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Objective physiological measurement of study-related and test anxiety in university students using biofeedback technology

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Abstract

Background Pre-exam anxiety is a very common feeling among university students that manifests at cognitive, behavioural, and physiological levels. It affects between 15 and 25% of students, generating avoidance behaviours towards evaluation, which can result in dropping out of school. The development of biofeedback-based devices that relay visual and auditory feedback on physiological symptoms, offers new options for individual programmes. Said devices can help a person acquire greater control over the bodily function that is being monitored and are currently being used in many fields. It is therefore worth assessing the effectiveness of this technology at processing information on the objective physiological response to anxiety in study situations. Furthermore, universities could develop health programmes implementing this technology to improve students' quality of life.

Objective During the biofeedback sessions, the aim is to collect physiological measures of the anxiety response before and after two independent preventive psychological programmes. It is also intended to assess the presence of differences between physiological and subjective data through questionnaires with Likert-type scales.

Methods Two experimental groups were formed for this quasi-experimental applied research: G1 (19 students), Students participating in a Self-Control and Study Techniques Programme; and G2 (12 students), Students participating in the Test Anxiety Control Programme. Their objective physiological responses were evaluated in two biofeedback sessions: pre-test (before the start of the programmes) and post-test (after their completion) (4 weeks for G1 and 12 weeks for G2). The biofeedback device used was Neurobit Optima 4 + BT. The inclusion criteria were: (1) age of majority (18 years); (2) voluntary participation in the programs offered by the University Health Care Service of the University of Burgos; (3) signing the informed consent form. A $P\text{-value} \leq 0.05$ was considered statistically significant.

Results Twenty-two adults divided into G1 (12 students, 1 man and 11 women) and G2 (10 students, 1 men and 9 women) completed the programmes. The mean age and Standard Deviation (SD) of G1 and G2 were, respectively, 24.20 (6.93) years



old and 25.00 (6.22) years old. There were significant temporal differences between measurement sessions (all $P < 0.045$). G1 presented significantly different galvanic skin responses (all $P < 0.011$) that tended to peak; G2 presented significantly different muscular tension and galvanic skin responses (all $P < 0.037$), both in total and by phases, showing progressively lower muscular tension, and galvanic skin responses that tended to peak. In G1, significant links were noted both between the items of the Test Anxiety Inventory (TAI) and the galvanic skin responses monitored during the pre-test session ($r = 0.229$; $P = 0.012$) and between the items of the Test Anxiety Inventory and the galvanic skin responses monitored during the post-test data-collection session ($r = 0.201$; $P = 0.028$). In G2, significant links were noted between the State-Trait Anxiety Inventory items and both muscular tension ($r = 0.278$; $P = 0.005$) and the galvanic skin response in the pre-test data-collection session ($r = 0.258$; $P = 0.010$) and between the TAI items and the galvanic skin response in the post-test data-collection session ($r = -0.232$; $P = 0.020$). Most participants reported useful and interesting biofeedback experiences.

Conclusions Promising preliminary evidence is advanced in this study on the effectiveness of biofeedback as a tool for monitoring and relaying objective physiological data to participants in real time. The significance of these results should be examined in future research in which the emotional reactions of students facing test-related anxiety may be monitored for the subsequent development of therapeutic programmes.

Keywords Biofeedback, Test anxiety, Mental health, Students, Universities

1 Introduction

Test anxiety (TA) refers to a tendency to experience heightened physiological arousal and worry when facing an evaluation. It manifests itself at physiological, behavioural, and cognitive levels. It is expressed through failure anticipation, low self-esteem, social judgement, and loss of expected outcomes. It is a specific situational trait, *i.e.*, repeated high-anxiety responses to test-related circumstances. High TA is generally associated with reduced academic performance and difficulties applying learned skills [1–3]. It is estimated that 15-to-25% of students experience from high levels of TA [1].

Students with TA experience increasing anxiety as the exam approaches – ranging from cognitive concerns at early stages to intense physiological, behavioural, and cognitive reactions immediately before, during, and after the exam [2, 4, 5]. The anxiety response may vary during and after completion of an exam, depending on the exam instructions, its importance, and difficulty [2].

Given its impact on academic performance, tailored intervention techniques are needed, targeting either anxiety control or study-skill improvement [2, 4]. Anxiety control techniques address *irrational anxiety*, where students feel very nervous despite adequate preparation. In contrast, study-skill techniques target rational anxiety, stemming from poor study habits and lack of self-control [6].

