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A Research Vision

IDENTIFICATION AND CLASSIFICATION OF ACADEMIC STRESS BY GALVANIC SKIN RESPONSE

IDENTIFICACIÓN Y CLASIFICACIÓN DEL ESTRÉS ACADÉMICO POR LA RESPUESTA GALVÁNICA DE LA PIEL

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Abstract*:* This paper presents an assessment of the level of academic stress from students of the Faculty of Electronic Engineering of the Francisco José de Caldas District University (FJCDU), combining the galvanic skin response (GSR) and the application of a psychological test inventory SISCO. An electronic prototype was designed for measurement of GSR, considering fundamental features, such as the electrodes type and location, and the working frequency, among other. With the information obtained, we built a database that allowed classification to the academic stress level, using a fuzzy inference system trained by a genetic algorithm. Through a

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statistical analysis, we found that 47.77% of students have low stress, followed by 38.88% of moderate stress level and finally 13.33% with high stress levels. Here is possible relationship between GSR and the body's reaction to stressful stimuli, suggesting the possibility of incorporating this variable for the diagnosis and monitoring of academic stress level.

Keywords: Academic stress, Galvanic Skin Response (GSR), psychological test.

Resumen: Este trabajo presenta una evaluación del nivel de estrés académico en estudiantes de la Facultad de Ingeniería Electrónica de la Universidad Distrital Francisco José de Caldas (UDFJ de C), utilizando como herramientas la combinación de la respuesta galvánica de la piel (GSR) y la aplicación de un test sicológico del inventario SISCO. Para realizar la medición de GSR se diseñó un prototipo electrónico que considera características fundamentales como el tipo y la ubicación de los electrodos, la selección de frecuencia de trabajo, entre otras. Con la información obtenida se construyó una base de datos que permitió analizar y clasificar el nivel de estrés académico, empleando un método estadístico y un algoritmo genético, respectivamente. Se encontró que un 47.77% de los estudiantes presenta un nivel de estrés leve; seguido de un 38.88% con presencia de estrés moderado; y un 13.33% con alto nivel de estrés. En consecuencia, existe relación entre la GSR y la reacción del cuerpo a estímulos estresores; y se evidencia la importancia de incorporar la medida

de ésta y otras variables fisiológicas para el diagnóstico y seguimiento del nivel de estrés académico.

Palabras Clave: Estrés académico, respuesta galvánica de la piel (GSR), test sicológico.

1. Introduction

Both nationally and internationally, stress has been referred to as a modern disease, prevalent in all societies, although no numerical-scale standard has been established to measure stress levels from physiological variables [1].

Academic stress is produced from the demands of education. Currently, different stressors stimuli exhibited by students directly interfere in academic performance [2].

Some of these studies focused on the conceptualization of academic stress, which revealed a presence of high percentage of stress (86% to 100%) for undergraduate and graduate students. The area of psychology of Institutional Welfare of the UDFJ de C revealed that the reasons for students enrolled in Electronic Engineering courses to consult specialists are mainly anxiety disorders, family crises, academic difficulties and vocational confusion, among other aspects [3].

The presence of stressors is usually identified from outpatients, which may or may not include the application of a test or psychological evaluation, which increases the variability intra-specialist and inter-specialist. This reflects the need to introduce tools that support the process from specialist-measuring physiological variables.

Some of the variables that allow finding a link between various physiological stress levels are electro-conductive properties of the skin or the GSR (galvanic skin response).

This variable provides direct information about physiological stimuli perceived by the brain, whereby the measurements of strength and electrical conductivity characterize the functional state of the skin, allowing an estimation of the activity of both the central and peripheral nervous systems [1].

In developing the prototype for measuring GSR, it is essential to establish ranges for grading the level of stress, with the support of a psychological test, and also to determine the optimum performance characteristics to measure the physiological variables (e.g. cleaning and preparation of the skin, type of electrodes, frequency) as well as other variables that influence the extent of each individual.

The focus of this paper is to; first provide a study to evaluate the level of academic stress obtained from the combination of psychological testing and the GSR. The evaluation was carried out on a group of students enrolled in the Electronic Engineering Program at UDFJ de C. The study contributes to search new tools that support the diagnosis of specialist academic stress assessment.

