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Reducing Test Anxiety and Related Symptoms Using a Biofeedback Respiratory Practice Device: A Randomized Control Trial

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Abstract
Test Anxiety is a widespread psychological phenomenon. With prevalence rates of 20–40 percent of university students, it impedes adaptive functioning and life quality. Many available treatments for Test Anxiety involve the intervention of clinicians and usually a few months are required before symptom reduction is reported. The present randomized controlled trial examined a simple behavioral intervention—the use of breathing tools—as an exclusive therapy for Test Anxiety. Specifically, the efficacy of a biofeedback respiratory practice device was examined. 34 students were assigned to 3 treatment groups during their exam period: Biofeedback device group, self-directed breathing exercise group, and psychoeducation group. Self-report measures of Test Anxiety were collected pre- and post-intervention. Participants also reported additional exploratory measures such as depression and anxiety, quality of life, and their perceived adaptive functioning post-intervention. The results reveal that only participants from the biofeedback device group reported a significant reduction in Test Anxiety symptoms (p's < 0.05). Participants from the biofeedback device group also reported a decrease in depression and anxiety symptoms and an increase in psychological wellbeing (p's < 0.05), a subscale of the quality of life questionnaire. Findings support the notion that using biofeedback respiratory devices may reduce students' Test Anxiety symptoms. Indications for further research are discussed.

Keywords Biofeedback · Slow breathing techniques · Test anxiety · Psychological well-being · Psychoeducation

Introduction

Anxiety disorders are among the most common psychological disorders reported nowadays, with prevalence rates estimated at 10–20 percent of the population (Wells 2013). Test Anxiety is a form of anxiety that appears when individuals believe their skills are being evaluated and they anticipate negative outcomes of this evaluation (Cizek and Berg 2006; Embse et al. 2013). In western societies, tests serve as a main tool for academic and professional decision making. Tests are frequently used to determine future career opportunities of individuals, and it is not surprising that former studies have found that 20 to 40 percent of higher education students experience Test Anxiety that impedes their academic performance (Cizek and Berg 2006; Embse et al. 2013). People who experience high levels of Test Anxiety tend to compare their performance to that of their peers, have low levels of confidence in their own performance, and experience loss of self-worth (Cassady 2004; Deffenbacher 1980).

Test Anxiety is known to affect students' performance both before, during, and after tests, therefore lowering their chances of achieving the grades required for later career opportunities (Beilock 2008; Bonaccio et al. 2012; Rothman 2004). Moreover, Test Anxiety not only affects academic performance—it affects students' quality of life as well (Dehghan-nayeri and Adib-Hajbaghery 2011; Mendlowicz and Stein 2000).

Available Treatments for Test Anxiety

A few psychological and educational interventions have been studied and used to reduce test anxiety symptoms and to improve academic performance (Huntley et al. 2016). These

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interventions focus on teaching study skills and test-taking strategies, as well as addressing the worry and emotionality that were identified as primary elements in Test Anxiety (Cassady and Finch 2015). Various forms of cognitive behavioral therapies were adapted for use with students who have Test Anxiety. Two meta-analytic studies have identified cognitive behavioral interventions that also included teaching of study skills as effective in reducing the cognitive and affective-physiological dimensions of Test Anxiety (Ergene 2003; von der Embse et al. 2013). Over the last decade, the increasing prevalence of psychological disorders such as depression and anxiety led to the development of various evidence-based treatment options that vary in their intensity, with the goal to make psychological care accessible to as many people as possible. Such treatments include self-help books, internet-based CBT, advice walk-in clinics, and large group psychoeducation classes (Bennett-Levy et al 2010; Cuijpers et al 2009).

Guided self-help treatments are defined as interventions based on the use of a self-help tool, combined with a minimal guidance of a clinician. Numerous meta-analytic studies have concluded that guided self-help tools are helpful in decreasing symptoms of various anxiety disorders, including specific phobias and panic disorder (Gellatly et al. 2007; Haug et al. 2012; Hirai and Clum 2006).

Two former studies examined the efficacy of guided self-help treatments in the context of Test Anxiety. In both studies it was found that internet-based cognitive behavioral therapy (I-CBT) protocols were effective in reducing Test Anxiety symptoms (Orbach et al. 2007; Zimmerman 2011). In the latter study it was also found that high-intensity clinician guidance was no more beneficial than a lower level of guidance (Zimmerman 2011). However, in both studies the patients were required to spend significant periods of time reading and practicing therapy materials. It is important to note that studying new material can be anxiety-inducing in and of itself for students suffering from Test Anxiety, especially during an exam period. In that light, we set out to examine simple self-help interventions aimed at reducing Test Anxiety without requiring investing time in learning new material.

The Role of Breathing in Reduction of Test Anxiety

Abnormal breathing is a main symptom of anxiety, anxiety attacks, and hyperventilation. When a given situation is perceived as dangerous, a "fight or flight" reaction is triggered by an activation of the sympathetic nervous system. The reaction of the sympathetic nervous system is identified by an increase in the breathing rate manifested mainly by shorter exhalation (Hugdahl 1995; Masaoka and Homma 1999). Breathing rate is also correlated with a feeling of anxiety. Peper and McHose (1993) have found that subjects who were instructed to breathe and limit their exhalation, reported hyperventilation and high levels of anxiety. When the same subjects were instructed to practice slow breathing, their anxiety levels were significantly reduced. Masaoka and Homma (2001) have found correlations between an increase in breathing rate, a feeling of perceived threat, and an increase in cortical and limbic activation. This correlation was stronger among subjects with high anxiety levels.

