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Determination of odor profile of university students using electroencephalography (EEG)

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Abstract

Sense of smell, a subjective sensation, has not been studied as much as the other senses hence interpretation of olfactory messages is still not a fully understood process. Olfactory perception, about which science made some significant advances only in the last 30 years, identifies a chemical substance coming to nose while also remembering past experiences. Therefore, in terms of odor appreciation profile it is important to reveal the difference between individuals as well as societies. The aims of this study are interpretation of EEG data with subjective statements, generation of a common denominator considering the gender variable and determination of odor appreciation profile for the Turkish sample.

In this study, subjects who have no detailed information about the olfaction and odor were selected. EEG measurements were of randomly selected thirty six (eighteen female and eighteen male) right-handed, aged 18-28 years university students. Odor panel consists of 13 pleasant smells from different odor families (orange blossom, jasmine, peach, aldehydes, musk, vanilla, sandalwood, grass, amber, bergamot, pine, rose and patchouli). After examination of participants' demographic characteristics, subjective statements and EEG data during smelling, The Odor Profile of University Students was provided and suggestions were made related to the conclusions.

Keywords: Odor Profile, Electroencephalography (EEG), Odor Appreciation.

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1. Introduction

Humans gather some information about chemical materials from surrounding environment via their sense of smell, which has not been studied as much as the other senses. It is known that fragrances affect physical and mental condition of humans since 5000 B.C. (Kose et al., 2007). Some of the effects of fragrances are controlling mood, reducing stress, refreshment, calming, etc. (Masago et al., 2000). Another important purpose of using fragrances is the desire to be accepted in the society. The sense of smell has highly personal characteristics. Moreover, lifestyle, cultural characteristics, age and gender affect the odor appreciation.

Subjective tests are widely used to determine odor appreciation. However, effects of odor vary among individuals. Currently, electrophysiological tests are employed to support subjective methods. Weizkrantz revealed a hypothesis in 1986: "The odor perception is a phenomenon that affects our lives without realizing it. Odor perception of a normal human is like a blind eye unconsciously reacting to light." Lorig (1989) advanced the hypothesis and indicated that a person's brain activities were affected unconsciously by odor that possesses complex and perceptually subtle effects. Lorig (1989) also provided EEG (electroencephalography) usage for this subject. EEG data usage is considerably important because it made possible to evaluate odor perception neurologically and to add value to subjective data obtained from subjective statements.

In this research, electrophysiological methods and subjective statement will be used in determining the odor profile simultaneously.

Sense of smell has completely personal characteristics besides responses to odor can vary with demographic characteristics, psychological differences, gender, age, and health status. The first study that demonstrated the relationship between individual differences and odor perception was made by Retiveau (2004). There is no other study found which addresses this issue neither in our country nor in foreign countries.

It is important to study the relationship between perceiving the odor and the factors such as habits, personality differences, cognitive behavior, experiences, and geographic are a characteristics and cultural background in order to determine perception, connotation and expression of scents in Turkish culture.

This study is limited to individual and gender differences and single experiment for each odor using only EEG measurements (alpha, beta and gamma bands with two channels) among all electrophysiological measurement techniques of randomly selected 36 students from Gazi University in Ankara province.

In this study, EEG changes and subjective statements of university students while inhaling fragrances in view of gender differences were investigated in order to determine odor appreciation profile in society.

1.1. Conceptual Framework

Brain imaging techniques are newly developing methods for consumer research. The various electrical patterns associated with different kinds of behavior are distinct in allowing reasonable assessments of what a person is doing at any time. However, the ability to decipher the brain's electrical activity has not progressed to the point at which researchers can tell what someone is thinking. It is possible to demonstrate whether someone is awake or asleep and whether the brain is working normally (Kolb & Whishaw, 2005).

Hans Berger, in the beginning of 1930s, discovered that electrical activity in the brain could be recorded by a noninvasive method. Placing electrodes onto the skull has opened a window for determining the mental processes that take place in the brain. Mendl, Burman and Paul (2010) states

that conscious experiences of emotions cannot be measured; however, neural, behavioral and physiological indicators of emotions can be measured objectively. Popularly known as "brain waves," recording the electrical activity produces an "electrical record from the head," or an electroencephalogram. EEG is preferred mostly in clinics and research because it is cheap, easy to apply and noninvasive. Besides medical usage, brain imaging methods are widely employed in consumer research. According to Sørensen (2008) "Although problematic and challenging, it is found that further work on the measurement of emotions in general and future-oriented emotions in specific are important to consumer research."

