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Influence of thermal environment on occipital EEG signal amplitude in sedentary activities

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Abstract

Even in sedentary activities, the workload is justifying more accurate studies about its impact on human beings mainly when related to different temperature and humidity conditions. One of these impacts is related to mental activity, which can be studied by the amplitude of Alpha and Beta waves. This study aims to evaluate brain activity in the occipital lobe from the amplitude of the EEG signal (*Alpha* and *Beta* waves) and to relate it to different conditions of temperature and relative humidity (RH) in sedentary tasks. Tests were performed under four different conditions (22°C-40%RH, 22°C-80%RH, 32°C-40%RH and 32°C, 80%RH) with 30 volunteers from which 15 were validated. Results suggest that both temperature and humidity influence the amplitude of the EEG signal (*Alpha* and *Beta* waves) in both hemispheres. The greatest amplitudes were found whenever environmental temperature and/or relative humidity values were higher. The results are in agreement with other authors.

1. BACKGROUND

Working conditions are changing worldwide meaning that more and more workers spend most of their time performing sedentary activities, exposed to the most diverse conditions of the thermal environment. This change means that a large number of workers is doing a more or less gradual transition from tasks with high physical demands to tasks that require a higher mental effort (Boff & Abel, 2005). On the other hand, physically demanding work performed concurrently with a cognitive task may impair mental processing or decrease performance (DiDomenico & Nussbaum, 2011).

The thermal environment in the workplace is a major factor to improve the quality of life and well-being of the workers. This becomes even more evident when temperature and relative humidity are high and associated with high mental workloads. These conditions can quickly lead to mental fatigue and hence to decreased productivity and increased mistakes and accidents (Lan, Lian & Pan, 2010). O'Neal & Bishop (2010) have shown that the accident rate and risk behaviour in industrial environments increases simultaneously with activity and elevated temperatures (DiDomenico & Nussbaum, 2011; O`Neal & Bishop, 2010).

Mental fatigue is here understood as the state of functional efficiency reduction, both physical and mental, which is determined by the duration and intensity of mental stress (ISO 10075-1, 1991). Mental fatigue can cause problems including labour dissatisfaction; low productivity; decreasing performance and lower worker's commitment to fulfilling their tasks conveniently (Shahrak and Bakar, 2011). Workers fatigue can come from both the physical and mental dimension. In their literature review, Shahrak and Bakar (2011) established a relationship between drowsiness and forgetfulness when performing tasks. Also according to these authors, both high temperature and relative humidity as well as low temperature, contribute to increasing stress and mental fatigue. This knowledge can help to define measures preventing the risk of fatigue caused by work. In 2003, Parsons (2003) stated that thermal environment, whether hot, neutral or cold could interfere with human activity, causing discomfort, affecting performance and influencing productivity. Thus there is a close relation among thermal environment, human health, well-being and performance. Hot environments effects may emerge in disorders associated with the state of attention and wakefulness, a situation that happens in different tasks, such as air traffic controllers, military agents or drivers. Furthermore, also according to Parsons (2003), stress caused by heat can affect several organs of the human body and some areas of the central nervous system. There are still other correlations, highlighted by several authors, for instance: brain activity with the thermal environment (Yao et al, 2008), workload (Danyang et al, 2015), physical activity (Coso et al 2011), cognitive aspects (Lan, Lian & Pan, 2010; Burzynska et al, 2015), mental fatigue (Ishii et al, 2015; Chen et al, 2013) and alertness (O`Neal & Bishop, 2010; Hirose & Nagasaka, 2014; Yosuke & Seiji, 2015; Zhang & Yu, 2010; Andreassi, 2009).

Brain's electrical activity can be recorded in different frequency bands. Regarding fatigue assessment, despite having been used by other authors a wide variety of psychophysiological methods, the electroencephalography (EEG) is considered the most reliable technique (Chen et al, 2013). The most studied waves are *Alpha* (α), *Beta* (β), *Theta* (θ) and *Delta* (δ), whose frequency bandwidths are, respectively (α) 8-13 Hz, (β) 13-20 Hz, (θ) 4-7 Hz and (δ) 0,5-4 Hz (Ishii et al, 2015; Hirose & Nagasaka, 2013).

Given the design of this study (brain activity assessment over one hour while performing a cognitive task), EEG was considered the adequate method namely because it is not invasive and does not exposes volunteers to any kind of radiation.

According to some authors (Nybo & Nielsen, 2001; Craig et al, 2012; Eoh, Chung & Kim, 2005), the possibility of occurring mental fatigue can be evaluated from the change in brain activity, measured by EEG, particularly Alpha and Beta waves.

A group of authors (Yosuke & Seiji, 2015; Lal & Craig, 2002; Tanaka, Hayashi & Hori, 1997; Trejo et al, 2005) reported a significant increase in the activity of Alpha waves when subjects felt tired. For the Beta waves, some researchers (Yosuke & Seiji, 2015) reported a decrease in the amplitude of these waves with fatigue, while others (Lal & Craig, 2002; Tanaka et al, 1997) reported an increase or no impact (Trejo et al, 2005). In another study (Craig et al, 2012), the authors reported that, most likely, the activity of the Alpha waves increases with fatigue. However, concerning Beta waves were unable to prove any link to this state.