Biofeedback represents an alternative approach to treating anxiety. It involves measuring physiological parameters (e.g. heart rate, muscle tension) and providing real-time feedback, enabling individual to consciously regulate otherwise unconscious processes.

It is considered safe, with minimal side-effects, and is increasingly integrated into treatment plans despite limited conclusive evidence [7]. When applied to mental health, biofeedback measures physiological changes linked to psychological states of mind, and it is one of the very few treatments that have been shown to mitigate the symptoms of

anxiety-related disorders. Furthermore, technological advances have made biofeedback affordable, cost-effective, and easy to use among health professionals working to improve the health of their patients [7–9].

Biofeedback has been applied in a wide range of conditions, including chronic pain, insomnia, migraine, epilepsy, urinary and faecal incontinence, and depression [7–20].

Beyond therapeutic use, biofeedback also serves as a precise tool for recording physiological variables, complementing traditional clinical assessments [21].

The main objective is to assess physiological responses to anxiety before and after two independent preventive psychological programmes: one focused on self-control and study skills (ST) (*rational anxiety*) and the other on exam-anxiety (EA) (*irrational anxiety*). The initial hypothesis is that, after completion of said programmes, the anxiety levels detected by the biofeedback device should decrease.

A further aim is to compare objective biofeedback data with subjective questionnaire data. Finally, correlations among physiological variables (muscle tension, respiration, skin conductance) will be explored to identify the most sensitive indicators for future protocols.

2 Methods

2.1 Study design

The study was quasi-experimental with two groups: G1 (Self-Control and Study Techniques (ST), 4 weeks) targeting rational anxiety, and G2 (Pre-Exam Anxiety Control Programme (EA), 12 weeks) targeting irrational anxiety. The ST and the EA course units took place during the months of March-to-April and February-to-May 2023, respectively.

The sample included 31 students (19 ST, 12 EA). The inclusion criteria were: (1) age ≥ 18 , (2) voluntary participation, (3) signed consent. The exclusion criteria were: (1) medical/psychiatric conditions interfering with measures, (2) incomplete programme attendance.

2.2 Recruitment and selection

Recruitment for both programmes was conducted via social media by the University Health Care Service (SUAS) of the University of Burgos (UBU) in January 2023. Interested students requested one of the programmes and completed a set of pre-tests and an interview. After that, they were assigned to G1 or G2 by the professional team.

2.3 Procedure

Physiological data were collected individually before (pre-test) and after (post-test) the programme using biofeedback, following a standardized 4-phase protocol: baseline, trait-anxiety, state-anxiety, return to calm. The objective responses measured with biofeedback were: (1) Respiratory tension (respiration belt), (2) Muscular tension (3 electrodes), (3) Electrodermal activity (EDA) (2 electrodes). Subjective anxiety-related responses were also collected, before and after the programme, using a set of tests/scales (questionnaire).

Having formed the groups for the programme, the pre-test biofeedback session took place during the week in which the sessions began. During the first sessions for both programmes, an explanation of the physiological data-collection project was given to the

students. They were told that their participation would be voluntary and unremunerated. The students who voluntarily joined the programme were given individual appointments with the researcher. The appointments took place in a separate space to ensure that confounding variables were controlled. During both the biofeedback session and the completion of the questionnaires, the participant was alone with the researcher, with no other people present.

Subsequently, the participants from both groups continued the normal development of the course units corresponding to the programme in which they were participating. The content of the units varied in accordance with the purpose of the programme: 5 units in the case of G1 (ST) and 12 in the case of G2 (EA).

At the end of the last course units of both the ST and the EA programmes, the post-test biofeedback session took place. Likewise, an individual meeting with each participant was arranged to collect the data and complete the questionnaire.

Each biofeedback session included a baseline adaptation (4 min), trait-anxiety questions (3 min), state-anxiety questions (3 min), and a recovery phase (2 min). Standardized questions were based on Spielberger's *State-Trait Anxiety Inventory* (STAI) (2015) [22].

2.4 Data-collection instruments

1. Informed consent.
2. Sociodemographic data: anonymous participation code, age, sex, studies.
3. Anxiety questionnaire. The versions used in the study were valid and reliable.

3.1 *State-Trait Anxiety Inventory* (STAI) of Spielberger et al.(2015) [22].

