BioFidget Demo: Biofeedback for Respiration Training Using an Augmented Fidget Spinner

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Abstract
This demonstration presents BioFidget, a biofeedback system that integrates physiological sensing and display into a smart fidget spinner for respiration training. We present a simple yet novel hardware design that transforms a fidget spinner into 1) a nonintrusive heart rate variability (HRV) sensor, 2) an electromechanical respiration sensor, and 3) an information display. The combination of these features enables users to engage in respiration training through designed tangible and embodied interactions, without requiring them to wear additional physiological sensors. The results of this empirical user study prove that the respiration training method reduces stress, and the proposed system meets the requirements of sensing validity and engagement with 32 participants in a practical setting.

Author Keywords
Biofeedback; physiological sensing; fidget spinner; stress; respiration training; tangible interaction

ACM Classification Keywords
H.5.2. Information Interfaces and Presentation (e.g., HCI): User Interfaces

Introduction
People encounter stress in daily life, especially when they are confronted with challenging tasks. When the

Figure 2: Hardware design of a BioFidget prototype. (a) Overview ofcomponents. (b) Center pad that consists of sensing and signal processing units. (c) Assembled state.

stress exceeds our coping ability [1], we feel anxious, fearful, and angry. In the long term, the accumulation of these negative stresses leads to the development of serious illnesses [2]. Hence, stress management is an important topic for physical and psychological well-being.

Stress management programs seek to engage the users in ongoing self-regulation; however, the key challenge is that users often drop out of these programs. HCI researchers attempt to build interactive biofeedback systems as an intervention solution to address this challenge. These systems provide user-friendly representations of the physiological signals as to increase the users' awareness of their inner states and help them to adjust their behavior with the adaptive feedback. Providing biofeedback for respiration training is clinically proven to be effective for stress reduction [3, 4]. A user who consciously employs this biofeedback technique and paces his or her breathing at around six breaths per minute (0.1 Hz) may regulate his or her heart rate at a resonant frequency [4], which maximizes the efficiency of pulmonary gas exchange and relaxes the responses of the autonomic nervous system.

One of the requirements for a biofeedback respiration training system is the utilization of a reliable physiological sensing mechanism. The reaction of a user experiencing stress can be observed from heart rate variability (HRV) [5], which can be detected using a pulse sensor with precise timing control; also, the way the user regulates his or her breathing pattern for stress reduction can be detected using a respiration sensor. However, the user has to attach these sensors to his or her body before the observation starts. The effort involved in deploying these devices seems to constitute an adoption threshold that should be removed for enabling a useful and casual means of stress management.

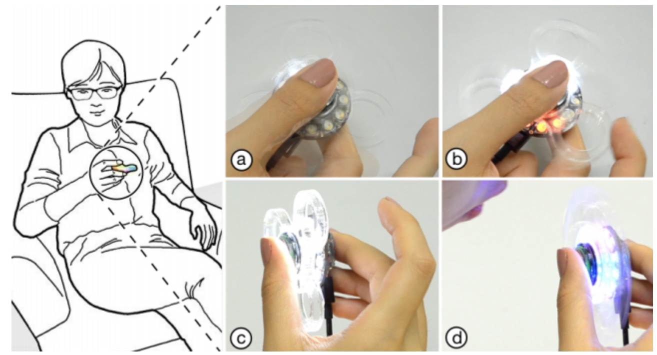

Figure 1: BioFidget is a biofeedback system that integrates physiological sensing and an information display into a smart fidget spinner for respiration training. The user (a) activates it with finger flicking, (b) reads his or her stress-related heart rate information from the display, (c) repositions it and switches it to training mode and moves it to his or her mouth, and then (d) blows on it for breathing training by using the adaptive visual feedback tool.

We present BioFidget (Figure 1), a biofeedback system that integrates physiological sensing and information display into a smart fidget spinner for respiration training. The fidget spinner, invented by Catherine Hettinger in 1993 [6], is a casual finger toy that is designed for stress reduction. A user takes it out of his or her pocket, spins it with little effort, and holds the center pad while it spins. During the rotation, the momentum of the toy provides a pleasant visual-tactile sensory experience. Unlike other conventional eyes-free fidget devices (e.g., fidget cubes, clickers, pens), fidget spinners provide immersive visual feedback, inertial

