QEEG STUDIES OF THE ACUTE EFFECTS OF THE VISIONARY TRYPTAMINE DMT

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ABSTRACT: Recent brain imaging studies in Psychedelic Brain Science are breaking new ground in our understanding of neurological substrate of biological consciousness in humans. The emerging field of inner experience and neuroscience is particularly well suited to the reexamination of the actions of psychedelics on subjective conscious experience. This approach is best understood as neurophenomenology. My work over the last few years has focused on the EEG correlates of the visionary tryptamine DMT action. I believe the researcher must also have the drug experience as part of the experimental protocol, in order to fully understand the richness of the phenomenon. The objective of this exploratory research was to examine the QEEG correlates of the psychoactive smoked inhalation of exogenous DMT action. Known as a potent visionary tryptamine, DMT is ubiquitous in nature and has also been localized in the brain and peripheral tissues of mammals, including humans. The exact function of this endogenous DMT is the subject of ongoing neuropharmacological research.

Three sources of DMT were tested: high purity synthetic 5-MeO- DMT, Bufo 5-MeO-DMT (an extract from the Sonoran desert toad venom, *Bufo alvarius*), and N,N- DMT from a natural extract of the Acacia tree *Mimosa hostilis* root bark.

The DMT was delivered by smoked inhalation (vaporization). The rapid onset (10-20 sec), short acting (5-15 min.), and reversible nature of the effects made such a QEEG study feasible. DMT dosage was adjusted to elicit an effective psychedelic experience (ca. 20-30 mg for N,N-DMT; 2-5 mg for synthetic 5-MeO-DMT, and 30-40 mg for the Bufo 5-MeO-DMT material). Healthy volunteers (age 25-60; N=15 men, N=8 women) were tested.

The protocol consisted of: 5-10 min. baseline control (resting eyes closed) was first acquired, followed by the DMT test condition, usually lasting 5-15 min. When subjects recovered from the DMT induced altered state, a report of their subjective experience was recorded on video and a post recovery EEG reading was made typically at 15-30 min. A statistical comparison (paired t-tests, correlated samples) of absolute power values for all EEG bands between baseline vs. DMT tests and post recovery conditions was carried out for all subjects. The DMT- induced profound alterations in consciousness were tracked with the shifts in the QEEG metrics analysed. The time course and intensity of the subjective experience correlated with the magnitude of the observed EEG effects.

The most consistent effect was a robust suppression of Alpha, obtained for both N,N-DMT and 5-MeO-DMT (Alpha decreased ave. 72%, N=6). During recovery, some subjects showed Alpha rebound increased power at 15-25 min. post DMT (ave. 43% incr., P<.0107, N=9) . A DMT induced reversible shift in FFT spectra from Alpha to Theta was recorded in some subjects. Also, very signifcant hypercoherence in all bands (especially Beta) was measured in most subjects. Gamma power (35-40 Hz) was also increased in some subjects. During post DMT Alpha rebound, subjects reported "being in peace, a calmed state of wellbeing and clarity". The significance of these findings is discussed with reference to DMT receptor pharmacology mechanisms and recent psychedelic brain imaging studies.

KEYWORDS: DMT; EEG; Psychedelic

A comprehensive theory of human consciousness must account for the diversity of brain states during wakefulness and sleep; including dreaming, lucid dreaming, and the manifestation of altered states of consciousness (ASC), induced by endogenous and exogenous agents; including psychoactive drugs and psychedelics, anesthesia, hypnosis and the wide spectrum of mind/body practices (eg. meditation, yoga, trance, shamanic rituals, fasting, extreme physical challenges, ecstatic dance, sensory deprivation, chanting, drums, etc.). Also, from Psychiatry and Neurology must account for the diverse mental disorders and neuropathologies resulting from abnormal brain function which afflict a proportion of the human population (eg. Epilepsy, schizophrenia, bipolar disorders, psychosis, etc.). We must also include research into paranormal phenomena that can be scientifically rigorously tested (eg. Psi, ESP, telepathy, remote viewing, etc.) with the advent of new technologies (Radin, 2010).