Each of the neurophysiological brain imaging techniques has different physicochemical principles and provides information about brain structure or how it is functioning. EEG, the oldest brain imaging method, is also the low-priced and most widely available brain imaging method and the data analysis is relatively less complicated compared to other brain imaging methods (Sørensen, 2008). EEG measures voltage fluctuation at brain surface on the outside of the skull. Good temporal resolution, needless cognitive processing, noninvasive, easy to analyze data and relatively cost-efficient equipment for data collection are the advantages of EEG whereas very limited spatial resolution is the disadvantage. Sense of smelling humans is often neglected and misunderstood. In the past, many scientists have stated that olfaction plays only a remnant role in humans.

Recent evidence suggests that human olfactory ability is not vestigial but exists most often in the background of awareness (Lorig, 1999). As mentioned earlier, since odor has complex and perceptually subtle effects on brain activity, person may not be aware that their behavior was affected by odor. Lorig (1999) emphasizes that widely used self-report techniques gives a limited picture in this field so electroencephalographic techniques play such a valuable role in understanding the effects of odor on humans.

There are no constant or acute boundaries for classification of odor (Sugano, 1992). Various herbal materials such as seeds, leaves, fruits, flower, wood, root, sap or sometimes the whole plant can be used to create a fragrance. In the past, various physical separation techniques have been used for the synthesis of natural products; however, in time artificial materials were developed. Benzaldehyde, one of the first artificial materials used in perfumery is derived from toluene in 1866 (Calkin & Jellinek, 1994).

In this study, the odor panel included bergamot, orange blossom, peach, rose, jasmine, grass, pine, vanilla, sandalwood, patchouli, amber, musk and aldehyde.

2. Materials and Methods

Subjective statements (self-reports) and EEG records were used in determining odor appreciation profile. EEG changes were obtained during inhalation of odor and after recording participants filled a self-report during inhalation of odor again. EEG measurement technique was first used by Moncrieff (1966) to measure odor stimuli systematically.

The participants for EEG measurements were randomly selected thirty-six (eighteen female and eighteen male) right-handed, aged 18-28 years university students. Before written consents were taken, every participant was informed about procedures. Participants stated that they are healthy in terms of nasal congestion, anosmia, drug use and neurological disorders prior to experiments. Subjects are taken one by one to the climatic chamber with 50% relative humidity, the average temperature of 23˚C and during daylight.

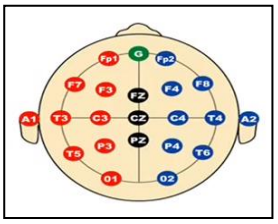
After subjects were told to lie down on the stretcher, close their eyes and breathe normally for every situation, electrodes were placed in the electrode cap on subjects' heads. After a 3 minute resting period for each odor, subjects smelled each odor within a proximity of around 2cm to their noses for 10-second periods and EEG record was taken for 1,5 minute. The order of odor stimuli was

not changed at any time. Climatic room was ventilated for an approximately 3 minute period between each trial to ensure a proper transition. Each opened vial quietly brought in front of nostrils and let the smelling occurred. Odors, absorbed into a paper were kept in 20ml test tubes. Each scent bottle was labeled with a code consisting of a three-digit number.

After EEG recordings completed, subjects were asked to fill a subjective statement questionnaire while smelling a random odor. Fully prepared odor samples were obtained from Erdogmus Perfume Industry.

The odor sample list is given according to chemical classification: *Bergamot, Pine, Sandalwood, Patchouli* and *Amber* as terpene compounds; *Vanilla* from the phenol group; *Orange Blossom* derived from naphthalene and also among terpene compounds (Sell, 2006); *Rose* both benzene and terpene compound (Sell, 2006); *Aldehyde, Peach* and *Grass* as aliphatic compounds; *Musk* from musks; *Jasmine* as toluene were included in our odor sample (7 groups; 13 fragrances).

