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Reducing Anxiety and Improving Academic Performance Through a Biofeedback Relaxation Training Program

Aitor Aritzeta[1] · Goretti Soroa[2] · Nekane Balluerka[3,4] · Alexander Muela[2] · Arantxa Gorostiaga[3,4] · Jone Aliri[3]

Abstract The aim of this study was to analyze the influence of a biofeedback relaxation training program on anxiety and academic performance. The program consisted of five biofeedback sessions coupled with three training activities focused on deep breathing, guided imagery, and muscle relaxation. The participants were second-year psychology undergraduates from the University of the Basque Country (UPV/EHU, northern Spain). The experimental group comprised 152 students ($M_{age}=19.6$, $SD=0.74$; 74% women) and the control group 81 students ($M_{age}=19.4$, $SD=0.92$; 71% women). Results showed that after participating in the program, students in the experimental group had lower levels of anxiety and increased academic performance. Furthermore, they scored lower on anxiety and higher on academic performance in comparison with the control subjects. This suggests that the inclusion of biofeedback training programs in educational contexts could be a way of reducing anxiety and improving academic performance. It may also deepen our understanding of the dynamic interplay between psychophysiological, cognitive, and emotional processes.

Keywords Biofeedback · Anxiety · Academic Performance · Emotion Regulation

Introduction

Anxiety has been defined as the subjective feeling of tension, fear, nervousness, and worry associated with stimulation of the nervous system (Spielberger 1983). Our approach to anxiety is a psychophysiological one in which physiological processes are considered from a dynamical point of view that takes into account both emotional and cognitive experiences (Damasio 2003). Specifically, physiological activity is both a consequence of emotional activation and a process determining our emotional experience (Friedman 2010). Emotions often occur without the involvement of the cognitive system but can nonetheless affect the cognitive process and its output (LeDoux 1996). Immordino-Yang and Damasio (2007) have suggested that the aspects of cognition which are most heavily recruited in the educational context, namely learning, attention, memory, decision making,

✉ Aitor Aritzeta
aitor.aritzeta@ehu.eus

Goretti Soroa
goretti.soroa@ehu.eus

Nekane Balluerka
nekane.balluerka@ehu.eus

Alexander Muela
alexander.muela@ehu.eus

Arantxa Gorostiaga
arantxa.gorostiaga@ehu.eus

Jone Aliri
jone.alliri@ehu.eus

[1] Department of Basic Psychological Processes and Development, Faculty of Psychology, University of the Basque Country (UPV/EHU), Tolosa Avenue, 70, 20018 San Sebastian, Spain

[2] Department of Personality, Assesment and Psychological Treatment, Psychology, Faculty of Psychology, University of the Basque Country (UPV/EHU), Tolosa Avenue, 70, 20018 San Sebastian, Spain

[3] Department of Social Psychology and Behavioral Sciences Methodology, Faculty of Psychology, University of the Basque Country (UPV/EHU), Tolosa Avenue, 70, 20018 San Sebastian, Spain

[4] Biodonostia Health Research Institute, San Sebastian, Spain

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and social functioning, are profoundly affected by and subsumed within the processes of emotion. In students, anxiety may be accompanied by psychological symptoms (feeling nervous before entering the classroom, tense in examinations, or incapable of doing a task) and physiological ones (sweats, racing heartbeat, chills, muscle tension, rapid breathing, or abdominal pain).

In the first years of university, anxiety, and especially test anxiety, is prevalent and persistent among students (Vitasari et al. 2010), affecting, on average, 25% of them (Gregor 2005). Students with high levels of test anxiety perform worse on tests and their overall academic achievement is lower (Segool et al. 2013). Despite this, and while acknowledging the rise in programs designed to improve emotional abilities (Serrano and Escolar 2011), most university students do not receive specific treatment to reduce their anxiety levels (Cranford et al. 2009). An educational system which does not teach students strategies for understanding and self-regulating the emotional stress associated with learning and test-taking is clearly deficient (Mayer et al. 2008).

