TEMPORAL, OCCIPITAL AND PARIETAL EEG-BRAIN-MAPPING CHANGES IN PRE/POST-THC-MUSIC AND REST

Jörg Fachner
Institute for Music Therapy, University Witten/Herdecke, Germany

ABSTRACT

Background: Cannabis (THC) is known to change auditory perception as many musicians and music listeners report in narratives, interviews and biographies. Audiological studies demonstrated a THC-induced preference for higher frequencies and expanded metric scaling of auditory events.

Aims: Topographic imaging studies on intensity and locality of cerebral processes investigating THC and music perception (MP) are not available.

Methods: An ethnographic pre/post study was conducted in a habituated naturalistic setting. EEG-Brainmapping Data (28 EEG traces; rest; pre/post music listening; smoked Cannabis 20 mg Δ^9 THC) were averaged and treated with a T-test and a visual topographic schedule. Comparisons between Pre/Post-THC-Rest (PPTR), and Pre/Post–THC-Music (PPTM) were performed.

Results: During Post-THC-Rest (PoTR) α-waves decreased; however, compared to Pre-THC-Rest (PrTR) and Pre-THC-Music (PrTM), the Post-THC-Music (PoTM) showed higher α-% and -power in the parietal cortex, while other frequencies decreased in power. T-Test of PrTR and PoTM, further PPTM comparisons elicited a significant change ($p<0.025$) in left occipital area. Comparing PPTM, differences ($p<0.025$) were also found in the right frontotemporal cortex on θ, and on α in the left occipital cortex. During PrTM listening θ-% increased but decreased more in PoTM than during rest. In both temporal lobes θ-amplitudes decreased during PoTM as well.

Discussion: Changes in temporal and occipital areas and increasing α-signal strength in parietal association cortex seem to represent an interindividual constant EEG correlate of altered MP and hyperfocusing on acoustic space. α-amplitude changes might represent altered, intensified attention and show a marked similarity to reverse α-findings in studies with gifted individuals. Changes of temporal and occipital areas, both known to be involved in MP might represent altered MP and an intensified insight into the 'space between the notes'.

Conclusion: THC has a measurable influence on cerebral music processing and seems to enhance acoustic perception. THC might provide benefits for the hearing impaired.

1. BACKGROUND

In the context of pop cultural developments, drugs with euphoric, sedative and psychedelic effects have been discussed to influence life-style and artistic manners of musicians (1-4). THC effect on auditory perception and musicians' creativity has been a crucial issue since the early days of jazz (5-8). Not only musicians, but casual listeners also seem to be convinced that THC enhances auditory perception, as revealed in psychological investigation (9). Research published gives reason to assume that perception of acoustic shapes and higher frequencies, spatial relationship of sound sources and even speech perception, seem to be enhanced (10, 11). Alrich (12) observed changes on the Seashore-Rhythm-Scale, a result replicated with higher changes by Reed (13). Studies done on THC and basic auditory perception revealed no significant changes (14-17). THC changed metric units of auditory (intensity) perception in terms of an expansion of the units (18) and induced preferences for higher frequencies (19). Investigations of selective and divided attention, state dependent learning and measuring of basic auditory functions under the influence of THC suggested that changes seem to be located in brain functions processing auditory information from periphery sensory organ (18, 20). "...locus of effect is very likely on attention or the central processing of the input data. There is no evidence to suggest that auditory sensory processes are effected by marihuana" (20). Further research has not been published.

2. AIMS

Do we have a chance to relate THC-induced auditory changes to an altered central processing of sensory data as visible in the EEG? Most EEG laboratory studies appear to lack sensitivity to the experimental setting. Perceptual field-dependence of drug action in personal set and experimental setting has to be taken into account in THC studies on human behaviour and cognition (21, 22). To explore how laboratory bias can be reduced, an ethnographic non-blind study in consumer's habituated setting of a living room has been conducted with a mobile bedside manner EEG system.

3. METHODS

The NeuroScience BrainImager® (IMAGE_1.GIF) samples and interpolates 28 traces of realtime EEG, allows to produce and analyse amplitude and significance mappings. 4 subjects (3 male/1 female) smoked a joint containing 20mg Δ^9-THC. They were listening with closed eyes to a piece of instrumental music and 2 Rock songs (IMAGE_2.GIF). EEG was recorded during rest and music listening. Pre/post rest and pre/post music listening was averaged as Individual- (IA) and Group Averages (GA). Averages were visually compared and treated with a T-Test (IMAGE_3.GIF). 1 subject (S.) has been investigated with follow-up. Details have been published elsewhere (23).

