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Analysis of the Human Reaction to Odors Using Electroencephalography Responses

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***Abstract*— The effects of scents on humans are divided into physiological and psychological effects. The physiological effect acts directly on the physical organism and the psychological effect acts via the sense of smell on olfactory system, which in turn may cause a physiological effect. Some parameters of the electroencephalogram wave brain signals are used to measure the aroma effects of the different odors. The studies of EEG signals through brain have revealed that odors are capable of causing changes in these signals. Substantial research has documented studies about the effects of pleasant and unpleasant odors. This paper shows the effects on EEG signals of six odors, which two of them are of the essential odors category and the rest are of the commercial odors category. The study was applied to twelve young healthy non-smoking subjects, five male and seven female in a small range of ages.**

***Index Terms*— *alpha* wave, brain stimulation, electroencephalography, signal analysis**

I. Introduction

The sense of smell is a primal sense for humans as well as animals [1], [2]. The human being is able to identify about 10 thousands of different odors, which one is defined by different chemical structure [3]. The perception of odors begins with the inhalation and transport of volatile aromas to the olfactory mucosa that is located bilaterally in the dorsal posterior region of the nasal cavity [4]. The immediate response to odors is based on a simple and binary answer: like or dislike, and the subject behavior and decisions are influenced by the value of this answer [5].

Many studies are being made to analyze the effects of the olfactory stimulation on the human being and to know if the odors can relax, excite or if they are part of the sexual behavior. Ride these studies is an easy and relative way to evaluate the human olfaction. It is relative because everyone is a specific case, although it is tried to minimize the differentiation factors, such as age, health and other important aspects [6].

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Despite of the recognized effects of the odors in the state of mind and in the human cognition, the neurophysiologists give less attention to the measurement of these answers as it needs. This measurement can be done into different ways: with the electroencephalography (EEG), which is the simple record of electroencephalographic signals from brain activity, and with evoked potentials, which use EEG to record EEG signals resulting from stimulation of some kind. Both are capable to demonstrate the response in the time of the Central Nervous System (CNS). Moreover, these techniques are able to display the neurophysiologic activity of the human organism in response resulting to other stimuli as sounds [7] and lights [8].

The effects of aromas are used in medicine [9] as well as in phytotherapy [10], where carminative, laxative or as a digestion aid and especially against infections of respiratory tract [11]. In aromatherapy some essentials oils have been used successfully in treatment of depression, anxiety and some forms of cognitive disorders as well as in insomnia and stress-induced ailments [12]. Other studies suggest that the EEG activity is susceptible to change during the exposure to odors [13], [14], [15], [16], [17]. The current studies in this field show some differences between the old results to the new ones, perhaps because the early studies made use of rudimentary EEG that recorded wick signals, less specific electrodes and without a control of the odor in the room [18].

In 1962, Moncrieff noted the most of the odors used in his experience led to a general reduction of EEG *Alpha* (α) activity. Here, only the fragrance of ylang-ylang did not produce any changes in these activities [19]. Some studies suggest that the olfactory perception is associated with a reduction in EEG α activity or a no change state of the same wave [13], [14]. However, others can display either an increase, but in this case the alterations are in the EEG *Theta* (θ) activity. In addition, to increase or decrease the brain activity, is noticeable, with the techniques mentioned above, the difference in activity with respect to the location of spatial electrodes, namely when the human is exposed to the fragrance, the activity of the left and the right hemisphere has different intensities [13].

The effect on cerebral activity has always different results if the subject may suffer from some type of disturbance, such as obsessive-compulsive disorders. To corroborate this fact, in the year 1996, it was conducted a study, whose subjects were victims of this pathology. To use as a control group, the EEG was applied during the sleep period and later compared with the results obtained during the olfactory stimulation. After the processing data, it is recognized significant changes in the *Delta* (δ) and α waves. These patients have an increased activity of the first wave and a flow in closed circuits within the brain cell receptor for its axons through the cell membrane into the extracellular space and, in this space, back to the synapses. Inhibitory inputs generate loops moving in the opposite direction. When it is added up all the entries and if the limit is reached, an action potential is triggered. Electrodes placed on the scalp record these currents after they leave the cells, and the resulting EEG show the excitement of entire groups of cells (pools) [20].

The technique of tracking and quantitative analysis of electroencephalographic data has been used in children [21] and in adults [22]. This technique has also certain disadvantages. On one hand it will elicit also trigeminal or gustatory sensations. On the other hand it does not allow studying olfaction in isolation [23]. Various responses to different odors from foods have been registered [24], [25]. All these studies have been a basic replication of the method used by Moncrieff. However, the number of electrodes has increased and with it amounts to measurement accuracy [18]. A study carried out in this field in 2007 documented records that indicate a different activity depending on preference or loathing to an odor from computer simulation [8].