EEG recordings were recorded via Power Lab (AD Instruments) digital data acquisition system. EEG recordings of the subjects were recorded digitally in 1kHz sampling rate by using a standard EEG electrode cap, according to international 10/20 system,T3 -T4andT5-T6(Fig. 1) ranges as bipolar. So EEG activity of the right and left temporal lobes were recorded continuously throughout the experiment. During the experiment, the moments, as soon as the odor stimuli were given were marked on the record. The results of the EEG recordings from individuals were obtained by elimination of contaminated EEG areas –primarily blinks and other motion artifacts- by using visual examination method. Each raw EEG recording was separated to Delta (0.1-3.5 Hz), Alpha (9-14 Hz), Beta (14.5-24 Hz) and Gamma (25-50 Hz) bands (Timofeev and Gordon, 2001) with digital band-pass filters and these bands were recorded to a log file as addition channels. After raw EEG of 3-minuteresting state and the RMS values of 1.5 minute period following inhalation of each odor for both right and left hemispheres were recorded automatically with macro feature of Chart software, Data Pad application, for each wave band, analyses were entered and arranged in MS Excel, then transferred to SPSS. The relationship between EEG activity data before smelling and after smelling was tested with Wilcoxon Signed Rank Test. The analysis results showed that the values which are smaller than Significance Level (P) <Table Value (α) = 0.05 to 0.10 have statistical relation on the other hand, between the values which are higher than Significance Level (P) > Table Value (α) = 0,05 to 0,10 have no statistical relation. The data are presented graphically. Frequency and percentage values of subjective statements data were calculated in SPSS and the resulting data were associated with EEG results.



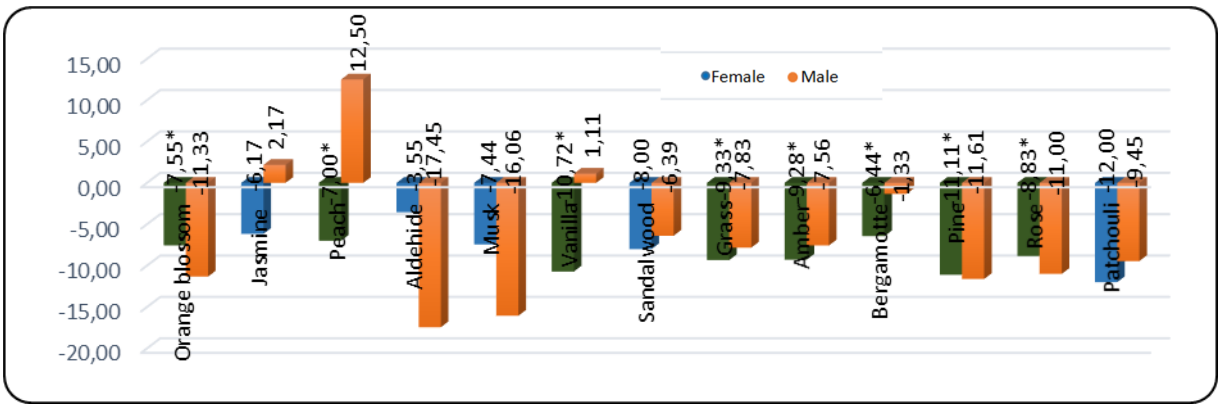
F: Frontal lobe
C: Central lobe
T: Temporal lobe
P: Parietal lobe
O: Occipital lobe
A: Ear (earth)
Z: Electrodes placed on the mid-line

(http://www.youtube.com/watch?v=IwGIF5aCnqg&feature=related)
Figure 1.EEG Electrode Placements on Skull

3. Results and Discussion

The results of spectral analysis showed that different odor affect different wave bands of both male and female in various rates. Brain wave bands were separated as alpha; delta, beta and gamma, as well as they were compared with left and right hemispheres. The effects of 13 odors on different wave bands were obtained from comparison of resting states and EEG data during smelling for each odor.