Anxiety-related high breathing rate causes excessive amounts of carbon dioxide to be removed from the body, resulting in a drop in the partial pressure of carbon dioxide, also known as PCO2 (Gavrieli 2001). In addition to decrease in blood supply due to limited release of nitric oxide which produces vasoconstriction, there is also a decrease in the oxygen supply to the brain, as a direct results of limited oxygen being released from the hemoglobin when CO2 levels are low (also known as the Bohr Effect). Some studies have shown that lower PCO2 levels contribute to cognitive symptoms of "black outs", distraction, exhaustion, and lower cognitive performance (Balestrino and Somjen 1988; Hauge et al. 1983). In the context of Test Anxiety, the reduction in cognitive performance can be crucial in terms of test performance (Brown et al 2011). Although a shorter exhalation could be the main reason for hyperventilation and for a panic attack, increased respiratory volume can also contribute to hyperventilation and panic. Deeper breathing, which always occurs with slower breathing, may also increase the tendency to hyperventilate. Studies that have checked the influence of slow-paced breathing on the autonomic nervous system showed the effect of slow-paced breathing on fatigue and/or hyperventilation and suggested that effect to be a sympathetic rebound effect (Sargunaraj et al 1996). Therefore, when looking for "the way out" from anxiety or hyperventilation, researchers have to look for inhalation that will not be too deep or too long, in combination with slow and long exhalation (Peper and MacHose 1993). This combination may help subjects maintain PCO2 balance and stop the "fight or flight" response during a test.

Unlike with other mechanisms of the sympathetic nervous system, people can control and modify their breathing by increasing their awareness to it. In light of that, respiratory training of prolonged exhalation has become an important element in many anxiety treatments (Masaoka and Homma 1999; Han et al. 1996). Many studies that were conducted in the last decades have focused on studying the effects of respiratory training in the context of Test Anxiety, and regarded its effectivity to the restoration of PCO2 balance (Cho et al. 2016; Ergene 2003; Larson et al. 2010; Embse et al. 2013). In most of these studies, respiratory training was taught and practiced with a clinician and was combined with an instruction for relaxation. For example, in the study conducted by Cho et al. (2016), participants practiced breathing techniques

with a clinician first and only then were they asked to practice at home.

One could assume that the instruction for relaxation would have beneficial aspects, yet some studies have concluded differently. Brown et al. (2011) have found that a combination of cognitive training with respiratory practice resulted in poorer test performance (Brown et al. 2011). The researchers suggested that the participants invested tremendous cognitive resources in the attempt to reduce disruptive thoughts, and therefore had fewer resources available for facing test demands. In their studies of thought suppression, Daniel Wegner and his colleagues showed that the attempt to remove disruptive thoughts is counterproductive, and can damage one's optimal functioning (Najmi and Wegner 2009).These research resources strengthen the need to examine whether a respiratory practice that does not include an instruction for relaxation, or any other cognitive effort, can assist in reducing Test Anxiety symptoms. Moreover, due to the large number of individuals who experience Test Anxiety, it is imperative to develop an intervention method that will not require long training by a clinician.

The Use of Biofeedback Devices in Reduction of Test Anxiety

Biofeedback is described as a process in which a patient receives information about a physiological reaction, and as a result the patient is able to choose whether and how to modify their physiological reaction (Olton and Noonberg 1980; Wenck et al. 1996). Biofeedback devices have been commonly used in many medical treatments, including treatments for GAD, PTSD, and ADHD (Brauer 1999; Meuret et al. 2001). Some studies have also found that the use of biofeedback was effective in reducing the physical symptoms of Test Anxiety (Meuret et al. 2001; Moss 2004). Most of these studies used devices measuring heart rate variability (HRV). An improvement in HRV can be reached through breathing at resonance frequency breathing rate, which is significantly slower than typical breathing (Leherer 2018; Eddie et al. 2015). Improvement in HRV was found to be effective in decreasing anxiety (Purwandini Sutarto et al. 2012) and Test Anxiety symptoms (Peper et al. 2016).

Other studies were conducted using respiratory biofeedback devices that offer feedback related to breathing duration, such as Sonic Respiration (Harris et al. 2014) and RESPeRATE (RESPeRATE, InterCure, Inc., Montclair, NJ). However, these devices involve wearing sensor bands around the chest and/or abdomen to monitor breathing rates and patterns and therefore are intended to be used with a clinician or at a specific environment that allows the required setting.

To the best of our knowledge, so far, no studies have tested the effects of a respiratory biofeedback device in reduction of Test Anxiety symptoms.

The current study aims to examine the efficacy of different levels of treatment on Test Anxiety symptoms. More specifically, we examine the use of breathing tools as a simple and exclusive therapy for Test Anxiety. We evaluate the efficacy of a new, handheld, portable, and easy to carry biofeedback respiratory practice device that provides feedback regarding the desired length of exhalation to users. The practice in the current study was conducted in the natural environment of the participants, without the presence of a clinician. As with all biofeedback devices, we evaluated the device with the goal of enabling the subjects to use it effectively while also being able to wean off it eventually.

Despite the efficacy of biofeedback treatments in reducing anxiety, some studies have found no differences in treatment outcomes between participants who practiced with a biofeedback device and participants who simply practiced relaxation techniques (Biondi and Valentini 2013; Counts et al. 1978). Nonetheless, the majority of these studies were conducted in a laboratory and did not target breathing specifically. We hypothesize that self-practice of slow breathing will lead to a decrease in Test Anxiety measures, and that practicing slow breathing with the biofeedback device will lead to an even greater decrease in Test Anxiety symptoms. The biofeedback device we test changes the feedback regarding the wanted exhalation length according to the participant's current state, thus optimizing the feedback to the participant's needs.

In other words, we hypothesize that a more directed breathing practice would lead to a greater effect size. We also hypothesize that practicing without guidance for relaxation will help the participants to invest cognitive resources in studying and performing on a test. In addition, we wish to examine the effect of the respiratory practice with and without the biofeedback device on other anxiety-related measures, such as depression and anxiety, psychological well-being, and perceived adaptive functioning.

Method

Pretest of the Biofeedback Device

The biofeedback device was tested in a small sample in order to assess its usability during an exam. In order to simulate the stress levels during an exam, an exam simulation was conducted, and a stress manipulation was used (Ramirez and Beilock 2011).

Participants

An advertisement was published on the campus, inviting students who experience high levels of Test Anxiety to participate in a study. Six (two females, four males)

undergraduate college students were recruited (average age = 24.8, SD = 2.3). Participants received credit for coursework for their participation. Institutional Review Board approval was obtained from the ethics committee of the university, and written informed consent was obtained from each participant before the experiment.

