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Large-Scale Assessment of a Biofeedback Breathing Guide

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Introduction

There is a trend in human-computer interaction toward the development of systems that can improve well-being, such as devices meant to pace users' breathing or applications that encourage users to regulate their physiology through the use of biofeedback (Calvo & Peters, 2014). At the same time, settings involving groups of users are more and more studied, with the assumption that collaboration motivates participants and encourages positive behavior (Fowler & Christakis, 2009).

To assess the effectiveness of these interventions, questionnaires such as the STAI (Spielberger et al., 1983) or physiological markers can be used — e.g. increase in heart-rate variability (HRV) correlates with stress relief (Cowley et al., 2016). When dealing with biofeedback applications, the latter might be deemed less disruptive because users already wear sensors. Even though the controlled environment of a lab is necessary to ensure that participants are properly equipped, it is however far from ideal in order to gather ecological measurements. In order to achieve a setup that enables sufficient control over the experiment while creating a scenario that more closely mimics real-life situations, we propose to take advantage of escape rooms. Indeed, in an escape room (or escape game), participants are confronted to a series of tasks and challenges in a fixed environment, all during which they are monitored by a “game master” who closely follows their progression, triggering events depending on the advance of the team. This represents an ideal situation for experimenters, as they can leverage on the apparatus in place to integrate the sought-after experiment, knitting the supplementary hardware and instructions to the existing scenario.

We were interested in evaluating a tangible breathing guide that doubles as a collaborative biofeedback exercise. Our first hypothesis is that an explicit breathing guide is more effective as a relaxation exercise, compared to simple instructions. Our second hypothesis is that a biofeedback at a group level, where users strive to complete the task together, will improve user engagement. Through the escape room, we were able to enroll hundreds of participants in groups of four, whose heart rate was recorded during the entire duration of the session, the signal synchronized with the events triggered by the game master. The number of participants, an order of magnitude greater than traditional experiments in the field, helped to alleviate inter-subject variability and extract physiological markers which dynamic significantly changed over time depending on the condition.

Methods

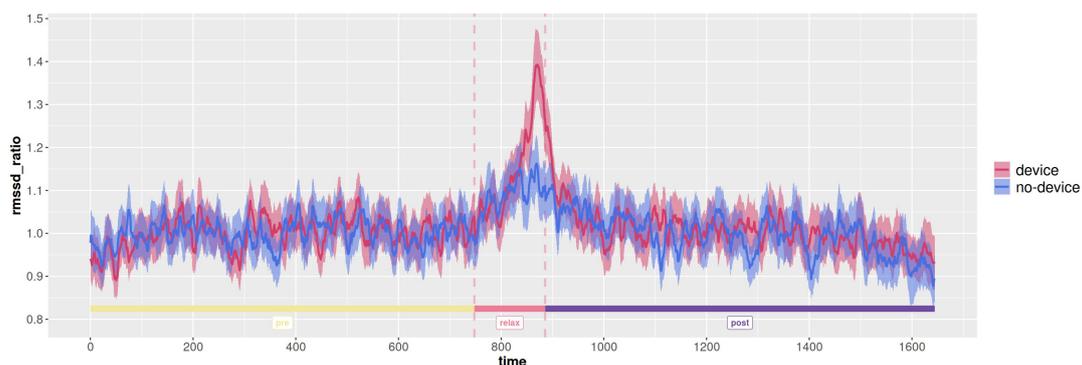
Participants were recruited while they were playing a “serious escape room” conceived by the company Tricky, a learning tool based on the concept of escape rooms. It was proposed to practitioners working in nursing homes to raise awareness about muscle-skeletal disorders, for example when they have to carry patients. The escape room involved groups of four participants. They signed a consent form about the study that would occur during the play, and were equipped with a smartwatch measuring heart rate (Polar OH1). In the middle of this scenario, which lasts around 30 minutes, players must take care of a patient not willing to get out of bed — a situation they are often confronted with in real-life. The patient (a mannequin delivering pre-recorded

messages) suggests to do a breathing exercise to reduce the stress they are feeling around them. The task is meant to help participants calm down and solve the issue as a team. In one condition (“no-device”) players were given instructions to do deep breaths, with inspirations and expirations of 5 seconds each. In a second condition (between-subjects) players used a dedicated display (Ullo Flower; Hamon et al, 2019). The device was shaped as a flower and was meant to guide players’ breathing, its light growing outward during inspiration and shrinking inward during expiration (same 5s/5s cycle). Additionally, the device’s color would change depending on the overall HRV, measured in real time as the mean RMSSD of all participants. The light would turn red on low variability and green on high variability, with thresholds defined during pilot studies. If all players were to follow the breathing guide they would steer the color toward green, as higher HRV correlates with deep and slow breathing. The relaxation session lasted 147 seconds on average. It was extended by game masters if participants were deeply involved in the exercise, or terminated early if it was not followed.

560 participants in total were involved in the study, 127 of whom data was incomplete due to connectivity issues and removed from subsequent analysis. Consequently, there were 222 participants kept in the “device” condition and 211 in the “no-device” condition.

Results and Conclusions

Significance was tested using permutation statistics (Voeten 2022). During the relaxation session, once sessions’ duration were normalized, we observed in the “device” condition a significant diminution of heart-rate, as much as 3.8%, and up to 27.8% of increase in HRV, compared to “no-device” (see Figure). This indicates that the device was more effective as a breathing exercise than simple instructions. On our sample there was also a slight and yet significant difference after exposure (240s after and onwards), with a reduced heart-rate in the device condition (-0.58 BPM). As a proxy for engagement, we used the duration of the relaxation sessions, that lasted on average 130s for the “no-device” condition and 161s for the “no-device”. Interestingly, the game masters reported that people tended to take the breathing exercise more lightly (e.g. making fun of the situation) without the device and would be more focused with. This could be explained by the playful nature of the biofeedback, that incited players to concentrate and take part in the exercise.



Evolution of HRV over time across all participants, normalized over the “pre” period.

Discussion

In this work, we used an escape room as a way to investigate the effect of a biofeedback breathing guide, with a sample size superior to traditional studies, and in settings that mirror real-life scenarios. Preliminary analyses support our hypotheses concerning the effect of a tangible device on stress and on user engagement. Further analyses will more closely focus on intra-groups dynamics, using synchrony measurements to better understand the effect of such devices when several persons are involved. We will also correlate physiological measurements with questionnaires filled before and after the experiment, inquiring about participants’ psychological traits and user experience. Future

studies will consider a third condition where the breathing guide does not provide a biofeedback, in order to pin-point the importance of a closed-loop system at a group level. We believe that this approach could help to answer long-lasting questions in the field of biofeedback application concerning the usefulness of an explicit biofeedback.

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