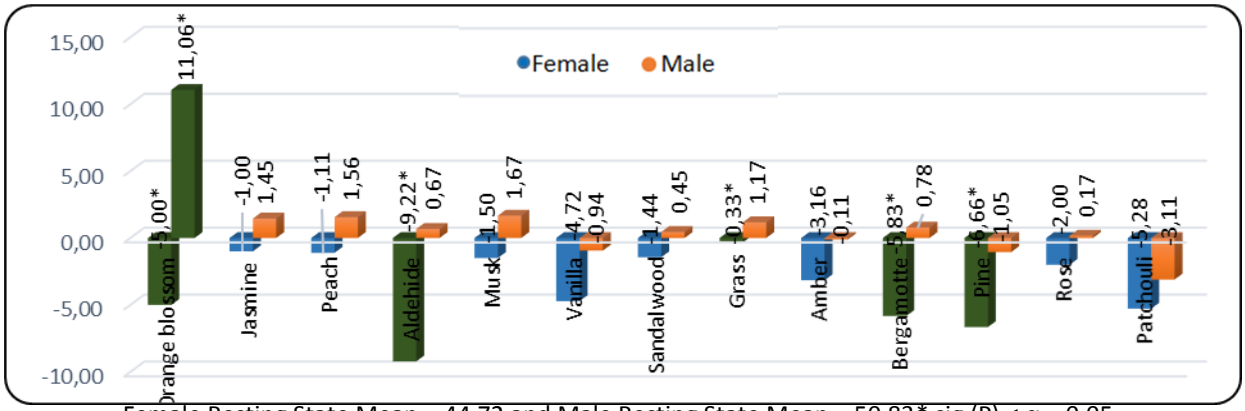
The EEG activity analyses are given in figure 2-8. The numbers that represent spectral power of wave bands are multiple by 10 thousand so that figures can be seen clearly. While interpreting, figures were associated with participant's self-report results. Different (P <α = 0.05) values according to the Wilcoxon signed rank test are shown in green colored cells, indicated with (*).



Female Resting State Mean= 47,61 and Male Resting State Mean = 47,89* sig (P) < α = 0.05
Figure 2. Left Alpha Band Results according to Gender

The analysis of the data in Figure 2 indicates that in temporal region records of female sample, there is a significant reduction in left alpha activity in response to orange blossom, peach, vanilla, grass, amber, bergamot, pine and rose odor in left hemisphere. It is possible to say that these odors were pleasant and popular fragrances for female students. The study of Toller, Behan, Howells, Kendal-Reed and Richardson (1993) revealed that the reduction of left alpha derives from pleasure. EEG findings were complied with subjective evaluation.

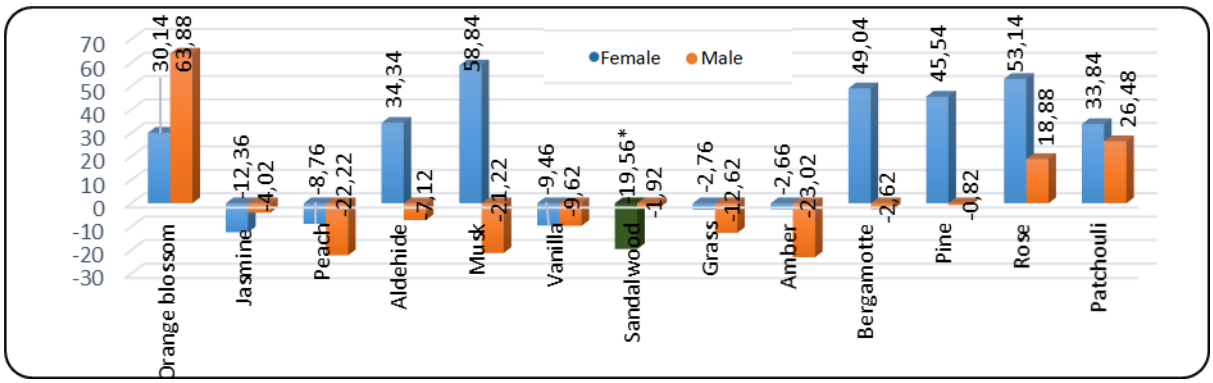
Lee et al., (1994) determined an increase in alpha band in jasmine odor along with other odor and concluded that the odor had calm perception, focusing or soothing effects. In Figure 2, a statistically insignificant increase was observed only in peach, jasmine and vanilla out of 13 odors in male left alpha band. Therefore, it is possible to say that peach, jasmine and vanilla odor have focusing or soothing effects. Our finding correlates to the study of Lee et al., (1994).