The STAI measures state and trait anxiety (20 items each, 4-point Likert). It shows high internal consistency ($\alpha = 0.84\text{--}0.93$).

3.2 *Test Anxiety Inventory* (TAI) of Spielberger (1980) [24] and *Inventory of Test Anxiety* (ITA) of Osterhouse (1969) [25].

The TAI (20 items, 4-point Likert) and ITA (16 items, 5-point Likert [26]) measure exam-related anxiety. Both show high reliability ($\alpha \geq 0.92$).

4. Biofeedback Device.

Neurobit Optima 4 + BT, manufactured by Neurobit Systems in Poland, was used in this study [27, 28]. This model is capable of recording the following physiological signals: heart rate (HR) and heart rate variability, respiratory tension and frequency (RF), superficial muscle tension, electrodermal activity (EDA), and skin temperature [33].

A diagram that depicts three signals was outlined for the development of this investigation [33]:

- *Respiration and respiratory tension* were measured with a chest belt. RF is a sensitive stress indicator, with normal adult values between 12 and 20 breaths/min [29–31].

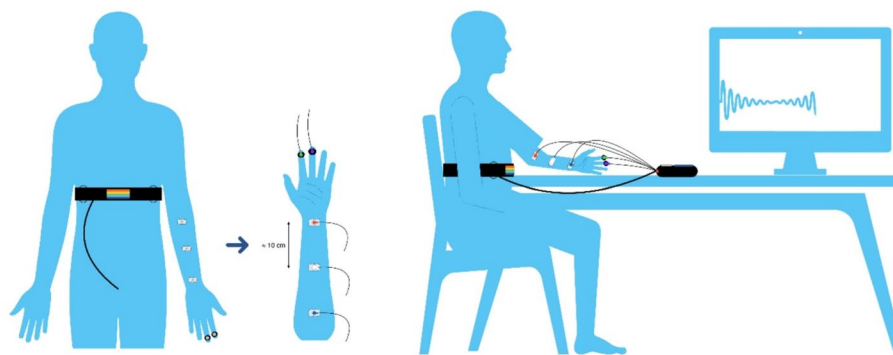


Fig. 1 Sensor placement

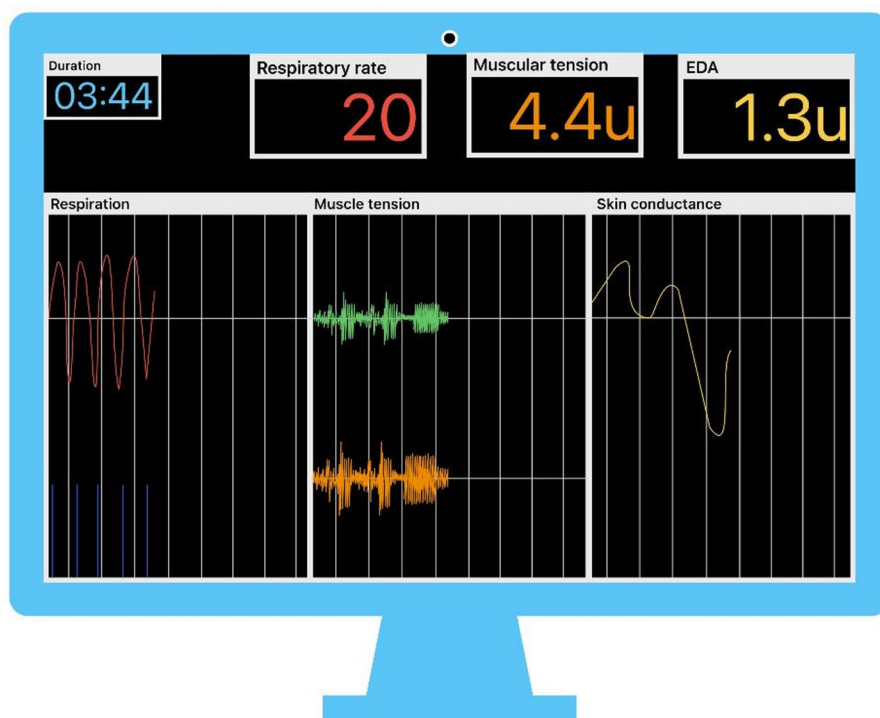


Fig. 2 Example of physiological feedback display

- *Superficial muscle tension* (sEMG) was measured with 3 electrodes positioned in the forearm. Values increase with stress, ranging from ~ 0 to $2.5 \mu\text{V}$ at rest to 2.5 to $6 \mu\text{V}$ under contraction [33, 34].
- *Skin conductance* was measured with two electrodes on the fingertips of the index and middle fingers. Increases in sweat gland activity under stress reduce skin resistance, producing higher values [35, 36].