In literature, several indices are proposed based on α, β, δ and θ waves as indicators of stress and/or mental fatigue. However, sometimes only the α and β amplitudes were analysed and the ratio between them, the index *Alpha*/*Beta*. The analysis of these indices is justified by being associated to fatigue (Ftaiti et al, 2010; Li et al, 2012). Yao (2008) also indicate that the amplitude of *Alpha* waves is dominant in thermal sensations of "neutral" or "a little cold" and that the amplitude of *Beta* waves is dominant when individuals relate thermal sensations of "hot" or "cold". Craig (2012), by his turn, state that when a person is tired the brain loses the ability and slows its activity. It was also reported that attempts to maintain surveillance levels leads to an increase in *Beta* activity. In the same study (Craig et al, 2012) was mentioned that became clear that fatigue is associated with significant changes in brain activity. However, the conclusions about where and what changes occur remains unclear

It was also reported, that *Alpha* and *Beta* amplitudes waves increase with temperature (Costa & Baptista, 2013). The same had been reported by other authors (Yao et al, 2008), meaning that the environmental temperature can influence the ratio *Alpha*/*Beta* reflecting fatigue (Nybo & Nielsen, 2001). In this context, it may be asked how the thermal environment can influence the amplitude of the EEG signal.

So, the main objective of this study was to evaluate brain activity based on the amplitude of the EEG signal (*Alpha* and *Beta* waves). For that purpose it has been selected the occipital lobe activity, relating it to different conditions of temperature and relative humidity in sedentary activities.

2. MATERIALS AND METHODS

2.1. Subjects

The trials followed the protocol developed by Costa et al (2018). A convenient sample of 30 volunteers of both sexes, with different occupations and ages, was tested according to a protocol approved by the Ethics Committee of the University of Porto (nº 04 CEUP/2012). A medical evaluation has been made, and each volunteer signed informed consent. Before starting each test the volunteers were informed that they could stop the trial if they wished so, the equipment was presented, and the test procedures were explained. The tests were performed only when the volunteers were as follows: without drinking coffee or alcohol or taking medications in the twelve hours before the test and rested well in the night before. The medical criteria for accepting volunteers were: not being medicated; not being smokers; having no chronic mental or physical diseases in the last 12 months, having a stable weight in the last 6 months and having good general health.

For professional reasons, twelve volunteers did not complete the four trials. So the tests were completed by eighteen volunteers, and fifteen were validated. The main reasons for exclusion were noise problems in EEG signal and incomplete trials. For the fifteen volunteers whose results were validated, average and standard deviation values of their age (37.2±13.76 years old), weight (74.47±12.23 kg), height (1.75±0.07 m) and BMI (25.07±4.45 kg.m^{-2}).

2.2. Equipment

To achieve the referred purpose, different equipment was used, including: climatic chamber (Fitoclima 25000 EC20, Figure 1) with a volume of 3.60×2.40×3.20m^3, with a temperature range between -20.0ºC and 50.0ºC (±0.5ºC) and a relative humidity (RH) range between 30% RH and 98% RH (±2%); skin temperature sensors (bioPLUX research NTC); electroencephalography device (EEG Emotiv SDK), as well as other equipment for measuring and weighting (ISO 10551, 1995), questionnaires to assess the thermal sensation of each volunteer inside and outside the climate chamber (Mueller , 2014) and also a battery of cognitive tests (Li et al, 2012).

Figure 1. Outside (left) and inside (right) climatic chamber

To evaluate brain activity, it was used a specific interface (brain-computer interface) that allowed the registration of Alpha and Beta waves. To register the EEG signal Emotiv SDK equipment was placed on the scalp of the volunteers after the sensors were adequately hydrated with a saline solution. The electrodes were placed on the scalp, according to the International System 10-20. The odd electrodes correspond to the left hemisphere and the even to the right one. Are labelled as front (F3, F4), central (C3 and C4), parietal (P3 and P4), occipital (O1 and O2), the temporal lobe (T3, T4, T5, T6, T7, T8).

Brain waves of the left and right occipital regions were analysed in this study being these regions generically considered suitable for the present purpose, however other regions were measured (Yosuke & Seiji, 2015; Craig et al, 2012; Lal & Craig, 2002; Tanaka et al, 1997; Trejo et al, 2005; Arnau, Möckel & Rinkenauer, 2017).

After registration and data collection Matlab and EEGLab (Delorme & Makeig, 2004) environments were used for data processing. EEGLab is a set of algorithms developed in Matlab environment for the continuous processing of EEG signals including electrophysiological independent component analysis (ICA), time/frequency analysis.

2.3. Procedures and methods

Each volunteer had to perform four trials, inside a climatic chamber to simulate a real working environment (Zwolińska & Bogdan, 2013), one in each of the following environmental conditions of temperature and relative humidity: 22°C-40% RH, 22°C-80% RH, 32°C-40% RH and 32°C-80% RH. A minimum interval between trials of one week was ensured in order to avoid acclimation effects. The trials were performed inside the climatic chamber.

Age, weight, height were registered before and after each trial. Skin temperature sensors were placed in 2 points of the body (in the middle of the forehead, preventing it to be covered by the hair, and at the back of the neck). After this procedure, each volunteer waited twenty minutes seated in the laboratory, under a controlled temperature around 20ºC, in order to guarantee the stabilisation of the skin temperature before entering into the climatic chamber. Then the volunteer went into the chamber and waited inside further ten minutes while the EEG device was installed on their scalp. This lapse of time allowed skin temperature to reach a new level of stabilisation according to trials environmental conditions (Costa, Costa & Baptista 2016).