A recent review of techniques for reducing anxiety in academic contexts (Miralles and Hernandez 2012) concluded that the most effective ones were behavioral interventions which took into account emotional states (e.g., relaxation, systematic desensitization, stress inoculation, and biofeedback). Prior studies using biofeedback reported significant reductions in anxiety levels among high-school students (McCraty et al. 2000), and the combined use of the biofeedback technique with autogenic training helped reduce anxiety, stress, and depressive states in both the general and clinical populations (Lantyer et al. 2013). Similarly, it has been observed that the technique of biofeedback reduces levels of anxiety in college students (Prato and Yucha 2013). Research conducted with university students are, however, scarce and have yielded contradictory results. Whited, Larkin, and Whited (2014) observed no clear improvement following training in the heart rate variability (HRV) technique, whereas other studies have found that biofeedback has positive effects on both general anxiety and test anxiety (Vitasari et al. 2010). Finally, a comprehensive review of test anxiety interventions concluded that the emWave® biofeedback software program reduced test anxiety and increased academic performance in both children and adolescents (Von Der Embse et al. 2013). Regarding this latter variable, it should be noted that biofeedback studies have mainly been conducted in elementary schools, middle schools, high schools, and colleges, where the technique has been found to improve emotional wellbeing and academic performance (Thurber 2006). However, a recent review indicated that the association between the use of this technique and academic performance was not so obvious (Regehr et al. 2013).

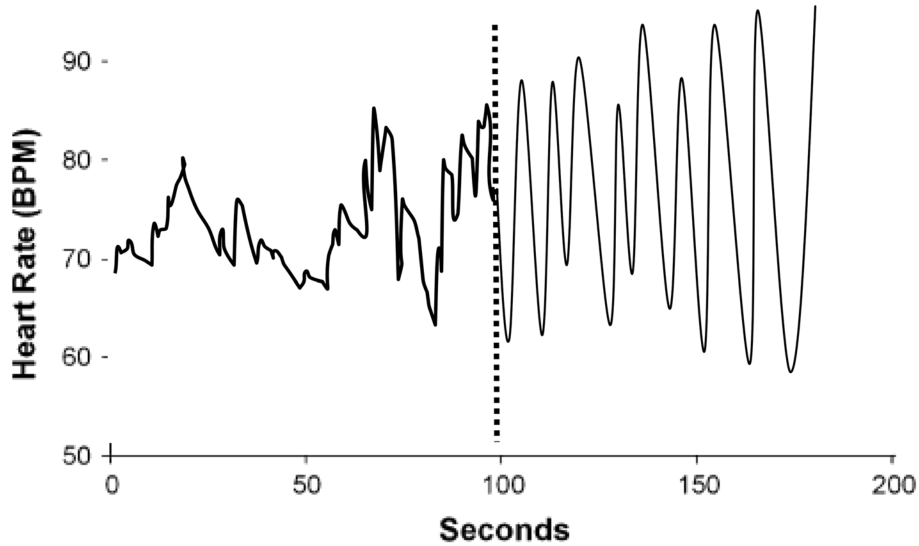
We have found no studies using biofeedback among university students in which different techniques are combined to restrain the negative effects of anxiety and improve test performance. In order to fill this gap and to shed some light on the relationship between anxiety and academic performance, the main goal of the present study was to design and implement a psychophysiological training program based on well-established relaxation techniques (deep breathing, guided imagery, and muscle relaxation), the ultimate aim being to reduce anxiety and improve academic performance in university students.

Biofeedback

The emWave® biofeedback software has been shown to be one of the most comprehensive and widely used approaches for reducing test anxiety in high-school students (Bradley et al. 2007). The emWave® biofeedback training sessions are functionally similar to HRV biofeedback sessions. HRV has been used as an objective measure of the regulatory processes involved in affective stability and cognitive function (Appelhans and Luecken 2006). The computer screen information on HRV that is offered by the emWave® software is fairly similar to that provided by the software used by HRV biofeedback researchers (Lehrer et al. 2003). One of the key concepts in biofeedback training is that of "coherence". The calculation of coherence uses information derived during power spectral density analysis of HRV. In sum, the coherence ratio is the proportion of the waveform immediately surrounding the peak of the spectral density analysis with respect to the remaining components of the waveform (Bradley et al. 2007). High coherence indicates consistent heart rhythm occurring within a frequency band around the peak waveform. Conversely, low coherence will appear as peak distortions and changing frequencies in the spectral waveform (see Fig. 1). McCraty (2005) indicated that biofeedback training is an efficient tool for helping students to use emotion-focused techniques and to self-generate increased coherence. Thus, one would expect that an improvement in coherence as a result of effective biofeedback training would lead to a concomitant improvement in HRV and, therefore, in coherence ratios.