Psychedelic Brain Science, using state of the art brain imaging technology (fMRI, PET, SPECT, MEG, EEG) is a promising emerging field that is making breakthrough contributions to the understanding of the mind/brain connection. Indeed, psychedelics have been favored valuable tools to explore consciousness for the past decades, and after decades of prohibition from restrictive drug laws, Psychedelic Science is now experiencing a renaissance. Furthermore, these recent studies are breaking new ground in our understanding of the neurological substrate of biological consciousness in humans. The field of inner experience and neuroscience (Price, 2012) is an emerging epistemology particularly well suited to the examination of the actions of psychedelics on subjective conscious experience as a neurophenomenology of consciousness.

My work over the last few years has focused on the EEG correlates of the visionary tryptamine DMT action. I believe the researcher must also have the visionary drug experience in order to fully understand the richness of the phenomenon.

Humans seem to have a natural drive to explore ASC and seek ecstatic and transcendent experience. The use of hallucinogenic or consciousness expanding plants for magico/religious/spiritual activities has been a part of the human experience for millennia. Archaelogical and paleoanthropological evidence points to the use of entheogens as far back as the Upper Paleolithic in diverse locations worldwide (Metzner, 2005; Shanon, 2002,2008). The sacramental use of psychoactive plants can bring spiritual awakening to healthy people and has the potential to offer mystical numinous experiences. The shamanic practices with entheogens form an impressive record of acquired knowledge of ASC and may contribute new insights in the neuroscience of consciousness (Perry, 2010).

Psychoactive plants and preparations have been used for millennia by shamanic cultures in the New World and the Old World to explore spiritual realms and for healing purposes (Ratsch, 2005). Psychoactive plants and mushrooms also played a key role in Old World religions (Shanon,2002; Rush, 2013). The use of psychedelic plant preparations among New World tribes is far more prevalent than in the Old World. Of chief importance is the pan Amazonian hallucinogenic brew Ayahuasca, which is a preparation containing Beta carboline alkaloids (viz.Harmine, Harmaline and tetrahydroharmine, which act as MAOIs) contained in the vine *Banisteriopsis caapi* , which is boiled with the leafs of DMT containing plants, commonly used are *Psychotria viridis , P. cabrerana.* The DMT is orally activated by the Beta carbolines and provides much of the psychoactivity to the brew (Callaway,1994, 1995; McKenna, 2015). Other DMT containing preparations, delivered as snuffs and smoked, such as Virola and Cohoba, have been used in Middle America, and Caribbean and Amazonian shamanic cultures for centuries and continue to this day. (Ratsch, 2005). Ethnobotanists and phytochemists have identified at least 11 genera comprising over 75 species of plants and fungi containing DMT (N,N and 5-MeO-DMT) (Ratsch, 2005). The genus Acacia trees (New and Old world species) contains high concentrations of DMT. Australia has also emerged as a rich source of DMT containing Acacia tree species (Palmer, 2014). In the Old World, the knowledge and use of DMT containing Acacia species combined with the seeds of the ancient sacred plant *Peganum harmala*, a known MAOI, has been suggested as a candidate brew pharmacologically equivalent to Ayahuasca (Ott,1993). In the Middle East, some scholars have implicated the use of DMT as Biblical Entheogens (Shanon, 2008; Strassman, 2014). In Brazil the Acacia tree *Mimosa hostilis* root bark preparation known as *Jurema* has been used in shamanic rituals in the past which continue to this day (Ott, 1993). In recent years, Ayahuasca based syncretic religions (Santo Daime, UDV, Barquinia) originating in Brazil, have been proliferating to Europe and N. America (Metzner, 2006; Labate, 2014). This

rapid global expansion of contemporary neo-shamanic Ayahuasca use for spirituality and healing is an emerging phenomenon with complex social and legal ramifications (Labate, 2011).

DMT was first synthesized in 1931 (Manske, 1931). It was then isolated from plant sources used by Amazonian shamans: *Mimosa tenuiflora, Anadenanthera colubrina* and *Piptadenia peregrine* in 1955 and its psychedelic effects were first reported in the academic world in 1956 (Szara, 1956). Chemically, DMT is closely related to psilocybin and psilocin (4-hydroxy-N-dimethyltryptamine), as well as to bufotenine (5-hydroxy-N-dimethyltryptamine). DMT is the methylated derivative of tryptamine, the decarboxylated product from tryptophan. The detection of N-methyltransferase, an enzyme capable of converting naturally-occurring tryptamine to DMT in human brain was first reported in 1972 (Saavedra, 1972). Research in the 1970's was focused on linking DMT to biochemical models of schizophrenia (Wyatt,1974; Szara, 1961).