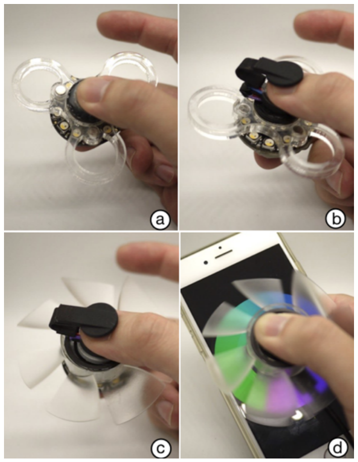

Figure 3: Alternative BioFidget designs. (a) Basic design. (b) BioFidget with an additional clip for PPG sensing stabilization. (c) Fan-shaped wing to react to respiration. (d) BioFidget with a handheld display forrich visual biofeedback.

tactile feedback, and adequate form factors that allow for holding still while playing with it. These unique features make the fidget spinner highly advantageous in designing physiological sensing mechanisms and tangible and embodied interactions for casual users.

Figure 1 shows the usage scenario of BioFidget. When the user feels stressed, she takes out a BioFidget from her pocket and spins it to enjoy the visual-tactile experience. After several seconds, she visually observes the change of her heart rate (the white part) and her pulse (the red part) from its display. Then, she re-orients the BioFidget and moves it to her mouth, turning it into a respiration trainer, which guides her to take deep breathes using a rhythmic breathing light. When she exhales, her breath makes the BioFidget spin and provides adaptive visual feedback corresponding to its speed, indicating the quality of her breathing and encouraging the user to play with it again. After 3 minutes of playful and relaxing experience, she puts the BioFidget back in her pocket and returns to work.

Design and Implementation

The design of a fidget spinner that can sense physiological information and provide biofeedback must meet two criteria: technical validity and playfulness. A technology that requires adaptation from the users original ways of playing often also reduces the user's willingness to engage in play. Based on these two design considerations, a BioFidget prototype (Figure 2) was developed for sensing various stress-related physiological signals and gestures from users. All sensor components were integrated into the center pad.

Figure 2 and 3a show the basic hardware that we developed to demonstrate the interaction. Each prototype device consists of a photoplethysmograph (PPG) sensor, which has proven to be effective for sensing the HRV values of healthy subjects at rest [7], an analog Hall sensor that senses the user's respiration through revolutions of the magnetic wing of the fidget spinner, a visual display for providing physiological information and adaptive feedback for respiration training, and an additional accelerometer for identifying interaction modes (i.e., respiration training or HRV sensing).

We further present several alternative designs that utilize various physical forms to optimize these biosensing and biofeedback features; these physical features include a clip to stabilize the PPG sensing (Figure 3b), a fan-shaped wing to increase the sensitivity of the device to respiration (Figure 3c), and a handheld display to enrich the visual expression of biofeedback (Figure 3d). Possible design implications and guidelines for further embodied interaction design are also discussed.

Evaluation Results

The evaluation was structured for testing whether the proposed system meets the requirements of sensing validity and engagement with 32 participants in a practical setting. The results show that the proposed biofeedback mechanism effectively supported respiration training and caused positive effects on stress reduction. Regarding sensing validity, the system reliably detects HRV and respiration signals when a user is in a static context. In more casual uses, the system reliably revealed that either the HRV information should be continuously monitored when the user blows on the device or discarded over time when the user flicks the device. In both cases, the physiological sensing remains valid.

Regarding engagement, user feedback indicates that BioFidget provides playful and engaging respiration training experiences. The results suggest that the three independent extensions (clip, fan-shaped wing, additional screen) can be applied for further generalizations.

Contributions

The main contributions of this work are 1) a physical design for a novel smart fidget spinner that both detects stress directly and provides an intervention to reduce stress, which requires no additional physiological sensors to be worn, and 2) user experiences and experimental results regarding this biofeedback system.

Conclusion

The fidget spinner is a popular toy that went viral in 2017. Although it is fun to play with, the general perception is that a fidget spinner is a useless machine which has a function but no direct purpose. Marketers sometimes claim that fidget spinners are a "treatment for people with attention-deficit/hyperactivity disorder, autism, or anxiety," and "a tool for focusing and relaxing." However, there is no peer-reviewed scientific evidence showing that fidget spinners are effective treatments for these conditions so far [8].

BioFidget integrates biofeedback, biosensing, and respiration training mechanisms into the form of a fidget spinner. The details of the physical, physiological, and visual designs have been disclosed. The results of technical and preliminary user testing also show that the proposed system and method provide valid and playful experiences that turn a popular toy into a useful stress management tool.

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