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# Exploring the Role of Self-efficacy in Biofeedback Video Games

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## Abstract

Biofeedback training and game-based biofeedback are increasingly used to improve mental health. When evaluating the effects of biofeedback however, the focus often lies solely on therapeutic outcomes. Meanwhile, it is known that psychological factors such as perceptions of competence, also known as self-efficacy, can significantly influence one's experience and psychological wellbeing. The current paper examined the role of self-efficacy in the context of biofeedback video games. A pilot study was conducted with DEEP, a Virtual Reality video game that uses respiratory-based biofeedback to help individuals cope with stress and anxiety. Self-efficacy was found to be a significant predictor of physiological regulation, highlighting the importance of taking psychological factors such as self-efficacy into account in the development and evaluation of biofeedback games designed to improve mental wellbeing.

## Author Keywords

Biofeedback; Virtual Reality; Video Games; Games for Health; Self-efficacy; Psychology; Interventions; Mental Health; Stress; Anxiety; Emotion Regulation

## ACM Classification Keywords

J.4 [Social and Behavioral Sciences]: Psychology; K.8.0 [Personal Computing]: General – Games; H.5.1

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**DEEP VR**

In DEEP [51] players have to use deep diaphragmatic breathing in order to navigate through an enchanted underwater world. The game utilizes a customized controller belt (Figure 1) that measures the expansion of the player's diaphragm. These values are subsequently fed back in the game and to the player. Deep, calm breathing allows the player to stay afloat and move smoothly through the world. Additionally, elements in the environment mirror the player's breathing (see Figure 2). By providing players with visual and auditory feedback they become more aware of their breathing and are incentivized to adapt to a more calm and relaxed breathing pattern.



**Figure 1.** DEEP controller

[Information Interfaces and Presentation]: Multimedia Information Systems - Artificial, augmented and virtual realities; H.5.m. [Information Interfaces and Presentation]: Miscellaneous - Biofeedback.

**1. The use of biofeedback in therapy**

Biofeedback is the process of measuring an individual's physiological activity such as brain activity, heart rate or breathing, and subsequently feeding back information about this activity to the individual. By providing this feedback it is thought that participants become more aware of their physiological activity and that with training they can learn how to gain control over this activity to improve their wellbeing [1]. Biofeedback has been effectively used to help individuals cope with various physical (e.g. migraine and chronic pain) [2-4] as well as mental health issues, including stress and anxiety [5-8]. Biofeedback can vary in complexity from raw signals to computerized tasks using images or sounds, as is often done in clinical and educational settings [9-11]. In standard protocols the individual is then instructed to try to keep their physiological activity at a certain level or below a specified threshold [9].

**1.1. Biofeedback video games**

In recent years there has been an increase in the development and use of game-based biofeedback to promote physical and mental wellbeing [11-21]. As biofeedback training programs often involve numerous sessions it is important to prevent drop-out. Especially for youth it is important to keep them engaged and motivated and games are seen as an ideal way to achieve this [22-25]. Promising results of game-based biofeedback have been found for emotion regulation and the treatment of stress and anxiety in youth [20-

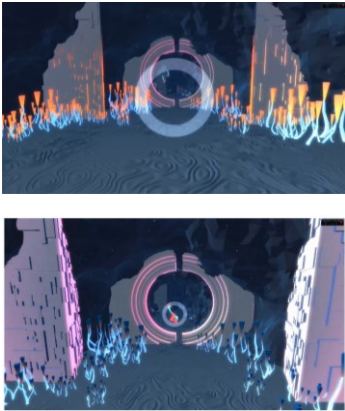
21, 26-30] with some games even being just as effective as a gold-standard treatment [31].