DMT is an endogenous hallucinogen (Barker et al., 1981). It is found in the mammalian brain and peripheral tissues, and in humans it has been found in urine, blood and cerebrospinal fluid. DMT is considered an endogenous synaptic neuromodulator and evidence suggests that it can be locally sequestered into brain neurotransmitter storage vesicles. Quantitative studies measuring the abundance of endogenous DMT have been difficult because of its rapid metabolism (Burchett, 2006; Barker, 2012). DMT is known as a ligand to 5-HT receptor(s); binding to the 5-HT2A receptor target is believed to confer its hallucinogen properties and DMT action is terminated by MAO metabolism (Nichols, 2004). More recent biochemical, physiological, and behavioral experiments indicate that DMT is also an endogenous agonist regulator for the Sigma-1 receptor and inhibits voltage-gated Na channels (Fontanilla, 2009).

The closely related molecule, 5-MeO-DMT has received recent scientific and public attention (see below). Pharmacological evidence indicates that MAOI largely affects 5-MeO-DMT metabolism and pharmacokinetics. 5-MeO-DMT is primarily inactivated through MAO-A-mediated deamination pathway. Although composite evidences indicate that there is likely a common site of 5-HT2A and other 5-HT2 receptors in the central nervous system responsible for the actions of indolealkylamine hallucinogens, 5-MeO-DMT has been shown to act mainly through the 5-HT1A receptor. Thus, 5-MeO-DMT is known as a nonselective 5-HT receptor agonist, and both 5-HT1A and 5-HT2 receptors seem to be involved in its complex pharmacological and toxicological effects. (Shen, 2010)

After decades of prohibition, DMT research was revitalized by the government sanctioned landmark studies exploring dose-dependent intravenous injection of N,N-

DMT effects on human volunteers, conducted at a medical school setting by Strassman. These studies examined the human psychopharmacology of the DMT psychedelic experience (Strassman, 1994, 1996). Strassman's groundbreaking book, DMT: The Spirit Molecule, published in 2001, revitalized the public's interest in this visionary tryptamine which links body and spirit, and it has become a favorite of the psychonaut/entheogenic community.

5-MEO-DMT EXPERIENCE: THE "GOD MOLECULE".

The 5-methoxy-N,N-dimethyltryptamine (5-MeO-DMT) molecule is also a potent endogenous hallucinogen often coexisting with N,N-DMT in many plant species and also associated with a rich history of shamanic ritualistic use. It is generally accepted that the 5-MeO-DMT experience is qualitatively different from the N,N-DMT induced experience. For extraordinary descriptions of the smoked 5-MeO-DMT subjective transcendent experiences the reader is referred to the book *Tryptamine Palace* (Oroc, 2009). Some quotations from this book: " I believe that what I have experienced is the universal state of consciousness before the knowledge of ego and self, a state of undifferenciated cosmic consciousness that historically William James described as Absolute Consciousness. This state is now commonly described among today's entheogenic community as God consciousness". This place of Oneness is described as a field of pure infinite Love; the brilliant bejeweled light of Love, the Godhead, the Void that is a Plenum, the Creation Principle. There is a recognition of the unity of all and that love is the principle that organizes the universe. Smoked 5-MeO-DMT has been described as " the encounter with God" experience. Of animal origin, the venom of the Sonoran desert toad contains 5-MeO-DMT, known to be toxic when consumed orally, but can be safely smoked to induce powerful psychoactive states (Weil, 1994; Oroc, 2009). There is ongoing archaeological research to trace its use to precolombian Mesoamerica.

QEEG DMT STUDIES

The objective of this exploratory research was to examine the objective QEEG correlates of the smoked inhalation of exogenous DMT experience.

The author's first encounter with DMT was in 2005 and motivated these exploratory QEEG studies conducted in Peru and Mexico. Three sources of DMT were tested: high purity synthetic 5-MeO- DMT, Bufo 5-MeO-DMT (an extract from the Sonoran desert toad venom, *Bufo alvarius*), and N,N- DMT from a natural extract of the Acacia *Mimosa hostilis* root bark. A preliminary chemical analysis,(GC/MS and TLC) of the material used in these experiments yielded mostly 5-MeO-DMT as the principal alkaloid, with no detectable bufotenin (P. Daley, personal communication).

