Breaking Through the Veil of Perception: Image Reconstruction of Mental Imagery from DMT Induced Psychedelic States

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Abstract

Psychedelics have been gaining greater attention for their promises in therapeutic applications, but they also can be an invaluable tool to study consciousness. This study uses Bayesian estimation image reconstruction (BEIR) to visualize mental imagery of DMT-induced altered states of consciousness. N,N-Dimethyltryptamine (DMT) produces profound alterations to consciousness, with users often encountering other-than-self entities, complete immersion into different 'worlds', and shared experiences across users. To explore these phenomena, functional magnetic resonance imagery (fMRI) and electroencephalography (EEG) readings were used to record brain activity of participants administered intravenous DMT. Brain activity data was then decoded into visual reconstructions using the BEIR technique to compare against subjective reports from the Mystical Experience Questionnaire (MEQ-30). The results reveal that semantic qualities consistent in participant reports of visuals, like geometric patterns and faint figures, were upheld in image reconstruction. The correlation between subjective reports of the MEQ-30 and reconstructed visuals, provides evidence to a new method of validating DMT phenomenology. These findings support the plausibility of using image reconstruction to gain insights into altered states of consciousness, with potential implications for therapeutic applications and consciousness research.

Keywords: DMT, Consciousness, Image Reconstruction, Neuroimaging, Psychedelics

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N, N-Dimethyltryptamine (DMT) is an endogenous psychedelic compound that produces profound alterations to consciousness. DMT interacts with the brain as an agonist of the 5-HT2A receptor, associated with altered perception, transient experiences, and shifts in cognition (Nichols, 2016). When DMT is taken orally or intravenously, effects are described as "breakthrough" experiences, where users report encountering other-than-self social agents and entering vivid immersive 'worlds' (Michael, Luke, & Robinson, 2021). DMT reliably produces such mystical experiences, making it an invaluable tool to probe consciousness and the mechanisms responsible for how the brain constructs reality (Davis et al., 2020).

To understand the mechanisms responsible for DMT's phenomenology, research has focused on neuroimaging techniques using functional magnetic resonance imagery (fMRI) and electroencephalography (EEG). In a study by Timmermann et al. (2023) assessing brain effects of DMT using EEG and fMRI, it was found that DMT facilitated dysregulation of brain activity to be a potential explanation of the hallucinations and reported phenomena. DMT increased global brain connectivity (GBC) and connectivity in the limbic network, theorizing that the experience occurs because of the disinhibition of limbic functions related to memory and emotional processing. Despite the relationship between changes in GBC induced by DMT, the correlation of visual imagery and other-than-self 'entity' encounters were unexplained from brain activity. However, it is also theorized that the 'breakthrough' immersive quality is due to theta/delta power combined with the 'collapse' of alpha/beta power, similar to dreaming during REM sleep (Timmermann et al. 2019). Timmermann et al. (2019) suggest that due to the emergent theta/delta rhythmicity, the visual phenomena experienced could be due to circuitry associated with REM sleep and medial temporal lobe stimulation. This offers a possible

foundation for the immersive visual phenomena and other-than-self ‘entities’ reported under DMT.

While neuroimaging data suggests what regions of the brain are correlated with DMT phenomenology, it does not fully capture the depth of what occurs in the subjective experiences users report. In a study by Michael, Luke, and Robinson (2021), researchers conducted a thematic and content analysis of DMT experiences, to identify common themes and elements of these altered states. Researchers found that nearly all participants reported encountering and interacting with autonomous 'entities' and being immersed in a vivid, otherworldly environment. Other themes included beings that had specific roles like guides, teachers, or observers, with the environments being filled with complex, symbolic imagery. While the subjective reports offer insight into the mystical nature of the immersion, interpreting these experiences with self-reports is unreliable to understand the phenomenology objectively. However, emerging technologies may allow for objective measurements, by mapping the visuals of subjective experiences.