Tools

CalmiGo® is a General Wellness device (see Fig. 1) that is designed to provide relief to users in states of distress, anxiousness, or stress. The device is battery-operated and provides biofeedback regarding the desirable exhalation length when breathed into, using adaptive feedback that consists of light, sound, and vibrations. CalmiGo's algorithm sets the desired exhalation length in each breathing cycle based on the users' previous breathing patterns. The feedback then guides the users to exhale until the desired length is achieved. The algorithm is designed to steadily extend the exhalation time while staying within the user's current capabilities. The device does not aim to control exhalation strength. Additionally, the device includes an optional solid scented element, but this feature was disabled in the devices that were used in the study. The device was tested and approved according to FCC (USA), CE (European Union) and ICES (Canada) regulatory standards.

Test Anxiety Inventory (TAI) is a 20-item self-report instrument designed to measure "individual differences in Test Anxiety as a situation-specific personality trait" (Spielberger 1980). It is the most common instrument used to measure Test Anxiety (Ziender 1998; Chapell et al. 2005). Participants report the frequency of a variety of anxiety symptoms occurring prior to, during, or after an exam. Responses are measured using a four-point Likert scale ranging from 1 (almost never) to 4 (always). The TAI yields three scores: a total score based on all 20 items, a score for worry (W) based on a subset of eight items, and a score for emotionality (E) based on another eight-item subset. In the current study, we used the Hebrew version of the TAI, developed by Zeidner and Nevo (1993). Total score Cronbach's alpha of 0.91; Worry scale Cronbach's alpha of 0.87; Emotionality scale Cronbach's alpha of 0.87.

Fig. 1 The CalmiGo® device

Perceived Change Questionnaire is a questionnaire looking at perceived change in four areas: perceived change in stress levels throughout the exam period, perceived change in stress levels while writing an exam, perceived change in overall functioning, and perceived change in academic achievement. Responses are measured using a five-point Likert scale ranging from 1 (significantly increased) to 5 (significantly decreased). Internal consistency was found to be sufficient with a Cronbach alpha of 0.78.

Procedure

After participants signed the consent form, they filled out the TAI online. They then received the CalmiGo® device for two weeks and were informed that after this period they will participate in a simulation of an intelligence test. During the simulation, participants were told that their score will determine the final score of the team they were assigned to. Following the test simulation, all participants completed the TAI again, as well as the perceived change questionnaire.

Results

Perceived Change

All participants reported no difficulties using the device. 4 participants reported using the device 3 times a day. 5 participants reported a decrease in their perceived anxiety levels after one week of practice. 5 out of 6 participants reported the test simulation had indeed triggered their anxiety. In addition, 5 out of the 6 participants reported they would have liked to receive the device for the next exam period.

Test Anxiety Differences Pre- and Post-Intervention

Wilcoxon signed-rank test analysis revealed a significant decrease in the total Test Anxiety scores [$c^2(5) = 13.65$ $P = 0.018$] of the TAI, but not in the worry and emotionality sub-scales. Following these positive preliminary results, the effect of a breathing practice using the biofeedback breathing device was tested in a bigger sample.

Primary Study

Participants 39 college students applied to participate in a Test Anxiety reduction program that was advertised one month prior to the exam period. Participants did not receive

compensation for their participation. Out of the 39 applicants, 34 participants took part in the study. The average age of the sample was 25.1 (SD = 2.6) with an age range of 18–32 years. Participants had an average of 13.8 years of education (SD = 1.14). Participants were randomly assigned to one of three groups: participants who received the CalmiGo® device ("device group"), participants who received instructions to practice self-directed breathing exercises ("self-directed breathing group"), and participants who only received a handout with information about Test Anxiety ("psychoeducation group"). All three groups were initially comparable for age, gender, year of study, and the number of participants who were in psychological or psychiatric treatment during the intervention (see Table 1). None of the participants were in treatment for Test Anxiety during the intervention. Out of the 34 participants in the pre-intervention stage, 12 participants did not complete the post-intervention self-report instruments. Dropout rates were similar between the different groups (Fisher's T exact p = 0.70). Even after the removal of these 12 participants, the demographic variables of the three groups remained comparable. The study was approved by the Institutional Review Board of the university, and written informed consent was obtained from each participant before taking part in the study.

Tools ***Calmigo®*** (See pretest).

Test Anxiety Inventory (TAI, see pretest).

Perceived Change Questionnaire (see pretest).

The Depression Anxiety Stress Scales (DASS-21) is a 21-item self-report instrument designed to measure the constructs of depression and anxiety in patients over the last week (SAQ; Lovibond and Lovibond 1995). Since its publication in 1995, the DASS-21 has been used in various studies (Henry and Crawford 2005). Responses are measured using a four-point Likert scale ranging from 1 (doesn't describe me at all) to 4 (describes me almost always). The DASS-21 yields 4 scores: total negative affectivity, depression score, stress score, and anxiety score. Internal consistency was found to be good with a Cronbach alpha of 0.93 for the total score, 0.85 for the depression scale, 0.89 for the stress scale and 0.81 for the anxiety scale.

WHOQOL-BREF—World Health Organization Quality of Life Group is a 26-item self-report instrument designed to measure quality of life (The WHOQOL Group 1998). Responses are measured using a five-point Likert scale ranging from 1 (not at all) to 5 (very much). The WHOQOL-BREF yields 5 scores: general quality of life, physical wellbeing, psychological wellbeing, social relationships, and environment. In the current study, changes in the general score and in the physical and psychological wellbeing scores were examined. Internal consistency was found to be sufficient with a Cronbach alpha of 0.87 for the total score, 0.72 for the *physical* wellbeing scale, and 0.77 for the psychological wellbeing scale.