The DMT was delivered by smoked inhalation (vaporization). The rapid onset (10-20 sec), short acting (5-15 min.), and reversible nature of the effects made such a QEEG study feasible. DMT dosage was adjusted to elicit an effective psychedelic experience (ca. 20-30 mg for N,N-DMT; 2-5 mg for synthetic 5-MeO-DMT, and 30-40 mg for the Bufo 5-MeO-DMT material). Healthy volunteers (age 25-60; N=15 men, N=8 women) were tested. EEG was acquired with a Mitsar 201 amplifier (St. Peterburg, Russia) using 10-20 system electrocap, 19 channels referential linked ears montage, 250 Hz sampling rate, 0.5-40 Hz bandwidth measured. The raw data was analysed with Neuroguide software (appliedneuroscience.com) after visual removal of ocular, muscle and movement artifacts. Qualitative comparisons were also made using WinEEG software.

The protocol consisted of: 5-10 min. baseline control (resting eyes closed) was first acquired, followed by the DMT test condition, usually lasting 5-15 min. When subjects recovered from the DMT induced altered state, a report of their subjective experience was recorded on video and a post recovery EEG reading was made typically at 15-30 min. A statistical comparison (paired t-tests, correlated samples) of absolute power values for all EEG bands between baseline vs. DMT tests and post recovery conditions was carried out for all subjects. The DMT- induced profound alterations in consciousness were tracked with the shifts in the QEEG metrics analysed. The time course and intensity of the subjective experience correlated with the magnitude of the observed EEG effects.

Results. A Statistical comparison of absolute power for all bands (mean +- SEM, P values two-tailed) yielded, for N,N-DMT: Delta (22.19 +-3.46 vs 18.48 +-3.6, N=18, N.S); Theta (17.97 +-3.54 vs 10.06 +-1.05 , P<.018, N=17); Alpha (133.65 +-27.06 vs 17.18 +-4.37, P<.0012, N=17); Beta1 (16.23+-4.16 vs 5.63+-1.9, P<.002, N=17); Beta2 (5.26+-0.66 vs 2.73 +- 0.4, P< .0001, N=16); Beta3 (2.63 +- 0.48 vs 2.21 +0.33, P<.013, N=6). For High Beta increase (2.74+-0.8 vs 4.53+-1.13, P<.05, N=10). The most consistent effect was a robust suppression of Alpha, obtained for both N,N-DMT and synthetic 5-MeO-DMT (Alpha decreased ave. 72%, N=6). During recovery, some subjects showed Alpha rebound increased power at 15-25 min. post DMT (ave. 43% incr., P<.0107, N=9). A DMT induced reversible shift in FFT spectra from Alpha to Theta was recorded in some subjects. Also, very significant reversible hypercoherence in all bands (especially Beta) was measured in most subjects.

The Bufo 5-MeO-DMT data (N=11 subjects) did not differ significantly from the synthetic 5-MeO-DMT findings, except the recovery time to baseline was more prolongued (typically 20-40 min.). Also, in most subjects a Theta peak (6-8 Hz) emerged during the altered state (not present in baseline EEG) which persisted 10-20

min. after intake and disappeared at recovery stage. Both N,N and 5-MeO-DMT increased Gamma power (35-40 Hz) significantly. The Bufo 5-MeO-DMT data revealed increased Gamma power in 10/11 subjects tested. During post DMT Alpha rebound (increased power) phase, subjects reported "being in peace, a calmed state of wellbeing and clarity".

Figures 1-4 illustrate representative results for both N,N and 5-MeO-DMT tests.