Female Resting State Mean = 44,72 and Male Resting State Mean = 50,83* sig (P) < α = 0.05
Figure 3. Right Alpha Band Results according to Gender

In Figure 3, there is a decrease in female right alpha in response to orange blossom, aldehyde, grass, bergamot and pine odor. Orange blossom odor significantly raised male right alpha waves. This odor can be considered as a stimulant for men.

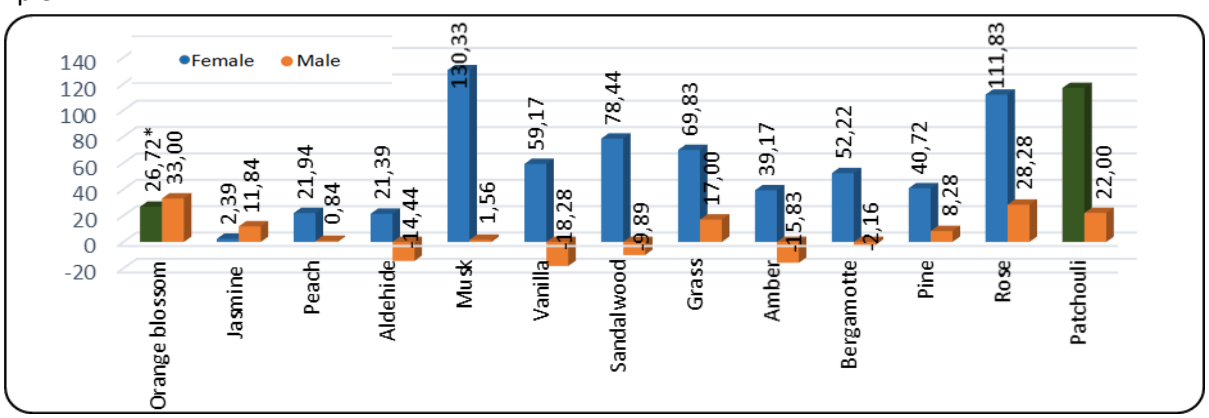
When the values in Figure 3 are relatively valuated, right alpha band was decreased for the entire odor in female sample on the other hand only patchouli had relatively same effect in male sample. In consideration of all alpha waves data, for female sample every odor reduced alpha waves but especially orange blossom, peach, vanilla, grass, bergamot, pine and rose odor had the high rate of decline. It is possible to say that, reduced alpha waves have an increasing concentration effect in brain or relaxing effect in women. However, relatively orange blossom, jasmine, and peach odor had higher alpha waves than resting state alpha waves in male sample. Statistically in significant increase of alpha waves for these fragrances means focusing or soothing effect for men. Our findings are correlated with study of Masago et al., (2000) and Lee et al., (1994). It can be said that orange blossom, aldehydes, grass, bergamot and pine odor have soothing effect for female students. However, there is no correlation to self-report for aldehyde and pine odor. Generally speaking, the increase in gamma band is responsible for the reduction of alpha activity.



Female Resting State Mean = 115,56 and Male Resting State Mean = 103,72* sig (P) < α = 0.05

Figure 4. Left Delta Band Results according to Gender

In Figure 4, for right delta band orange blossom and patchouli odor significantly increased delta waves more than in resting state in female sample. There is no significant relation for any odor in male sample.



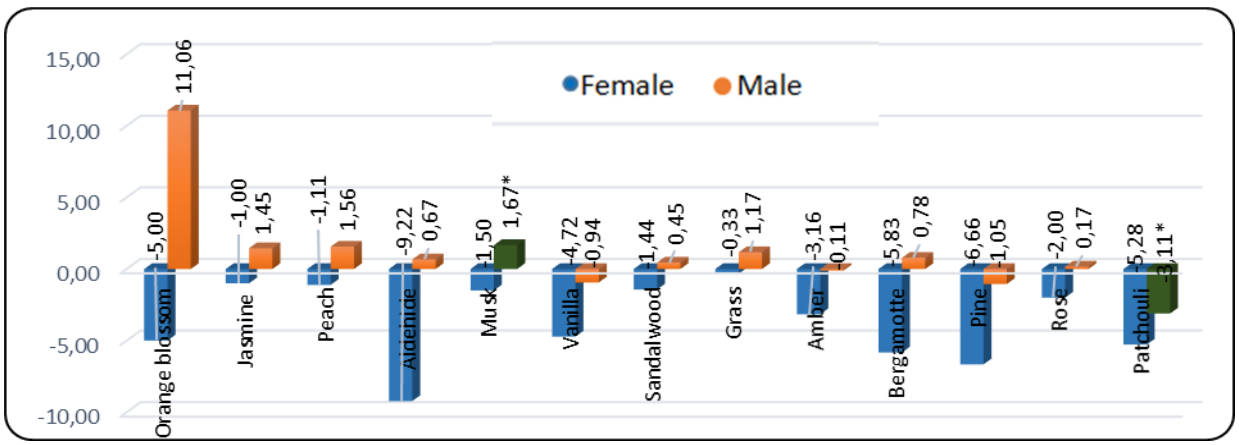
Female Resting State Mean = 115,89 and Male Resting State Mean = 109,72* sig (P) < α = 0.05

