

# A Critical Review Investigating whether there are similarities in EEG band waves between Schizophrenic patients and participants given DMT or Ayahuasca Tea

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## Abstract:

Early research suggests that the endogenous neurobiological chemical Dimethyltryptamine (DMT) may be responsible for schizophrenic symptoms <sup>[1]</sup>. This article investigates EEG band waves between participants given Dimethyltryptamine (DMT) or Ayahuasca Tea and schizophrenic patients. Evaluation of articles on EEG band wave monitoring of DMT or Ayahuasca participants was compared to articles on EEG band wave monitoring in schizophrenic patients. It is hypothesized that adult DMT and Ayahuasca participants and adult schizophrenic patients would have similar EEG oscillation-band waves. Ranlund *et al.* <sup>[2]</sup> found that schizophrenic patients produced lower band waves, and this review supported the findings that there were similarities, especially in lower band waves between the two groups. Although the reviewed Ayahuasca articles produced higher EEG wave band oscillations, the additional plant compounds added to Ayahuasca Tea may account for the resulting discrepancy in this review. The similarities in EEG band wave oscillations between the pure DMT injection and the schizophrenic patients did support the hypothesis, although, the EEG band waves only show neuron activity and not specific DMT brain chemicals. There may be a connection between the symptoms reflected in schizophrenic patients, suggestive of endogenous DMT, due to the similarities when DMT is administered.

## INTRODUCTION

Endogenous Dimethyltryptamine (DMT) is a naturally occurring compound in plants, animals, and humans <sup>[3]</sup>. It is believed to help in the neuroprotection of cell death by using antioxidant properties which are involved in suppressing the apoptosis mechanism <sup>[4]</sup>. The entheogenic tea Ayahuasca contains DMT, which produces hallucinations, unlike any other psychedelic drug <sup>[5]</sup>. During schizophrenia, people have been known to experience ‘realistic’ alternative realities, which have the same kind of images seen with endogenous DMT <sup>[1]</sup>. This novel article investigates the established literature by linking EEG band waves, in schizophrenic patients with the band waves observed after ingesting DMT or Ayahuasca. The focus will be on adults participating in EEG monitoring after ingesting Ayahuasca <sup>[6]</sup>, intravenous DMT <sup>[7]</sup>, and EEG monitoring taken from schizophrenic patients <sup>[8]</sup>.

This study uses quantitative data to show that DMT or Ayahuasca ingestion may

produce the same EEG results seen in schizophrenic patients and that endogenous DMT may be responsible for these results. EEG oscillation-band waves can be monitored alongside subjective experiences being verbally relayed to the researchers by questionnaires on changes in consciousness while under the influence of DMT or Ayahuasca. Previous results from the subjective experience are needed to show the similarities between the EEG changes and any changes to consciousness that are experienced by the participants. This review will question some of the subjective methods, including neurophenomenology <sup>[7]</sup> and the Hallucinogen Rating Scale <sup>[6]</sup>, in relation to understanding DMT or Ayahuasca participation and schizophrenia symptoms. It also reviews whether EEG methods are satisfactory given the spatial limitations in understanding what occurs in the brain during DMT or Ayahuasca ingestion and schizophrenia.

Previous research has shown a correlation between EEG band wave changes

and DMT administration <sup>[7]</sup> or ingesting Ayahuasca tea, containing DMT <sup>[6]</sup>. EEG monitoring of schizophrenic patients <sup>[8][9]</sup> has also shown band wave changes similar to that of DMT research by Timmermann *et al.* <sup>[7]</sup>. Although using EEG monitoring for this purpose is acceptable in terms of reliability and validity, there are methodological limitations to this when confirming that these changes are due to DMT circulating within the brain.

It has been suggested that the development of some schizophrenic systems may be due to changes in endogenous DMT production in patients <sup>[1]</sup>. DMT is known to be produced in the body and may produce the same altered realities, voices, and visions experienced by schizophrenic patients <sup>[10]</sup>. Research into this phenomenon is difficult to establish due to the reliability and validity of the methods and procedures that have been used to date.