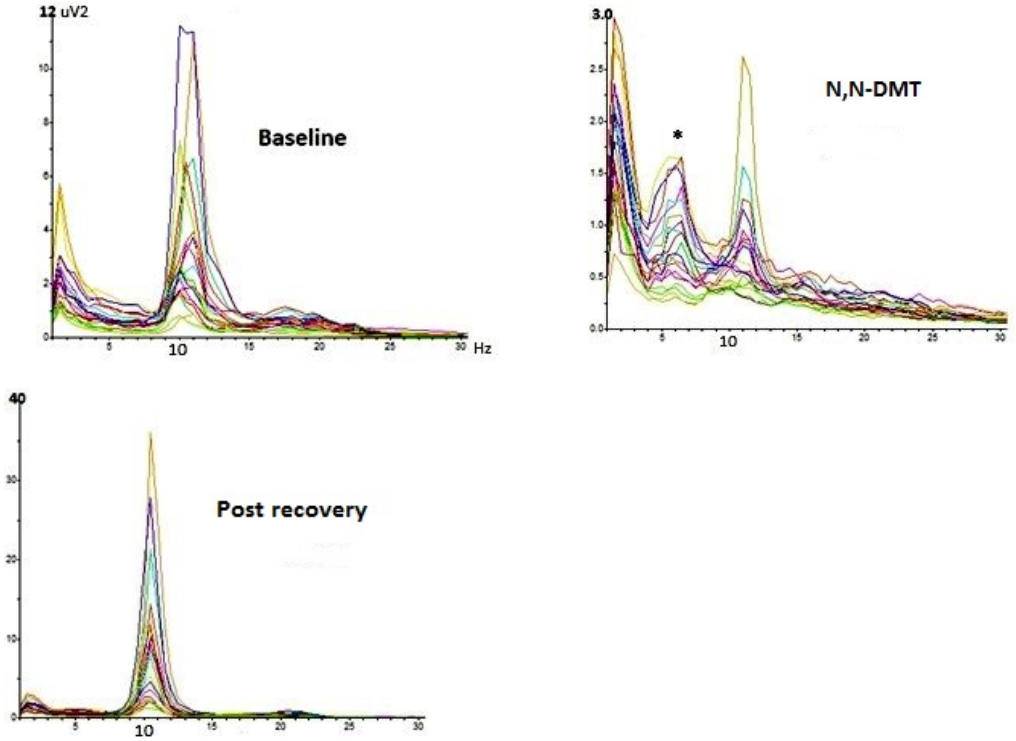

Fig. 1 FFT power frequency spectra shows effects of N,N DMT. Baseline Alpha peak (ca. 10 Hz) was suppressed (ca. 75%) and a Theta peak (ca. 5.5 Hz) is now evidenced (*). At 20 min. post recovery, Alpha peak rebound increased ca. 190%. Note different power scales.

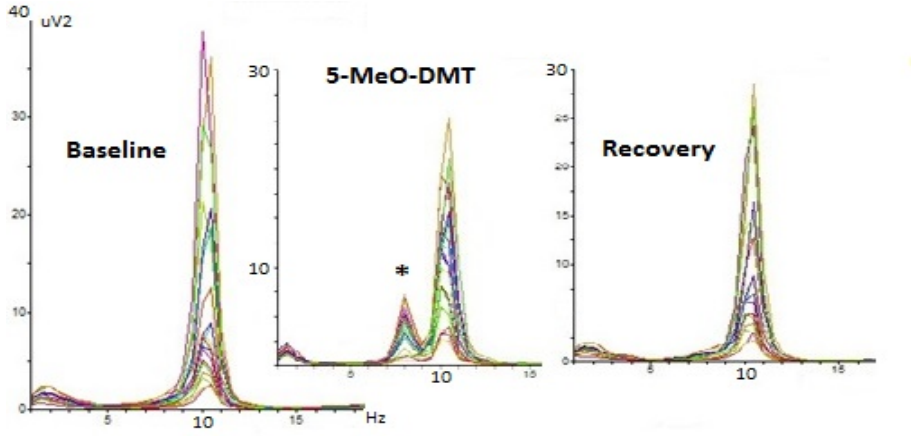

Fig. 2 FFT power frequency spectra shows effects of 5-MeO-DMT .
Bufo 5-Meo-DMT induced suppression of peak Alpha (37% decr.) and Theta peak ca. 8 Hz now evidenced (*). Recovery trend at 20 min. post was observed.