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3. RESULTS

IMAGE_4.GIF shows the T-Probability mapping of the EEG changes from pre- to post-THC listening for the first piece of music for one S. The reference file was pre-THC listening and it was compared to post-THC music listening. From the upper left to the right we see Delta(δ)-, Theta(θ)-, and Alpha(α)-probabilities, below Beta(β) I+II and the spectral mapping. The view is from above the head. What seems to be of interest for a possible THC-induced auditory perception style are the obvious α-changes in the left and especially in the right temporal cortex. The temporal cortex hosts the auditory system and main association areas. While listening to the first piece of music, highly significant changes ($p<0.001$) with 3 Ss in the pre/post-comparison from pre-THC-music to the first post-THC-music average have been observed. Highly significant changes after ten minutes of smoking mark the first plateau of drug action and a changed listening state. It shows that Ss experience and process music in a different way from previously. In all Ss, significance decreased with the second and third song in the sequence.

Upon examination of T-Test changes of the second piece of music, we can see δ-, θ- and β-changes, as well as spectral frequency speed changes on left side of brain (IMAGE_5.GIF). The left side hosts motor and sensory speech centers, which seem to change more when listening to Rock songs with words.

IMAGE_6.GIF shows highly significant changes from pre-THC-rest to the post-THC-music EEG of the first piece in the series. As observed before, this T-Test again shows α-changes over the temporal regions. This might indicate changes in auditory cerebral processing.

However, α-mapping showed remarkable changes in amplitude levels, as we can observe in the following IMAGE_7.GIF. It shows the α-GA over 4 Ss for the pre/post rest condition. In this figure, the 16 colours of the 30 µV Scale represent a 2-µV step on a dynamic range of 256 µV. Comparing pre/post-rest visually, a decrease of α-percentage (α-%) and amplitude in the post-THC-rest-EEG was observed with all Ss. The post-THC-rest amplitude decrease in the parietal areas showed an individual range from 6-10 µV. The GA over 4 Ss seen here shows a difference of 2 µV. Decrease of amplitudes in rest over the whole frequency range was reported by Hanley (24) and is similarly observed in the present study.

In IMAGE_8.GIF we see the pre/post α-GAs of listening to music. An increase of relative α-% in parietal regions was observed in the post-THC-music GA for all 4 Ss. Compared to the pre-THC-music EEG, the individual increase of amplitudes ranged from 2–4 µV. The α-range even indicated changes on higher and lower frequency ranges, mapping of α-standard deviance showed highest deviance in the parietal regions. A decrease of α-amplitudes in post-THC-rest and an increase in the post-THC-music EEG has been observed with all Ss, as well as a decrease of % and power of the other frequency ranges.

Post-THC-decrease of δ-, θ-, and β-amplitudes was a constant observation throughout the individual averages of the 4 Ss and was observed here in GA of the 4 Ss as well (IMAGE_9.GIF). Higher amplitudes, especially on δ- and θ- range, but also on central parietal β-areas, were observed in the pre-THC-mapping. In temporal areas the θ-decrease is remarkable.

Pre-THC-music listening caused an increase of θ-% compared to the resting state (IMAGE_10.GIF). In the post-THC-music-maps the percentage decreased in central and frontal regions more than in rest condition, but most decreases appear in both temporal regions.

As seen before, significance mapping of individuals showed highly significant changes ($p<0.001$) between pre-THC-rest, pre-THC-music and post-THC-music (IMAGE_4.GIF + IMAGE_6.GIF). Comparing the pre/post music listening GA of the 4 Ss, a significance of $p<0.025$ on α-range for the left occipital region was detected (IMAGE_11.GIF). Pre-THC-rest compared to post-THC-music showed a small change in the left occipital, comparison of pre/post GA of music listening added temporal changes (IMAGE_12GIF). Further, occipital region around electrode O1 exhibited faster frequency in the spectral map (IMAGE_13.GIF). The occipital region is known to change under the influence of music (25-27). In this context, the change of occipital α might indicate changes in visual association linked to music. Occipital region should be investigated with further studies.

Comparing pre/post music listening over 4 Ss, a significant change ($p<0.025$) at T4 (right temporal lead) was observed in the right temporal cortex (IMAGE_14.GIF). It seems that the θ-decrease over the temporal lobe reported above is more prominent in the right hemisphere. Comparing post-THC-rest and post-THC-music GA, a small change in this temporal area was also observed on β-1. This region seems to change constantly with all 4 Ss and should be regarded as a region of interest with combined methods like PET and EEG.