Previous studies used for mental health issues, such as schizophrenia, are predominantly defined by a psychiatric diagnosis classification system, such as the Diagnostic and Statistical Manual of Mental Disorders (DSM) or the International Statistical Classification of Diseases and Related Health Problems (ICD). Neuropsychiatry is now investigating biological differences and responses to understand schizophrenia <sup>[11]</sup>, as symptom classification for the definition of health issues is becoming more controversial because the classification criteria are ever-changing <sup>[12]</sup>. Therefore, the objective of this article is not to investigate the different types of schizophrenia. Instead, it is to encourage ways of moving forward to substantiate the possibility of endogenous DMT being associated with psychotic episodes.

Electroencephalography (EEG) records high temporal resolutions of brain activity and can be presented using five different Hertz (Hz) band waves. It is useful

for detecting changes in many neuropsychiatric diseases and may be considered a biomarker as the results usually show changes in specific wave bands <sup>[13]</sup>. The results explore the similarities between EEG wavebands (*delta, theta, alpha* and *beta*) between different groups of people. For example, a group drinking Ayahuasca tea containing DMT, a group intravenously injected with pure DMT and research carried out using EEG on psychotic patients. The review will also touch on various rating scales used alongside the EEG research, which provides subjective information about the various levels of consciousness experienced.

This project aims to highlight the possibility of the same EEG wavebands correlating to both psychotic episodes and when partaking of exogenous DMT. It will also address the controversies of quantitative and qualitative techniques presented in specific research papers when examining the similarities between DMT ingestion and psychotic episodes via EEG.

## **METHODS**

It may be that the studies covered here, are based on methodological procedures that lead to inconsistent sampling due to inconsistent psychiatric classifications. For example, the DSM or ICD diagnosis of schizophrenia relies purely on symptoms rather than genetics or other biomarkers such as DMT in urine or blood <sup>[14]</sup>.

There may be altered or increased endogenous DMT production in patients with schizophrenia <sup>[1]</sup> and therefore, there is merit in understanding the limitations, reliability, and validity of the core EEG research findings to date. This understanding should allow a judgment about whether these methods are suitable for investigating similarities between band wave changes for

Critical Review Investigating whether there are similarities in EEG band waves between Schizophrenic patients and participants given DMT or Ayahuasca Tea

DMT or Ayahuasca administration and schizophrenic patients.

This article is not a full systematic review, but a narrative literature review, consisting of English articles found initially using Google/Scholar. Manual searches were conducted from the reference lists of the initial articles. In an attempt to avoid unbiased dissemination, thesis and unpublished papers were also investigated from psychedelic blog webpages covering EEG and Ayahuasca<sup>[15]</sup>. Additional articles were found using Medline and PsycInfo with Medical Subject Headings (MeSH) terms such as N,N-Dimethyltryptamine AND Electroencephalography. Other searches included schizophrenia AND EEG AND oscillations.

Exclusions to this review were papers discussing 5-methoxy-N,N-dimethyltryptamine, bufotenine (toad venom), and animal studies of DMT. The inclusion criteria were defined as participants partaking in DMT or Ayahuasca administration and schizophrenia patients with any kind of EEG band wave oscillations e.g. *delta* to *gamma* on any skull location. Thus, the DMT or Ayahuasca individuals were healthy participants, and the intervention was DMT. The comparisons were DMT and schizophrenia EEG band waves, with the outcome being any similarities in oscillation-band waves.

The search criteria highlighted a scarcity of research articles that were available for this review. This lack of information may have been for several reasons, including the lack of null result publications. There was also a lack of reproduced experimental findings, which may be due to publishers unwilling to publish reproduced findings unless outcomes changed.

Many DMT research study articles were unavailable online as they were published in the 1950-1960's. Therefore, the information may be available in hardcopy but

was unavailable for this review. As the interest in psychedelic compounds increases there is likely to be a steady increase in the literature produced.