Table 1 Demographic Information across Groups

	Number	%	Range	Mean	SD
Female	21	62%	–	–	–
Male	13	38%	–	–	
Age	–	–	18–32	25.1	2.6
Psychological treatment during the study	5	15%	–	–	–
Psychiatric treatment anxiety during the study	3	9%	–	–	–

Procedure

Participants were invited to meet the research team at the beginning of the exam period. After filling out the consent form that was approved by the university's ethics committee, all participants completed the self-report pre-intervention questionnaires. All participants received a handout with information about Test Anxiety. Participants were then randomly assigned to one of three groups: device group, self-directed breathing group, and psychoeducation group. Participants from the psychoeducation group did not receive any intervention except for the handout given to all participants (see Appendix 1). They were informed that they were placed on a waiting list. Participants from the self-directed breathing group also received written instructions for practicing slow breathing that focused on deeper inhalation (deeper than usual but without using the chest and shoulders) and prolonging their exhalation. They were instructed to do so while sitting in a chair, putting one hand on their belly, in order to better notice their belly breathing and avoid chest breathing as much as possible. The participants also received a link to a video with filmed instructions for this method. The video presented the self-directed breathing technique lying down. Participants were asked to practice it first as shown and then while being seated (see Appendix 2). Participants from the device group received the biofeedback device with user instructions and were guided to inhale through the nose and exhale through the mouth. Participants from two practice groups were instructed to practice three times a day for a period of three minutes each time. At the end of each week, they reported their practice frequency. Participants that reported low practice frequency were contacted by the research team and were encouraged to practice according to the instructions. At the end of the three week exam period, participants from all three groups were asked to complete self-report questionnaires. Differences in scores between pre- and post-test measures were analyzed

using a-parametric statistical tests due to the small sample. In addition, the research team contacted the participants who were told they were placed on a waiting list and those who were still interested in receiving the intervention received the biofeedback device (N = 3) for a period of three weeks.

Results

Kruskal Wallis test analysis of the pre-intervention self-report instruments revealed that the three research groups were comparable for all the main study measures: Test Anxiety, worry, emotionality, negative emotionality, depression, anxiety and stress, and quality of life ($p > 0.05$).

Out of the 34 participants who completed the pre-intervention questionnaires, 12 participants did not complete the post-intervention questionnaires. Groups remained comparable for initial measures, also after removing the data of the 12 participants who did not complete the post-intervention questionnaires.

Differences in Test Anxiety Scales of the TAI

In order to test our primary hypothesis that a more directed breathing practice would lead to a greater decrease in Test Anxiety, a Wilcoxon signed-rank test analysis was conducted on the pre- and post-intervention scores on the TAI for all three groups (see Table 2 for mean scores). In line with our hypothesis, a significant decrease in Test Anxiety scores was found in the device group: [$W(8) = -2.55$, $p = 0.011$]. Participants from the self-directed breathing group and the psychoeducation group also presented a slight decrease in Test Anxiety scores, however this decrease was not statistically significant ($p > 0.05$). In the device group, the decrease was significant on the two subscales of TAI as well. These results, as depicted in Fig. 2, panels A-C, indicate that participants from the device group experienced a reduction in their anxiety levels following the practice with the device.

In order to check if the Test Anxiety scores changed differently among the different study groups following the intervention, the participants' total score on the TAI was analyzed using a mixed Analysis of Deviance (Type III Wald F tests with Kenward-Roger df), after being ranked using an aligned rank test. The results indicated a significant main effect for the intervention ($F = 7.50$, $p < 0.013$). A smaller effect size for the type of group was found as well, with marginal significance ($F = 3.09$, $p = 0.06$). Since the groups did not differ from one another on the TAI scores prior to the intervention, these results indicate that the differences between the groups are a result of the intervention they

Table 2 Means (and Standard Deviations) for Test Anxiety Levels across groups

	Device group (N = 9)		Self-directed breathing group (N = 8)		Psychoeducation group (N = 5)	
	Pre M (SD)	Post M (SD)	Pre M (SD)	Post M (SD)	Pre M (SD)	Post M (SD)
TAI total score	2.76 (0.67)	2.13 (0.59)*	2.84 (0.56)	2.69 (0.51)	2.8 (0.61)	2.65 (0.59)
TAI Worry score	2.66 (0.72)	1.81 (0.69)*	2.73 (0.7)	2.54 (0.84)	2.52 (0.66)	2.3 (0.6)
TAI Emotionality score	2.64 (0.71)	2.26 (0.72)*	2.81 (0.58)	2.78 (0.43)	2.9 (0.8)	2.72 (0.74)

*Statistically significant differences ($p < .0.5$)

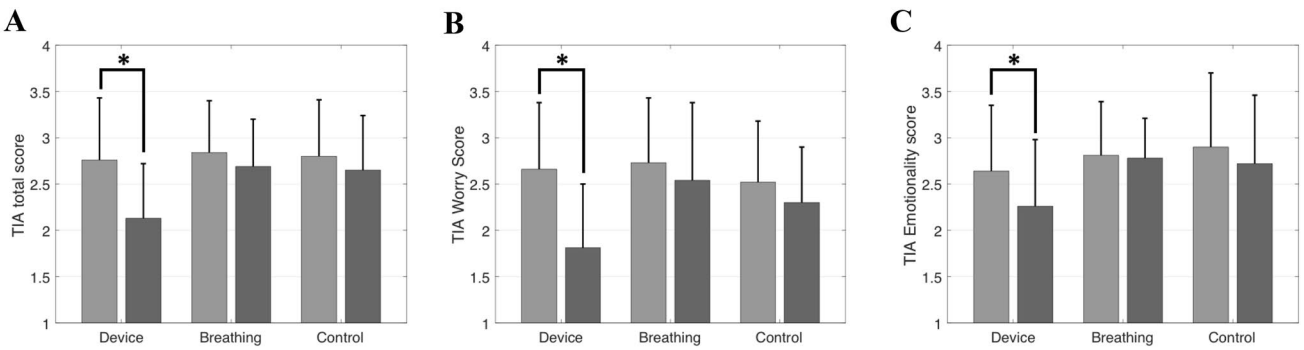

Fig. 2 Panels A-C: Differences in each of the TAI scale scores, by group. Differences in exploratory measures: Negative Affectivity, Depression, Anxiety and Stress; Quality of life

received. No significant effect for the interaction between group and time was found ($F = 0.32$, $p < 0.726$).