2. Stress Level Measurement

The methodology is divided into 3 main blocks, as shown in Figure 1. The first step corresponds to the data acquisition stage (Test psychological and GSR), which uses the prospective model for the construction of a lengthwise database. In step two, ranges are set for the classification of academic stress levels, applying fuzzy systems and Bivariate

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on changes of the GSR with respect to psychological testing. Finally, in stage three, stress levels are obtained through the classification of the academic stress present in the population under study.

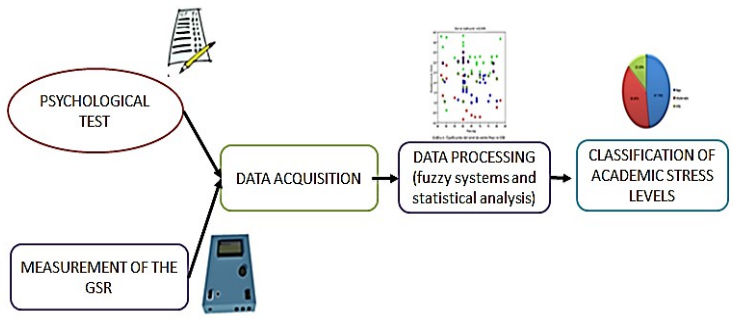


Figure 1. Description of the stages of the project development. **Source:** own.

A. ***Data Acquisition***

The GSR measurement and evaluation of the level of stress through psychological test was collective and was conducted in two sessions conducted in the classroom. The first session includes a stress factor presentation of a test (session 1) and the second session does not include any type of stress factor presentation (session 2), in order to identify and compare changes between sessions.

The study was made from 54 students enrolled in a course on power electronics (at UDFJ de C). Excluded from the analysis were students who did not answer the complete test, or those who did not attend the two sessions of data collection, It also excluded those who were on academic probation or students who perceived no stress at all during the semester (filter employee, Part 1 of the questionnaire). From the analysis group, 83.4% of respondents met all the requirements to be part of the sample, and the remaining 16.6% did not meet the selection criteria, leaving a total of 45 participants for data analysis (Table 1).

Gender	Study Population	Including Students (%)	Excluded Students (%)	Total Participants
Male	45	82.2	17.8	37
Female	9	88.8	11.2	8
Total	54	83.4	16.6	45

Table 1. Number of students who participated in the study. **Source**: own

B. Psychological Test

In academic stress measurement, SISCO Stress Inventory Scholar was used. This is a questionnaire designed from interrelated variables, namely self-perceived stress levels, stressors and symptoms [4]. The questionnaire consists of six parts and follows the following structure. First part is a filter to find out whether the students surveyed have the same characteristics (to avoid a biased sample).At this stage students who have perceived stress and students who are on academic probation are identified. The second part of the questionnaire allows knowing the level of self-perceived stress. The third part deals with information about the independent variable (stressors); and finally, parts four to six reveals the dependent variables (symptoms) and the strategies used by students to cope with stress [4]. The time spent by students to answer the questionnaire ranged from 5 to 7 minutes.

The reliability of this questionnaire was previously assessed using two methods that consider a scale from 0-1, namely for reliability by halves with a score of 0.87, and a Cronbach alpha reliability with a value of 0.90. This data allows considering the reliability of the test as really good. Finally the test that provides classification, based on the sum of all points, is shown in Table 2, [5].