In this specific work, it was used an Emotive SDK EEG device (Figure 2a). The electrodes were installed in the standard positions: parietal and frontal temporal, as shown in Figure 2b. The headset/electrode was adjusted so that two references electrodes are positioned in the mastoid area. The electrodes were adjusted carefully to ensure good contact. In Figure 2c each circle represents a sensor and its colour the contact quality. When all sensors are marked in green, it means that the best overall contact quality has been achieved.

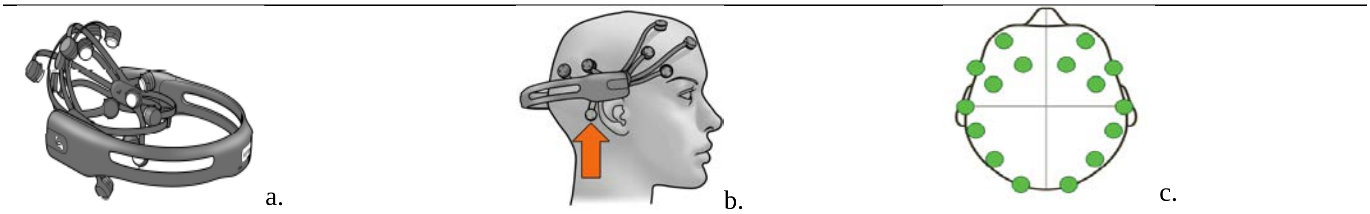

Figure 2. Emotiv SDK EEG equipment and respective sensor location (www.engr.ucr.edu)

Once the EEG device was placed and its signal received on the computer, the volunteers began a repeated task for a total period of one hour (Go/No-Go) (Mueller & Piper, 2014). The reason for using Go/No-Go was only to maintain the volunteers mentally alert although it has not been considered an element of the study. At the end of the test (and inside the chamber) the volunteer repeated the same wind chill questionnaire. All the trials were performed at the same time of the day.

The presented results represent the average of the fifteen volunteers over time for each test condition, for both skin temperature (forehead and neck) as well as for brain activity (*Alpha* and *Beta* waves of the left occipital and right occipital). Before calculating the moving average of the *Alpha* and *Beta* waves values for the data of each one of the fifteen volunteers, the measurement's outliers and noise were removed, namely, signal artifacts caused by the movement of facial muscles and particularly eye blinking. These artifacts are generically considered a hindrance to proper signal interpretation, that is, noise that should be filtered from the EEG signal. EEG signals are often contaminated by many different artifacts caused by diverse situations (Craig et al, 2012). These artifacts were removed using EEGLab toolbox and specialised EEGLab plug-ins that utilise independent component analysis (ICA) and related strategies.

The choice of the occipital lobe is because it was the only one of the measured lobes that presented different results in both hemispheres (right and left) for all the temperature and humidity conditions to which the volunteers were subjected. Thus, it seems to present, in relation to the other cerebral lobes, higher sensitivity to respond to the variation of the temperature and humidity conditions that are the basis of the present study.

3. Data processing and results

3.1. Skin temperature

The evolution of the average temperature of the forehead and neck of the 15 volunteers for the four test conditions is shown in Figure 3 and Figure 4. The settling times of skin temperature are perfectly defined. The first twenty minutes outside the chamber and then the following ten minutes inside the chamber before starting the tests.