In addition to our primary interest in reduction of Test Anxiety symptoms, we measured differences in several psychological measures that are usually positively correlated with Test Anxiety. We conducted a Wilcoxon signed-rank test analysis on the pre- and post-intervention scores on each of the DASS21 scales for all three groups (see Table 3 for mean scores). In the device group, a significant decrease in the DASS21 scores was found on the total scale [$W_{(8)} = -2.52$, $p = 0.012$] and on the stress scale [$W_{(8)} = -2.25$, $p = 0.024$] but not on the depression and anxiety scales. Participants from the self-directed breathing group and from the psychoeducation group did not present a significant decrease in the DASS21 scores. The results for the general scale and for each subscale of the DASS are presented in Fig. 3, panels A-D.

We also examined whether the intervention had an effect on the participants' scores on measures of quality of life. A series of Wilcoxon signed-rank tests were conducted on the pre- and post-intervention scores of the *WHOQOL-BREF* scales for all three groups (see Table 4 for mean scores). In the device group, a significant increase in scores was found only for the psychological wellbeing scale [$W_{(8)} = -2.12$, $p = 0.034$], but not for the total scale or for the physical wellbeing scale. No significant differences in any of the

Table 3 Means (and Standard Deviations) for Negative affectivity, Depression, Anxiety and Stress Levels across groups

	Device group (N = 9)		Self-directed breathing group (N = 8)		Psychoeducation (N = 5)	
	Pre M (SD)	Post M (SD)	Pre M (SD)	Post M (SD)	Pre M (SD)	Post M (SD)
DASS21 total score (Negative affectivity)	2.07 (0.59)	*1.63 (0.52)	2.32 (0.55)	2.1 (0.58)	2.12 (0.47)	2.01 (0.59)
DASS21 Depression score	2.06 (0.63)	1.81 (0.48)	2.32 (0.74)	2.14 (0.86)	2.07 (0.66)	1.91 (0.65)
DASS21 Anxiety score	2 (0.4)	1.71 (0.34)	2.12 (0.64)	2.02 (0.64)	1.85 (0.62)	1.68 (0.68)
DASS21 Stress score	2.46 (0.89)	*1.98 (0.8)	2.43 (0.53)	2.38 (0.43)	2.64 (0.51)	2.45 (0.82)

*Statistically significant differences ($p < 0.05$)

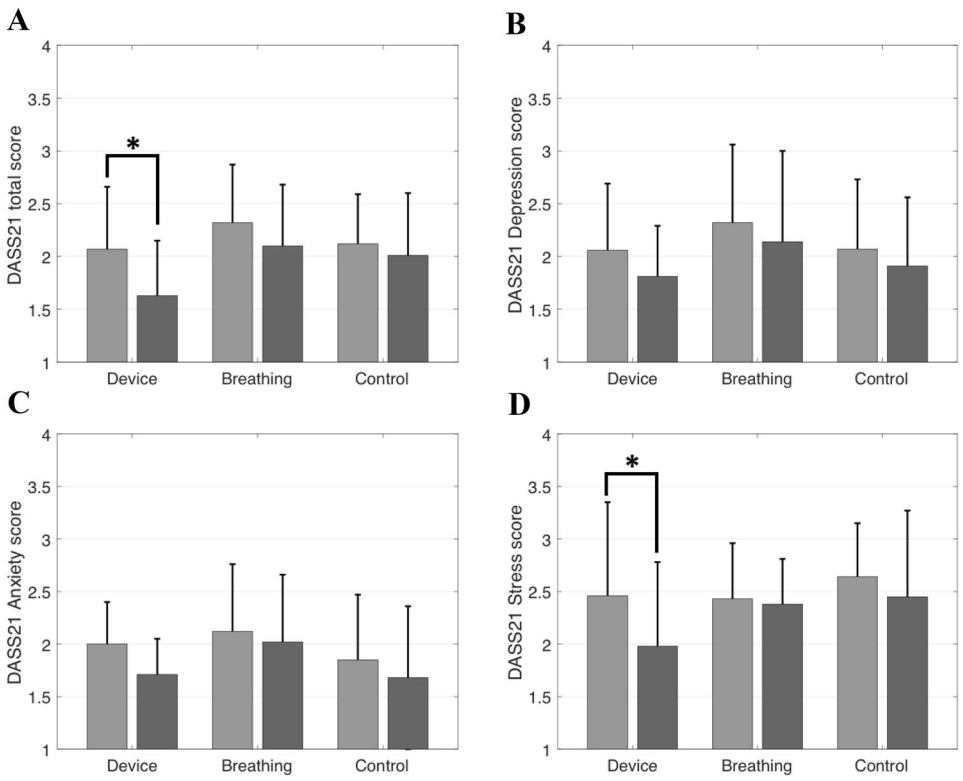

Fig. 3 Panels A-D: Differences in each of the DASS21 scale scores, by group

WHOQOL-BREF scales were found in the self-directed breathing group, or in the psychoeducation group. The results for each scale of the *WHOQOL-BREF* are presented in Fig. 4, panels A-C.

Amount of Practice

In order to test whether participants from the device group practiced more than the participants from the other groups, an average amount of practice measure was calculated for each participant, according to their self-reports. The Mann Whitney U test was conducted in order to reveal differences in the amount of practice between the two test groups. The results revealed a significant difference in the amount of practice per day [$U_{(15)} = 10.5$, $p = 0.014$] so that on average, participants from the device group practiced more times a day than participants from the self-directed breathing group (see Table 5 for mean scores). Participants from the device group also practiced on more days, with a marginal trend towards significance [$U_{(15)} = 16.5$, $p = 0.05$].

Pearson correlations were computed between the amounts of practice to the therapeutic effect (change in scores on the TAI). These correlations were computed only for variables in which significant differences were found between the pre- and post-intervention scores. The results revealed that the correlation between the amount of practice and the therapeutic effect was non-significant ($p > 0.05$).