The previously mentioned distribution of the sensors on the body is shown in Fig. 1. In Fig. 2, an example is shown of the objective physiological responses that the participants can see on-screen.

5. Satisfaction survey: An ad hoc satisfaction survey (Likert 1–5 points, plus open questions) evaluated students' perceptions of the data-collection process.

2.5 Statistical analysis

The analysis of the results includes the FD (proportions and their confidence intervals, in the case of the qualitative variables); the measures of the central trends (averages and their confidence intervals) and scatter (standard deviation) with regard to the quantitative variables.

The Chi squared (χ^2) test was applied as the hypothesis test for the qualitative variables, and wherever the criteria of application were not met, Fisher's exact test.

The Student *t*-test was used for paired data, to compare the data on anxiety with the PRE and POST physiological data measures, as those data were quantitative variables in related groups; if the criteria for its application were not met, then the Wilcoxon Signed Rank Test was used. The Shapiro-Wilks *W* test for small samples (<30) was used and the IBM Statistical Package for Social Sciences (SPSS) version 25.0 (IBM Corp., Armonk, NY) for data analysis. An *p* bilateral value of 0.05 was taken for the determination of significant differences.

3 Results

3.1 Participant enrolment

The flow diagram of participants included in this study is shown in Fig. 3. From 31 students enrolled 22 met eligibility and consent criteria ($G1 = 12$, $G2 = 10$). Attrition was higher in $G1$ (33–67%) than $G2$ (17%).

Reasons for attrition included non-completion of units (86%) and missed post-test session (14%).

3.2 Participant demographics

The initial characteristics of participants are shown in Table 1. Baseline characteristics did not differ significantly between groups (all $P > .72$). Most participants were female (91%) and undergraduate students (95%), with 45% in Engineering/Architecture.

3.3 Temporal analysis—data-collection sessions

Sessions lasted ~ 12 min (baseline, trait-anxiety, state-anxiety, recovery).

Post-test sessions were significantly shorter than pre-test for both groups, especially in adaptation and anxiety phases (see Tables 2 and 3).

3.4 Physiological measures

Table 4 lists the pre- and post-test data-collection results for average respiratory tension, muscular tension and skin conductance for $G1$. It likewise shows the maximums and minimums of each signal. Table 5 shows the previous data for $G2$.

In $G1$, skin conductance increased significantly post-test ($P < 0.001$). In $G2$, muscular tension decreased ($P < 0.001$) while skin conductance increased ($P < 0.001$).

Tables 6 and 7, and 8 list the mean values for respiratory tension, muscular tension, and skin conductance pre- and post-test for $G1$ (ST), divided into the different phases of the data-collection sessions.