Neuroimaging data from fMRI and EEG readings can be input into neural decoding technologies to visualize the content a person is seeing (Li, 2024). The use of deep neural networks (DNNs) and generative models, allow for the creation of higher-fidelity image reconstruction from brain activity (Koide-Majima, Nishimoto, & Majima, 2024). Most image reconstruction studies recreate physical imagery, but mental imagery reconstruction remains challenging. One study conducted by Koide-Majima, Nishimoto, and Majima (2024) used Bayesian estimation image reconstruction (BEIR), which allowed researchers to produce more coherent images from partial or abstract brain data. This technique used pre-trained DNNs to decode neural activity to capture semantic qualities. Given the success of BEIR in enhancing

mental image reconstruction, BEIR can allow for visualization of the DMT subjective experience to validate and quantify phenomenological elements.

Methods

The present study followed materials and procedures from the methods of Timmermann et al. (2023) to maintain a safe and reliable administration of DMT, with minor modifications to incorporate image reconstructions and measure subjective experiences.

Participants. This study followed a within-subjects design to evaluate the effects of DMT on participants. Twenty healthy adults (50% male, 50% female) aged 24 to 37 (M_{Age} = 30.5, SD = 3.73), all with prior experience with psychedelic substances, were selected. Ethics approval was obtained from the institutional review board before recruitment. Participants were recruited from the MAPS Psychedelic Science Conference through online surveys. Volunteers were excluded if they had any history of psychiatric illness, physical illness, family history of psychotic disorders, current medication use, substance abuse, and pregnancy. Participants underwent an initial screening process to assess physical and mental health and provided written informed consent.

Procedure and materials. Materials included fMRI and EEG equipment for capturing neural data. IV bags, syringes, and a saline solution were used for intravenous DMT administration. The Mystical Experience Questionnaire (MEQ-30), a validated questionnaire, measured the intensity and quality of psychedelic experiences. Participants were hooked up to an EEG and placed in an fMRI before administering the substance. The DMT condition used 20 mg of DMT dissolved in 10 mL of sterile saline intravenously, with 10 mL of sterile saline used as a placebo. Participants wore an eye mask to reduce any external visual input. Participants then completed the MEQ-30, were debriefed, and monitored to see if there were any remaining side effects from DMT.

Results

Image Reconstructions. Using the fMRI and EEG data, the brain activity was processed using the BEIR model. This method uses the pre-trained DNN's VGG19, VQGAN, and CLIP to decode brain data into visualized mental imagery (Koide-Majima, Nishimoto, & Majima, 2024). This approach aimed to capture the visual and semantic content experienced, with the reconstruction quality compared to subjective reports from the MEQ-30 scores.

Repeated Measures ANOVA. To evaluate the differences in brain activity between the DMT and placebo conditions, a repeated measures ANOVA was run. There were significant differences in global brain connectivity (GBC) between the two conditions, ($F(1, 19) = 15.62$, $p < .001$), indicating that brain activity under DMT is associated with greater connectivity compared to the placebo group. Figure 1 shows a bar graph of the mean GBC levels across conditions, demonstrating increased connectivity during DMT-induced altered states of consciousness.

Linear Regression Analysis. A linear regression was run to assess the correlation between brain activity and the visual quality of the reconstructed images. This analysis provided insight into whether higher activation predicted more coherent image reconstructions. Figure 2 shows a scatter plot indicating a positive linear relationship between brain activity and coherence of reconstructed images, with a significant correlation coefficient ($p < .05$).

Pearson Correlation with MEQ-30 Scores. A Pearson correlation was conducted between the MEQ-30 scores and image reconstruction quality. This analysis aimed to determine if higher MEQ-30 scores were correlated with more vivid or coherent reconstructed imagery. Results indicated a moderate positive correlation ($r(18) = .837$, $p < .01$), suggesting that participants who reported more intense mystical experiences had more coherent reconstructed images. Figure 3 displays a scatter plot of MEQ-30 scores compared to image quality scores.

