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RESEARCH ARTICLE

Odor-induced modulation of electroencephalogram waves in healthy controls

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ABSTRACT

Background: It has been found in some of the electrophysiological studies that odor does affect the rhythm of brain waves. However, there is a lot of inconsistency in terms of the reported findings. Some have reported an increase in alpha activity, whereas others observed increase in theta activity and no change in alpha. **Aims and Objectives:** The purpose of this study is to observe what changes occur in electroencephalogram (EEG) in healthy participants on administration of two types of odor (lavender and peppermint). **Materials and Methods:** This study was conducted on 25 healthy, right-handed male and female volunteers. Baseline EEG for 20 min was recorded, followed by test recording for 9 min comprising inhalation of odor 1 (lavender) for 3 min, no odor (for 3 min), and odor 2 (peppermint) for 3 min. Odors were administered through an odor delivery system, which comprised an inlet and outlet rubber tubes connected to a container for placing odoriferous substance. **Results:** EEG was inspected qualitatively for abnormalities in prominent locations and hemisphere. Both the odors elicited significant EEG abnormalities when compared to baseline recording, which served as control. Odor 1 and 2 both elicited diffuse slowing, focal slowing, and sharp waves mainly in temporal region and partly in centro-parietal and frontotemporal region, with more right hemispherical involvement, and increased theta rhythm. Odor 2 also produced left hemisphere dominant asymmetry. **Conclusions:** Both lavender and peppermint odor inhalation produces EEG abnormalities which are transient, predominantly affect right hemisphere, and temporal region. Lavender has relatively more relaxing effect on brain compared to peppermint.

KEY WORDS: Brain; Odor; Electroencephalogram; Hemisphere

INTRODUCTION

Sense of smell is important for us as at many instances, it helps in determining our behavior, emotions, and social response. The effect of perfumes and balmy fragrances on our mood in our day-to-day life has been experienced by most of us. It has also been observed in various studies that the presence of good aroma around has certain role in relieving stress, causing mental relaxation, and increasing working capacity.[1] Benefits of pleasant odor on human body are being utilized in aromatherapy as well. Therefore, it is important to investigate what physiological changes are occurring in human body in the presence of odors. Many researchers have tried to ascertain these effects using various parameters and attempts have also been made to observe the effects of odor on brain's electrical activity using electroencephalogram (EEG).[2]

EEG is a safe electrophysiological technique which is frequently done to study the electrical activity of the brain in health and diseased state. EEG recordings show brain

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waves (alpha, beta, theta, and delta) which have different amplitude and frequency and they change with the level of consciousness and degree of arousal of the participant.

Brain's electrical activity associated with olfactory stimulation has been studied previously. It has been found in some of the electrophysiological studies that odor does affect the rhythm of brain waves.[3] However, there is a lot of inconsistency in terms of the reported findings. Some have reported an increase in alpha activity, whereas others observed increase in theta activity and no change in alpha.[4,5]

The objective of this study is to find out how odors affects the electrical activities of the brain, using EEG. Two odors have been used. One is lavender, commonly present in perfumes and aromatic essential oils and second is peppermint, which is a component of essential oil and also present in chewing gums and lozenges.

MATERIALS AND METHODS

Selection of Participants

This study was conducted in Baba Raghav Das Medical College, Gorakhpur, Uttar Pradesh, India, on 25 healthy right-handed male and female participants, selected according to following inclusion criteria: Age 18-30 years, normal body mass index (BMI), non-smoker, participants having no evidence of infection or any systemic disease, and not taking alcohol or any drug including caffeine in last fortnight.

The participants with a history of head injury, central nervous system infections, epilepsy, migraine, sleep disorders, drug abuse (nicotine, alcohol, and opium)/drug intake, any systemic illness, family history of epilepsy, and epileptic syndrome were excluded from this study. Ethical clearance was obtained from College's Ethics Committee.

Pre-test Procedure

Participants were selected after history taking, general, and systemic examination. All paticipants were informed about the procedure and written informed consent was obtained. Participants were instructed not to use perfumes and deodorants 48 h before recording. They were asked to use shampoo before the test and avoid application of oil, gel, or spray on scalp before recording. They were instructed to take adequate natural sleep, the night before recording.

Baseline EEG Recording

EEG was recorded on Medicaid 24 channel EEG machine connected to a desktop computer. Silver-silver chloride disc electrodes were applied on the scalp according to the International 10–20 system. Paste of china clay with glycerine was used as conductive medium between electrodes and scalp. Electrodes were referenced to earlobe and impedance was kept below 5 kΩ, high- and low-pass filter setting used was 1-70 Hz.