4. DISCUSSION

4.1 Changes in temporal and occipital areas

Comparing pre/post-THC-music, differences ($p<0.025$) were found in the right fronto-temporal cortex on θ, and on α in the left occipital cortex (IMAGE_11.GIF). During pre-THC-music listening, θ-% increased but decreased more in post-THC-music than during rest. In both temporal lobes, θ-amplitudes decreased during post-THC-music as well (IMAGE_10.GIF). Several studies noted observed music-induced changes in the right temporal fronto-temporal lobe, but with varying frequency ranges (26, 28-32). Even results of dichotic listening indicate changes in the right hemisphere (33, 34). Alterations in the temporal lobe EEG might represent changes in the hippocampus region as well. The hippocampus is rich in CBR (cannabinoid receptors) (35) and has a strong impact on memory functions and information selection. Weakening of hippocampal censorship function and overload competing of neuronal conceptualisations during information selection (36) might be connected to THC-induced prolonged time estimation and intensity scaling. THC-induced sensory information flooding might be processed in a more effective manner. Time expansion might induce a changed metric frame of reference (10), which leads to a different cognitive style of holonomic perception of memory retrieval (8). This might enable musicians to get temporarily increased insight into the 'space between the notes' (4) and to handle rhythmic patterns with more sophistication. A skilled and trained musician might benefit from "losing track" (8) during an improvisation and even while

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playing composed structures. This way of reducing irrelevant information offers spontaneous rearrangement of a piece, vivid performance with enlarged emotional intensity scaling, and the opening of improvisational possibilities by breaking down pre-conceptions and restructuring habituated listening and acting patterns. It seems that this change of auditory perspective in perceiving musical Gestalten (8) is mediated throughout an extension of auditory metric scaling during internal sound staging of music perceived. Listening to a record via headphones becomes a wider 3-dimensional moving soundscape, there seem to be "broader spatial relations between sound sources"(9). Expanded auditory metric units promote a frame of reference that seems to fit more precisely into an audio-visual way of perceiving acoustic relations. The drummer Robin Horn said (1), "it (pot) does create a larger vision, and if that's the case, then it would apply to your instrument because the more you see, the more you can do." Changed left occipital and right temporal EEG activity might represent a change of auditory perspective on musical acoustics. These issues have been discussed more intensively elsewhere (3, 10, 23).

4.2 Parietal changes

A comparison of the individual pre/post averages Ss showed intra-individual stable EEG-Gestalt, for one S even in the follow-up. Intra-individual stability of the whole EEG-Gestalt in rest and activation replicated findings on personality and situational sensitivity of the EEG (33, 37-39). The α-focus in parietal regions showed individual topographic shapes of receptive activity (IMAGE_15.GIF). This indicates personality factors represented in the EEG, but changes on α-amplitude suggest a functional intensification of individual hearing strategy, as can be observed in. Compared to pre-THC-rest and pre-THC-music in the post-THC-music EEG, a rise of α-% and power was observed in the parietal cortex on 4 Ss, while other frequencies decreased in power.

Present results suggest that music seems to be processed temporarily more easily with THC than without. The rise of average α-amplitudes about 4 μV might be a neurophysiological indicator for the so-called state of "being high". α-amplitude changes show a marked similarity to "reverse alpha" findings in studies with gifted individuals. Following Jausovec we can observe more effective information processing. Jausovec associated higher α-scores with a more efficient information processing strategy, less mental workload and flow (40, 41). Only in parietal parts of the brain did we observe an increase of α-power. This might be due to the receptive process, which seems to be intensified by THC effects. But this reverse relationship of increased amplitudes in parietal areas during stoned music listening and decreases in most other areas (IMAGE_9.GIF) of the brain seems to be a typical action mechanism representing this THC-specific state of perception and aesthetic cognition. It reduces energy and permits a more effective processing of the intentionally perceived content. This might be reflected throughout increased parietal α-power and represents THC-induced increased cell firing mediated by CBR activity.

Curry proposed a "hyperfocusing of attention on sound" as an explanation for changes in the figure-ground relationship while listening to music (42). This cognitive change of hearing strategy might be mediated via changed time perception for the rhythmical grid and synchronically expanded intensity scaling for frequency patterns in acoustic relationships. De Souza described a THC-induced change of preference for higher frequencies (19). High frequencies represent overtone patterns and provide, along with time delay patterns, localization information about sound sources in acoustic space. This preferred focus on higher frequencies might result in the way an enhancer or exciter in studio technology works. No wonder that some dub and psychedelic music is produced with virtually moving soundscapes done with reverb and delay effects. It permits to create and play with "sound staging" (43) effects adequate to the state of a THC high. Basic research on cannabis-induced auditory changes seems to be indicated to estimate possible benefits for the hearing impaired. Enhanced perception of musical acoustics as perceived in prosodic and suprasegmental properties of speech as indicated in IMAGE_5.GIF might be of interest for aphasia research.