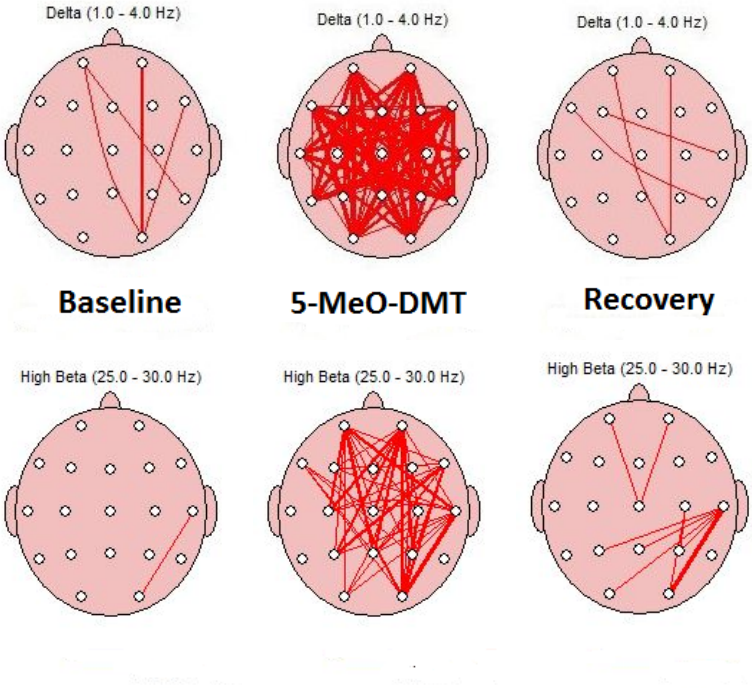

Fig. 3 5-MeO-DMT induced reversible increase in Coherence. Examples of Delta (1-4 Hz, top) and High Beta (25-30 Hz, bottom) hypercoherence and recovery at 15-20 min. post, recorded in two different subjects.

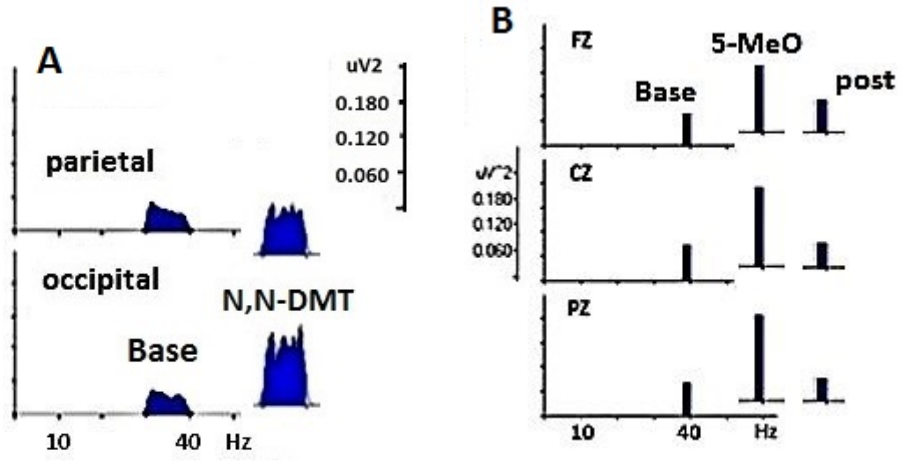

Fig. 4 FFT power frequency spectra shows effects on Gamma oscillations. A. N'N-DMT induced increase in Gamma averaged power (30-40 Hz) at 3 parietal sites (150% incr.) and 2 occipital (300% incr.) sites. B. Bufo 5-MeO-DMT 40 mg reversibly increased Gamma spectral power (38-40 Hz), shown as bar graph comparisons for 3 midline sites (FZ, CZ, PZ). Similar results were obtained in N=10/11 subjects.

The magnitude of the EEG effects correlated with the time course and intensity of the subjective experience. The most significant EEG changes occurred in the first 2-5 min. This is consistent with a rapid metabolic turnover of the DMT receptor binding mechanism of action, as demonstrated in biochemical and pharmacokinetic studies of the metabolic termination of DMT effects. Furthermore, the partial to full reversibility of the EEG effects suggest the brain is quite resilient and capable of rapid reorganization to baseline status. It appears that DMT action produces a reversible reconfiguration of network dynamics.

The few EEG studies of Ayahuasca have reported overall suppression of power across many frequency bands, notably Theta, Alpha, and less consistent for low to mid Beta (15-25 Hz), and increased power in High Beta band (25+ Hz) (Riba, 2002; Don, 1998; Stuckey, 2005). A recent study reported biphasic effects: initial suppression of Alpha power, followed later by increased Gamma power (Ekman Schenberg et al. 2015). These results are in general agreement with the QEEG DMT findings reported by the author.