Rank (%)	**Category**
O a 33	Low
34 a 66	Moderate
67 a 100	High

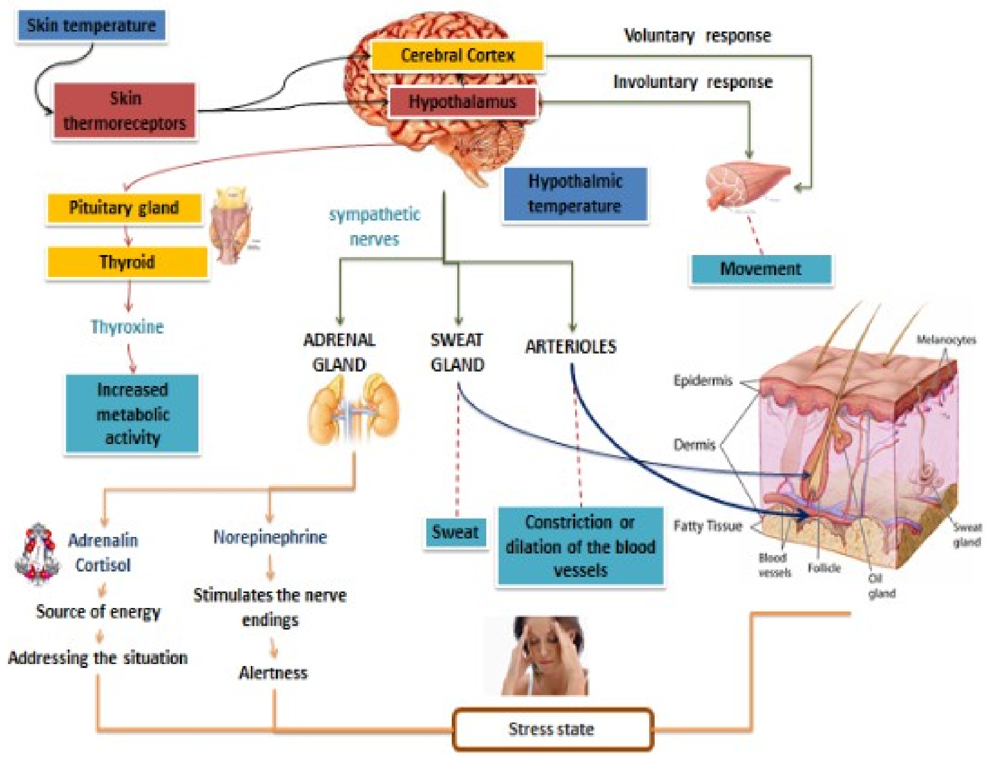
Table 2. Classification of the Type of Stress. **Source**: [6]

C. Measurement of the GSR

The sequence of stress response starts with the stressor stimulus, which is perceived by the hypothalamus, which in turn excites the pituitary gland to release hormones that activate the adrenal glands. They release three hormones: adrenaline, noradrenaline (known as catecholamine) and cortisol. Adrenaline and cortisol provide the body with an energy source to address the situation and norepinephrine stimulates the nerve endings (Figure 2) and drives the body into alertness. In this condition, senses sharpen, breathing accelerates while the lungs absorb more oxygen, glucose and fats are released into the blood stream to provide more energy and the production of sweat increases [7].

In response to stress, electro-conductive properties of the skin increase and a decrease of the ohmic resistance occurs to allow the flow of neurotransmitters, whose effect is known as psychogalvanic reflection (SGR) or galvanic skin response (GSR) [8], if the stimulus is relaxing, the electro-conductive properties of the skin decrease, thus increasing the skin resistance [9].

Figure 2. Human body's response to stressful stimuli. **Source**: [7].



Currently, devices that measure the GSR already exist, but these do not relate to the measurement of such a parameter within the stress level. Instead, measurements are associated with biofeedback[1] related processes connected with monitoring of other physiological functions, such as heart rate, oximetry, brain waves, and muscle tension, among others, [10].

1 Biofeedback is a technique through which physiological activity is monitored. It gives information to patients, whether auditory or visual, about the functions of the body, so patients learn to control such functions at will, so that the degree of control is sufficient to produce learned clinically important effects [7].

For GSR measurements, a prototype was designed, consisting of three fundamental stages.

In the first stage the epidermis is excited using the current injection method. The system begins with a multivibrator oscillator which generates a sinusoidal signal at a frequency of the signal then enters a notch filter which removes noise frequency mains and finally amplifies the signal to generate a $1mA_{AC}$ constant current. Current intensity within the threshold area of perception [11-15].

The second stage corresponds to the voltage measured, which occurs due to current injection. The signal is then amplified by an instrumentation amplifier (INA 128), and finally passed through a conditioning stage for digitizing though an ADC (analog-digital converter).

The third stage corresponds to digitization, where the resulting signal is conditioned and processed by the microcontroller's ADC that allows calculation of the value of the electrical skin resistance. Then information can be seen on the alphanumeric display.

Figure 3 shows a functional-blocks prototype for GSR measurement.