The study design of EEG monitoring implemented for DMT injection consisted of a small sample of healthy male and female adult participants<sup>[7]</sup>. They were screened for psychiatric conditions along with other physical conditions.

The Timmermann *et al.*<sup>[7]</sup> research using EEG during DMT administration only highlights neural correlations, which are similarities between band wave changes due to DMT administration. There is no direct evidence that a higher level of DMT is circulating in the brain. Both Timmermann *et al.*<sup>[7]</sup> and Riba *et al.*<sup>[6]</sup> used DMT placebo during research.

Another issue arising from making comparisons between the DMT administration<sup>[7]</sup> and Ayahuasca tea participants<sup>[6]</sup> is that they show inconsistencies in oscillation-band wave ranges – respectively *delta* (1-4Hz) and *delta* (1.3-3.5Hz). Thus, not using a standardized measurement range makes it difficult to ascertain which band wave the participants adhere to in general. Nayak and Anilkumar<sup>[16]</sup> raise this issue along with the fact that EEG is a specialized topic and that the methodological planning needs detailed knowledge of all the areas within EEG that would need to be considered. This is evident in the Begić *et al.*<sup>[9]</sup> study of schizophrenic patients, which used quantitative EEG (qEEG), a specialized system of algorithms providing better EEG procedures and analysis than standard EEG<sup>[17]</sup>. Some of the review articles also show inconsistent methodological procedures allowing ingestion of substances such as nicotine, alcohol and caffeine before EEG monitoring. These substances have been shown to affect EEG band waves<sup>[18]</sup> and may affect the experiment's external validity and thus results.

The unequivocal 96% EEG quantitative biomarker for paranoid schizophrenia identified by Buettner *et al.* [19] is rooted in collected computational datasets with machine learning classifiers. Thus, the importance is not so much in relying on the EEG recording but, in the methods and procedures used to investigate specific schizophrenic phenotypes. For example, other research on EEG monitoring has reached an 85% accuracy, although this was for monitoring chronic schizophrenia responding to clozapine [20]. Therefore, EEG monitoring of schizophrenia may need specific methodological algorithms for detecting specific types of schizophrenia.

Although there are nine different types of schizophrenia classified in the International Classification of Diseases (ICD-10), the Buettner *et al.* [19] EEG monitoring article focuses on paranoid schizophrenia. The EEG results on paranoid schizophrenia may have some significance. Paranoia has been known to present in both DMT [21] and Ayahuasca ingestion [22]. The schizophrenic participants in the research were defined using the DSM classification system [8][9]. The Begić *et al.* [9] patients were hospitalized at the time, but there is no evidence to show that they were hallucinating while the research was being carried out, and there were no subjective questionnaires like in the DMT or Ayahuasca research linking EEG monitoring to any subjective experience.

This review's main limitation is the small number of DMT and Ayahuasca ingestion studies completed to date. Additionally, limitations lie with the initial methodological procedures of defining schizophrenia classifications, along with what the EEG is monitoring. For example, the monitoring does not show endogenous or exogenous DMT production in the brain as EEG is not equipped to monitor chemicals but finds correlations between administration

of DMT and changes in brainwaves. More effective methods and procedures to address DMT administration and the brain connection may lie in carbon labeling *in vivo* animal studies enabling a detailed understanding of DMT dispersion neurobiologically [23]. It may be that advances in radioligands could be applicable and available using human participants. For example, results from tagging of DMT (or the metabolite) could be compared between labelled DMT in schizophrenics and exogenous DMT participants. This would enable any quantities and similarities to show in specific brain regions as they appeared. Additional approaches could be assays using single nucleotide polymorphisms (SNPs) to provide a plethora of chemical and metabolites that are connected to DMT and how they interact with some of the known schizophrenic gene phenotypes [21].