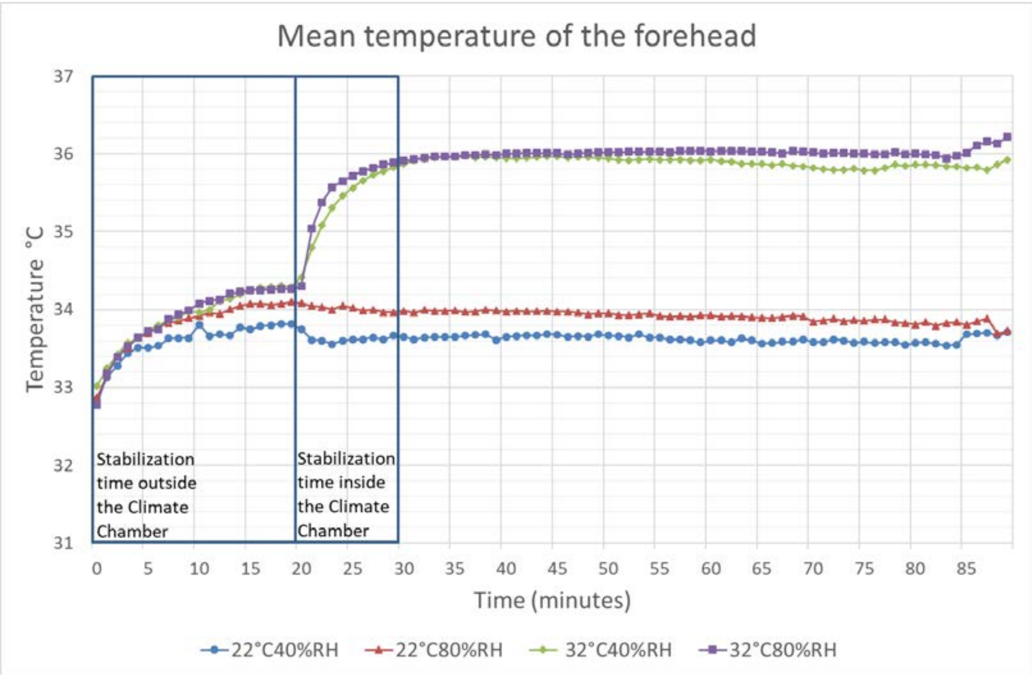

Figure 3. Forehead mean temperature in different environmental conditions

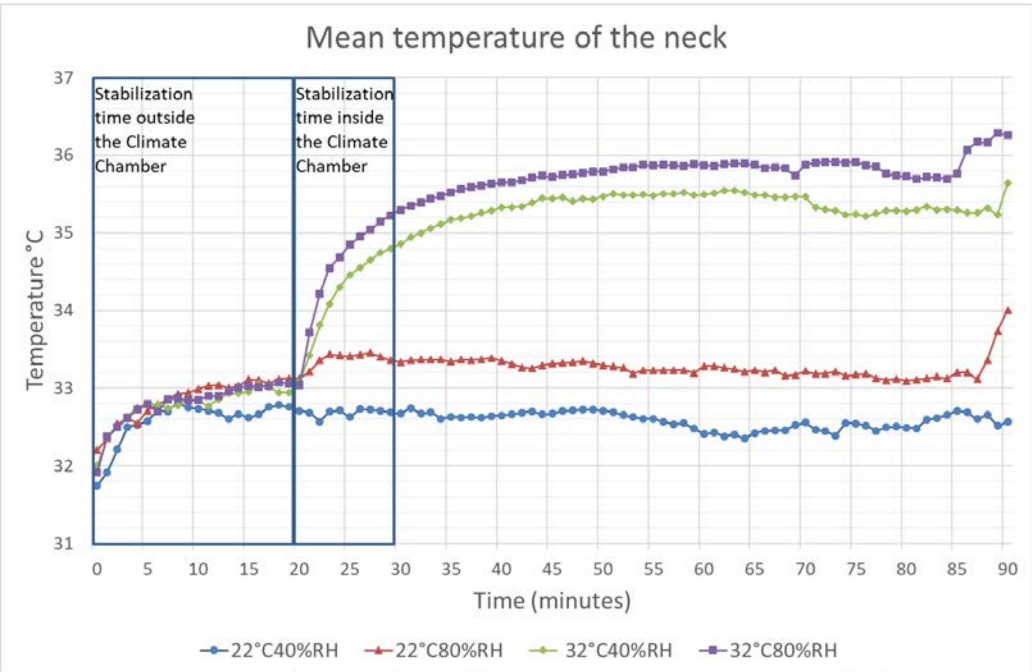

Figure 4. Neck mean temperature in different environmental conditions

In Table 1, the mean and standard deviation values are presented respectively for the forehead and neck temperature, for all the volunteers, between minute 30th and the end of the test, minute 90th. From this table, it can be seen that the average of forehead temperature is slightly higher than neck temperature, while the standard deviation is slightly higher on the neck.

Table 1. Statistical parameters for forehead and neck temperature (ºC) between minute 30th and minute 90th.

	22ºC40% RH		22ºC80% RH		32ºC40% RH		32ºC80% RH	
	Forehead	Neck	Forehead	Neck	Forehead	Neck	Forehead	Neck
Mean	33.6	32.6	33.9	33.3	35.9	35.4	36.0	35.8
Standard Deviation	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.2
Maximum	33.9	33.3	34.6	34.0	36.5	36.0	36.4	36.4
Minimum	33.4	32.3	33.6	33.1	35.8	34.9	35.9	35.3

3.2. *Alpha* and *Beta* waves: evolution over time

Figures 5 to 8 show the mean values of Alpha and Beta waves throughout the 60 minutes of the test. Data were collected from the left occipital (O1) and the right occipital (O2) under the four conditions in analysis: 22ºC-40% RH, 22ºC-80% RH, 32ºC-40% RH e, 32ºC-80% RH

A 3rd-degree polynomial regression model was fitted to the data records (Tables 2 and 3).

Table 2. Polynomial 3rd degree fitted models (Alpha O1 waves and Alpha O2 waves)

Alpha O1	Polynomial 3rd-degree equation
22ºC 40% RH	$y = 4E\text{-}05x^3 + 0{,}0036x^2 - 0{,}0989x + 1{,}3005$
22ºC 80% RH	$y = 0{,}0001x^3 + 0{,}0124x^2 - 0{,}3552x + 5{,}879$
32ºC 40% RH	$y = -0{,}0001x^3 + 0{,}0122x^2 - 0{,}3607x + 4{,}9063$
32ºC 80% RH	$y = 4E\text{-}05x^3 - 0{,}0047x^2 + 0{,}127x + 6{,}0217$
Alpha O2	
22ºC 40% RH	$y = -7E\text{-}05x^3 + 0{,}0067x^2 - 0{,}1763x + 6{,}1104$
22ºC 80% RH	$y = -6E\text{-}05x^3 + 0{,}009x^2 - 0{,}3346x + 10{,}387$
32ºC 40% RH	$y = -8E\text{-}05x^3 + 0{,}0081x^2 - 0{,}2494x + 11{,}005$
32ºC 80% RH	$y = -0{,}0001x^3 + 0{,}0135x^2 - 0{,}2952x + 14{,}202$