HRV is central to determining the level of emotional coherence achieved by an individual, and, therefore, physiological reactions coming from the heart play an important role in the process of emotional generation and intensification (Lane et al. 2009). The heart possesses an independently functioning nervous system and, compared with other major organs, it has a massive communication system with the brain (Cameron 2002). The rhythmic patterns of the heart affect the function of both the brain and the body. Moreover, afferent communications from the heart affect not only the autonomic regulatory centers in the

Fig. 1 Heart rate variability pattern for an individual participating in a deep breathing session: prior to initiating the deep breathing technique (*left* of the *dotted line*) and after starting with the technique (*right* of the *dotted line*). Note the change in emotional stress indicated by the shift from an erratic and disordered heart rhythm pattern (low coherence) to a sine wave-like (high coherence) pattern



brain but also the higher brain centers that influence emotional and cognitive processing (e.g., thalamus, amygdala, and cortex). Thus, the patterns of information generated in the heart and captured by the emWave® software influence the processes affecting our perceptual and emotional experience (Lane et al. 2009; McCraty and Tomasino 2006; Thayer 2007). In this context, some studies have related HRV to performance on tasks requiring executive function (McCraty et al. 2006; Thayer et al. 2009), as well as to self-regulatory effort and fatigue (Segerstrom and Nes 2007). This is in line with the well-established relationship between positive emotions (i.e., better HRV) and both cognitive function and task performance (Fredrickson 2002; McCraty and Tomasino 2006).

The training program designed in the present study seeks to give students a mental sensation of control over unpredictable anxiety-provoking situations that are accompanied by unpleasant physical reactions. The goal of the intervention was to teach students a set of relaxation techniques in order to help them to prepare themselves mentally and physically to confront anxiety during their studies and when sitting exams. The biofeedback program we created combines deep breathing, cognitive visualization, and muscle relaxation.

Relaxation Techniques

Deep Breathing

The psychophysiological arousal generated by deep breathing training has been shown to improve handling of anxiety (Johnson et al. 2009). One of the purposes of this kind of training is to increase breath awareness by helping individuals to perceive their natural and slow rhythm (Gill et al. 2004). Deep breathing training consists in learning to breathe more slowly and deeply, which slows diaphragmatic breathing, balancing out the oxygen and carbon dioxide levels in the body and, therefore, lowering the individual's heart rate. In this type of breathing, where respiration is controlled, it is important that air is inhaled through the nose and exhaled through the mouth, as this will help the body to react with less severe symptoms in situations of anxiety or panic. Heart rate can be decreased by lowering the respiration rate and this may help to counteract the effects of a fast heart beat activating the parasympathetic nervous system (Prato 2009), thus increasing cognitive control over the autonomic nervous system and decreasing psychophysiological arousal. In this regard, research has reported 75% success among 1000 patients with anxiety and hyperventilation after using breathing therapy (Gill et al. 2004).

Guided Imagery (Positive Visualization)

Guided imagery is commonly used as a tool to encourage subjects to enter a calm, safe, content, and relaxed state. A positive visualization activity is verbally introduced by the guide as a narrative of thoughts and suggestions that guide the listener's imagination. Although visual images are the most commonly evoked stimuli, sounds, smells, tastes, and sensory or affective feelings may also be induced (Jost 2004). Psycho-neuro-immunological theories propose that the psychological response to guided imagery may down-regulate the hypothalamic-pituitary-adrenal-axis, resulting in a reduced stress response, increased immune function, and greater sense of well-being (Roffe et al. 2005). Several studies have shown that guided imagery reduces anxiety and associated symptoms both in clinical samples (Apóstolo and Kolcaba 2009; Cupal and Brewer 2001; Foji et al. 2015) and among students (Peck et al. 2003). In our training program, images of love, compassion, and forgiveness were intentionally generated with the aim of producing a change in the pattern of afferent cardiac signals sent to the brain, reinforcing the self-generated positive emotional shift and making it easier to sustain.