Figure 5. Right Delta Band Results according to Gender

In Figure 5, statistically significant lower left delta waves can be seen for sandalwood odor in female sample. Low left delta waves were observed in female sample for jasmine, peach and vanilla odor but in male sample statistically insignificant same result was seen for peach, musk, amber and vanilla odor.

It is known that delta waves are observed when the brain is in a low activity state. Murakami (2005) states that increased low-frequency waves in delta band have soothing effects. According to this, sandalwood has a soothing effect for female sample. Murakami (2005) detected that vanilla odor generated low delta waves in both female and male sample. Moreover, vanilla odor generated relatively low delta waves in both female and male sample in our study. The correlation between Murakami's and our study suggests that vanilla odor has a soothing effect on both Japanese University Students and Turkish University Students. Aldehyde, vanilla, sandalwood, amber, peach and musk odor generated low delta waves so these odors also had relatively soothing effect in male sample. In female sample, jasmine, peach and vanilla odor generated low delta waves so these odors also had relatively soothing effect.

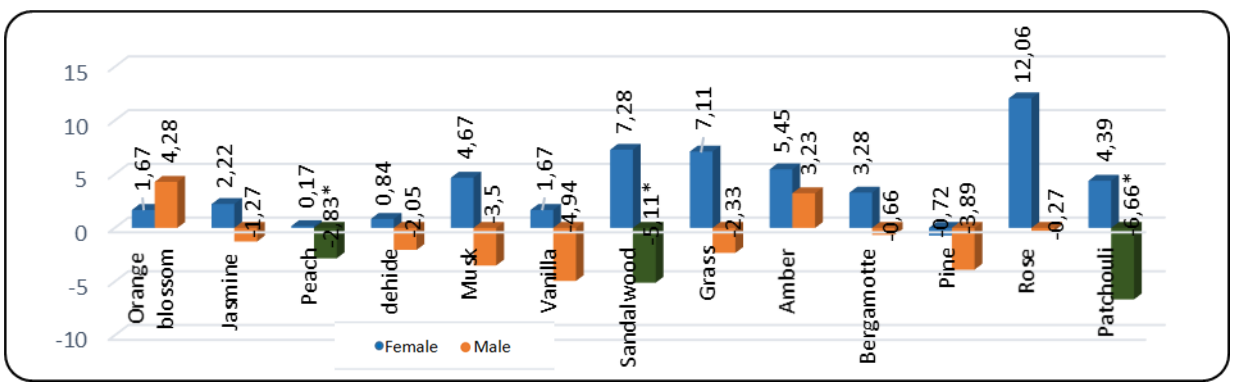
Our sample group stated these odor separately as "soothing" in their self-reports. There is a correlation between EEG results for delta band and subjective evaluation results.



Female Resting State Mean = 32,33 and Male Resting State Mean = 30,89* sig (P) < α = 0.05

Figure 6. Left Beta Band Results according to Gender

Musk and patchouli odor did neither significantly increase nor decrease left beta waves in female sample on the contrary in male sample left beta waves significantly reduced. Therefore, musk and patchouli odor can be suggested as soothing and focusing fragrances for men. This finding indicates that musk odor complied with self-reports, patchouli odor did not.