The human response to an odor is highly subjective; different people find different offensive odors in different concentrations. These results in different forms of subjects perceive odors and then make the odors play an important role in social interaction too [26]. Aroma molecules have direct effects on human behavior and physiology ranging from activation of memories to change in mood or emotional states [27]. The relationship between smell and emotion can be understood from the investigation of olfactory information processing by the sensory system [28]. When an aroma is felt, immediately the tonsils function and relation that odor to action or emotional state of the subject. The smell is then stored into memory accompanied by emotion triggered at the moment. When you feel the same smell, the affective memory is activated, and the connection between the smell and the corresponding emotion becomes noticeable. The preferences of a person for certain smells are related to specific memories and associations.

Physiological researchers and neuro-psychologists are concerned with odors as interface to our emotional center and the long-term memory. The sense of smell is unique in influencing emotions and in recalling long-forgotten memories [26]. The memories that include memory of odors tend to be more intense and emotionally stronger. An odor that has been felt at once in life can be associated with a single experiment and so their memory can be raised automatically when you reconnect with the aroma. And the first association is made with an odor seems to interfere with the formation of subsequent associations [2], [26], [29].

The pleasant odors have positive effects on the humor in all age groups, increasing performance at work. People exposed to pleasant odors are more attracted to other people, which prove the connection of emotion with the smell. Unpleasant odors may affect the perceptions and evaluations. Studies indicate that positive emotions are processed primarily in the left hemisphere of the brain, while negative emotions are processed mainly in the right hemisphere[2], [5].

The EEG has been used to study the smell, with the aim of finding brain wave abnormalities [14]. The EEG can be used to monitor the State of relaxation and brain alert [30].

The EEG is simpler, but imprecise to understanding odor processing. To register EEG signals are required electrodes capable of measuring potential differences between scalp points with relevance to the concerned study. The assembly used must be designed for easy interpretation of EEG characteristics intended to analyze. An assembly can be referential, i.e. monopolar, when the potential differences are measured between each electrode and a reference electrode (usually in a position with minimal possible activity, as for example in the earlobe). This assembly was used in this work.

The method involves the recording of EEG data segments during sensory stimulation. This article reviewed some work done in this field. It is also presented the methods used to record EEG signals while is presented some aromas in section II, and the obtained results in section III. In section IV is discussed what was conclude and is given some ideas for future work.

II. Methods

A. Subjects

The participants of this study were 12 faculty members of University of Beira Interior (7 females, 5 males, *M* age = 21.89, range 19 to 26). They were all Caucasian, nonsmokers and with normal sensibility to common odors. They were asked not to drink alcohol or caffeine since the day before and not to chewing gums. They had to sleep at least 6 hours and do normal meals and medication. The last meal had to be 2 hours before the tests. They could use perfume only if it was put 3 hours before. Their clothes had to be comfortable and their hair had to be cleaned, dry, with no cosmetics or accessories. Subjects were instructed to set a comfortable position, be relaxed, and breathe normally through their noses and sit quietly with their eyes closed.

B. Equipment and Materials

The device used for this study was the PowerLab/4st connected to the computer through a USB port. Then, the Bio Amp cable that is connected to the main device has 3 derivations. These 3 derivations are connected with an electrode each. It was used in the subjects with a hair ribbon to prevent the movement of the electrodes and increase the contact between the electrodes and the subject skin scalp. At the same time, was used a blindfold to reduce the visibility to prevent visual stimuli and the blink. To minimize the auditory stimuli was put into the subject auditory cavity a piece of cotton.

The odors presented belong to one of two groups: essential or commercial. The essential odors are a set of substances that by convention are presented naturally in the environment at pressure and temperature normal conditions. The commercial odors are produced by human and they are

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a mixture of essential odors with water to provide a lasting and pleasant aroma. The odors from the essential group are: mint and lemon. The other ones are marketed in the form of soaps, and were assigned gently by the Ach Brito, Claus Porto, a centenary Portuguese company that produces soaps, and the used commercial odors were: Criton-Verbena, sweet aroma of citrus blossoms and verbena; Lize, produced from the morning-glory flower and musk; Melody, which presents itself as a good option within the soaps fruit flavorings conjugates, and in this special case, the melon and peach; and Rozan, extracted from paradise-rose. These commercial odors could not have alcohol. The odors were chosen in different odors classifications: citric, musky, fruity and floral.

C. Test Procedure

First, it was ensured that odors are perfectly identifiable. The smells should not be presented to the subject who goes to be tested. Also should be avoided other stimuli than those in the study, such as sounds, that is why the subject had put cotton in the hearing cavity to reduce this impairment factor. Visual stimuli should not exist, so it was placed a blindfold and this way they cannot open their eyes. The act of a single eye blink would be detrimental. Since we were only using a system with 3 electrodes placed in the frontal lobe of the skull, which is responsible for much of the motor activity of the body, the movements referred would be easily detectable and the overlap of these waves would be full of noise.