Dropouts and Validity

A series of Mann Whitney U tests were conducted in order to reveal differences in Test Anxiety levels between

Table 4 Means (and Standard Deviations) for Quality of life levels across Groups

	Device group (N = 9)		Self-directed breathing group (N = 8)		Psychoeducation group (N = 5)	
	Pre M (SD)	Post M (SD)	Pre M (SD)	Post M (SD)	Pre M (SD)	Post M (SD)
WHOQOL-BREF total score	3.33 (0.43)	3.79 (0.54)	3.25 (0.4)	3.27 (0.53)	3.33 (0.74)	3.36 (0.65)
WHOQOL-BREF physical wellbeing	3.40 (0.41)	3.44 (0.54)	3.37 (0.45)	3.36 (0.58)	3.13 (0.84)	3.26 (0.68)
WHOQOL-BREF psychological wellbeing	*3.38 (0.68)	*3.95 (0.77)	3.21 (0.63)	3.30 (0.72)	3.34 (0.78)	3.46 (0.59)

*Statistically significant differences ($p < 0.05$)

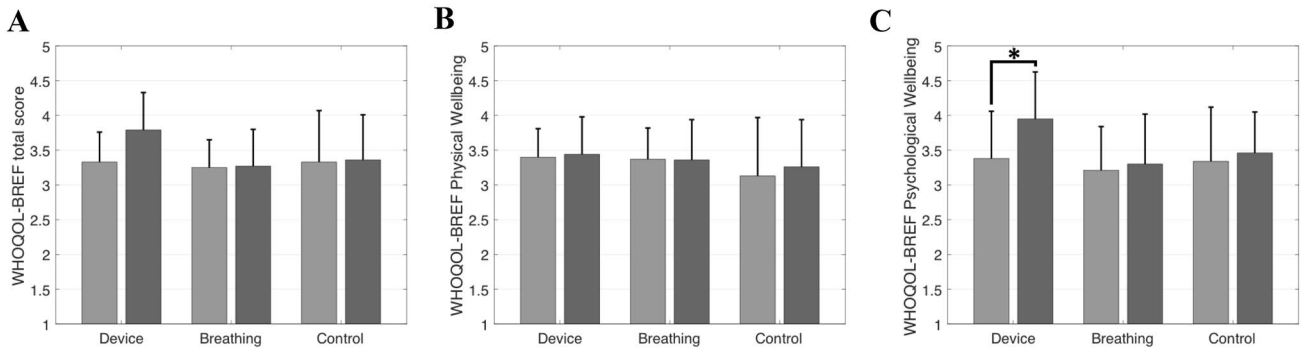

Fig. 4 Panels A-C: Differences in each of the WHOQOL-BREF scale scores, by group

Table 5 Means (and Standard Deviations) for amount of practice for the two intervention groups

	Device group (N=9)	Self-directed breathing group (N=8)	Effect size of group differences (U)
Number of days practiced	13.77 (3.36)	10.12 (2.47)	16.5
Daily practice frequency	2.49 (0.17)	2.13 (0.25)	10.5*

*Statistically significant differences ($p < 0.05$)

the participants who completed the study and those who dropped out after the first measurement. Although no differences were found on our primary measure of total Test Anxiety score, the results reveal some other significant individual differences in the self-directed breathing group dropouts scored lower on the worry scales of the TAI [$U_{(11)} = 3$,$p = 0.016$]. In the psychoeducation group, dropouts scored marginally higher on the same scale [$U_{(9)} = 3$, $p = 0.056$]. No differences on the TAI were found in the device group. Some differences were found on the exploratory measures; in the device group, dropouts scored lower on measures of quality of life [$U_{(11)} = 1.5$, $p = 0.026$] and higher on the depression scale of the DASS21 [$U_{(11)} = 4.5$, $p = 0.09$]. In the self-directed breathing group, the dropouts scored lower on the stress scale of the DASS [$U_{(11)} = 1$,$p = 0.008$]. Since these differences may affect the validity of our study, we decided to conduct another analysis that included the dropout participants in the post-intervention measure, by using the same score they received in the pre-intervention stage, in line with the intent to treat model (Zimmerman 2011). A series of Wilcoxon signed rank tests revealed no significant effects after the intervention, when the initial scores of the dropouts were included ($p > 0.05$). The indications of this result are discussed in the discussion section. In summary, the number of dropouts in the current study was typical to studies in this field of research. It is likely that in a bigger sample, significant differences would have been found even after including the initial dropouts' scores.

Perceived Change

Perceived change was surveyed in 4 different domains: perceived change in stress levels throughout the exam period, perceived change in stress levels while writing an exam, perceived change in overall functioning, and perceived change in academic achievement. None of the participants in the two intervention groups reported a decrease in their adaptive functioning. However, 40 percent of the participants in the psychoeducation group reported an increase in their stress levels. All the participants in the device group reported a decrease in their stress levels, whereas only 50 percent of the participants in the self-directed breathing group reported a similar decrease in their stress levels. Kruskal Wallis test analysis of the post-intervention ratings of the perceived variables revealed a marginal trend towards significance [$\chi^2 2(2) = 0.49$, $p = 0.087$]. These findings indicate that in line with our hypothesis, participants in both intervention groups perceived the intervention as helpful in reducing their stress levels, with higher agreement prevalence of perceived change in the device group.

Discussion

The current study aimed to examine the efficacy of breathing practice in reduction of Test Anxiety symptoms of students during an exam period. In order to do so, three different levels of interventions were examined: psychoeducation about Test Anxiety provided with a handout, self-directed breathing practice, and breathing practice with an easy-to-carry biofeedback device. In line with our hypothesis, participants who practiced with the biofeedback device presented a significant decrease in their Test Anxiety levels on all scales of the TAI. These findings indicate that using the biofeedback device as a breathing tool can be helpful in significantly reducing Test Anxiety symptoms among students. There are several possible explanations for these findings. Although participants from both practice groups were instructed to use slow breathing, the biofeedback device provides accurate feedback regarding the wanted exhalation duration, whereas participants from the self-directed breathing group did not receive such feedback. Moreover, we believe that relying on simple feedback from the device, instead of intentionally trying to extend exhalation, requires minimal emotional and cognitive engagement. We believe that the unique contribution of the device is not only in providing accurate feedback regarding the exhalation length, but also by creating cognitive distance from the test situation.