## **RESULTS**

EEG Hertz frequency bands are used in the analysis and are separated into five different band waves, *delta*, *theta*, *alpha*, *beta*, and *gamma* [24]. Several studies show increased activity in the *delta* and *theta* band wave frequency in patients with psychosis [8] [9]. There is evidence that chronic psychosis produces increased EEG *delta* and *theta* band activity [2]. Although these results were statistically significant, they are estimated differences calculated using linear regression models, which show correlations and specific *p*-values for the wave bands were not separated in this study. Some studies have shown a decrease in *alpha* frequency in psychosis [13]. All these differing band waves are important in linking the neurological experience of psychosis to the possible experience of endogenous DMT that is produced naturally in the body [3].

Although the objective and subjective measurements complement each other by providing evidence that EEG band wave

## Critical Review Investigating whether there are similarities in EEG band waves between Schizophrenic patients and participants given DMT or Ayahuasca Tea

changes record consciousness experiences, it is essential to note that the EEG monitoring cannot produce evidence of any specific chemical changes in the brain.

Riba *et al.* [6] used high and low dose Ayahuasca to show that there were changes in the EEG band waves relating to the amount of Ayahuasca taken and the effects experienced. They did this by comparing controls to participants in which it showed significant changes to EEG band waves between controls and low to high dose Ayahuasca ingestion. The *delta* and *theta* bands showed increased different ( $p < 0.05$ ) between baseline (PRE-2) values in the absolute power (*theta* band 3.5-7.5 Hz) at low dose at 120 minutes after ingestion (-1.70 +/- 1.45 SEM) and (*delta* 1.3-3.5 Hz) at high dose 90 minutes after ingestion (-1.40 +/- 1.10 SEM). There was also a reduction in *beta* levels (-0.10 +/- 0.16 SEM) at a low dose and (-0.10 +/- 0.27 SEM) at a high dose in relative power that was also statistically significant with a  $p$ -value  $< 0.05$ . These results suggest that DMT affects different band waves so much that the oscillations' resonance is a different frequency than baseline or controls. For example, the lower band waves increased (*delta*, *theta*), while the higher band wave (*beta*) was decreased.

Timmermann *et al.* [7] also endeavored to measure EEG band waves alongside the subjective experience using a rating scale during intravenous injection of DMT fumarate straight into blood system. They found reduced *alpha* (cluster  $p = 5.33e-04$ ) and *beta* wave (cluster  $p = 0.033$ ) bands in the time averaged component, suggesting that the higher frequency band waves showed a significant reduction from controls. In contrast, the lower frequency band waves increased for *delta* (cluster  $p = 0.024$ ) and *theta* (cluster  $p = 0.007$ ) bands in the oscillatory power frequency. These  $p$ -values show that the changes in participants from controls are statistically significant.

The rating scales measuring the subjective DMT experience complement the EEG wave band patterns found. Although subjective measures within consciousness are being debated [25], the qualitative data gathered is generally acceptable for validity and reliability [26].

Using different  $p$ -value measures of reporting between the research papers may elicit some controversy as it suggests that what is statistically significant in one paper will not be in another, even though the same tests may be applied. For example, Timmermann *et al.* [7] and Riba *et al.* [6] have different  $p$ -value targets for the subjective measures.

Rating scales are commonly used to collect and measure patients' experiences using a questionnaire, but discrepancies in rating scales may also produce problems when analyzing any correlations between papers [27]. For example, Timmermann *et al.* [7] used the neurophenomenology framework [28], which integrates the first-person subjective experience while taking psychedelics, with the objective recordings of the EEG. This framework uses an intensity rating scale, relayed verbally to the researcher, at specific times, due to DMT having an influence on key areas such as visual, emotional and bodily feelings. These scales are then coded by the researcher and are analyzed alongside the EEG's time sequences [7].