Jacobson's Muscle Relaxation

Jacobson's muscle relaxation (PMR; Jacobson 1929) is a systematic technique for achieving a deep state of relaxation through a progressive tensing and relaxation of various muscle groups. Because muscle tension is associated with various types of psychological tension, anxiety can be reduced by learning to reduce muscle tension. PMR plays an important role in the modern treatment of anxiety disorders in the clinical context (Blanco et al. 2014; Conrad and Roth 2007), and it has also formed part of strategies for reducing the anxiety symptoms of non-clinical university students (Dolbier and Rush 2012; Gill et al. 2004). Application of PMR has been shown to reduce stress and anxiety, to improve symptoms such as tension headaches and insomnia, and to make a positive contribution to adjunctive therapy in cancer, chronic pain management in inflammatory arthritis, and the treatment of irritable bowel syndrome (Innes et al. 2010; McCallie et al. 2006). Furthermore, PMR has been reported to improve the quality of life of patients after bypass surgery and of patients with multiple sclerosis (Ghafari et al. 2009). A reduced version of the original muscle relaxation technique was used in the present program. In our approach, and compared with the original version, students learned how to tense and relax larger groups of muscles. These muscle groups were (a) feet and legs; (b) stomach and chest; (c) arms and hands; (d) shoulders, back, and neck; and (e) face.

As mentioned before, the three described techniques (deep breathing, guided imagery, and muscle relaxation) have been shown to be effective in reducing anxiety and stress. Consequently, and taking into account the aforementioned results, we expected to observe a reduction in anxiety in students after completing the training program. We also expected that the reduction in anxiety would help them to improve their academic performance.

Method

Participants

A total of 152 psychology undergraduates from the University of the Basque Country (UPV/EHU) received the biofeedback program (experimental group). Their mean age was 19.6 years (SD = 0.74) and 79.7% of them were women. The control group comprised 81 second-year psychology undergraduates from the same university. Their mean age was 19.4 years (SD = 0.92) and 76.5% of them were women. This study received the approval of the Ethics Committee for Human Research of the University of the Basque Country (UPV/EHU).

Instruments

The coherence ratios were determined by continuous HRV recordings, which were gathered by noninvasive measurement of the pulse throughout a 10-min period using the emWave® desktop system developed by HeartMath (McCraty et al. 2006). From the inter-beat interval data, a number of standard indices of HRV, a measurement of the heart rhythm coherence and the key marker of the psychophysiological coherence state, were derived. The emWave® system transforms these HRV values into high, medium, and low coherence values on a scale ranging from 0 to 100. Thus, each student obtains a total of 100 points divided into high, medium, and low coherence ratios. The program also offers four challenge options: low, medium, high, and highest. All students started at the low challenge level and remained at that level from session 1 to session 5.

Anxiety was measured by the State-Trait Anxiety Inventory (STAI) (Spielberger et al. 1970) in its 8th revised Spanish version (Buela-Casal et al. 2011). The STAI is a brief, easily administered scale consisting of 40 items coded on a 4-point Likert scale (ranging from 0 to 3), and it comprises two anxiety self-evaluation scales: State Anxiety and Trait Anxiety. The State Anxiety scale comprises 20 items and examines actual levels of anxiety, a more contextual anxiety factor (e.g., "Me siento calmado/a"/"I feel calm"). The Trait Anxiety scale is also composed of 20 items and examines a more stable predisposition of subjects to respond to situations with anxiety (e.g., "Suelo tomarme las cosas demasiado seriamente"/"I usually take things too seriously"). The STAI shows acceptable psychometric properties in both the original and the Spanish versions. Moreover, it is sensitive to experimental manipulations of stress by discriminating between stable and transient factors contributing to anxiety. In this study, the two STAI factors showed good internal consistency, with Cronbach's alpha values of 0.83 for State Anxiety and 0.86 for Trait Anxiety.

Academic performance was assessed through exams based on a multiple choice format in which students could score from 0 to 10 points. These exams assessed the students' objective knowledge that had previously been worked on in theoretical lessons. For example, the first test examined physiological, cognitive, sociocultural, and neurobiological theories of emotions. The second test evaluated the functional perspective of basic and complex emotions, while the third tested students' knowledge of current research on emotion. The results of these tests were used for the students' final records.