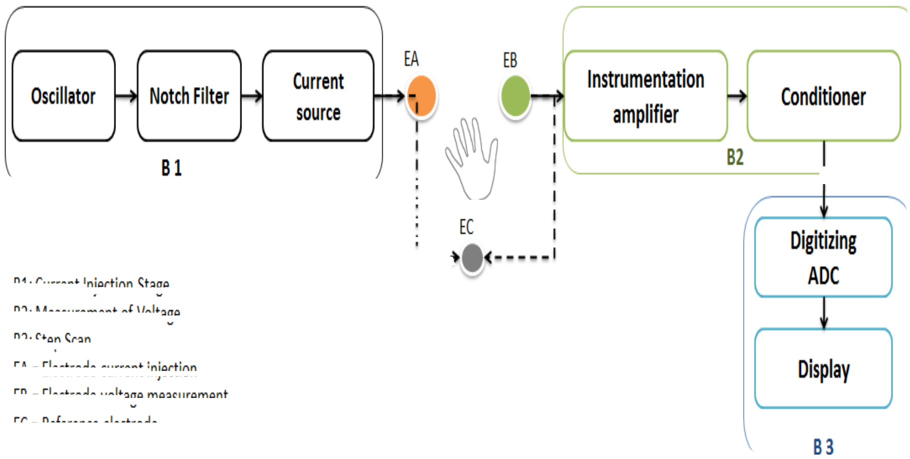


Figure 3. Prototype functional blocks designed and implemented for measuring the galvanic skin response. **Source**: own

In order to measure GSR, surface electrodes are used (gold cup) as shown in Figure 4. These electrodes are coated with 20 micro inches of gold and have a diameter of 10 mm. The electrodes are reusable and their lifespan is approximately six months. These electrodes are highly conductive when compared to disposable electrodes; the former have a conductivity of $4{,}44 \times 10^{7}\ {}^{S}/_{m}$, and the second set of electrodes has a conductivity of $3.78 \times 10^{7}\ {}^{S}/_{m}$..

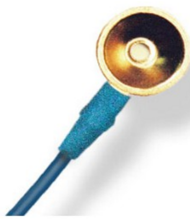


Figure 4.Gold cup electrodes. Source: own.

As shown in Figure 3, the prototype has three electrodes (EA, EB, and EC) for the measurement of GSR, located as shown in Figure 5. Electrode EA is to be placed on the skin of the first dorsal interosseous muscle, EB must lie on the opposite thumb muscle and EC on the adductor pollicis transverse section, a 1.5 cm radius to the EB electrode radius [12].

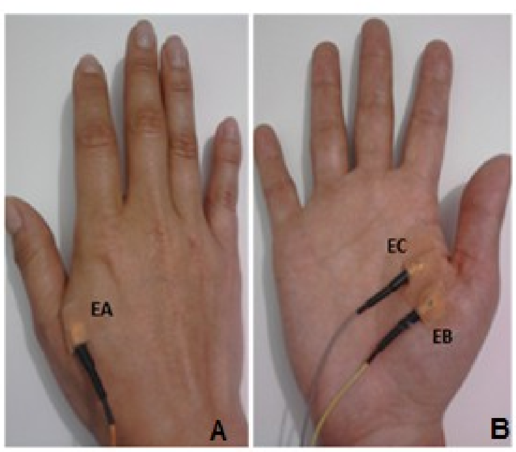


Figure 5. Location of the electrodes. A. Location of electrode EA, B. Location electrodes EB and EC. **Source**: own

Finally, Figure 6 shows the final prototype HMI interface (English Human Machine Interface).

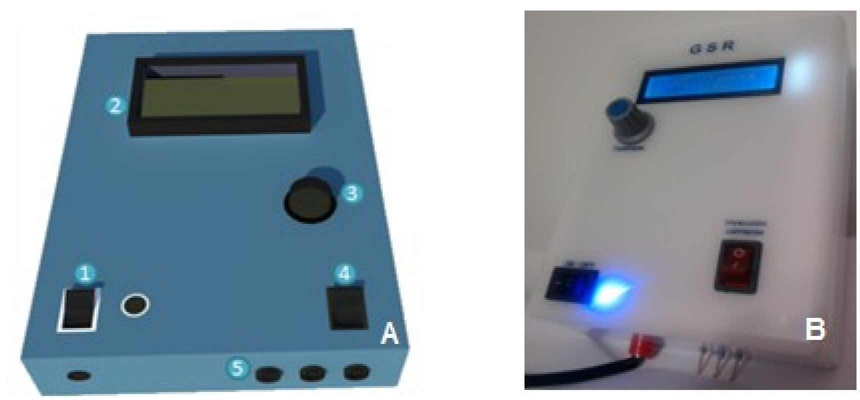


Figure 6. A. Schematic of the prototype and its interface HMI. 1. Switch on / off, 2. LCD 3. Knob, 4. Power switch 5. Connectors. B. Display of the final prototype. **Source**: own

3. Results

To obtain the level of academic stress, changes in GSR were observed within the frame of a psychological evaluation, which was used for fuzzy inference through genetic algorithm training and statistical analysis. The purpose was to determine and quantify these changes between sessions.