These results are based on time measured sequences of both the EEG in relation to the subjective experiences while under the influence of DMT. The results showed that visual intensity correlated with reduced *alpha* waves ( $p = 2.67e-04$ ) (.0002.67) and *beta* ( $p = 0.04$ ), whereas there were increases in *delta* ( $p = 0.004$ ) and *theta* ( $p = 0.01$ ). These results may suggest that the visual experience of DMT is related in some way to the increase of *delta* and *theta* band waves, which have been found in other neuropsychiatric conditions [8][9].

The alternative to neurophenomenology is the Hallucinogen Rating Scale (HRS) questionnaire, specially designed for subjective experiences under psychedelic drugs [29] and was used by Riba *et al.* [6] in the Ayahuasca research. This consists of six subscales, including perception, cognition, and emotion. A one-way ANOVA with repeated measures for high and low dose ayahuasca was used. They used this method to test the mean differences between the groups of high and low, repeating each mean subscale of the HRS to find the results. The results showed that the ratings for perception, cognition, and emotion were all statistically significant, with the  $p$ -value  $< 0.001$  on the HRS compared to controls. However, the mean score of 1.35 (SD 0.61) in decision making (Volition), was only slightly significant on a high dose with a  $p$ -value  $< 0.05$ . Again, these results suggest that DMT (via Ayahuasca ingestion in this instance) may affect the body in substantially different ways by changing consciousness, like in emotional processing, as assessed using the HRS.

It is interesting to note the divergence from the HRS to neurophenomenology for subjective measures in the Timmermann *et al.* [7] research, because the reliability and validity of the HRS had already been assessed in 2001 using both Ayahuasca and DMT injections [29]. This contrasts with Winkelman [30] highlighting the lack of studies in psychedelic research using neurophenomenology. This suggests that competing techniques for qualitative data within psychedelic research can become problematic when comparing data when no official design for subjective psychedelic experiences is used as standard practice.

On the other hand, the Brief Psychiatric Rating Scale (BPRS) is used as a rating scale measurement for psychotic patients when researching EEG wave band differences [31]. This is an entirely different

rating scale that is used when researching subjective Ayahuasca experiences and is analyzed differently by using a point system rated 1-7 with 18 items, but only one of these items focusing on hallucinations [32].

Future research could incorporate a standardized analysis protocol when reporting EEG band wave ranges that monitor participants under the influence of DMT. This standardized protocol should extend to qualitative measurements using one specific rating scale for measuring the subjective experience, which may extend to psychotic patients, and the DSM criteria. For example, using the HRS on psychotic patients may well highlight similarities to the subjective experience of DMT and psychotic episodes. A significant limitation to this overall review is that EEG band waves cannot measure a particular chemical present in the brain. Other limitations are the discrepancies between research papers regarding different  $p$ -value targets, EEG band wave ranges, and subjective framework methods that make it harder to properly investigate the exact similarities between them.

The overall results show that there are indeed changes to EEG wave bands under the various administrations of DMT. These changes include DMT administration when compared with controls and also the amount of DMT administered. Therefore, there is evidence that DMT affects the body and that depending on the amount residing in the body has sufficient changes to subjective consciousness ratings and correlations to EEG band waves. The measurements in psychotic episodes show the same changes to EEG wave bands, and some studies show that DMT is present in this health condition [1].

## **DISCUSSION**

The hypothesis was evaluated by focusing on specific EEG band waves and looking for

## Critical Review Investigating whether there are similarities in EEG band waves between Schizophrenic patients and participants given DMT or Ayahuasca Tea

similarities between the groups specified. The results may indicate another method for monitoring the possibility of endogenous DMT influencing any schizophrenic symptoms. This review may be a valid contribution to science by evaluating a biological mechanism for psychotic episodes in schizophrenia. This review takes advantage of previous research, implying that Ayahuasca and DMT chemical composition induces schizophrenic symptoms<sup>[33]</sup>.