5. CONCLUSION

Significant ($p<0.025$) changes in temporal and occipital areas and increasing α-signal strength in parietal association cortex seem to represent a neural correlate of altered music perception and hyperfocusing on the musical time-space. This study gives promising insights into quantified EEG changes of pre/post THC music listening as provided by amplitude and significance Mapping over averaged EEG epochs of music. Results are not based on a high number of Ss but on ethnographic EEG correlation of "stoned" listening to music. If we accompany this process in the life world we discover naturalistic authenticity of tendencies occurring during those processes. Further laboratory research could compare several issues reported and discussed in this ethnographic intervention.

6. REFERENCES

1. Boyd, J. (1992) *Musicians in tune* (New York, Fireside, a Simon & Schuster imprimateur).

2. Shapiro, H. (1998) *Sky High - Drogenkultur im Musikbuisineß* (St. Andrä-Wördern, Hannibal).

3. Fachner, J. (2002) The space between the Notes - Research on Cannabis and Music Perception, in: Kärki, K., Leydon, R. & Terho, H. (Eds.) *Looking Back, Looking Ahead - Popular Music Studies 20 Years Later*, pp. 308-319 (Turku, Finland, IASPM-Norden).

4. Whiteley, S. (1992) *The space between the notes - Rock and the counter culture* (London, Routledge).

5. Mezzrow, M. (1946) *Really the Blues* (London, Flamingo / Harper Collins Publishers).

6. Sloman, L. (1998) *Reefer madness : the history of marijuana in America* (New York, St. Martin's Griffin).

7. Fachner, J. (2002) Jazz, Improvisation and a Social Pharmacology of Music, Paper presented at the *10th World Congress of Music Therapy - Dialogue and Debate Music Therapy at the 21th Century: A Contempory Force for Change - E-Book of Articles*, Oxford, UK.

ISBN 3-931852-67-9
ISSN 1617-6847

8. Webster, P. (2001) Marijuana and music: A speculative exploration, *Journal of Cannabis therapeutics*, 1, 105.

9. Tart, C. (1971) *On Being Stoned, A psychological Study of Marihuana Intoxikation* (Palo Alto, Science and Behaviour Books).

10. Fachner, J. (2000) Cannabis, Musik und ein veränderter metrischer Bezugsrahmen, in: Rösing, H. & Phleps, T. (Eds.) *Populäre Musik im kulturwissenschaftlichen Diskurs - Beiträge zur Popularmusikforschung*, pp. 107-122 (Karben, CODA).

11. Fachner, J. (2000) Der musikalische Zeit-Raum, Cannabis, Synästhesie und das Gehirn, in: Erben, A., Gresser, C. & Stollberg, A. (Eds.) *Grenzgänge - Übergänge: Musikwissenschaften im Dialog*, pp. 171-198 (Hamburg, von Bockel).

12. Aldrich, C. K. (1944) The effect of synthetic marihuana-like compound on musical talent, *Public Health Report*, 59, 431-435.

13. Reed, H. B. C. (1974) Cognitive effects of marihuana, in: Mendelson, J. H., Rossi, A. M. & Meyer, R. E. (Eds.) *The use of marihuana; a psychological and physiological inquiry*, pp. 107-114 (New York, Plenum Press).

14. Caldwell, D. F., Myers, S. A. et al. (1969) Auditory and visual threshold effects of marihuana in man, *Percept Mot Skills*, 29, 755-9.

15. Martz, R. E. A. (1972) The Effect of marihuana on auditory thresholds, *J Auditory Res*, 12, 146-148.

16. Thaler, S., Fass, P. & Fitzpatrick, D. (1973) Marihuana and Hearing, *Can J Otolaryng*, 2, 291-295.

17. Liedgren, S. R., Odkvist, L. M. et al. (1976) Effect of marihuana on hearing, *J Otolaryngol*, 5, 233-7.

18. Globus, G. G., Cohen, H. B. et al. (1978) Effects of marihuana induced altered state of consciousness on auditory perception, *Journal of Psychedelic Drugs*, 10, 71-76.

19. De Souza, M. R., Karniol, I. G. & Ventura, D. F. (1974) Human tonal preferences as a function of frequency under delta8-tetrahydrocannabinol, *Pharmacol Biochem Behav*, 2, 607-11.