D. Measurement of the GSR

The histogram displayed in Figure 7 (A), and Table 3, shows the difference between the values of GSR. The data collected during one session exhibited an average value of, whereas session two had an average value of $2.6432\ \mathrm{K\Omega}$, which indicates the presence of changes between sessions.

Figure 7 (B) shows the dispersion of data around the mean GSR. This suggests that for quantifying GSR statistical difference between sessions, it is not sufficient to overlap data with the data analysis (standard deviation) and the average values.

In order to establish whether there is a statistically significant difference, a test is performed on the data distribution (parametric test) and the groups (sessions) are compared including other variables of interest (psychological test).

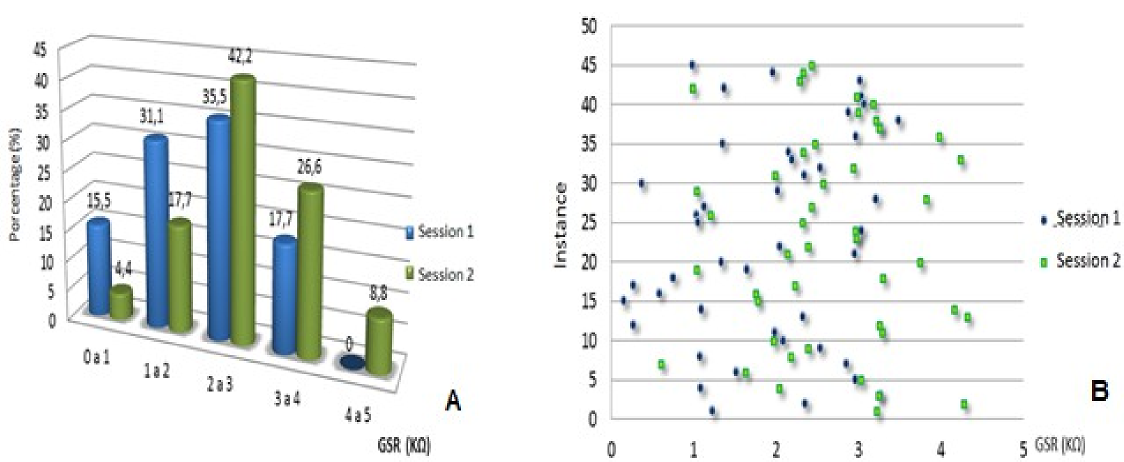


Figure 7. A. GSR comparison between session 1 and 2. B. Dispersion of GSR data.

Source: own

Characteristic	Session 1	Session 2
Average (KΩ)	1,955422 22	2,6432
Standard Deviation	0,969000 57	0,9234455 6
Maximum Value	3,486	4,32
Minimum Value	0,154	0,607

Table 3.Gsr Measurements, Sessions One and Two. **Source**: own

E. Statistical

For comparison of the samples, the dependent variable (GSR) must be set, and the independent variable included (psychological test) to provide information on these changes. In order to do so, it is essential to consider features such as the distribution of groups, the degrees of freedom on the means, and the levels of significance (confidence intervals of the data).

To determine the type of distribution exhibited by the data, an assessment was made using a nonparametric test (or free distribution). The Kolmogorov-Smirnov test is considered a process of "goodness of fit". It measures the degree of agreement between the distribution of a data set and a specific theoretical distribution, in this case normal distribution [16], In this case, a test is applied to verify the type of distribution that lies in the dependent variable (GSR).

Table 4 presents the analysis of this test, posing a normal distribution as a null hypothesis. Considering a significance level α of 5%, to retain the null hypothesis (confidence level of 95%), it was clear that in both cases there was a greater significance level of 5%, so the null hypothesis was not rejected and it was concluded that the data are normally distributed.

Null Hypothesis	**Level of significance (%)**	**Decision**
GSR distribution of session 1 is normal with average 1.96 and standard deviation 0.97.	39.2	Retain the null hypothesis
The distribution of session 2 GSR is normal with average 2.64 and standard deviation 0.92.	84.9	Retain the null hypothesis

Table 4. Type of distribution according to Kolmogorov-Smirnov test. **Source**: own

After determining the type of data distribution, a statistical method was selected, which allows for the exchange of the two sessions regarding the GSR, considering the type

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distribution. This is achieved from test "t" by Student-Fisher, comparing two groups with respect to a quantitative variable (requires dependency between the two). In this method, there are two moments, one before and one after. This experiment performs the changing conditions on the same individual for GSR measurement; for this reason, both the dependent variable (psychological test) that describes the variation, and a dependent variable (GSR) should be incorporated into the analysis.