All recordings were done around 9:00 am in a quiet room in isolation. Experimental chamber was maintained with controlled air temperature at 24 ± 1°C. Initially, a full 20 min baseline EEG recording was obtained, which was used for comparison with test recording. During this period, the participants were instructed to lie still, with eyes closed, and relaxed mental state. This was followed by test recording for 9 min (Table 1).

Odor Delivery Setup

Lavender scent (attar) and peppermint crystals were used as two different odor stimuli. Odor delivery system comprised a central container in which odor is placed; this is connected to an inlet rubber tube attached to a pump with a capacity of 80 ml (pumped 12 times/min). Outlet rubber tube is connected to a face mask (Figure 1). Separate setup was used for different odors.

Test Procedure

It comprised inhalation of odor 1 (lavender for 3 min), intervening period (no odor for 3 min), and odor 2 (peppermint for 3 min). EEG was continuously recorded during this period.

EEG Analysis

After recording, each EEG tracing was carefully inspected and analyzed qualitatively by an experienced neurologist, for background activity, rhythm, symmetry, presence of sharp waves, slow waves, spikes, and focal slowing, Following each, olfactory stimuli EEG was further analyzed for any change in waveform or appearance of new wave or generalized discharge and they were compared for two different Odor stimuli. Each EEG tracing was carefully

Table 1: Experimental protocol

Baseline EEG recording	Odor 1	No odor	Odor 2
Used as control	Lavender	Wash off period	Peppermint
For 20 min	For 3 min	For 3 min	For 3 min

EEG: Electroencephalogram

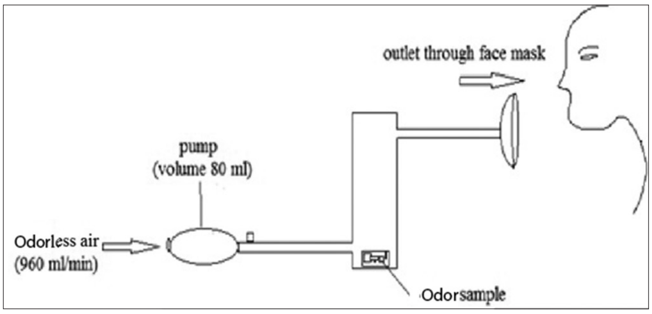

Figure 1: Odor delivery setup

inspected for artifacts such as excessive noise, eye blinks, such tracings were excluded from analysis.

RESULTS

EEG abnormalities during odor administration and intervening period were compared with baseline EEG recording and Fisher's exact test was applied to find the statistical significance of the presence of EEG abnormalities and odor inhalation.

Among the study group of 25 participants (male:female = 19:6, age mean 22.56 ± 2.74 years, and BMI mean 22.62 ± 1.7 kg/m^2), EEG abnormalities were statistically significantly present with odor 1 ($p < 0.05$) and odor 2 ($p < 0.05$) administration. (Table 2)

EEG abnormalities with lavender odor were diffuse slowing, focal slowing, and sharp waves. Diffuse slowing was in the range of 7 Hz (theta) with amplitude of 56 µV. Focal slowing was observed in three participants, two over right hemisphere and one over left hemisphere. On the right side in one participant, slowing was in the range of 6 Hz (theta waves) with amplitude of 56 µV, in the other participant frequency range was 7 Hz (theta) with amplitude of 42 µV. On the left side, the previous beta rhythm was converted to alpha (8 Hz) with amplitude of 49 µV. Sharp wave over right hemisphere had amplitude of 91 µV and that over left hemisphere had amplitude of 70 µV.

Table 2: Significant and non-significant phases (*N*=25)

EEG abnormality	Baseline EEG	Odor 1	Intervening period	Odor 2
Present	00	06	00	06
Absent	25	19	25	19
P value	NS	<0.05	NS	<0.05

NS: Non-significant, EEG: Electroencephalogram

During the intervening period of 3 min between odor 1 and odor 2 administration, there was no abnormality in EEG.

EEG abnormalities with peppermint odor included diffuse slowing, focal slowing, sharp waves, and asymmetry. Participant with diffuse slowing showed rhythm in the range of 5 Hz (theta) with amplitude of 56 µV. Focal slowing over right hemisphere was in the range of 7 Hz (theta) with amplitude of 77 µV and focal slowing over left hemisphere was in the range of 6 Hz (theta) with amplitude of 84 µV. Sharp wave over right hemisphere had amplitude of 63 µV in one participant and an amplitude of 77 µV in other participant. One participant showed left hemisphere dominant asymmetry with amplitudes of 100 µV (Table 3).