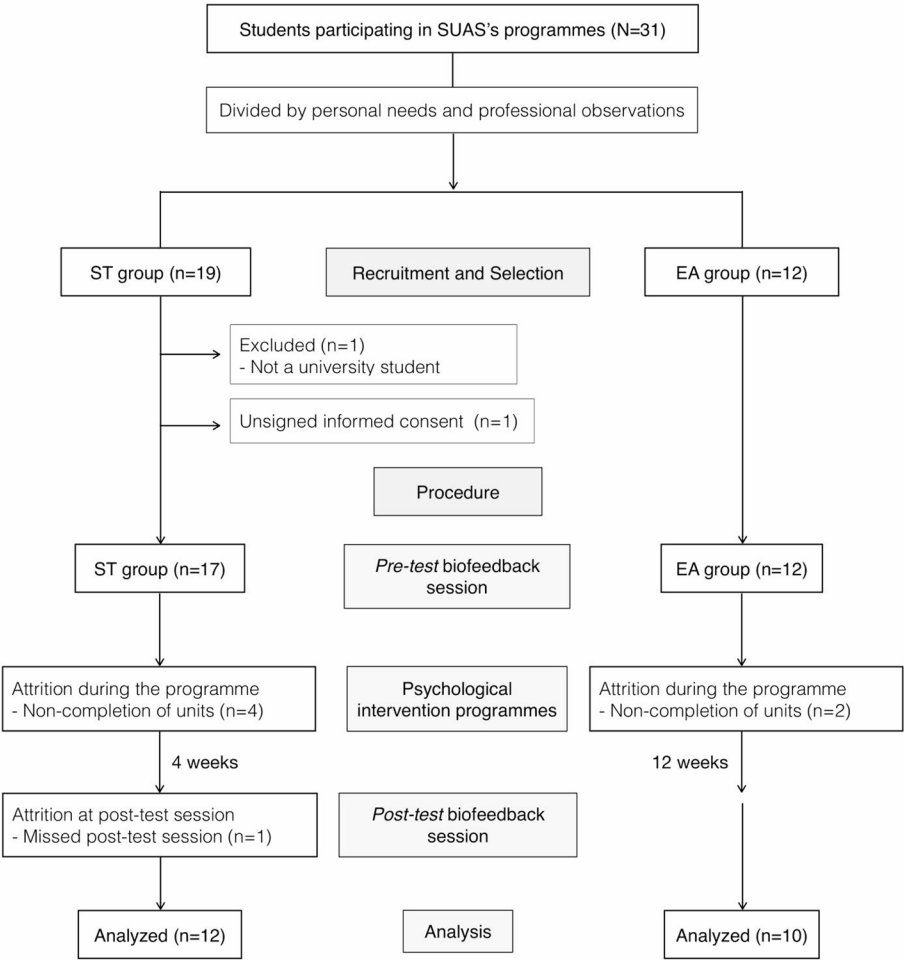


Fig. 3 Flow diagram of participant enrolment, exclusions, and retention

Table 1 Baseline demographic characteristics of participants (N = 22)

Characteristics	G1 (ST) (n = 12)	G2 (EA) (n = 10)	P-value
Age (years) ^a average	24.20	25.00	0.46
Sex, n (%)			1.000
Men	1 (8)	1 (10)	
Women	11 (92)	9 (90)	
Type of studies followed, n (%)			1.000
Degree	11 (92)	10 (100)	
Master's	1 (8)	0 (0)	
Doctorate	0 (0)	0 (0)	
Studies by branch of knowledge, n (%)			0.717
Arts and humanities	2 (17)	0 (0)	
Sciences	1 (8)	0 (0)	
Health Sciences	1 (8)	2 (20)	
Social and Legal Sciences	3 (25)	3 (30)	
Engineering and Architecture	5 (42)	5 (50)	

^a Adjusted and weighted by sex

Table 2 Duration of the data-collection sessions—G1 (ST)

Session phase	Pre	Post	P-value
Total duration (mm: ss) ^a , mean (SD)	12:45 (3:13)	8:42 (3:41)	0.045
(1) Adaptation (mm: ss), mean (SD)	4:46 (2:18)	3:03 (1:48)	0.041
(2) Trait-anxiety (mm: ss), mean (SD)	3:24 (1:06)	2:21 (1:08)	0.041
(3) State-anxiety (mm: ss), mean (SD)	2:53 (1:07)	1:50 (0:34)	0.028
(4) Return to calm (mm: ss), mean (SD)	1:40 (0:52)	1:27 (1:01)	0.814

^a mm: ss – minutes: seconds**Table 3** Duration of data-collection sessions – G2 (EA)

Session phase	Pre	Post	P-value
Total duration (mm: ss) ^a , mean (SD)	15:10 (3:37)	8:59 (2:05)	0.005
(1) Adaptation (mm: ss), mean (SD)	6:53 (2:34)	2:22 (1:00)	0.009
(2) Trait-anxiety (mm: ss), mean (SD)	3:34 (2:00)	2:35 (0:54)	0.241
(3) State-anxiety (mm: ss), mean (SD)	3:06 (1:11)	2:40 (0:44)	0.333
(4) Return to calm (mm: ss), mean (SD)	1:36 (0:40)	1:20 (0:29)	0.139

^a mm: ss – minutes: seconds**Table 4** Average values of respiratory tension, muscular tension, and skin conductance – G1 (ST)

Variable	Pre			Post			P-value
	Avg. (SD)	Min.	Max.	Avg. (SD)	Min.	Max.	
Respiratory tension (μV)	0.00042 (0.47)	−3.812	3.363	0.00163 (0.39)	−3.637	1.852	0.445
Muscular tension (μV)	0.99162 (111.68)	−800.000	799.976	−1.01755 (144.60)	−779.752	799.976	0.442
Skin conductance (μS)	4.60325 (4.33)	1.000	19.999	4.70186 (2.13)	1.000	10.330	< 0.001