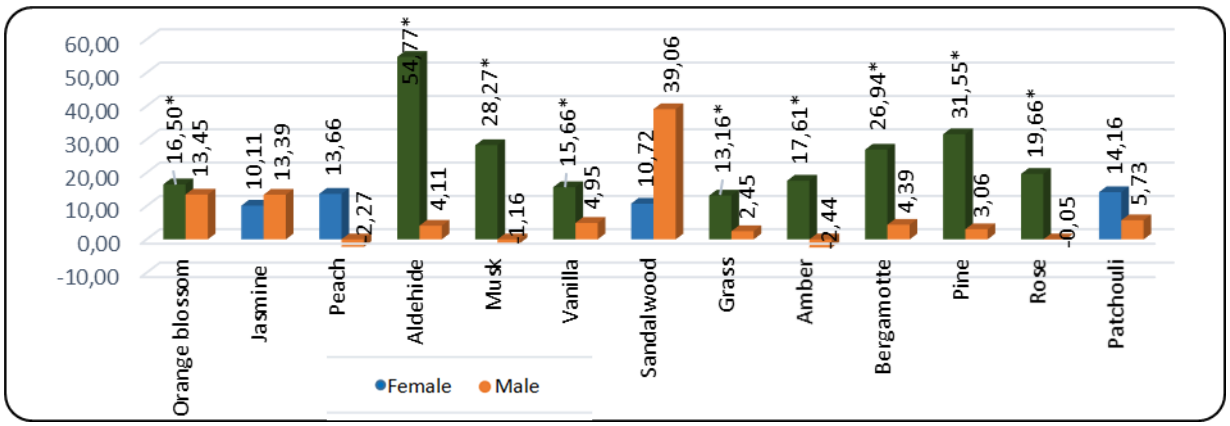


Female Resting State Mean = 26,72 and Male Resting State Mean = 33,33* sig (P) < α = 0.05

Figure 7. Right Beta Band Results according to Gender

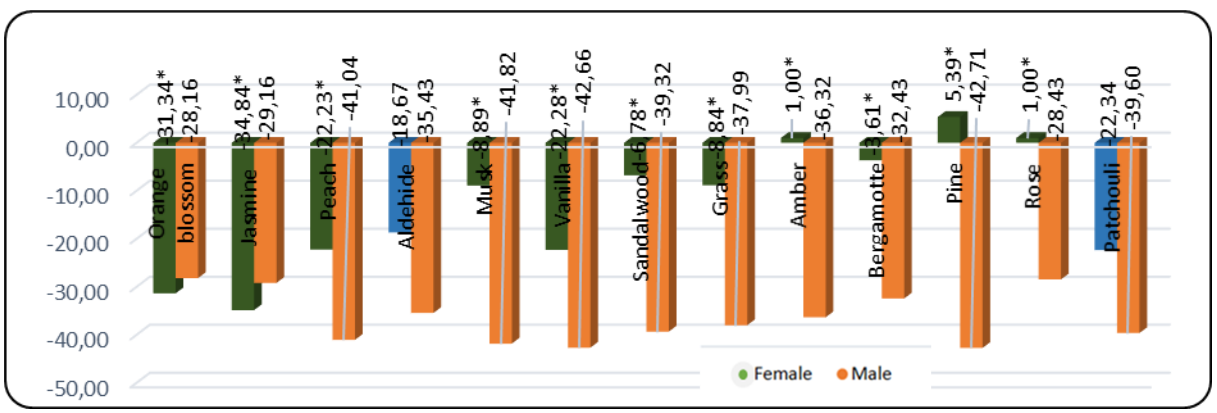
When we compared right and left hemispheres in the male sample, it is observed that peach, sandalwood and patchouli odor generated significantly reduced beta waves in the right hemisphere whereas musk and patchouli odor generates significantly reduced beta waves in the left hemisphere.

It is known that reduced beta activity indicates alertness and focused attention therefore it is thought that these odors have sedative and hypnotic impact on men. Besides Diego et al., (1998) associated increased beta waves with drowsiness. Consequently, we can suggest that any of the odors in this study did not cause drowsiness for our sample group.



Female Resting State Mean = 34,67 and Male Resting State Mean = 33,33* sig (P) < α = 0.05
Figure 8. Left Gamma Band Results according to Gender

In Figure 8, there is no significant left gamma wave in male sample, whereas in female sample there is a significant increase for aldehydes, musk, vanilla, grass, amber, bergamot, pine and rose odor.