Indeed, former studies have regarded the unique contribution of biofeedback devices in helping practice become automatic, with minimal cognitive and emotional involvement (Wenck et al. 1996). The current study shows that despite having relatively little time to practice, participants in the device group reported a significant decrease in Test Anxiety and related measures. The participants who practiced using the biofeedback device also reported practicing more frequently (more times a day) than the participants who practiced self-directed breathing, however no significant correlations were found between the amount of practice and the therapeutic effects. This finding supports the hypothesis that the significant differences we found are a result of the device's accurate feedback regarding the desired length of exhalation and not a result of more frequent practice. This explanation aligns with recent findings suggesting that sustained engagement with skills practice may be more important than the overall volume of practice in predicating positive treatment outcomes (Segal et al 2019). Nevertheless, the difference in the amount of practice supports the notion that having a device encouraged the participants to practice prolonged exhalation more frequently.

It is important to note that former studies have not found a significant reduction in Test Anxiety levels after

practicing with a biofeedback device (Biondi and Valentini 2013; Counts et al. 1978). However, these studies used devices that did not provide direct feedback regarding exhalation length, such as the one used in the current study. In addition, these studies were conducted in a lab and the devices were not taken home by the participants. It is possible that the presence of a research team who provided support and guidance in those studies limited the possible contribution of the biofeedback device, hence reducing its efficacy in a real time scenario. In the current study, participants used a device in their home environment and no other guidance was provided except the encouragement to practice that was given to all groups.

There is another aspect that has to be taken into consideration when discussing the device that was used in the current study. The device is designed in such a way that it can also be used in real time and not only for practicing, especially for patients who suffer from chronic anxiety attacks. It is designed to resemble an inhaler used by asthma patients in order to attract less attention. In that sense, the use of this device is slightly different from most biofeedback devices where part of the training is dedicated to preventing device dependency. The general instruction to the participants was that "at some point you will not need the device because you will know how to breathe well without it" but there was no instruction to quit using the device or any direction to use it or not in times of anxiety/exams. It is important to note that the participants in the current study did not report using the device during the exams, thus supporting the notion that practicing with the device itself before the test increased their ability to cope with stress. Nevertheless, we believe that just having the device as a tool to rely on could calm the participants down and lower the chance of an anxiety attack happening. In this sense, in any device (in fact in any technique, although maybe to a lesser degree) there is probably a placebo component that is very difficult to isolate from the effect of the practiced technique itself. Unfortunately, we don't have data on how much the participants actually used slow breathing during the exams, data that will be important to collect in future studies. We are now designing a new study with chronic PTSD patients who may benefit from the device's use in real-time, and we are considering all the above issues in this study.

We expected to find a reduction in Test Anxiety levels among the self-directed breathing group as well. However, no such significant reduction was found in the current study. We found a significant effect for the intervention across groups, as well as an effect with marginal significance between the groups that resulted from the decrease in Test Anxiety among the device group. We did not find an effect for the interaction between time and group. One explanation for these findings could be rooted in our small sample size, as former studies have found that self-directed breathing practice is effective when it comes to reduction of anxiety symptoms (Brown et al. 2011; Ergene 2003; Larson et al. 2010; Embse et al. 2013). It is likely that in a bigger sample size, significant results would have been revealed as the lack of differences between the self-directed breathing group and the psychoeducation group would have probably been more significant. Moreover, we believe that the lack of standardization of self-directed breathing in the current study could also have affected their efficacy, resulting in smaller effect sizes. Participants from this group received no breathing demonstrations except for an information sheet and an instruction video. In the absence of breathing training, it is likely to assume that some participants controlled their breathing better than others, and these variations led to a variation in their ability to practice controlled slow breathing, resulting in smaller effect sizes of Test Anxiety reduction (Han et al 1996; Hugdahl 1995). In that context, the biofeedback device promotes a more accurate practice, since it provides feedback regarding the individual desired length of exhalation, required in order to achieve relaxation. Future studies should therefore examine whether a more comprehensive breathing training increases the efficacy of self-directed breathing in reducing Test Anxiety levels.

Participants who practiced with the biofeedback device also reported a significant decrease in negative affectivity and stress as measured by the DASS21 and significant increase in their quality of life scores. However, no significant changes in any of these variables were found in the psychoeducation group, nor in the self-directed breathing practice group.

These findings are in line with former findings indicating that reduction in symptoms of a disease (including anxiety) is linked to greater quality of life (Lin et al. 2013). Since no significant reduction in Test Anxiety and in the additional measures were found in the psychoeducation group, nor in the self-directed breathing group, it is not surprising that participants in these groups also did not report a significant increase in their quality of life.

In the current study, the proportion of dropouts was similar in each of the three research groups. It is important to note that the dropouts/remaining participant scores did not differ on our primary measure of interest (total score of the TAI). However, the differences on several additional measures are concerning. Therefore, we conducted a post hoc analysis, and included the dropouts by using their initial scores as outcome scores. We received no significant effects after including the dropout's initial scores in the analysis. This information limits the findings of our study and can be attributed to the small sample size and the fact that in some of the research groups, those who dropped out initially scored higher on measures of worry and lower on measures of quality of life. Therefore, using their initial scores as if they received the treatment but did not improve at all

resulted in a smaller effect size. In future studies, it is important to carefully consider the severity of symptoms reported, as some of the dropout participants may have responded better to a more intense or face-to-face treatment. This consideration should be addressed when building treatment plans for mental health problems in general, and for Test Anxiety in particular.

There are a few limitations to the current study that should be taken into consideration when designing future studies. One possible limitation of the findings concerns the external validity of the results which are limited due to the small sample size and the use of convenient sampling. Furthermore, due to the small sample size the results were analyzed primarily using a-parametric tests that are characterized by reduced statistical power, and use ranks, instead of the actual data. The internal validity of the results may be limited due to a possible placebo effect within participants from the device group; the mere use of a device can make the participants experience improvement in their symptoms. Future studies should address these limitations by investing more effort in recruiting a bigger sample using probability sampling. A larger sample will also allow to control for the participants' level of practice in order to ascertain whether the use of a biofeedback device has a unique contribution that exceeds encouraging participants to practice more frequently. Conducting post-experimental interviews could also shed more light on that aspect.