Procedure

Intervention using emWave® (formerly Freeze Framer) is based on the induction of positive emotional states, which are related to psychophysiological coherence as defined by its creators at the HeartMath Institute (McCraty et al. 2006). The electrophysiological study presented was designed as a controlled laboratory experiment, using measures of HRV (transformed into coherence values) to investigate the degree to which students have learned the emotion self-regulation techniques developed in the program.

The biofeedback training program consisted of five sessions coupled with three training activities focused on deep breathing (before session 2), guided imagery (before session 3), and muscle relaxation (before session 4). The program was applied over an 8-week period, during which time three exams were set: the first before session 1 (course week 4), the second after session 3 (course week 8), and the last after session 5 (course week 12). After each training session, students were provided with a notebook in which they had to write down the details of the exercises (i.e., time, place, hour of the day, subjective perceptions of how they felt during and after each exercise and their subjective view about the efficacy of the technique to reduce their stress level). This notebook was kept by the students throughout the period of the program. Following each training session, students were asked to train at home. A summary of the training program is shown in Table 1.

In course week 4, students had to sit a multiple choice test in which they had to show how much they knew about classical emotion theories. During this same week and on the day before the test, each student was assigned to a workstation equipped with a PC and was connected to an optical earlobe sensor to measure his/her pulse. The room in which the program was implemented had 20 PCs and was a comfortable and silent space. In order to train the students properly, the total sample of the experimental group ($N = 152$) was divided into 8 subgroups of about 20 students each. During the biofeedback sessions each participant's pulse was continuously recorded for approximately 10 min, except in session 1 (baseline period), where the recording time was only 5 min. In this session, baseline HRV data were collected for both the experimental (academic year 2014–2015) and control groups (academic year 2013–2014). In this resting baseline session, students were asked to sit quietly and to refrain from talking, moving, falling asleep, or engaging in any specific technique or practice.

In course week 6 and before the second biofeedback session, a deep breathing technique was taught to students in the experimental group during a 30-min training period. Students were shown to breathe deeply and cyclically, and instructed to place one hand on their chest and the other on their abdomen. The aim here was to enable them to perceive that when they took a deep breath in, the hand on the abdomen rose higher than the one on the chest, which ensures that the diaphragm is pulling air into the bases of the lungs. The exercise was repeated until they felt comfortable and had all achieved a deep breathing cycle. Once the training had finished, students underwent another 10-min biofeedback session, during which time they applied the deep breathing technique they had learned. After the session, students were provided with the aforementioned exercise monitoring notebook and were asked to practice the deep breathing technique twice a week for 10 min each time.

In course week 8, students sat another exam, the day before which they were introduced to a guided imagery technique. A visualization of an image formed by green grass, blue sky, soft wind, birdsong, trees moving gently in the wind, and a lake with blue and green colors was presented verbally by the researcher in order to guide the participants' imagination. The narrative was accompanied by classical music. After this first guiding narrative, students had the option of deciding whether to retain and go further into the proposed image or to find their own relaxing image associated with feelings of flow. With the aim of visualizing the image more vividly, students spent 15 min individually describing it in detail by indicating in a notebook the place, the colors, any people or animals present, and the smells, etc. They were then asked to spend 10 min writing down the feelings associated with the image. After concentrating on the details of the selected image and on the associated feelings, a 10-min biofeedback session was then conducted with eyes closed and deep breathing. Students were asked

Table 1 Summary of the biofeedback training program for the experimental group

	Biofeedback Session 1	Biofeedback Session 2	Biofeedback Session 3	Biofeedback Session 4	Biofeedback Session 5
Course week	4 (Baseline)	6	8	10	12
Exam	Yes	No	Yes	No	Yes
Relaxation technique	None	Deep breathing	Guided imagery	Muscle relaxation	Combination
Anxiety measured	Yes	No	No	No	Yes

to practice the visualization at home at least once a week and to record in their notebook the details of the exercises.

In course week 10, Jacobson's muscle relaxation technique was performed in another room in which students could move their body with no restrictions. The room was darkened and the students were sat comfortably with their eyes closed. A reduced version of the Jacobson progressive relaxation technique was applied for 45 min. This technique involves learning to deliberately induce tension in each specific muscle group of the body. This tension is then released by paying attention to the contrast between tension and relaxation. Once the training had finished, students returned to the biofeedback room for another 10-min session. Students were told to continue practicing the muscle relaxation technique at least once a week in their daily lives, and to focus especially on those muscle groups they found difficult to relax.