Odor 1 showed EEG abnormalities over the right frontotemporal region, centro-parietal, centro-parieto-temporal, and temporal region, whereas abnormalities were more marked over temporal and frontoparietal region with odor 2. None of the odor elicited spike waves (Table 4).

DISCUSSION

The administration of lavender odor leads to diffuse and focal slowing in the range of theta waves. In the left temporal region, high amplitude alpha waves replaced beta rhythm in one participant, this is consistent with studies done in the past.[6,7] It points toward relaxing effect produced by lavender.

No EEG abnormality was seen during the intervening period. Probably, the effects of odor had disappeared in the meantime leading to clear EEG.

Table 3: A comprehensive view of EEG abnormalities in different phases of EEG recording

EEG abnormalities	Odor 1 (lavender)		Odor 2 (peppermint)	
Present (%)	06 (24)		06 (24)	
Types of abnormality				
Diffuse slowing	θ wave, 56 µv		θ wave, 56 µv	
Generalized discharge	-		-	
Asymmetry	-		Left hemisphere 100 µv	
Focal abnormality	Right	Left	Right	Left
Slowing				
Frontoparietal			θ wave, 77µv	
Frontotemporal	θ wave, 56 µv			
Centro-parietal	θ wave, 42 µv			
Temporal		α wave, 49 µv		θ wave, 84 µv
Sharp wave				
Temporal	91 µv		63 µv, 77 µv	
Centro-parieto-temporal		70 µv		
Spikes				

EEG: Electroencephalogram

Table 4: Comparison of location of EEG abnormalities during odor 1 and 2 administration

Type of EEG abnormalities	Odor 1	Odor 2
Diffuse slowing	+	+
Generalized discharge	-	-
Asymmetry	-	+
Focal abnormality		
Frontoparietal		A
Frontotemporal	A	
Centro-parietal	A	
Temporal	A, B	B, B, A
Centro-parieto-temporal	B	

EEG: Electroencephalogram, A: Slowing, B: Sharp waves, +: Persent, -: Absent

Peppermint odor leads to diffuse and focal slowing in the range of theta rhythm. Similar to our finding, there are studies showing that peppermint produces slowing of EEG waves from baseline rhythm, especially in those who rate it as intense.[8,9]

We observed left hemisphere dominant asymmetry in the presence of peppermint odor, alpha waves with difference in amplitude of 100 µv. Previous studies have shown that pleasant experience generally activated the dominant (left > right brain) hemisphere.[10-13] Furthermore, there is unilateral right frontal activation during perception of unpleasant odor.[14] It seems that peppermint odor was perceived as a pleasant odor in participantt with this finding (asymmetry) leading to greater activation of the left hemisphere.

Focal sharp waves appeared in the temporal region in the presence of lavender and peppermint odor with amplitudes from 60 to 90 µV. Various researchers have found significant sharp waves in monkeys and humans.[15,16] It seems that appearance of sharp wave during odor administration, in the temporal region perhaps indicates their association with memory as shown in previous research.[17]

The EEG abnormalities (slowing and sharp waves) were mainly observed in right temporal region and occasionally in frontotemporal, centro-parieto-temporal, and centro-parietal regions. From previous researches, the role of temporal lobe and frontal cortex in olfaction is clear and occurrence of EEG abnormalities at these locations coincides with the anatomical location of olfactory cortex and olfactory processing in the brain.[18-20]

Many researchers have also found greater activation of right hemisphere with odor which is consistent with our study.[21] Others found greater left hemispherical activation.[22]

Furthermore, lavender in contrast to peppermint has produced effects which are anatomically more diverse, involving frontotemporal, centro-parietal, temporal, and centro-parieto-temporal regions. This is consistent with work done in the past.[23] Work done by Gottfried et al. shows that there is a functional heterogeneity in areas related to perception of olfactory stimuli.[24]

CONCLUSION

There is a definite effect of odor on electroencephalographic findings. Both lavender and peppermint odor inhalation produces EEG abnormalities which are transient, predominantly affect right hemisphere, and temporal region of the brain with dominance in centro-parietal and frontotemporal region. Lavender has relatively more relaxing effect on brain compared to peppermint. Inhalation of peppermint odor caused left hemisphere dominant asymmetry. This may be a reflection of pleasantness experienced by the participant during peppermint odor inhalation. A comprehensive study including the effect of odor on functional magnetic resonance imaging and positron emission tomography scan may further add to research in this domain.

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