The 3 electrodes for the EEG signals recording are placed in the subject head. One of the 3 electrodes is connected with the corresponding cable to Earth and it is placed in the forehead, down of line of the hair, 5 cm left of the middle line. The negative electrode is the frontal electrode, and it is placed the same way than the Earth cable, but in the opposite side. The electrode missing is the occipital electrode. It is placed in the back head as near as possible of the scalp, and in the same side of the negative electrode. Before the placement of the probes was applied a small amount of conductive gel for EEG, in order to increasing the conductivity between the surface electrode and the scalp.

Subjects experienced the test in a dimly lit room, and silent. The experimental session included 3 steps: 5 minutes to capture baseline signal for comparison purposes, and stated as the control group or neutral group; 2 minutes of inhalation of odor and, furthermore, 2 minute rest with inhaled water steam to decrement the fatigue or odorant adaptation. Each subject had only one session of about 30 minutes.

It was suggested to the subject under test that found the most comfortable position and then the electrodes were placed. The data began to be collected by the PowerLab and displayed on the monitor of the computer receiving the data output device. The odors were in a different room so that the subject does not feel its presence and was placed with him only at the time of testing. We carried out the record during the 5 minutes of activity at the base of the subject and, subsequently proceeded to the presentation of other odors, each them lasting 2 minutes interspersed with 2 minutes of rest, as has already been mentioned above in this article.

The data collected were processed by PowerLab/4st. This device provides the software required for the computer to receive signals, already under waveform after have been converted. With the software it is possible to view and choose some wanted options. Thus, to obtain data to be used in this work, after correctly placed the electrodes in the subjects, were connected through a biopotential cable to the PowerLab, which was connected to the computer with the software installed. The program was then initialized and chosen the proper acquisition channel, from the multiple channels available. In the Channel 3 was chosen the number of samples in the upper right corner, i.e., 2 hundred samples per second, and the range 200mV.

Some filters, were also applied. The first option is to choose the filters for 50Hz, which corresponds to noise generated by the power source cables, where the voltage is 230V and the frequency is 50Hz. Beyond this, it was build a band pass filter, i.e., in the same window was selected the 1Hz high pass and low pass of 20Hz filters. Ideally with these last 2 filters, the source noise on the power supply should not be necessary to choose, however, even cutting selected frequencies of that value, it interferes because it is possible to see in the spectrum of the data, existing frequencies of this nature.

At the end of the test it was carried out a survey to determine which odors were recognized, which of them caused the reactions, as good or bad memories, or which of them were nice or not. These data will be taken into account for the discussion of the results in section III.

The data collected by the software are displayed in graphical form wave. However, it is possible to manipulate them according to our pretensions. As already known, the brain activity varies from person to person, but it is possible to see small similarities between them, a type of standard. To ensure the validity of the results, we tried to reduce the presence of external stimuli, such as light, sound, and others. The data obtained was based on the activity peaks in each test segment.

III. Results

It should take into account that the obtained results, as it is possible to visualize as example in Fig. 1, are under influence of 3 main causes: an electromyographic activity of the muscles of the face and the scalp, the electrical potential of eyes movement, and mechanical movement of the electrodes.

It was used an important tool of the PowerLab that is the *Spectrum*, which has an interface of the Fig. 2. It uses the Fourier transform to analyze the selected data, using the Welch method of estimation of the power spectrum.

The physiological response to six odors was constructed from the amplitude and frequency spectra in α frequency bands. Five minutes of representative and artifact-free EEG were selected for FFT analysis before onset of odor delivery. EEG was also quantified at 30 seconds after stimulus termination. Subjects differed in their subjective responses

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to the odors. Was analyzed in detail the frequency of the signals and it was considered that the subject responded to an odor whenever the frequency of its wave reduces its value.

In general, the odors were pleasant. Regardless of whether it is male or female, all mostly like every smell (75 to 83.33%), there is none whose largest percentage were unpleasant, nor any that stand out by the amount of positive reviews.