**1.2. Current gaps in biofeedback research**

Despite promising recent findings, biofeedback is not widely implemented in psychological treatment [32]. Furthermore, while biofeedback has a long scientific history there remain important gaps in our knowledge about this type of intervention. In particular, the focus of the vast majority of biofeedback studies are on therapeutic outcomes [33]; the specific underlying mechanisms by which these outcomes are achieved remain understudied. In order to maximize the positive outcomes of biofeedback interventions and biofeedback games it is essential to understand which mechanisms lead to these outcomes so that interventions can be designed to better facilitate these mechanisms. While some working mechanisms of biofeedback have been proposed such as changes in interoceptive awareness and physiology [e.g. 1, 8-9] there is little empirical evidence to support these hypotheses. In fact, positive treatment outcomes can be achieved without significant changes in physiology [34-35] and even when incorrect or sham-feedback is provided [36-37], indicating that other factors must play a role as well [38].

**2. The role of self-efficacy**

An important psychological factor that might determine the extent to which people are able to sufficiently tune into and change their physiology is the belief that they can do it, i.e. their self-efficacy. Self-efficacy is a person's confidence in their own capabilities [39] which is strongly linked to how we feel [40]. Low levels of self-efficacy are often accompanied by high levels of anxiety [40-42]. In youth self-efficacy has been found



**Figure 2.** The environment of DEEP resonates with the player's breathing seen here in the form of a circle reflecting the expansion of the diaphragm as well as plants that change in color and illumination.

to be predictive of anxiety symptoms over time and even of the development and maintenance of affective disorders [43-44]. Self-efficacy has also been indicated as an important predictor of treatment outcomes [45]. However, the role of self-efficacy in biofeedback is unclear. One way in which biofeedback may contribute is in a person's perception of control which is a key element related to self-efficacy [39, 47]. Control is a key factor that determines how distressed a person will feel in a given situation [39, 46-48]. In biofeedback paradigms physiological activity is continuously measured and fed back in real time [1, 8-11]. By providing this feedback a person can observe how they control their physiology and can then evaluate their ability to self-regulate. In turn, this evaluation can influence their psychological state [46-47]. As for game-based biofeedback, besides being a great motivational tool, they may also contribute to a sense of self-efficacy. Videogames evoke general positive emotion [23] as well as specific positive feelings, such as flow [49]. Flow is evoked when a player is immersed in a highly rewarding activity and is accompanied by a high sense of control [50]. Whether self-efficacy can indeed predict differences in therapeutic outcomes of biofeedback and biofeedback games has yet to be scientifically examined. The current study therefore explored whether a biofeedback game can contribute to feelings of self-efficacy and in turn whether it can positively influence physiological regulation.

### 3. A pilot study on DEEP: a virtual reality biofeedback game

DEEP [51] is a novel virtual reality biofeedback game that is controlled by deep diaphragmatic breathing (see first sidebar) and is being further developed to help youth regulate their anxiety and stress [21]. The

current pilot study tested whether playing DEEP could facilitate self-regulation after being exposed to a potent social stressor. Furthermore, it was examined whether feelings of self-efficacy would moderate this effect.