Earlier studies suggested that the ‘transmethylation hypothesis’ was a disruption of metabolism that resulted in endogenous DMT, producing symptoms of schizophrenia<sup>[34]</sup>. Further investigations on urine samples confirmed that DMT levels were higher in some patients who experienced schizophrenia<sup>[1]</sup><sup>[35]</sup>. Detection of DMT levels in blood and urine samples in schizophrenic patients has shown inconsistent results<sup>[36]</sup>. This conflicting evidence may imply insufficient methods of detection. In addressing this situation, neuroscientists incorporated EEG monitoring of schizophrenic patients finding differences to healthy controls<sup>[37]</sup>.

The psychiatric condition exclusion is a double-edged sword. On the one hand, DMT administration in subjects with psychiatric conditions has been known to intensify symptoms such as changes to thought and perception<sup>[22]</sup>. Thus, it would be ethically challenging to include these patients in DMT research. On the other hand, including these subjects could shed some light on why schizophrenic phenotype people experience enhanced symptoms of schizophrenia when they participate in recreational DMT. Alternative methods to EEG monitoring may be to use genetics to associate mutations with endogenous DMT production<sup>[21]</sup>, thus understanding why enhanced symptoms are experienced with DMT administration.

Research has shown that there are differences in EEG band wave oscillations in schizophrenic patients compared to controls<sup>[38]</sup><sup>[39]</sup>, although this EEG biomarker can only be assessed by using the specific methodology, which still needs to be established for different phenotypes of schizophrenia. Changes in cortical activity have not been compared between subjects under DMT or Ayahuasca influence and patients experiencing psychotic episodes. This article addresses this gap with the hypotheses that schizophrenic patients and DMT ingestion participants exhibit similar changes in EEG band wave oscillations. These findings may affirm previous studies on EEG monitoring on schizophrenic patients<sup>[40]</sup> and DMT ingestion participants<sup>[7]</sup> where oscillations were found in the lower range band waves, e.g., *delta*, *theta*.

Further research found changes in cortical activity and altered consciousness in subjects under the influence of DMT or Ayahuasca. This was evaluated by simultaneously using questionnaires, thus recording changes of emotional or visual experiences<sup>[6]</sup><sup>[7]</sup>. Interest in this research area is increasing due to the cognitive similarities between the symptoms of DMT and Ayahuasca participation and schizophrenic patients<sup>[41]</sup>.

Table 1 shows varied and contradictory findings for comparison. Most of the *gamma* band waves in the articles were either unmonitored or did not significantly change. The *beta* band wave increased in some of the Ayahuasca reviews, and one of the schizophrenia monitoring reviews, but decreased for the DMT study. The *alpha*

band waves decreased in two of the Ayahuasca studies and the DMT study. It, however, increased in one schizophrenia study and decreased in the other. The *theta* band waves were all reduced in the Ayahuasca studies but increased in the DMT and schizophrenia studies. The *delta* band

waves decreased in one of the Ayahuasca studies but increased in both the DMT and one schizophrenia study. Although, Table 1 is a basic representation of overall findings, it does not represent differences in overall EEG techniques. For example, Hong *et al.* [8] found increased *delta* bands in resting states

Table 1:  
A schematic representation of results using band wave monitoring of Ayahuasca or DMT participants and schizophrenic patients.

EEG Oscillation-Band Waves	<i>DELTA</i>	<i>THETA</i>	<i>ALPHA</i>	<i>BETA</i>	<i>GAMMA</i>
<b>Ayahuasca</b> Effects of Ayahuasca...[42]		▼	▼	▲	▲
Topographic pharmaco-EEG mapping ...[6]		▼		▲	
Inhibition of alpha oscillations...[43]	▼	▼	▼		
<b>DMT</b> Neural correlates of the DMT...[7]	▲	▲	▼	▼	
<b>Schizophrenia</b> A shared low-frequency...[8]		▲	▲		
Quantitative Electroencephalography... [9]	▲	▲	▼	▲	

Increase in Hz. ▲

Decreased in Hz. ▼

Critical Review Investigating whether there are similarities in EEG band waves between Schizophrenic patients and participants given DMT or Ayahuasca Tea

but reduced *delta* in sensory gating. Overall, these results were inconsistent, although there were some similarities.