Table 3. Polynomial 3rd degree fitted models (Beta O1 waves and Beta O2 waves)

Beta O1	Polynomial 3rd-degree equation for each adjustment line
22ºC 40% RH	$y = -4E\text{-}05x^3 + 0{,}0042x^2 - 0{,}1149x - 1{,}9984$
22ºC 80% RH	$y = 6E\text{-}06x^3 - 0{,}0001x^2 + 0{,}0029x - 2{,}2356$
32ºC 40% RH	$y = -5E\text{-}05x^3 + 0{,}0055x^2 - 0{,}1781x - 1{,}5976$
32ºC 80% RH	$y = 7E\text{-}05x^3 - 0{,}0072x^2 + 0{,}1888x - 1{,}7365$
Beta O2	
22ºC 40% RH	$y = -8E\text{-}05x^3 + 0{,}0072x^2 - 0{,}1862x + 3{,}334$
22ºC 80% RH	$y = -4E\text{-}05x^3 + 0{,}0066x^2 - 0{,}2215x + 4{,}1356$
32ºC 40% RH	$y = 4E\text{-}05x^3 - 0{,}0028x^2 - 0{,}0204x + 7{,}0352$
32ºC 80% RH	$y = -0{,}0001x^3 + 0{,}0119x^2 - 0{,}2914x + 8{,}5271$

Alpha O1 and O2 waves

In Figure 5, an overview of Alpha O1 waves' evolution can be observed from the adjusted curves at different temperature and humidity conditions. In this lobe, at 32°C-40% RH and 22°C-80% RH, Alpha waves present a similar tendency, although with higher amplitude in the condition of 22°C-80% RH. In general, it is verified that the curve with smaller amplitude is 22ºC-40% RH and the one with greater amplitude corresponds to the test condition 32ºC-80% RH. The higher amplitudes are found in the curves corresponding to the highest relative humidity (80% RH), precisely at 22-80% RH and 32-80% RH.

As regards the right hemisphere (Alpha O2 - Figure 6) in general and taking into account the adjustment curves, there is a greater amplitude in the most extreme situation of temperature and humidity, in this case of 32ºC-80% RH. On the other hand, a smaller amplitude and a more stable curve are found in the situation closest to the neutral environment condition, i.e. 22 ° C-40% RH. These two curves present the same relative positions as that in the left hemisphere (O1). Concerning the amplitude of the waves' variation in the left hemisphere (O1), in the right hemisphere (O2) it is verified that the average amplitude of the Alpha O2 waves is higher than the average amplitude of the Alpha O1 waves, under the studied test conditions.

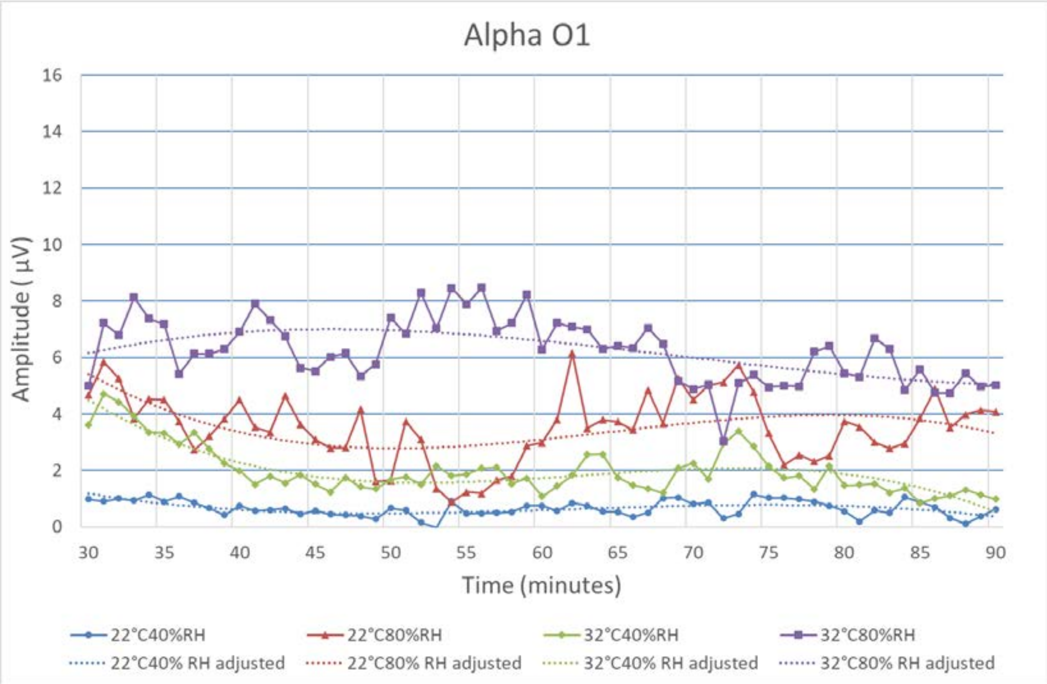

Figure 5. Mean values of Alpha O1 waves from the 15 volunteers at different temperatures