20. Moskowitz, H. (1974) Effects of marihuana on auditory signal detection, *Psychopharmacologia*, 40, 137-45.

21. Dinnerstein, A. J. (1968) Marijuana and perceptual style: a theoretical note, *Percept Mot Skills*, 26, Suppl:1016-8.

22. Weil, A. (1998) *The Natural Mind* (Boston, Houghton Mifflin).

23. Fachner, J. (2002) Topographic EEG Changes Accompanying Cannabis-Induced Alteration of Music Perception - Cannabis as a Hearing Aid?, *Journal of Cannabis Therapeutics*, 2, 3-36.

24. Hanley, J., Tyrrell, E. D. & Hahn, P. M. (1976) The therapeutic aspects of marihuana: computer analyses of electroencephalographic data from human users of cannabis sativa, in: Cohen, S. & Stillman, R. C. (Eds.) *The therapeutic potential of marihuana*, pp. 187-204 (New York, Plenum Medical Book Company).

25. Konovalov, V. F. & Otmakhova, N. A. (1984) EEG manifestations of functional asymmetry of the human cerebral cortex during perception of words and music, *Hum Physiol*, 9, 250-5.

26. Petsche, H. (1994) The EEG while listening to music, *Eeg-Emg-Z Elektroenz Elektrom*, 25, 130-137.

27. Walker, J. L. (1977) Subjective reactions to music and brainwave rhythms, *Physiological Psychology*, 5, 483-89.

28. Auzou, P., Eustache, F. et al. (1995) Topographic EEG activations during timbre and pitch discrimination tasks using musical sounds, *Neuropsychologia*, 33, 25-37.

29. Bruggenwerth, G., Gutjahr, L. et al. (1994) Music induced emotional EEG reactions, *EEG-EMG-Z Elektroenz Elektrom*, 25, 117-125.

30. David, E., Pfotenhauer, M. et al. (1989) Localisation of auditory evoked potentials in man during awakeness and sleep, *Int J Neuroscience*, 47, 41-45.

31. Duffy, F. H., Bartels, P. H. & Burchfiel, J. L. (1981) Significance probability mapping: an aid in the topographic analysis of brain electrical activity, *Electroencephalogr Clin Neurophysiol*, 51, 455-62.

32. Petsche, H., Pockberger, H. & Rappelsberger, P. (1986) EEG-Topography and mental performance, in: Duffy, F. H. (Ed.) *Topographic mapping of the brain*, pp. 63-98 (Stoneham, Butterworth).

33. Davidson, R. J. & Hugdahl, K. (1996) Baseline asymmetries in brain electrical activity predict dichotic listening performance, *Neuropsychology*, 10, 241-246.

34. Kimura, D. (1967) Functional asymmetry of brain in dichotic listening, *Cortex*, 3, 167ff.

35. Joy, J. E., Watson, S. J. & Benson, J. A. (1999) Marijuana and medicine: assessing the science base, in: Medicine, I. o. (Ed.) *National Academy of Sciences - Division of Neuroscience and Behavioral Health* - (Washington, D.C., National Academy Press).

36. Emrich, H. M., Weber, M. M. et al. (1991) Reduced binocular depth inversion as an indicator of cannabis-induced censorship impairment, *Pharmacology, Biochemistry & Behaviour*, 40, 689-690.

37. Hagemann, D., Naumann, E. et al. (1999) EEG asymmetry, dispositional mood and personality, *Pers Indiv Differ*, 27, 541-568.

ISBN 3-931852-67-9
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38. Koukkou, M. & Lehmann, D. (1978) Correlations between cannabis-induced psychopathology and EEG before and after drug ingestion, *Pharmakopsychiatr Neuropsychopharmakol*, 11, 220-7.

39. Machleidt, W., Gutjahr, L. & Mügge, A. (1989) *Grundgefühle: Phänomenologie, Psychodynamik, EEG-Spektralanalytik* (Berlin, Springer Verlag).

40. Jausovec, N. (1997) Differences in EEG activity during the solution of closed and open problems, *Creativity Res J*, 10, 317-324.

41. Jausovec, N. (1997) Differences in EEG alpha activity between gifted and non-identified individuals: Insights into problem solving, *Gifted Child Quart*, 41, 26-32.

42. Curry, A. (1968) Drugs in Rock and Jazz music, *Clinical Toxicology*, 1, 235-244.

43. Moylen, W. (1992) *The Art of Recording: The creative Resources of Music Production and Audio* (New York, Van Nostrand Reinhold).

ISBN 3-931852-67-9
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