It is interesting to note these similarities, especially with the pure DMT [7] and the schizophrenia participants [9]. These both showed increases in lower band wave oscillations, for example, *delta* and *theta*, and there were also similarities in the decreased *alpha* oscillations.

Also noteworthy are the articles concerning Ayahuasca participation [6][42][43]. These showed a reduction in *Theta* band waves compared to DMT and schizophrenic patients, while some of the Ayahuasca articles reported higher amplitude in *beta* and *gamma* ranges. These results challenge the initial hypothesis producing an opportunity to discuss why conflicting results appear.

There are a few points that may have influenced these contradictions. For example, Ayahuasca is a mixture of plants containing DMT and plants containing monoamine-oxidase inhibitors (MAOI), which allow orally taken DMT to metabolize in the body [44]. The MAO inhibitors have different psychoactive qualities [45]. The use of heterogeneous Ayahuasca plants used in the review articles may account for the differences between the Ayahuasca groups.

There were very few exogenous DMT studies as it is an illegal substance in many countries [46] and requires Home Office approval in the UK for research use [47]. Ayahuasca is legal in some countries; therefore, research is more accessible. Research studies with band wave monitoring of DMT or Ayahuasca proved to be sparse. One article had a conflict of interest [43] which may influence the results. There was a need to include Ayahuasca studies, as there was only one DMT research article exploring EEG monitoring that was relevant to this review. Therefore, there is a heterogeneity issue when comparing the studies as the

Ayahuasca tea contains several plants, which may have influenced the results.

The *beta* band wave increase that occurs in both schizophrenia patients [9] and Ayahuasca participants [42] (Table 1), may warrant further investigation. For example, the plant used for this Ayahuasca contains 5-Meo-DMT, another natural endogenous chemical, that may trigger psychotic symptoms [48]. This could lead to further research using exogenous 5-Meo-DMT injections and EEG monitoring.

There were differences between the schizophrenic patient band waves. Although the criteria for schizophrenia were based on the DSM-IV [49] for both studies, one patient group was drug naïve [9]. Interestingly, there are more similarities between this article and the DMT participants. Other inconsistencies in results may be due to differences in the ranges used to define the EEG band waves.

Although both Timmermann *et al.* [7] and Riba *et al.* [6] use absolute power values (e.g., *delta*, *theta* etc.), these results may be subject to variation, and only Riba *et al.* [6] normalize the frequencies to remove any inconsistencies. Therefore, it is difficult to compare the two papers as they use different analytical approaches, which can, in some cases extend to different procedures when processing the raw data for extracting the power spectrum of frequencies [50]. Another dissimilarity between the papers is the difference in range for each wave band frequency. For example, Timmermann *et al.* [7] defines the range in *delta* as 1-4 Hz and *theta* as 4-8 Hz, which is different from the Riba *et al.* [6] ranges of *delta* as 1.3-3.5 Hz and *theta* band of 3.5-7.5 Hz. This could mean that some wave bands may be included in *alpha* as the ranges are so inconsistent throughout, and therefore, in some cases discrepancies regarding ranges to the specific band waves may produce inconsistent values. For example, Ranlund *et al.* [2] highlight inconsistent findings within EEG on psych-

otic patients, which may be influenced by the inconsistent values.

Placebos are used to validate the research conducted, although some psychedelic drug research has shown a placebo effect. For example, placebo administration resulted in 61% of participants reporting drug effects following subjective questioning methods after ingestion <sup>[51]</sup>. Omitting EEG and plasma DMT baseline level recording may reduce validity, but this could be a perfect opportunity in future studies to repeat the experiment while using EEG monitoring to detect any placebo brain changes from baseline levels.