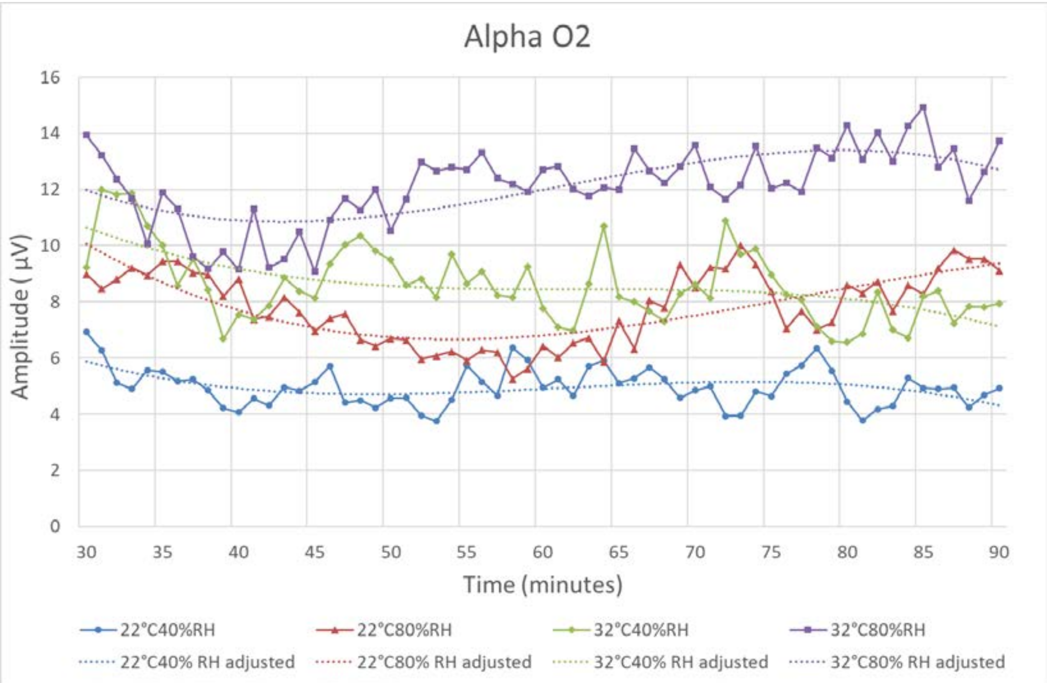

Figure 6. Mean values of Alpha O2 waves from the 15 volunteers at different temperatures

Beta O1 and *O2* waves

In Beta O1 waves (Figure 7) analysis, it is verified by the general evolution of the curves, that at 22ºC-40% RH and 32ºC-40% RH, the curves have an identical evolution and with close values. Once again it is possible to see similar behaviour in the curves with the same relative humidity. This seems again to indicate that relative air humidity may induce physiological changes that are reflected in brain activity, possibly due to the greater or lesser need for thermoregulation effort.

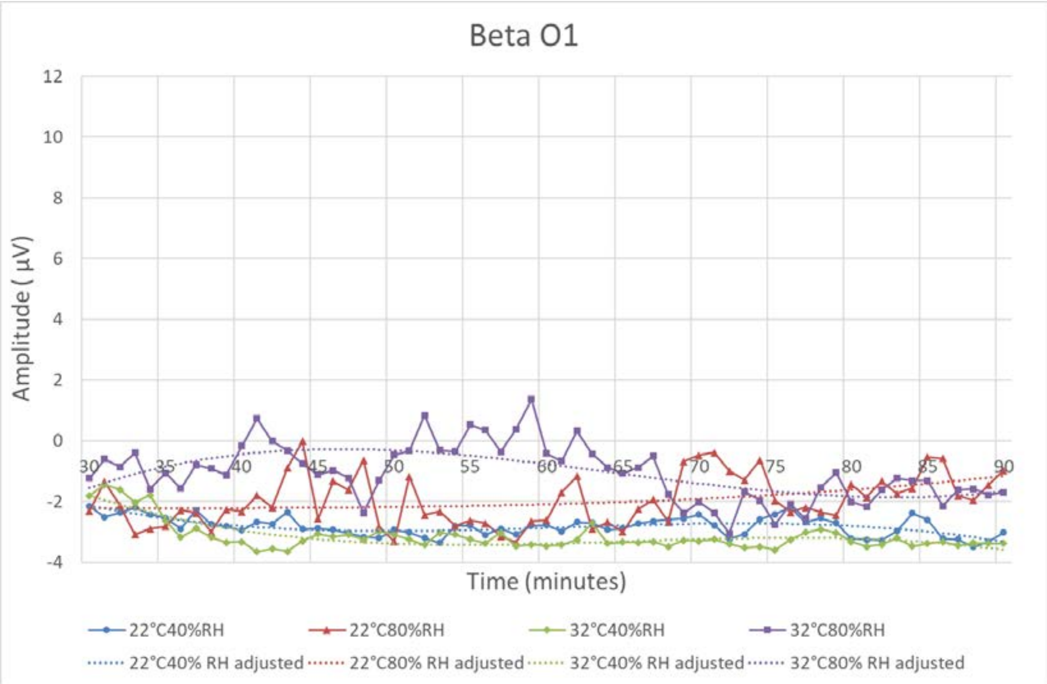

Figure 7. Mean values of Beta O1 waves from the 15 volunteers at different temperatures

In the first half of the test, in the Beta O2 waves (Figure 8), the same behaviour was observed for two of the adjusted curves (22ºC-40% RH and 22ºC-80% RH). In the second half of the test, the two curves diverge, increasing the amplitude of the signal in the condition 22ºC-80% RH and lowering to 22ºC-40% RH.