Table 5 Average values of respiratory tension, muscular tension, and skin conductance – G2 (EA)

Variable	Pre			Post			P-value
	Avg. (SD)	Min.	Max.	Avg. (SD)	Min.	Max.	
Respiratory tension (μV)	0.00575 (0.45)	−4.625	3.766	0.00459 (0.40)	−2.920	4.446	0.604
Muscular tension (μV)	0.46796 (104.59)	−800.000	799.976	−9.95960 (65.18)	−596.766	486.553	< 0.001
Skin conductance (μS)	6.42011 (4.80)	1.000	19.999	7.51499 (6.03)	1.000	19.999	< 0.001

Table 6 Mean average values of respiratory tension over the data-collection phases – G1 (ST)

Session phase	Respiratory tension (μV)		P-value
	Pre Average (SD)	Post Average (SD)	
(1) Adaptation	−0.00298 (0.08)	0.00655 (0.10)	0.579
(2) Trait-anxiety	0.00248 (0.08)	0.00013 (0.09)	0.624
(3) State-anxiety	−0.00048 (0.09)	0.00019 (0.10)	0.797
(4) Return to calm	−0.00337 (0.08)	0.00625 (0.20)	0.488

Table 7 Mean average values of muscular tension over the data-collection phases – G1 (ST)

Session phase	Muscular tension (μV)		P-value
	Pre Average (SD)	Post Average (SD)	
(1) Adaptation	3.50592 (23.53)	−1.94552 (25.80)	0.198
(2) Trait-anxiety	−2.86662 (21.40)	−0.13153 (45.17)	0.232
(3) State-anxiety	2.48628 (18.08)	3.01736 (37.13)	0.737
(4) Return to calm	−1.63255 (31.10)	−1.35625 (63.43)	0.931

Table 8 Mean average values of skin conductance over the data-collection phases – G1 (ST)

Session phase	Skin conductance (μS)		P-value
	Pre Average (SD)	Post Average (SD)	
(1) Adaptation	3.58015 (3.39)	3.94317 (1.63)	0.002
(2) Trait-anxiety	4.24537 (3.88)	4.68711 (1.93)	0.006
(3) State-anxiety	4.37874 (4.03)	4.95604 (1.96)	0.004
(4) Return to calm	4.35274 (4.04)	5.31664 (2.26)	0.011

Table 9 Mean average values of respiratory tension over the data-collection phases – G2 (EA)

Session phase	Respiratory tension (μV)		P-value
	Pre Average (SD)	Post Average (SD)	
(1) Adaptation	0.00573 (0.07)	0.00295 (0.12)	0.660
(2) Trait-anxiety	0.00916 (0.10)	0.00094 (0.09)	0.276
(3) State-anxiety	0.00045 (0.10)	−0.00055 (0.09)	0.951
(4) Return to calm	−0.00370 (0.12)	0.00486 (0.21)	0.394

Table 10 Mean average values of muscular tension over the data-collection phases – G2 (EA)

Session phase	Muscular tension (μV)		P-value
	Pre Average (SD)	Post Average (SD)	
(1) Adaptation	1.87873 (20.47)	−32.05641 (67.04)	< 0.001
(2) Trait-anxiety	−1.38788 (23.25)	−7.38451 (21.32)	0.037
(3) State-anxiety	1.96758 (41.71)	0.95440 (19.63)	0.366
(4) Return to calm	0.82233 (31.77)	−1.35505 (19.02)	0.594

Tables 9 and 10, and 11 show the pre- and post-test data for G2 (EA). G1 showed higher post-test skin conductance across all phases, while G2 showed reduced muscular tension but higher skin conductance.

3.5 Comparison between physiological data and subjective perception

Correlation values between the objective physiological measurements and subjective perception of anxiety in G1 (ST) are shown Table 12. The values for G2 (EA) are shown below in Table 13.

In G1, skin conductance correlated with TAI (pre-test) and ITA (post-test). In G2, muscular tension and skin conductance correlated with STAI-Trait, and ITA correlated with skin conductance (post-test)."