#### 3.1. Measures and Procedure

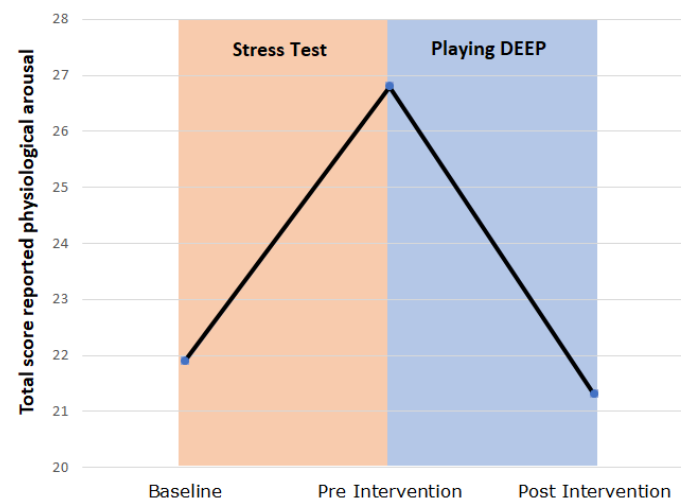
A total of 72 university students between the ages of 18 to 30 ( $M = 21.5$ ,  $SD = 2.7$ ), 31% of which identified as male, 69% as female and 0% as other, participated. All participants first received a stress induction in the form of a shortened version of the validated Trier Social Stress Test [52]. Specifically, the instruction and preparation phase of the public speaking task was used which has been shown to reliably increase physiological arousal [53]. In this task participants were asked to imagine that they were applying for a new job. They were told that they would have to give an actual speech, convincing three jury members of their qualifications. They were then given 3 minutes to prepare. Following the preparations all participants played DEEP for approximately 10 minutes. Participants filled out the Physiological Arousal Questionnaire [54] which included questions such as "Are you nervous?" or "Do you feel your heart beating?". They filled this out immediately after arriving in the lab (baseline), after the stress induction (pre-intervention) and after playing DEEP (post-intervention). Furthermore, several questions related to self-efficacy were asked at post-test. These included eight questions of the self-efficacy scale for youth [51] assessing their emotional self-efficacy (e.g. "How well can you control your feelings"). In addition, players were asked about the general sense of competence they felt in the game using the Experience of Need Satisfaction questionnaire [56] (e.g. "I feel very capable and effective when playing"). Furthermore, two specific questions were asked

pertaining to their breathing ability (“How well can you control your breathing?”) and their overall performance (“How well can you perform in the game?”). Finally, participants were asked several evaluative questions regarding DEEP such as how much they enjoyed playing it (measured using the Intrinsic Motivation Inventory [57] and how nauseous they felt (as nausea is often reported in VR games). They were also asked to give DEEP a final grade (on a scale of 1-10). Half of the participants practiced with an paced breathing application before playing DEEP. However, this did not influence the efficacy of the game and therefore all reported results are based on the entire sample.

### 3.2. Changes in physiological arousal

To check whether there were significant changes in self-reported physiological arousal a Repeated Measures Analysis of Variance was performed with participants’ total scores of the physiological arousal questionnaire as the dependent variable and time (baseline/pre-intervention/post-intervention) as independent variable. There was a significant quadratic effect of time,  $F(1,69) = 47.46$ ,  $p < .001$ ,  $\eta^2 = .41$ , indicating that there were significant differences in reported physiological arousal between time points. There was a significant increase in physiological arousal from before ( $M = 21.9$ ,  $SD = 8.2$ ) to after the stress test ( $M = 26.8$ ,  $SD = 8.8$ ) indicating that stress was successfully induced. In addition, there was a significant decrease from before ( $M = 26.8$ ,  $SD = 8.8$ ) to after playing DEEP ( $M = 21.3$ ,  $SD = 10.7$ ) indicating that players’ physiological arousal was successfully reduced (see Figure 3). Post-Hoc Bonferroni pairwise comparisons further indicated that all differences between time points were significant,  $p < .001$ , except for the difference between baseline and post-

intervention,  $p > .05$ , indicating that stress-levels were reduced to baseline values after playing DEEP.



**Figure 3.** Changes in total scores of reported physiological arousal from arrival at the lab (baseline) to after the stress induction (pre intervention) and after playing DEEP (post intervention).

### 3.3. Effects of Self-efficacy

To investigate whether self-efficacy would moderate the effect of DEEP on physiological regulation moderation analyses were performed (using the PROCESS extension for SPSS by Hayes [58]). Results indicated that competence, emotional self-efficacy, breathing self-efficacy and game performance self-efficacy all significantly predicted physiological arousal after playing the game (these results remained significant after a Bonferroni correction for multiple comparisons). Specifically, the higher someone’s feeling of self-efficacy, the lower their reported physiological arousal scores were (see Table 1 for specific values).