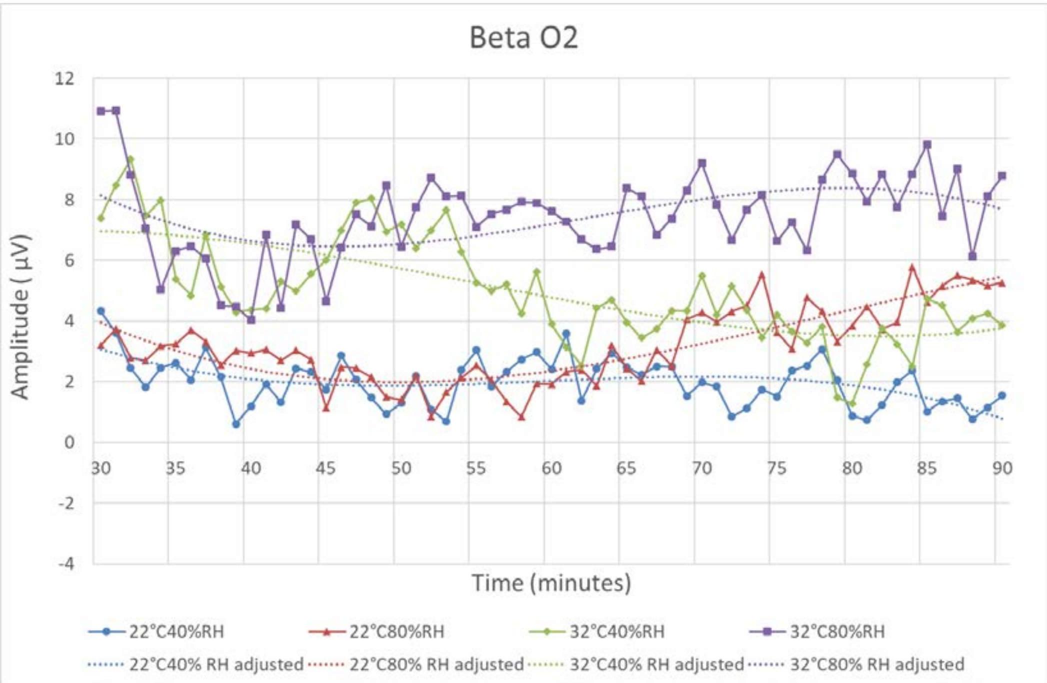

Figure 8. Mean values of Beta O2 waves from the 15 volunteers at different temperatures

4. DISCUSSION

4.1. Skin temperature behaviour

Analysing forehead and neck temperature evolution was possible to confirm the importance of the stabilisation periods, outside and inside the climatic chamber. These periods allowed performing the tests with very similar skin temperature, for each one of the environmental conditions. As can be seen in Figure 2, ten minutes after entering into the climatic chamber for each specific environmental condition, the temperature of the volunteer's forehead reaches a value that can be considered stable throughout the test.

The mean temperature of the neck presents some instability throughout the test (Figure 3). This instability is reflected in the standard deviation values. This can be explained by the measuring conditions on this point at the neck posterior area. At this point, the temperature recorded was influenced by the movement of the volunteer´s head, by the amount of hair which is usually different when dealing with males or females, as well as the garment's collar. Although in the trunk, the volunteers just wear one piece of clothing, the kind of garment was not controlled. In summary, it is a body area for which data monitoring results, can have externally induced noisy fluctuations (Table 1).

Under all environmental conditions, the highest temperatures were registered on the forehead, contrary to the results of Zhang (2003) who considered the hottest temperature on the neck (back) presenting a difference of 0.4°C between the neck and the forehead for neutral (26.9ºC) and hot (31.8ºC) environmental conditions. For cold environment (22.1ºC) this difference was of 3.8ºC. However, this author did not refer to the relative humidity during their tests. Also, the use of a specific radiant heat source (250 W lamp) may have influenced these results since they do not guarantee a homogeneous distribution of the ambient temperature.

4.2. The behaviour of the waves Alpha and Beta on the occipital lobes

It is known that heat exposure can change the cognitive performance and lead to changes in brain activity and, consequently, to changes in the EEG signal, specifically in the *Alpha* and/or *Beta* waves, as a result of an increased effort to accomplish a particular task (Costa & Baptista, 2013).

Considering the conclusions of several authors (Chen et al, 2013; Nybo & Nielsen, 2001; Ftaiti et al, 2010; Ribeiro, 2010), symptoms of mental fatigue consist of tiredness, drowsiness and consequently high risk of decreased performance. The possibility of occurring mental fatigue can, therefore, be evaluated from the change in brain activity signal, measured by an EEG, particularly Alpha and Beta waves (Nybo & Nielsen, 2001). An increase in EEG *Alpha* activity has been reported as mental fatigue signal (Craig et al, 2012).

4.2.1 Waves *Alpha O1* and *Alpha O2*

Third-degree polynomials regression models were adjusted to the results of the tests in order to facilitate their analysis and comparison. *Alpha* O1 waves generic behaviour, for the different conditions of temperature and humidity (Figure 5), can be evaluated based on the fitted trend models.