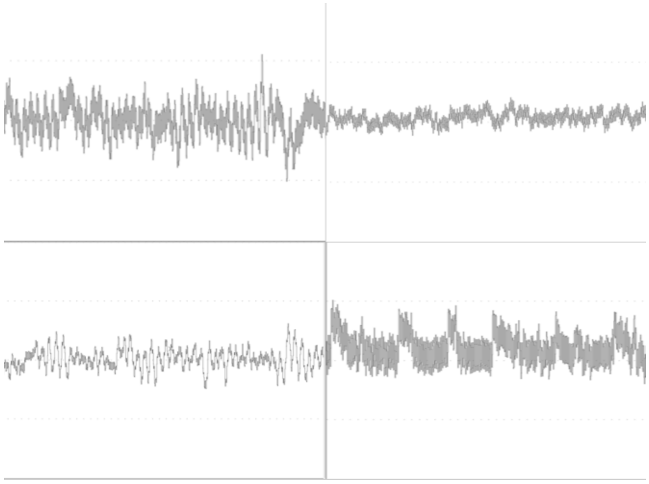

Fig. 1. Electroencephalographic signals from subjects tested. On top and on the left is the base activity of a male, and on top and on the right is activity for the Melody odor. Below and on the left is the base activity of a female, and below and oh the right is the activity for the Melody odor.

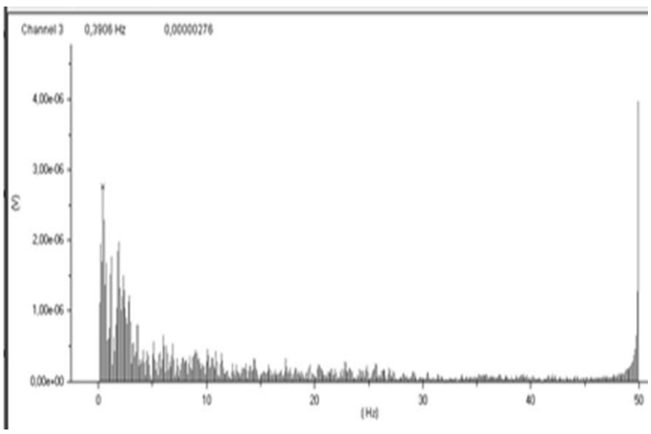

Fig. 2. Spectrum of a selected electroencephalographic signal part.

In the case of females, Subjects A to G, each of the odors stimulated more than those who did not produce any effect, as seen in Fig. 3. In the case of males is the opposite, because just the smell of mint and Lize stimulated more than those whose did not produce any effect. There is no differentiation in these two odors. When we speak of Citron-Verbena and lemon, the rate of subjects who did not react is greater. For the lemon 80% did not react. For Citron-Verbena there was any subject reacting to this. Overall, subjects react more than the cases that did not produce modifications, where 52.78% of the sample reacted.

In the case of the male, Subjects H to L, sample did not happen this way because 60% did not react to essential odors and 65% did not react to commercial odors, as seen in Fig. 4. For the female sample, the percentage of those who reacted to the odors was equal to the essential and commercial odors, 64.29%.

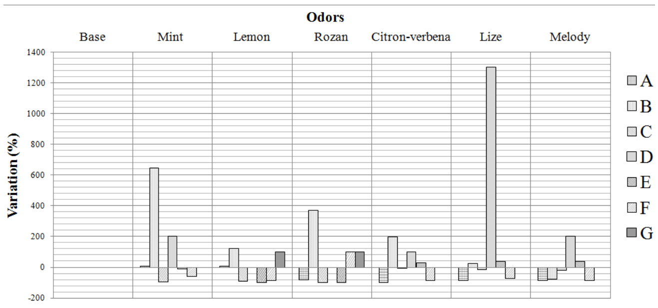

Fig. 3. Bar graph of the female frequency changes (in %) relatively to base activity.

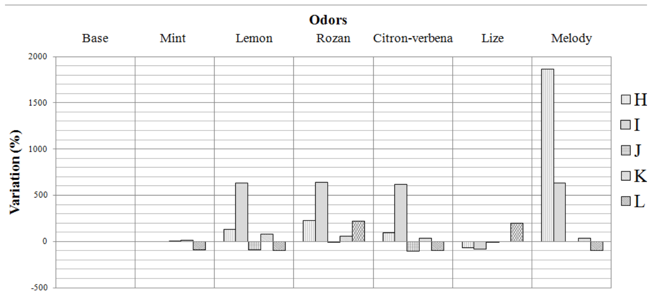

Fig. 4. Bar graph of the male frequency changes (in %) relatively to base activity.

IV. Conclusions

For the male sample, citrus aromas aroused little or no interest. Despite the difference of the values being small, essential odors stimulated more than commercial odors. In the case of females, they reacted more than males and always reacted more in each odor. With this sample, we can conclude that women are more sensitive than men. We can also conclude that all odors affected the EEG waves in at least some subjects, and all subjects responded to at least some odors.

For future work, it would be interesting introduce in the odor sample some other essential odors, such as camphor, musk, floral, ethereal, acrid e putrid. It would be interesting too, add to our subject sample people with different social status to analyze whether the social class, the level of schooling among other parameters influence the brain waves resulting from the human reaction to the odors.

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