It is important to note that while the findings of the current study attribute efficacy to breathing practice when it comes to reducing Test Anxiety symptoms, the reason for the improvement in symptoms remains unclear. For example, the improvement can stem from the ability to regain balance in PCO2 levels, but also from the perceived feeling of reassurance provided by the use of a self-help tool. In the current study, PCO2 levels were not measured directly. The results of the perceived change questionnaire indicate that participants from the biofeedback device found the intervention helpful in decreasing their symptoms. Finally, the outcome variables in the current study were measured using self-report questionnaires. Scores obtained using self-report questionnaires are exposed to personal interpretation, perceived feeling of reassurance, distraction, and dishonesty, and should be interpreted cautiously. Future studies may overcome this limitation by adding physiological measures, such as breath measurement by capnometry that can provide further insight to the unique contributions of breathing practice in reducing Test Anxiety symptoms (Lang et al. 2000; Lissek et al. 2005). We also suggest examining whether the use of the biofeedback device not only decreases Test Anxiety but also contributes to better academic achievement, and exploring mediating factors should such improvement in achievement be found. Finally, since the current study provides evidence supporting the benefits of the respiratory biofeedback devices, we suggest examining its efficacy in reducing anxiety symptoms in other populations as well, including younger participants who can benefit from using a simple easy-to-carry self-help tool.

The findings of the current study contribute to the growing body of evidence-based literature regarding simple and short treatments not only for Test Anxiety but for anxiety and other related disorders as well. Former studies have demonstrated that breathing practices can be beneficial in reducing anxiety symptoms (Masaoka and Homma 1999) as well as Test Anxiety symptoms (Dehghan-nayeri and Adib-Hajbaghery 2011). The efficacy of biofeedback treatments in reducing anxiety symptoms (Wenck et al 1996) and Test Anxiety symptoms (Ergene 2003) was also reported. The current study seems to be the first random control trial that tested the efficacy of a biofeedback device that does not require practice with the help of a clinician. The results of the current study suggest that breathing practice using a biofeedback device is beneficial in helping students reduce Test Anxiety symptoms during exam periods. The results also suggest that a respiratory biofeedback device may serve as a simple, accessible and easy-to-use treatment for Test Anxiety symptoms, as it does not require assistance from a clinician nor extensive training prior usage. Therefore, it can serve as a self-help treatment tool in low intensity cognitive behavioral therapy, or in other treatments that focus on acquiring emotional regulation strategies using behavioral tools (Hayes et al 2004).

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Appendix 1

Test Anxiety Information Handout (Was Given to all the Participants)

Tests are an inseparable part of daily life in modern society. Our society is test-oriented, and exams serve as a means of decision-making in study and career processes throughout students' lives. Therefore, it is not surprising that many experience significant levels of stress before exams. It is estimated that in the USA alone, more than 10 million elementary and high school students' performances are impeded due to Test Anxiety. It is also estimated that 25%-30% of university students in the USA experience Test Anxiety. Test Anxiety predicts a broad spectrum of unwanted outcomes, such as lower cognitive performance, psychological distress, reduction in physical health and lower academic

achievement. The term "Test Anxiety" refers to the psychological, physical, and behavioral reactions that stem from worry or physical arousal when one is concerned by the possible negative outcomes of failing a test. Test Anxiety may be triggered when people believe their intellectual abilities are being examined and questioned. Test Anxiety is a process that is affected by many factors, such as the specific test situation, anxiety traits of the subject, the ability to properly assess the possible threat, and the coping skills one has acquired to adjust to stressful situations.

Causes

Scientists today agree that a combination of a few factors contribute to the development of Test Anxiety

-Biological factors such as tendency to become anxious, learning disability, or attention deficits.
-Cultural or environmental factors such as high-achieving society.
-Personal factors, such as how one perceives the importance of a specific test or perfectionism.

How does Test Anxiety Develop?

The combination of the above-mentioned factors creates non-adaptive reactions when facing exam situations. These include physiological reactions, "black outs", avoidance behaviors (procrastination) or on the contrary, over-studying and burn out.

How does Test Anxiety Influence Performance?

Whereas low levels of stress may increase emotional awareness and alertness and increase academic performance, high levels of stress significantly decrease the examinee performance. Examinees with low baseline levels of anxiety may find some stress helpful for their performance, whereas for examinees with high baseline levels of anxiety, even a small addition of stress caused by an exam may be harmful for their performance and wellbeing.

It was found that the worry aspect of Test Anxiety, e.g. the amount of negative thoughts an examinee experiences during a test, creates distraction, lowers the ability to focus, and hence impedes the performance on a test.

Treatment

According to the current findings, the most effective treatments for Test Anxiety combine behavioral and cognitive training with the acquisition of study skills.

Behavioral training refers to the teaching of relaxation skills that can assist an examinee to overcome "black outs" and remain calmer before and during the test.

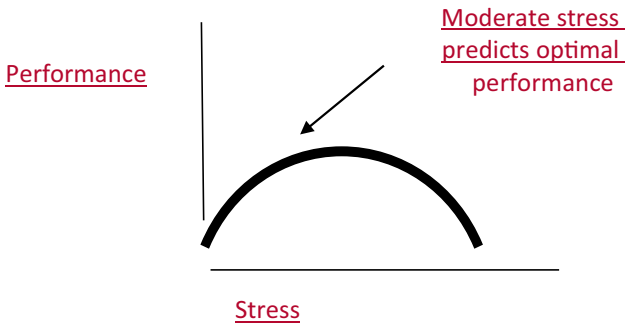
Cognitive training refers to changing ones view of test and their implications when it comes to one's personal life. Examinees are being taught to shift their attention to adaptive coping strategies (e.g. to study instead of worrying what will happen/constantly thinking about the importance of the specific test).

Study skills refer to learning better strategies for studying, such as planning breaks effectively and specific strategies to support different learning difficulties.

When anxiety levels are very high and influence many aspects of one's life, medical treatment is considered as well.

The Correlation Between Stress and Performance

The effect of stress over performance is well-studied and many studies have come to the same conclusion: moderate levels of stress increase performance whereas high levels of stress reduce performance.



Appendix 2

Link to a Video with Instructions for Practicing Slow Breathing (was Provided only to the Participants from the Self-Directed Breathing Group)

https://www.youtube.com/watch?v=vVO5noRsS_Q.

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