Discussion

This study aimed to test the effectiveness of BEIR for mental imagery of DMT-induced psychedelic states. The results support the hypothesis, with the repeated measures ANOVA showing increased GBC due to DMT, linear regression analysis showing a significant correlation between the quality of the image and brain activity, and the Pearson correlation showing a strong relationship between image coherence and subjective MEQ-30 scores. Utilizing BEIR can capture the semantic qualities of the experiences, such as the silhouettes of the 'entities' and geometric pattern. While BEIR allowed for the visualization of subjective experiences, the image reproductions did not fully capture the experiences in their entirety. The image reconstruction model needs to be refined in order to be more effective to fully validate the mental imagery seen in the DMT subjective experience.

Results from the study add to the literature by providing a new technique for measuring and understanding the phenomenology of DMT experiences. Previous research has focused on understanding the neural activity under DMT (Timmermann et al., 2018; Timmermann et al. 2019; Timmermann et al. 2023) or understanding the content of the subjective experiences (Michael, Luke, & Robinson, 2021). This study aimed to use BEIR to validate the subjective experiences by visualizing the phenomenology and advance the understanding of what occurs during these mystical experiences. It provides efficacy that BEIR can be a suitable method to apply to mental imagery of psychedelic experiences, dreams, or out-of-body experiences.

While the results demonstrate the efficacy of BEIR for psychedelic states, several limitations should be considered. First, the sample was relatively small (N=20), limiting the generalizability of the findings. Although the BEIR framework allowed for higher reconstruction accuracy, the completeness and coherence of the reconstructed images are limited by the current

state of decoding technologies and do not fully depict an accurate representation of subjective mental imagery. Finally, the MEQ-30 scores may introduce variability due to the subjective nature of the experience. More experienced users may rate the experience as being more or less vivid due to previous experiences. Additionally, not all aspects of a DMT experience may be adequately captured by the standardized questionnaire, which could skew the correlation of image reconstruction accuracy compared to the subjective experience.

Future studies should implement larger and more diverse samples to verify the generalizability of findings and reliability of the methodologies. These experiences can vary among populations with previous experience, personality traits, and expectations. Additionally, future research can benefit from advances in image reconstruction, that may enhance the coherence and completeness of reconstructions to reveal more precise understandings of the subjective experience. This limitation may be due to the spatial resolution of fMRI, which may not be able to fully capture the minute neural activations associated with mental imagery (Koide-Majima, Nishimoto, & Majima, 2024).

This study provides the evidence that BEIR can capture the features of DMT-induced psychedelics state. By visualizing the cognitive experiences, subjective phenomenology can be bridged with objective neural data to gain a more compressive understanding of what consciousness looks like in these profoundly altered states of consciousness. As image reconstruction technologies continue to advance, they may unlock a new understanding of the nature of human consciousness and the mechanisms responsible for creating our reality.