Table 11 Mean average values of skin conductance over the data-collection phases – G2 (EA)

Session phase	Skin conductance (μS)		
	Pre Average (SD)	Post Average (SD)	P-value
(1) Adaptation	5.61903 (4.35)	7.39137 (6.70)	< 0.001
(2) Trait-anxiety	6.93566 (5.59)	7.84887 (6.69)	< 0.001
(3) State-anxiety	7.56190 (6.04)	8.04402 (6.67)	< 0.001
(4) Return to calm	7.62675 (6.06)	8.16931 (6.57)	0.003

3.6 Satisfaction

All participants reported high satisfaction ($M = 4.94/5$). The research team scored highest, while information provision scored slightly lower. Most valued visual feedback and device precision.

Participants described the experience as calm and reassuring; no negative perceptions were reported.

4 Discussion

4.1 Main results

This study evaluated the effectiveness of biofeedback for recording objective physiological data on study- and test-related anxiety and compared these measures with subjective reports. We hypothesized that respiratory tension, muscle tension, and skin conductance would decrease between pre- and post-test sessions.

Even though biofeedback is applied in numerous studies as a data-collection tool to reduce anxiety in study-related situations [37–40], few studies have examined it as a purely objective measurement tool rather than as an intervention.

The results revealed significant differences between both groups that were studied. These differences, however, varied in direction and magnitude, reflecting the independent nature of the two programs.

The *temporal analysis* was done to ensure that pre- and post-test were similar in duration and thus allow for accurate comparison. It was deemed necessary to verify whether participants were capable of quicker undergoing an anxiety-inducing stimulus in the post-test session.

Post-test sessions were shorter than pre-test, partly due to consent procedures at baseline and shorter surveys at follow-up. However, P-values in G1 approached 0.05, suggesting weak evidence that may not hold in larger samples. This could also be useful in designing future studies, adjusting the recording session protocol to ensure limiting variability.

The *measures of the physiological variables* were studied globally and in relation to their four phases. G1 showed higher post-test skin conductance, while G2 showed reduced muscular tension and increased skin conductance.

Contrary to expectations, biofeedback did not yield uniform reductions across variables, likely because it was used only for measurement rather than intervention, contrary to existing literature [37–40]. Differences may reflect program duration and focus: G1 (1 month, study skills) vs. G2 (3 months, anxiety control with relaxation training).

By *phases*, G1 consistently showed increased skin conductance, while G2 showed decreased muscular tension (early phases) and increased skin conductance across all phases.

Table 12 Correlations between physiological and subjective anxiety measures (G1)

Test	Respiratory tension			Muscular tension			Skin conductance		
	Pre		Post	Pre		Post	Pre		Post
	<i>r</i>	<i>P</i> -value	<i>r</i>	<i>r</i>	<i>P</i> -value	<i>r</i>	<i>r</i>	<i>P</i> -value	<i>r</i>
STAI ^a Trait	−0.065	0.484	0.062	0.046	0.620	0.085	0.124	0.176	0.117
STAI ^a State	0.152	0.097	0.039	−0.024	−0.798	−0.014	−0.010	0.917	−0.043
TAI ^b	−0.039	0.674	−0.026	−0.026	0.776	−0.104	.229 ^d	0.012	−0.141
ITA ^c	−0.009	0.924	0.003	0.028	0.761	0.165	0.177	0.053	.201 ^d

^a STAI – State-Trait Anxiety Inventory

^b TAI – Test Anxiety Inventory

^c ITA – Inventory of Test Anxiety

^d The correlation was significant at *P* < .05 (bilateral)

Correlations between physiological and subjective measures were weak but significant: G1—TAI/ITA with skin conductance; G2—STAI-Trait with muscle tension/skin conductance, ITA negatively with skin conductance.

Unlike prior studies [8] using biofeedback as intervention (e.g., with music therapy [41, 42]), the present study only used it for measurement, which may explain the absence of uniform physiological reductions. Additionally, the devices were similar but used other sensors, which can also limit comparison.

In previous studies, skin conductance was widely used for measuring psycho-physiological reactions in mental health pathologies [35] given their sensitivity and response to emotional stimuli, such as stress [43]. With regard to muscular tension, it is used less within the field of psychopathology despite its proven efficacy [44, 45], given that it is principally applied to the treatment of pathologies affecting the musculoskeletal system. No significative differences were noted in relation to respiratory tension in either group. In G1, whose programme was focused on study techniques, there were no relaxation exercises. However, those techniques were taught in G2, whose objective was to confront exam-related anxiety, for which reason the results were not consistent with the expected reduction.