DMT neuropharmacological mechanisms are believed to be mostly mediated via 5-HT2A receptor binding (Nichols, 2004). However, the recent discovery of novel Sigma-1 receptors suggests that coactivation of serotonergic pathways and Sigma-1

receptor mediated cascades may be at work. A tentative hypothesis is offered concerning the contribution of DMT sigma-1 receptor interactions: Broadband desynchronization and the overall suppression of power in many EEG bands (viz. Theta, Alpha and low-mid Beta) reported in Ayahuasca studies and the DMT findings described here, may be linked to the DMT-induced inhibition of Na+ channels, which would effectively reduce neuronal activity and synchronization across networks in brain areas targeted by DMT Sigma-1 receptor binding. The increase in Hi Beta and Gamma power during Ayahuasca and the acute DMT tests may involve inhibition of the GABAergic inhibitory input to neuronal populations (eg. Pyramidal neurons) that generate Gamma rhythms.

GAMMA OSCILLATIONS

Large scale neuronal synchronization of brain networks is believed to underlie distinct characteristics of conscious experience. This concept of a global coordinated activation of patterns, "the brainweb", was proposed in Cognitive Neuroscience (Varela et. al. 2001). Synchronous neuronal activity in the Gamma frequency band (30-100 Hz) has been recorded in numerous brain regions and linked to a wide range of cognitive functions. Gamma oscillations have been extensively researched as EEG signature correlates of diverse conscious states, including visual perception, sensory processing, attention, learning and memory (LeBeau, 2010; Singer, 2001; Fries, 2009). Also, contemplative neuroscience research is revealing the roles of Gamma in higher states of consciousness, reporting increased Gamma power and coherence in meditative states (Lutz,2004) and also during Ayahuasca visionary states (Stuckey, 2005; Don et al., 1998; Riba et. al, 2002, Ekman Schenberg, 2015). This remarkable convergence of findings linked to Gamma frequency band is propelling new research directions. It is well established that visual processing is associated with Gamma synchronization across occipital brain regions (Muthukumaraswamy, 2008), and the recent studies linking lucid dreaming to increased occipital Gamma (Voss, 2009, 2014; Filevich et al., 2015) are of great interest as they may shed light on the possible mechanism of psychedelic visionary states which closely resemble conscious dreaming states, and also involve increased Gamma power. The N,N-DMT QEEG findings of increased Gamma power are also consistent with the vision and lucid dreaming EEG data as the hallmark of the smoked N,N-DMT experience is characterized by a rich visionary experience with exquisite visual displays that overwhelm the user with their beauty and strangeness.

THE DMN INVOLVEMENT IN MYSTICAL STATES

Psychedelic brain science has matured in recent years with groundbreaking findings on the role of the DMN in mediating the psychedelic experience. Neuroimaging fMRI studies of the psychedelic state induced by intravenous administration of psilocybin in healthy human subjects have reported reduced activation of subnetworks embedded in the Default Mode Network (DMN) (Carhart-Harris et al., 2011; Roseman et al. , 2014). This finding has been linked to the familiar ego dissolution and unity state of being and the experience of transcendence commonly described in the psychedelic state. Further evidence for the involvement of the DMN in mediating mystical states and meditation has been provided by studies demonstrating that the neural correlates of some meditation states are linked to suppression of activity in the DMN. Subjects in these studies report attainment of non-dual awareness states that correlate strongly with reduced DMN activation at key nodes in fronto-parietal cortical sites (Brewer et al. , 2011; Jopovich et al., 2012, 2013).

Converging evidence from a recent Brazilian fMRI study in healthy volunteers has also reported DMN deactivation during the Ayahuasca experience (Palhano-Fontes, F. et.al. ,2015). The Ayahuasca visionary experience is largely mediated by the actions of DMT. Thus, a neuroscience of mystical states is emerging, following from the pioneering early SPECT imaging studies of meditation that birthed the field of neurotheology (Newberg, 2001), and follow-up research on the spiritual brain (Beauregard, 2007). It is interesting to add here that subjects who have an established Vipassana meditation practice have reported that the Ayahuasca experience potentiates their meditation (personal communications). This observation is consistent with the reduced DMN findings abovementioned and points to the shared neural network mechanisms in mystical and psychedelic states.

CONCLUSION

Psychedelic drugs are unique in their abilities to profoundly alter human awareness and perception. The neurophysiological study of psychedelic brain states is contributing important hints regarding the neuronal substrates of human consciousness and yielding clues to the nature of the Mind/Body spiritual consciousness experience that is the common heritage of all mankind.

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