There is a similar generic behaviour between the curves in the conditions 32ºC-40% RH and 22ºC-80% RH, although with a higher mean amplitude in condition 22ºC-80% RH. Overall, it can be seen that the lower amplitudes correspond to the test condition 22ºC-40% RH and the highest amplitudes to condition 32ºC-80% RH. The higher amplitudes correspond to the highest relative humidity (80% RH), precisely 22ºC-80% RH and 32ºC-80% RH. The increase of relative humidity from 40% to 80% RH, does increase the signal amplitude. When the temperature raises from 22°C to 32°C while maintaining the relative humidity at 40%, there is an increase in signal amplitude but less significant than when the relative humidity raises to 80%.

Regarding the right hemisphere (*Alpha O2*), in general, and taking into account the respective trend models (Figure 5), it can also be observed greater amplitude in extreme conditions of temperature and humidity (32 °C-80% RH). On the other hand, and similarly to the *Alpha* O1 case, the signal with smaller mean amplitude and more stable is observed near the neutral conditions (22°C-40% RH). Regarding the amplitude of *Alpha* waves in the left hemisphere (O1) and in the right hemisphere (O2), it is evident that the amplitude of *Alpha O2* waves is greater than the amplitude of *Alpha O1* waves, in the conditions under study.

The relative position of the *Alpha* waves collected at 22°C - 80% RH and 32°C - 40% RH is different when read in the left hemisphere (O1) or the right hemisphere (O2). In O1, the *Alpha* waves have values greater for 22°C - 80% RH than for 32°C - 40% RH. At O2, the *Alpha* waves have higher values, with 32°C - 40% RH than 22°C - 80% RH, almost for the entire test (Figure

5).

4.2.2 Waves *Beta O1* and *Beta O2*

The general evolution of the trend models (Figure 6) for *Beta O1* waves shows close values and a similar evolution, under the conditions 22°C-40% RH and 32°C-40% RH. In these cases, there is no visible effect of the temperature on the evolution of these signals. At 22°C-80% RH and 32°C-80% RH conditions, the signals have higher values, but different development over time. Once again it appears that the variation of relative humidity by itself can induce changes which are reflected in brain activity, possibly, in this case, due to different levels of thermoregulation effort.

Concerning the *Beta O2* waves (Figure 6), under the conditions 22°C-40% RH and 22°C-80% RH, the behaviour is identical in the first half of the test. However, in the second half they diverge, increasing the signal amplitude in the condition 22°C-80% RH and decreasing in the condition 22°C-40% RH.

Under the conditions 32°C-40% RH and 32°C-80% RH, the *Beta O2* waves have similar behaviour in the first 15 minutes, from where they begin to diverge.

It is noted that after 15 and 22 minutes, the curves corresponding to conditions of greater humidity (80% RH), increase in amplitude.

5. CONCLUSIONS

The tests were performed at two temperatures, 22ºC, 32°C and two different humidities, 40% and 80% RH. Skin temperature was controlled in two points, forehead, and neck in order to ensure the stability of test conditions. Figure 2 and Figure 3 reflect the results of temperature variations on these two points over time, for the different studied environmental conditions. The conclusions drawn from this control are the following:

- It is noted that skin temperature at the selected points increases not only with room temperature but also with relative humidity, these results may be explained by the higher difficulty of thermoregulation when the humidity increases;
- When, in the environment relative humidity increases from 40% to 80%, forehead mean temperature increases 0.3°C at 22°C and 0.1°C at 32°C;
- In the neck, when the environment relative humidity increases from 40% to 80%, the mean temperature increases 0.7°C at 22°C and 0.4 °C at 32°C;

Regarding the presented results of brain activity analysis, they point to and confirm that the environmental temperature and humidity can influence EEG Alpha and Beta waves on the occipital lobe. It was also found, in terms of mental effort measured by amplitude values of *Alpha* and *Beta* waves, that the mean values over time are higher with increasing temperature or relative humidity. The relative humidity influence is more significant for Alpha waves than for Beta waves. The behaviour of *Alpha* and *Beta* waves with temperature and relative humidity is different in left and right brain hemispheres

Considering the objective defined for this study, it seems possible to state that:

- In a sedentary task, the brain activity measured by the amplitude of the EEG signal is generally higher for higher temperatures and humidities. This statement is more evident when the relative humidity increases, maintaining the same temperature. This can be explained by the greater thermoregulation effort of the human body when the humidity increases

It is evident the importance of studying the influence of the thermal environment on human activity, taking into account the diversity of results found by researchers working in this area of knowledge. Due to the complexity of the issue, the diversity of methodologies and critical aspects, the results are not always comparable.

In this study, the test conditions were guaranteed for all subjects in the four test conditions. However, the size and heterogeneity of the sample and the fact that only four environmental conditions have been tested can be considered as a limitation. Therefore, there is still a lot of work to be done, and the aforementioned limitations will be solved by the development of new projects.

Nevertheless, despite these constraints, it can be stated that the results obtained are in line with current knowledge and with the results of some other authors working in this area (Yao et al, 2008; Yosuke & Seiji, 2015; Craig et al, 2012; Lal & Craig, 2002; Tanaka et al, 1997; Trejo et al, 2005; Ftaiti et al, 2010; Ribeiro, 2010). It can also be stated that the results obtained in this study may justify results of other authors, such as Jazani et al. (2016), which point to a direct relationship between the predominant meteorological conditions and the mental workload.

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