system for biofeedback-based mind-body practice. The research aims to address the following questions:

1. Compared to the classical biofeedback diagram, what parts should to be adaptive? What should be an adaptive biofeedback model?
2. How should the biofeedback system adapt its feedback source, information load in feedback and interface modality?
3. What are the effects of adaptive biofeedback on the effectiveness of training and user relaxation experience in mind-body practice?

Research Goals and Methods

Study 1: *Developing the Adaptive Biofeedback Model*

The study aims to make a general review on existing biofeedback systems and aims to understand the users' learning behaviors in a biofeedback-assisted mind-body practice. Based on literatures, we propose the adaptive biofeedback model as shown in Figure 1.

Methods: (1). Conduct a literature review about the existing biofeedback systems used in mind-body practices. (2). Analyze the literatures and identify the typical feedback source and modalities that would facilitate mind-body practices and relaxation. (3). Understand user learning behavior in a biofeedback-assisted practice. (4). Based on the findings, spot the key points in a biofeedback loop that should be adapted to the users, and propose the model of adaptive biofeedback.

Study 2: *Explore the adaptive biofeedback interface*

We apply the proposed adaptive biofeedback model into a standard biofeedback system, enabling the system to adapt itself to both the user's physiological states and achieved performance, and training time. Then, we explore the adaptation of biofeedback in three aspects: namely feedback source, information load and feedback modality.

Methods: (1). Develop an adaptive algorithm that exploits a user states and behaviors to adapt the feedback. (2). Start with auditory modality, apply the adaptive algorithm in a standard biofeedback system. (3). Conduct an experiment to evaluate the effect of the adaption on feedback source and information load in a short-term mind-body practice. (4). Implement a multi-modal biofeedback by developing and integrating visual and haptic interfaces into the system and update the adaptive algorithms for achieving an optimal effectiveness of practice and user experience during short-term mind-body practice.

Study 3: *A longitudinal evaluation of the proposed adaptive biofeedback system in mind-body practices*

Methods: Conduct a long-term user study to examine in which extent the applied adaptation is beneficial on users' mind-body practice and relaxation.

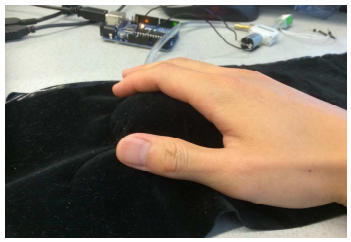

Figure 3: Haptic interface designed with an inflatable airbag

Figure 4: Biofeedback through ambient lighting interface

Figure 5: Biofeedback through shape-changing surfaces

Dissertation Status

Early on in my PhD program, I focused on exploring the role of sensory modality in biofeedback training; a Heart Rate Variability (HRV) biofeedback system has been developed with five different interfaces in auditory, visual and haptic modalities. We developed a visual interface named ”Light Bird” to give the user a experience of flying in the clouds and present feedback information by adjustment angle of view [10]. "Breathing on Touch" is a haptic interface designed with an inflatable airbag, which could provide feedback via its shape changes [11], see figure 3. An auditory interface is designed by direct-mapping HRV data to the rhythm of a chord [4]. We also explored the ambient lighting [12] and shape-changing wallpaper (see figure 4, 5) as *the* environmental interfaces.

In the second year, the adaptive biofeedback model has been proposed. And the first prototype of adaptive biofeedback system is being developed as the research tool. We started with a focus on auditory modality, which could provide with breathing and heart rate variability by using sound or music. The system could adapt itself in feedback source and information load based on users’ physiological state and achieved performance. The effectiveness of the system needs to be evaluated in the future. The adaptation of the interface modality could be implemented using the OOCSI[1] platform, which can connect computers (i.e. running Java and Processing), devices (i.e. Arduino), Web browsers and mobile devices. In the proposed adaptive biofeedback system, the feedback could be presented separately or jointly via projection, music, shape-changing objects and ambient lighting. The biofeedback system could also control the shift between these modalities based on user interaction and practice time.

[1] https://github.com/iddi/oocsi

Expected Contributions

The main contribution in this study lies in making biofeedback techniques adaptive and enjoyable to people performing mind-body practices. The outcome of this research will inform the design of more personalized biofeedback system.

A summary of my contribution:

- An adaptive biofeedback model is constructed to guide the design of the adaptation of a biofeedback system.
- The mechanisms to achieve biofeedback system adaptation based on user’s states, achieved performance and user’s interaction.
- An adaptive biofeedback system that enhance the effectiveness of biofeedback training and user relaxation experience in a mind-body practice.
- Evaluation results from studies.

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