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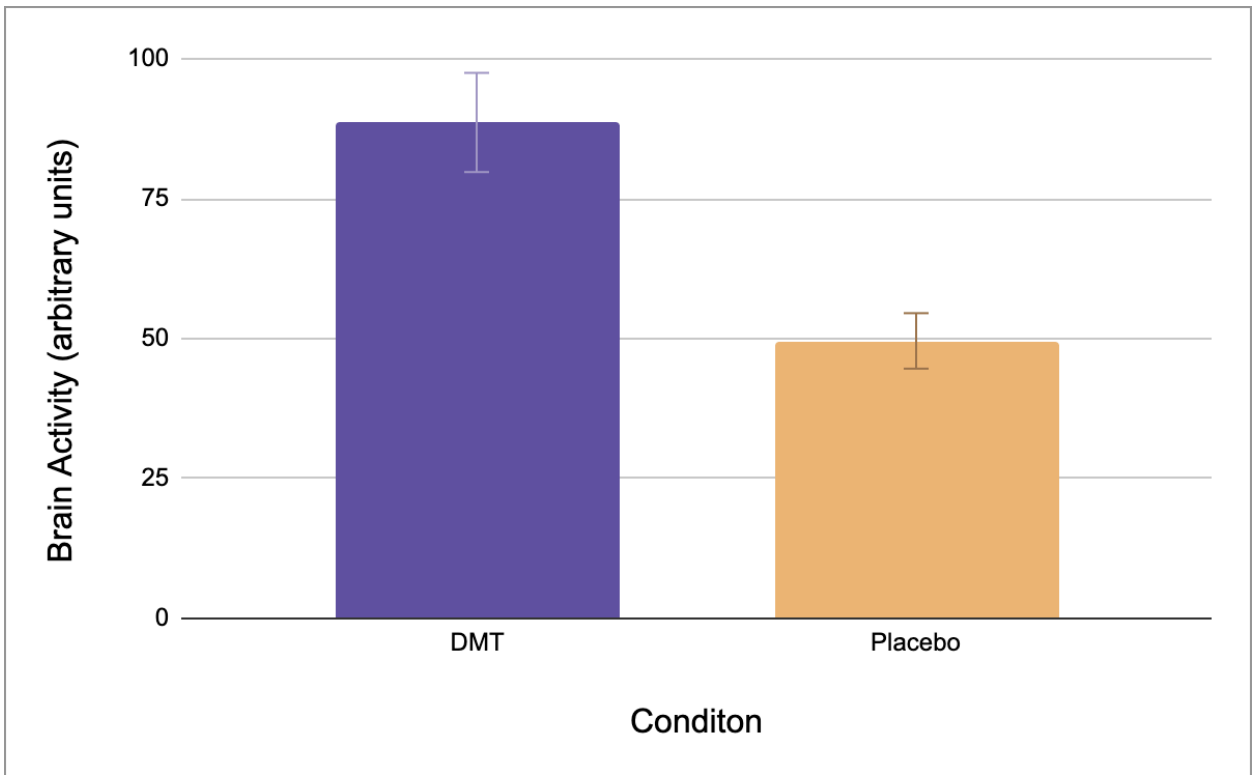
Figure 1

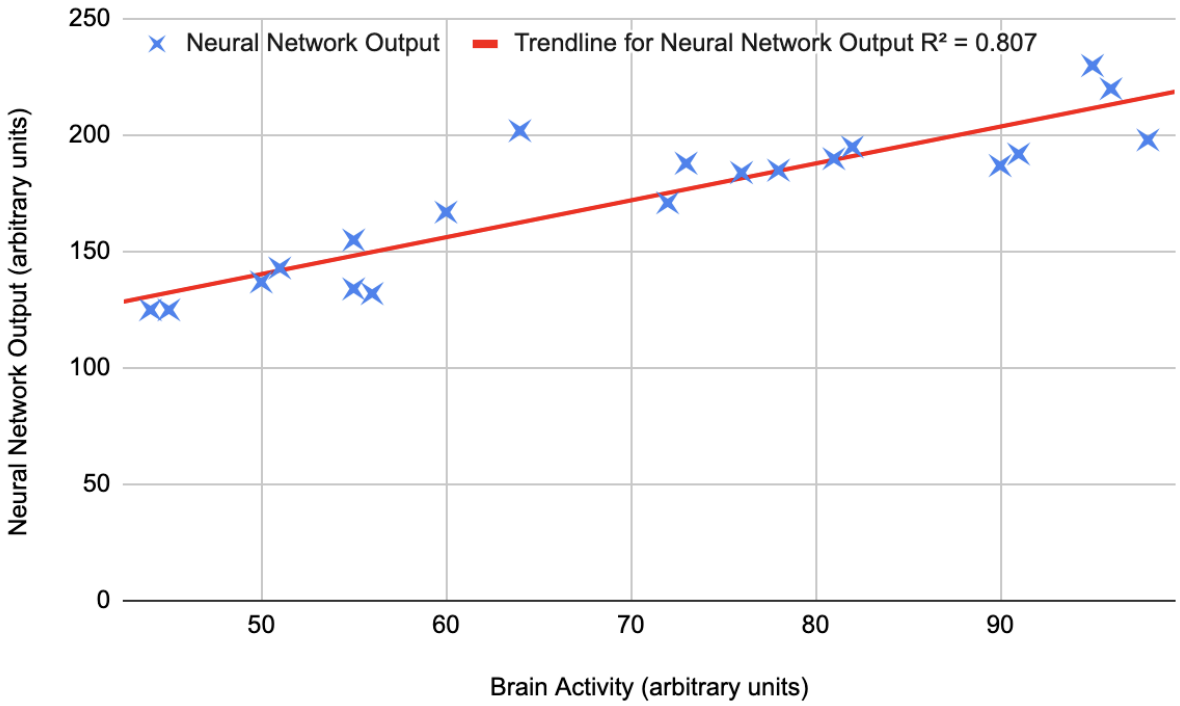
Comparison of brain activity in DMT and placebo conditions.