Predictor	$\beta$	se	t	p
Competence	-0.93	0.26	-3.56	.001
Emotional SE	-0.48	0.15	-3.15	.002
Breathing SE	-3.21	1.05	-3.07	.003
Performance SE	-3.62	0.97	-3.72	.000

**Table 1.** Self-efficacy measures as a predictor of physiological arousal after playing DEEP. SE = self-efficacy.

### 3.4. Evaluation of DEEP

Overall, participants seemed to enjoy playing DEEP reporting a mean score of 37.7 (SD = 9.1) out of a maximum of 49 in the Intrinsic Motivation Inventory [57]. The mean grade that participants gave to DEEP was a 7 out of 10 (SD = 1.5). Furthermore, the majority of players reported very low levels of nausea as a result of playing DEEP. In fact, most players (40.3%) reported not feeling any sickness at all.

### 4. Implications

Participants enjoyed playing DEEP and were able to significantly reduce their arousal levels, arousal that was evoked by a highly stressful experience. Although it was merely a simulated job interview this type of situation is a potent stressor for many individuals. These results provide a promising outlook for using biofeedback video games such as DEEP to help individuals learn how to regulate their physiological arousal in an engaging manner. In addition, more insight was provided into factors that may influence therapeutic outcomes of biofeedback interventions. Specifically, it was found that individuals who felt more confident in their ability to perform in the game or to regulate their emotions and physiology seemed to benefit more from their experience with DEEP which was reflected in lower arousal levels. Because of this pilot's design we cannot confirm whether lower arousal

was felt due to higher self-efficacy or whether participants felt better about their capabilities because they did not feel significantly stressed after playing. Furthermore, in the absence of a passive control group we cannot primarily attribute the reduction in arousal to DEEP. Lastly, the current pilot study used a normative sample so future research should investigate whether results can be generalized to a clinical population. However, we can conclude that psychological factors such as self-efficacy are important to take into account when developing and empirically evaluating biofeedback interventions and biofeedback video games that focus on improving players' self-regulation and mental wellbeing.

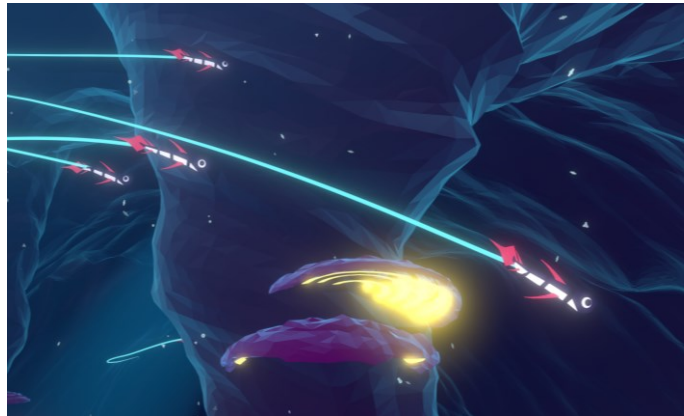
### 5. Future steps

Based on the findings of this study we recommend that the following points are taken into account for future design, implementation and evaluation of biofeedback games:

- Biofeedback games should be designed in such a way that feelings of self-efficacy are maximized. For instance, by adapting the difficulty to a player's current level of performance and by providing enough feedback so they feel confident in their ability to self-regulate.
- Trainers or therapists should consider to work on increasing self-efficacy early on in the intervention. For instance, by reassuring players that everyone is eventually able to efficiently self-regulate, even though it may take some effort at first.
- When testing the effectiveness of biofeedback interventions or biofeedback video games it is

recommended to assess self-efficacy at various time points during one or across multiple sessions, so that changes in self-efficacy can be observed and can be linked to positive outcomes in self-regulation.

- Finally, future research should continue to investigate the underlying mechanisms and factors that may contribute to the effectiveness of biofeedback so that (game-based) interventions can be designed and delivered in such a way that positive therapeutic outcomes are maximized.



**Figure 4.** Screenshot of DEEP

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