Skin conductance emerged as the most sensitive measure, followed by muscular tension; respiratory tension added little and may be replaced by heart rate in future protocols [13, 16, 46–48].

Participants valued biofeedback as useful, engaging, and informative for observing their own physiological responses.

4.2 Limitations

Although the findings of this study were promising regarding the capability of gathering and recording objective data using biofeedback devices, various limitations should be considered.

In the first place, sample was small, mostly young female engineering students, limiting generalizability and external validity. In future studies, it will be important to explore the effectiveness of biofeedback in more varied samples (e.g., sex, in-class/on-line studies, and branches of knowledge). Likewise, sample size should be increased. If not possible, effect size calculations could be done to complement significance testing.

In second place, subjective measures relied on self-report, which may be influenced by social desirability.

In third place, non-randomized design may introduce selection bias, though groups were analyzed independently rather than compared directly.

In fourth place, high dropout reduced sample size and may have affected findings; future studies should address reasons for attrition.

In fifth place, differences in pre- vs. post-test session duration may have affected comparability; standardized timing is recommended.

In sixth place, negative values may reflect measurement error or genuine relaxation; results should be interpreted cautiously until replicated in larger samples.

Table 13 Correlations between physiological and subjective anxiety measures (G2)

Test	Respiratory tension			Muscular tension			Skin conductance		
	Pre		Post	Pre		Post	Pre		Post
	<i>r</i>	<i>P</i> -value	<i>r</i>	<i>r</i>	<i>P</i> -value	<i>r</i>	<i>r</i>	<i>P</i> -value	<i>r</i>
STAI ^a Trait	0.021	0.834	0.088	0.007	0.944	.278 ^d	0.115	0.255	.258 ^d
STAI ^a State	−0.119	0.240	−0.120	−0.032	0.752	0.050	−0.024	0.814	−0.103
TAI ^b	−0.045	0.657	−0.139	−0.037	0.718	0.006	0.022	0.955	−0.028
ITA ^c	0.064	0.526	−0.063	0.078	0.441	0.130	0.152	0.131	−.232 ^e

^a STAI – State-Trait Anxiety Inventory

^b IAE – Test Anxiety Inventory

^c ITA – Inventory of Test Anxiety

^d The correlation was significant at *P* < .01 (bilateral)

^e The correlation was significant at *P* < .05 (bilateral)

5 Conclusions

This study provides preliminary but promising evidence that biofeedback can objectively capture physiological data in applied research. Biofeedback appears effective as a tool for monitoring physiological responses. These devices may help students cope with exam stress and other anxiety-provoking situations. They are accessible and moderately inexpensive, making them feasible for university psychological services. University psychological services could integrate these tools to support students.

Future studies should confirm the effectiveness of biofeedback and explore different sensors for specific physiological responses. This could inform the development of targeted programmes for students and potentially other populations.

Abbreviations

TA	Test anxiety
ST	Study techniques
EA	Exam anxiety
SUAS	University Health Care Service
UBU	University of Burgos
EDA	Electrodermal activity
S-A	State-anxiety
T-A	Trait-anxiety
STAI	State-trait anxiety inventory
TAI	Test anxiety inventory
ITA	Inventory of test anxiety
HR	Heart rate
RF	Respiratory frequency
sEMG	Superficial electromyography

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1007/s44202-025-00532-3>.

Additional file 1.

Author contributions

P.R.G. and M.C.E.L.L. wrote the main manuscript text. P.R.G. and I.Q.V. performed statistical analyses. P.R.G. prepared all figures and tables. M.C.E.L.L. and M.A.M.M. reviewed the manuscript.

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Data availability

Data availability statement: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study complied with ethical and legal research guidelines and was approved by the *Bioethics Commission of the University of Burgos* (IR 11/2023). Confidentiality was ensured by assigning anonymous codes, restricting access to data, and storing personal information separately from research data. All participants were over 18 years old, and informed consent was obtained. The study adhered to the Helsinki Declaration and institutional ethical standards. All participants provided written informed consent, in line with Spanish Organic Law 3/2018 on Data Protection.

Consent for publication

Consent to publish was not necessary, as the manuscript contains no identifiable data.

Competing interests

The authors declare no competing interests.

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