Note. Repeated-measures ANOVA of mean brain activity levels for DMT and placebo conditions. Error bars represent ±1 standard error of the mean.

Figure 2

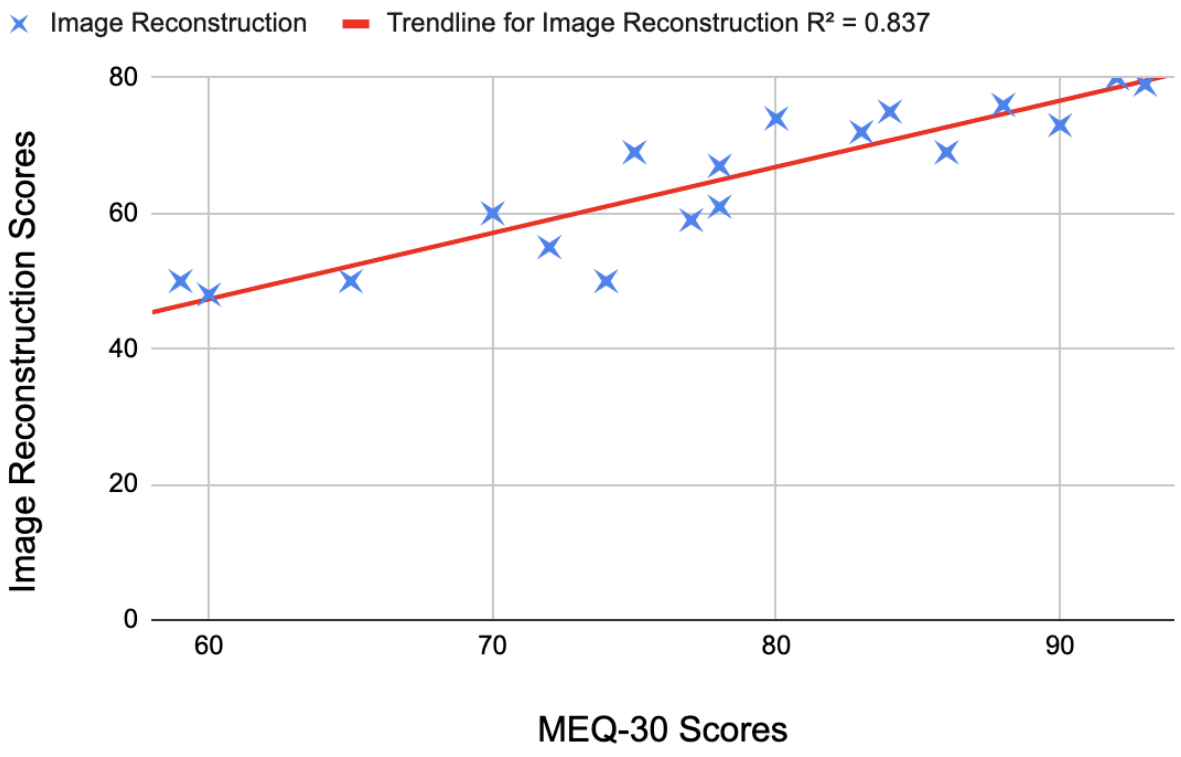
Linear Regression of Brain Activity Data and Neural Network Outputs.



Note. Linear regression analysis showing the relationship between brain activity and neural network output scores.

Figure 3

Pearson Correlation of MEQ-30 Scores with Image Reconstruction Complexity.



Note. Scatter plot showing the correlation between MEQ-30 scores and image reconstruction quality. Each ‘x’ represents a participant’s data point.