Finally, in week 12 and 1 day before the last exam, students had the last biofeedback session, in which they were invited to progressively use all the techniques (deep breathing, visualization, and muscle relaxation) learned during the previous sessions. The aim here was to improve their HRV values and obtain high coherence values.

For the control group there was no biofeedback training program. However, in course week 4, control participants had to take the same test as did the students in the experimental group, and one day before this test they each underwent a 5-min biofeedback session. In this session the control students were asked to sit quietly and to refrain from talking, moving, falling asleep, or engaging in any specific technique or practice. Students from the control group sat the same three tests at the same time points (weeks 4, 8, and 12) as the experimental group. They also completed the same anxiety tests as the experimental group did, that is, in course week 4 and in course week 12 prior to the final test.

Data Analyses

In order to examine the impact of the program on the studied variables, two types of analyses were performed. First, the Student´s *t*-test for related samples was calculated to compare pre- and post-program scores on anxiety and academic performance for the experimental group. For each comparison of means the effect size was also calculated by using the *r* index. Second, univariate and multivariate analyses of covariance were used to compare the scores obtained by the students in the experimental and control groups, taking as the predictor variable the experimental versus control condition and as covariates the scores for anxiety and performance prior to implementation of the program. Hedges' *g* was calculated for each comparison as a measure of the effect size.

Third, a repeated measures analysis of variance was carried out to examine the improvement in the level of coherence of the participants in the experimental group over the five biofeedback sessions. Finally, a mixed factor analysis of variance was performed to analyze change in the academic performance of both groups across the 12 weeks study period. In both cases, the *r* value was used as an index of the effect size.

Results

As can be seen in Table 2, the differences between the pretest and post-test measures were statistically significant and showed a large effect size for state anxiety ($r=0.82$), trait anxiety ($r=0.84$), and academic performance ($r=0.81$). After the program, levels of anxiety were reduced and levels of performance improved.

The results obtained in the analysis of covariance showed that, when controlling for pretest scores, anxiety levels in the experimental group were significantly lower than in the control group (M = 35.37 vs. M = 42.04, and M = 35.99 vs. 42.61 for state and trait anxiety, respectively). The effect sizes for these comparisons were large ($g=2.48$ and $g=2.50$). In addition, and compared with the control group, the experimental group achieved a significantly better test performance, with a high effect size (M = 7.89 vs. M = 6.27; Hedges' $g=1.63$). These results are displayed in Table 3.

The results of the repeated measures ANOVA indicated that differences in coherence scores were statistically significant ($F_{(2.21,\ 335.5)}=445.87$; $p=0.001$), with an effect size of $\eta^2=0.77$. The comparisons between pairs of means showed statistically significant differences between each of the means and its preceding value, with effect sizes ranging from $r=0.59$ to $r=0.76$. The increase in coherence measures across successive sessions is depicted in Fig. 2.

Table 2 Mean scores and standard deviations for anxiety and academic performance for participants in the experimental group before and after the training program; Student's *t*, and *r* values

	Pretest		Post-test		$t_{(152)}$	*P*	*r*
	M	*SD*	*M*	*SD*			
State anxiety	40.09	6.99	35.36	6.37	17.69	0.001	0.82
Trait anxiety	40.80	6.76	35.90	5.85	18.80	0.001	0.84
Performance	6.29	1.41	7.81	1.57	−17.30	0.001	0.81

Finally, the mixed ANOVA results reveal a statistically significant main effect of time ($F_{(1.76,\ 407.70)}=59.06$, $p=0.001$; $\eta^2=-0.20$) for the experimental condition ($F_{(1,\ 232)}=10.32$; $p=0.002$; $\eta^2=0.04$), as well as a statistically significant interaction between these two variables ($F_{(1.76,\ 407.70)}=91.91$; $p=0.001$, $\eta^2=0.28$). This interaction implies that the change in academic performance was different among students in the experimental group compared with those in the control group. In order to explore further the meaning of this interaction we conducted mean comparisons of performance, comparing performance in the first test with that in the second, and performance in the second test with that in the third. As can be seen in Fig. 3, these comparisons revealed that the increase in performance between test 1 and test 2 is greater for the experimental group than for the control group ($F_{(1,\ 232)}=61.14$; $p=0.001$; $r=0.46$). Likewise, the performance of the experimental group increased between test 2 and test 3, whereas that of