Whether these findings help answer the research question is debatable. On the one hand, there are some similarities between pure DMT and schizophrenic patient band waves, especially with the increase in lower band waves. Although, EEG monitoring does not detect specific chemical interactions, it does produce strong links to cognitive and perceptual processes that are invaluable in providing significant information when detecting changes in consciousness <sup>[52]</sup>. The results from this review suggest similarities between pure DMT and schizophrenic patient EEG band waves, unlike the Ayahuasca ingestion band waves. This may be due to different plants used in the Ayahuasca, which may have different DMT chemicals included (e.g., 5-Mexoy-DMT), or that properties of the MAO inhibitors are affecting band waves. It could also be due to different dosages.

The definition and application of specific protocols could be an invaluable opportunity for future Ayahuasca participation in EEG monitoring research. For instance, applying a diet used by Amazon tribes before ingesting Ayahuasca <sup>[53]</sup> may lead to more substantial EEG similarities with individuals with schizophrenia. Other research could investigate the DMT levels involved in circadian fluctuations within the plants <sup>[45]</sup>, thus enabling control of the

amount of DMT ingested from the plants. This could enable DMT quantities to be monitored and may produce similar results to schizophrenic patients' band waves if the DMT content is higher within the Ayahuasca tea. It would also be interesting to use the Buettner *et al.* <sup>[19]</sup> method to establish a precise and validated method for EEG monitoring of DMT ingestion, although this would require a very large sample size.

Ideally, reproducing each experiment, carried out using DMT or Ayahuasca, would allow other potential issues to be found. For instance, this would allow detailed information and findings to be collected in a consistent manner. Other limitations of this review are comparability. For example, Ayahuasca tea may contain different plant genus or species, and the tea may be administered in different quantities.

The Timmermann *et al.* <sup>[7]</sup> research can only assess EEG neural correlations in relation to injection of DMT. It cannot conclude any causal relationship between DMT administration and brain wave changes because it cannot monitor chemicals circulating in the brain. This warrants further investigation, perhaps using animal models to measure DMT absorption post-EEG measurement. Although, this method may also be unreliable as post-mortem asphyxiation allows many chemicals to rush to the brain <sup>[54]</sup>, potentially confounding results of DMT circulating in the brain. Alternative methods to quantify the amount of DMT in blood plasma, at various times after administration, may be able to provide a validated association between DMT administration and blood plasma levels <sup>[7]</sup>.

Building on this review, with the initial hypothesis of linking EEG band waves in schizophrenic patients and DMT ingestion participants, future study designs could move towards experimental, randomized control studies. Using schizophrenic patients under the same protocol and methods and pro-

## Critical Review Investigating whether there are similarities in EEG band waves between Schizophrenic patients and participants given DMT or Ayahuasca Tea

cedures without DMT ingestion would provide better heterogeneity when comparing the two groups.

### CONCLUSION

The results of this review showed similarities in EEG band waves between pure DMT injection and schizophrenic patients. Results showed increasing lower band wave frequencies within these groups. The lack of replication of results for the band waves in this group may be due to the different plants added to the Ayahuasca. It was hypothesized in this review that schizophrenic patients and DMT ingestion participants would have the same EEG band wave oscillations. The finding of this review corroborated this hypothesis. Another confounding variable to this review was the amount of DMT administered, either via injection or Ayahuasca that might account for differences in the results.

Future research could reproduce this review by incorporating a wider data base and search criteria; for example, 'hoasca' is used by the religious Uniao do Vegetal members [22]. This information was found after the initial search, so it was not included. Future studies may also include repeated protocols of EEG monitoring of DMT or Ayahuasca, reinvestigating any new results, and reviewing the inconsistencies raised in this review.

This review highlights the need for future research, for example, published studies on DMT or more chemically controlled Ayahuasca EEG band wave monitoring. EEG monitoring using other chemicals such as 5-methoxy-DMT or MAO inhibitors could contribute to the present results. This review may stimulate future research to investigate the similarities occurring in schizophrenic patients and DMT ingestion.

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## Critical Review Investigating whether there are similarities in EEG band waves between Schizophrenic patients and participants given DMT or Ayahuasca Tea

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