Hypothesis testing is conducted as follows:

- Null Hypothesis (Ho): The GSR is the same in both tests.
- Alternate Hypothesis (H_1): The GSR is different in both tests.

Table 5 shows the results of test "t" Student-Fisher, where the correct hypothesis is selected, analyzing the critical value of t, with $\alpha = 0.05$ (confidence level) and 44 degrees of freedom. This critical value is given by the t student table [17], with an approximate value of 2.0. The calculated value is higher, about 4.018, and so we reject the null hypothesis and accept the alternative, where the GSR is different for both sessions.

Related Differences							
Difference	Average	Standard deviation	Standard error of the mean	95% confidence interval for the difference		Degrees of freedom	*"t"*
				Inferior	superior		

GSR1-GSR2	0.6877	1.1483	0.1711	0.3427	1.0327	44	4.018

Table 5. Results Student- Fisher T test. Source: own

These results suggest that the more stress, the more electro-conductivity and thus lower GSR. Conversely, in the second session, no intervention of a stressor stimulus (therefore leading to lower stress, smaller electro-conductance hence greater GSR) was recorded compared to the active one.

F. Classification Using Genetic Algorithm

Holland at University of Michigan provided the theorical fundamentals of Genetic Algorithms (GA) [18]. This type of training is based primarily on biological evolution and mutation, i.e. genetic theory of natural selection (genetic process of living beings), where only limited changes are applied to the best genes. Therefore, the GA is an adaptive method that can be used to solve search and optimization problems [18], [19].

By using a genetic algorithm, advantage is obtained as qualitative and quantitative variables accurately incorporate human experience (from linguistic modeling, building rules and sets) to resemble human thinking and analysis.

In addition to numeric and symbolic processing within a single inference scheme [20], the contributions of other variables are identified through the GA, considered for classification of academic stress levels, in this case, not only for the psychological test, but also, in terms of weight and height of each individual.

Figure 8 shows that the dispersion of the variable "psychological test", like the GSR, presents extensive metropolitan data between sessions. However, to unite these variables, a little more group data is gathered for each session, as shown in figure 9. These dispersions reflect the high complexity of the system to be trained only with the analysis of these attributes.

However, the system is assisted by the entry of other physiological variables such as weight and height.

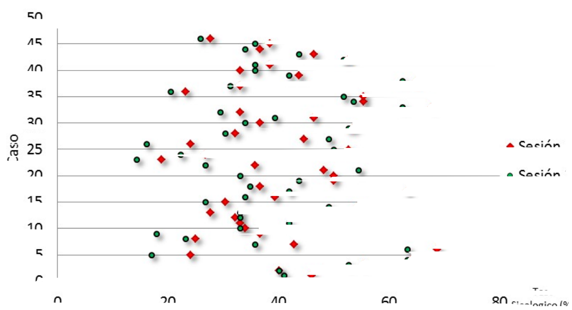

Figure 8. Dispersion of psychological test data. **Source**: own

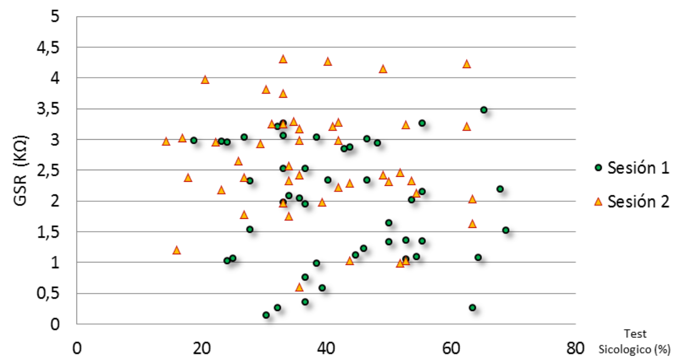

Figure 9. Dispersion of psychological test data vs GSR. **Source**: Own

The genetic algorithm used for classifying the level of stress in students employed 60% of the data for training and 40% for validation.