Table 3 Mean scores and standard deviations for anxiety and academic performance for participants in the experimental and control groups after the training program; *F* values, and Hedges' *g* values

	Experimental group		Control group		*F*	*P*	Hedges' *g*
	M	*SD*	*M*	*SD*			
State anxiety	35.37	6.37	42.04	6.66	321.78	0.001	2.48
Trait anxiety	35.99	5.85	42.61	6.40	328.61	0.001	2.50
Performance	7.89	1.57	6.27	1.22	139.42	0.001	1.63

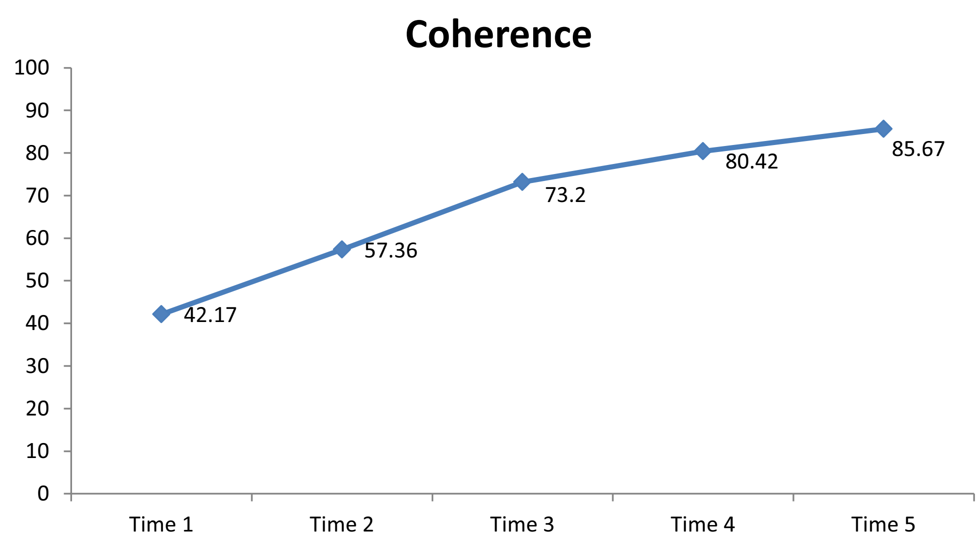


Fig. 2 Change in the mean scores for coherence across the five measures

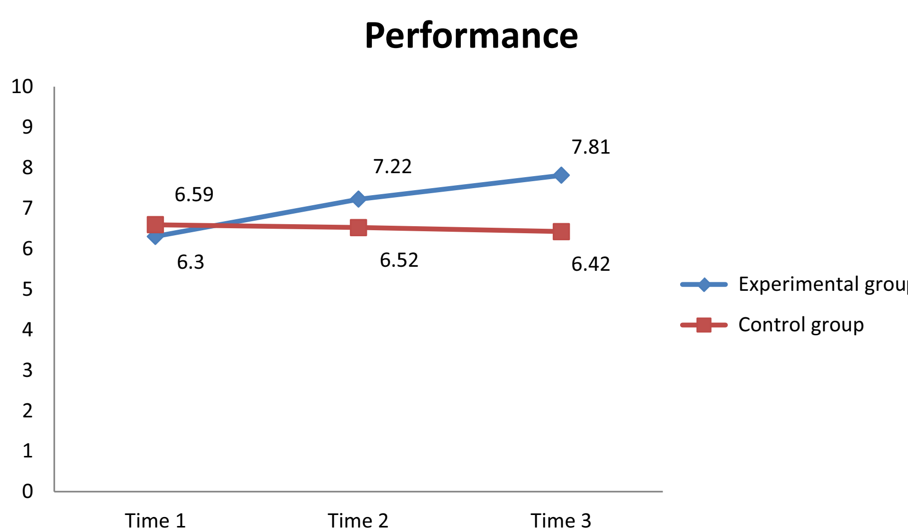


Fig. 3 Change in the mean scores for academic performance over the three tests and according to the experimental condition

the control group decreased ($F_{(1, 232)}=45.32$, $p=0.001$; $r=0.40$).