Female Resting State Mean = 72,67 and Male Resting State Mean = 71,10* sig (P) < α = 0.05
Figure 9. Right Gamma Band Results according to Gender

In Figure 9, there are no significant right gamma waves in male sample yet female sample findings are complicated. It is observed that right gamma waves were significantly increased by pine, rose and amber odor but decreased by orange blossom, jasmine, peach, musk, vanilla, sandalwood, grass and bergamot odor.

When left and right gamma waves are evaluated together, reduced gamma activity in right hemisphere by the least recognized odor (especially aldehyde, musk and amber) and increased gamma activity in left hemisphere suggest that to identify odor descriptive integrative cortical activity is increased in the analytical brain. Integrated processing causes these increased gamma waves depending on high-frequency communication in between many cortical regions. In particular, it may be necessary to use multiple cortical areas in the identification process. Because of affecting the entire

brain and having a direct sensory pathway to brain, odor perception differs from other senses so the observed common gamma activity may be specific to odor.

It is thought that increased gamma waves originated from rapid cognitive communication between distant brain regions. In this case, it can be suggested that women employ gamma activity to identify odor and to activate memory

Components associated with odor. This indicates that women establish closer cognitive relevance with fragrances compared to men. It can also be said that women want to understand and recognize fragrances.

4. Conclusion and Recommendations

The studies about EEG responses to pleasant and unpleasant odor were investigated in the literature. Besides being out numbered, these studies were conducted in different wave bands. It seems that it is not possible to reach a systematic conclusion in this field so further investigations are a necessity.

In correlation with subjective statements, delta wave results indicate that sandalwood odor has soothing effect on female. For male students, none of the odor caused a significant reduction in delta waves. In female sample, the relatively reduced delta waves in response to jasmine, peach and vanilla odor, in accordance with subjective statements, have soothing effects. Peach and vanilla are favorite odor for female students. In male sample, the relatively reduced delta waves in response to musk, peach and amber odor, in accordance with subjective statements, have soothing effects. Peach is favorite odor for male students. Low frequency delta band indicates soothing and desirable fragrances.

A significant reduction of electrical activity in left alpha band was observed in response to orange blossom, peach, vanilla, grass, amber, bergamot, pine and rose odor in female sample. This decline was interpreted as admiration. However, pine and grass odor results do not correlate with subjective statements. In male sample, electrical activity in right alpha band was significantly raised by orange blossom odor. Jasmine and peach odor relatively raised right and left alpha band. Orange blossom, jasmine and peach odor has relaxing or increased focus effect on male students. None of the odor in our panel has statistically and/or relatively stimulating effect on female students.

It is concluded that the electrical activity in beta band is not related to appreciation. However, because of significant reduction, it is possible to say that musk and patchouli odor have relaxing, calming and increasing focuses effect on male students. Musk, peach and sandal wood odor effects are correlated with subjective statements whereas there is no correlation for patchouli odor. In female sample, neither a significant result has achieved nor beta band has increased. Therefore, none of our fragrance samples create numbness.

According to gamma wave band results, female students, compared to male students, establish closer cognitive relevance with fragrances and are enthusiastic to realize and recognize the odor.

The most distinctive findings related to gender were observed in the EEG data. Female students tried to identify the odor by establishing cognitive communication in their brain, on the other hand, male students had no such cognitive activity. It is thought that orange blossom (statistically significant), peach and jasmine (statistically relative) have increasing focus and soothing effects on male students. None of the odor in our panel has stimulating effect on female students.

It is recommended that a panel which consists of only most favorable scents can be tested in delta band and also gender variable can be added to support the further study. Gamma band findings are quite interesting although there are no previous studies about EEG activity of gamma band during

smelling. Therefore, it is recommended that odor panel can be tested in gamma band in addition to gender variable.

The oldest study on brain waves was made in 1962 by Moncrieff. Conclusions were reached on the alpha waves. More studies will bring more systematic EEG data which include many variables. Supporting studies might be conducted with frontal and temporal region delta band EEG data for favorite scents which are determined by subjective statements.

The further studies about appreciation might be pertinent while frontal and temporal brain is functioning at the same time.

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