There was an error of 22.82% over the 90 samples (45 session one and 45session two). Figure 10 shows the distribution of the cases with respect to weight and GSR. The stress level classification by color corresponds to: low level (green), and moderately high levels (blue and red). The cases that were incorrectly classified are enclosed in red boxes.

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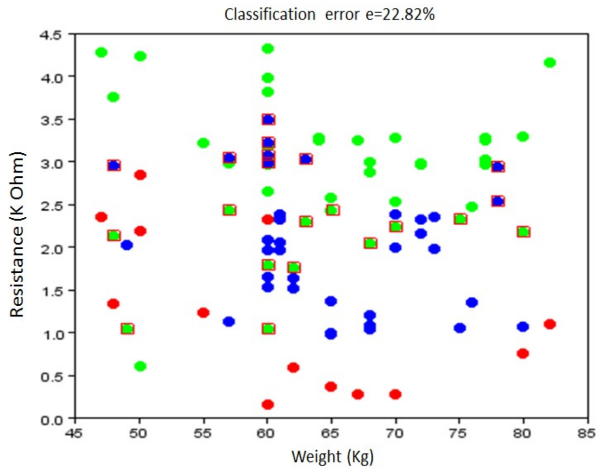

Figure 10. Stress level classification GSR vs Weight. Source: own

The results of the classification of the academic stress levels are shown in Figure 11, where 47.7% of the students exhibit a low-stress level, 38.8% had moderate-stress levels and 13.3% show a high level of academic stress.

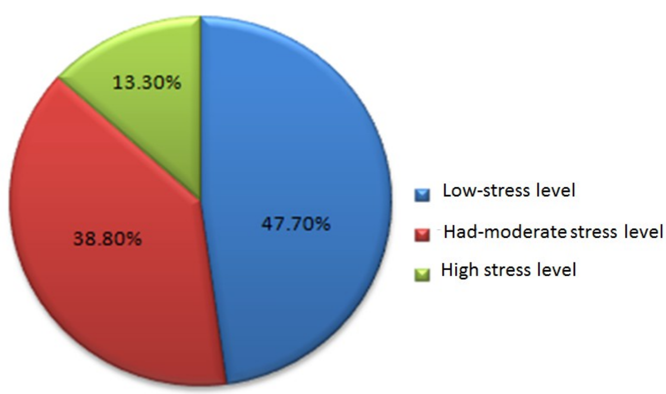

Figure 11. Results of the classification of academic stress including all parameters.

Source: own

4. Conclusions

The GSR measurement provides information about the human body's reaction to stressful stimuli, which cannot be detected with a psychological test or through verbal assessment. The results show the close relationship between this variable in its electro-conductive properties and the stress levels present in each individual.

For the measurement of GSR, it is vital to know the different methods and their characteristics before building any prototype (i.e. the optimum working frequency and safety offered by each method when applied on users). In this case, a current injection method was employed, which provides, among its advantages, greater security regarding the currents supplied to users. Additionally, the method is easy to use and its implementation is low-cost compared to existing devices in the market.

From measuring the GSR and conducting a psychological assessment (test stress level), we obtained the first classification level of stress present in academia, contributing to the creation of new tools that permit easy specialist diagnosis. This work also built a database, which is of great importance for the study of the academic stress present in students and further provides great information for future work. The tools provided also managed to surpass the population when compared with previous studies measuring GSR (electro-conductivity studies), considering this project represents a test pilot.

For classification of academic stress levels, an approximate model was employed using a genetic algorithm, yielding three categories, namely mild stress, moderate and high stress. From the whole set individuals, 47.77% of the population fell into the category of low stress, followed by 38.88% in the category of moderate stress, and finally 13.33% in high stress.

These results allow us to analyze the importance of measuring physiological variables in the diagnosis, analysis and prevention of stress levels, not only in the academia but also in extended applications to all areas of human development, such as labor and personal interactions, among others.

5. Future Work

It is proposed that future work should include the assessment of other physiological variables to observe changes in the body regarding stimuli stressors (such as heart rate, salivary amylase, muscle tension, and others) following the scheme of an easy-to-use, non-invasive device. The idea is to reduce the number of electrodes or elements for measuring these variables, which may disturb or alter the response of the individual's stress level. It is also proposed that the test should be applied to larger populations, with other stressful situations and within different environments.

It is also suggested that the algorithm should be improved in order to reduce the classification error as well as incorporating this hardware in an integrated area, together forming a device interface that requires no additional.

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