Conclusions

This study examined the effect that a biofeedback training program involving emotional regulation techniques had on anxiety levels and academic performance. The results showed that after participating in this program, students improved their ability to physiologically self-regulate their emotions, thereby reducing their anxiety levels. Furthermore, when compared with students who did not participate in the program, they also showed better academic performance and lower anxiety levels.

These results are in line with previous studies supporting the efficacy of this approach in educational settings, in which HeartMath programs have been shown to improve emotional stability, psychosocial functioning (Arguelles et al. 2003), learning (Bradley et al. 2009; Hartnett-Edwards 2008), and academic performance (McCraty 2005; McCraty et al. 1999) in students at different grade levels. All these studies, though some of them are not peer reviewed, support the idea that an improvement in autonomic nervous system function positively affects health and cognitive functions, since HRV is considered a psychophysiological indicator of cognitive functioning, emotion self-regulation abilities, and core regulatory functions (Bradley et al. 2009; Segerstrom and Nes 2007; Thayer et al. 2009). High HRV reflects high emotional coherence, which increases psychological and physiological flexibility and adaptability to environmental demands. Low HRV reflects low emotional coherence ratios, which could affect the parasympathetic activity that is associated with a loss of inhibitory control over anxiety (Friedman and Thayer 1998a, b). Thus, biofeedback training programs may be useful for the physiological self-regulation of emotions and, as shown in our study, for managing and reducing levels of anxiety.

Our findings are also consistent with those of Segerstrom and Nes (2007), who reported that HRV measures of self-regulatory strength and effort can be successfully investigated outside the laboratory in a controlled field context (McCraty et al. 1999). If coherence-building techniques are regularly practiced, then the learned physiological, emotional, and cognitive patterns become increasingly familiar to the brain. These patterns feed-forward neurological connections to a new set point, a point which the cognitive processes activated by these techniques then strive to maintain through a feed-forward process (McCraty and Tomasino 2006). This psychophysiological re-patterning process has been observed in other studies that have documented enduring improvements in health, psychological well-being, and socio-emotional function in individuals who used coherence-building tools over a period of several months (e.g., McCraty et al. 2009, 2003).

The present study does have certain limitations that need to be mentioned. First, from a methodological point of view, we measured coherence values reported by the emWave® software rather than direct physiological HRV values. Thus, further research is needed in order to compare the data obtained by these two measurement methods. Second, the time invested in training students in physiological relaxation techniques was quite short, and we could not control entirely what the trained students did while they were not at the university. Therefore, it may be useful to gather further longitudinal data by extending the training time and controlling participants´ behavior outside the training sessions. Third, the correlational nature of this study does not allow any conclusions to be drawn regarding causal effects. Thus, more research (with an experimental design) is needed to disentangle the causal relationships between anxiety and performance.

Students mentioned in their written reports that they found it difficult to progressively combine the three techniques in the last session. Besides, observed the evolution of the coherence ratios along the five sessions, the improvement change ration from session 4 to 5, where they should combine them, was the lowest one. In this sense, a possible direction for future inquiry would entail examining the degree to which the use of just two techniques (deep breathing and visualization) would be a more feasible and effective approach to reduce test anxiety.

Acknowledging such limitations, we consider that electrophysiological measurements of the kind used here can contribute to our understanding of the interplay between students´ cognitive functions, emotions, and anxiety management. Coherence values based on HRV provide an index of the physiological substratum of anxiety and emotional function, and we believe that this could help to clarify how interconnections among physiological, emotional, cognitive, and social processes affect students' learning behavior. The inclusion of biofeedback programs in educational contexts may provide an opportunity to further our understanding of the dynamic interplay between psychophysiological processes, emotions, learning, and academic performance, due to the connections that exist between emotion, social functioning, and decision making.

Compliance with Ethical Standards

Conflict of interest All authors of this work declare that have no conflict of interest.

Ethical Approval This study followed the ethical guidelines for research involving human subjects and all procedures performed in this study were in accordance with the 1964 Helsinki declaration and its later amendments. This investigation was approved by the Ethics Committee for Human Research of the University of the Basque Country (UPV/EHU). Informed consent was collected from all participants included in the study.

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