Quantitative Phenomenology: Embedding Psychedelic Trip Reports

7 January 2025

Author

Daniel Lundgaard
Undergraduate Student
Cognitive Science
Aarhus University

Supervisor

Rebekah Baglini
Associate Professor
Interacting Minds Centre
Aarhus University

Abstract

Psychedelics are fascinating, mind-altering compounds showing promise as novel treatment modalities targeting a range of mental afflictions. While the neurobiology and psychopharmacology of psychedelics have been studied extensively, research on their phenomenology is comparatively held back by dated technologies like psychometric inventories based on visual analogue scale ratings. This study explores the feasibility of quantifying the phenomenological dispositions of psychedelic compounds by means of semantic vector embeddings. This is operationalized with a computational approach to cognitive linguistics, leveraging a state-of-the-art transformer embedding model to compute vector embeddings for a corpus of textual, unstructured first-hand narrative reports chronicling psychedelic experiences obtained from curated archives of Erowid, a psychoactive drug-safety advocacy group. 3817 experience reports across five psychedelic compounds are embedded in a latent semantic space along with textual characterizations of three established dimensions of psychedelic phenomenology before quantifying the alignment of each experience report with each phenomenological axis by virtue of computing cosine similarity between the resultant embedding vectors. The functional relationship between the eliciting compound and the phenomenological qualities of the experience is modeled using a multivariate multilevel generalized linear model while controlling for potential confounding due to unbalanced demographics, yielding per-compound distributions of experience similitude with each phenomenological dimension. Findings suggest that the prospect of using semantic embeddings to quantify the comparative phenomenology of psychedelic compounds is a promising one. Limitations pertaining to the empirical source and employed methodology are discussed.

Keywords: *psychedelics · quantitative phenomenology · NLP · semantic embeddings*

Introduction

Psychedelics, a subclass of hallucinogenic drugs, have recently seen a comeback from a blotted past (Hadar et al., 2023; Lu, 2021). They have asserted themselves as a promising therapeutic avenue for a swathe of mental disorders and afflictions, both clinical and subclinical (Erritzoe et al., 2024; Goodwin et al., 2022; Griffiths et al., 2006; Ly et al., 2018; Marks & Cohen, 2021; Reiff et al., 2020). Psychedelic compounds are noteworthy not least because of the curious psychomimetic effects attending consumption and metabolism: the principal subjective effects in the acute phase are characterized by the occasioning of "non-ordinary" mental states — so-called altered states of consciousness — marked by profound alterations in affect, sensory perception, patterns of thought and sense of self (Brouwer & Carhart-Harris, 2021; Vollenweider & Preller, 2020). Such episodes are referred to colloquially as *trips* or, more formally, *psychedelic experiences*.

Pharmacology & Phenomenology

The psychoactive effects of psychedelic compounds are thought to be mediated by selectively binding to certain receptor types (often the serotonin 5-HT_{2A} subtype), altering the functional and structural connectivity of the brain (Aghajanian & Marek, 1999; Ly et al., 2018; Nichols, 2018; Vargas et al., 2023). Downstream, this allows for the emergence of cortical states that were previously highly improbable, resulting in novel, often strange, experiences. Borrowing an analogy from the field of statistical mechanics, one can think of a topological landscape representing the relative likelihoods of all theoretically realizable cortical states (see Figure 1) being *warped* (see Figure 2), such that certain regions of this landscape go from being practically unreachable to being readily accessible (Carhart-Harris & Friston, 2019; Gallimore, 2014; Singleton et al., 2022). Between psychedelic compounds, the manner in which such a landscape is contorted varies with the particular chemical composition and resultant receptor affinities, giving rise to distinct phenomenological expressions (Gallimore, 2022). This differentiation in experiential character may account for how certain compounds appear especially well-suited for treating psychophysiological trauma (Smith et al., 2022) while others appeal more to existential issues (Qiu & Minda, 2021).

While much work has been done to establish a relatively firm understanding of the neurobiology and psychopharmacology (Vollenweider & Smallridge, 2022), research is comparatively lacking when it comes to one more elusive aspects of psychedelics: their *phenomenology*. That is, the manner in which consciousness is experienced from the first-person perspective. Attempts at establishing an empirical taxonomy of ASCs (altered states of consciousness) using standardized psychometric scales to measure phenomenological dimensions of psychedelic experiences date back to before the turn of the century, where Dittrich (1998) proposed the APZ scale ("Aussergewöhnliche Psychische Zustande", German for "Extraordinary Psychological States") which has since morphed, due to Studerus et al. (2010), into the 11D-ASC (11-Dimensions Altered States of Consciousness Rating Scale). Hitherto, these psychometric scales have been administered in the form of bespoke questionnaires with quasi-continuous visual analogue scale ratings of identification with a sequence of statements. These constitute a narrowly targeted and arguably somewhat inflexible approach of measuring these kinds of constructs, and, almost by definition, do not capture any other information than they were designed for.

Novel Opportunities

This study takes a computational cognitive linguistics approach to studying the phenomenology of psychedelics, aiming to explore and evaluate the feasibility of identifying such phenomenological dimensions from semantic features in retrospective written reports chronicling first-hand psychedelic experiences. The prospect of extracting phenomenological profiles directly from unconstrained written narratives presents an opportunity for exploring and understanding, at scale, the phenomenological world of these fascinating compounds. To do this, a state-of-the-art neural-network transformer model is employed to operationalize and quantify the semantic contents of experience reports, with the aim of recovering phenomenological dimensions from latent semantic features. At a high level, the aim is to measure the same mental constructs as validated, questionnaire-based scales of phenomenology, but doing so by using sophisticated tools to extract this information from a much more flexible medium, i.e., unstructured narrative text reports.

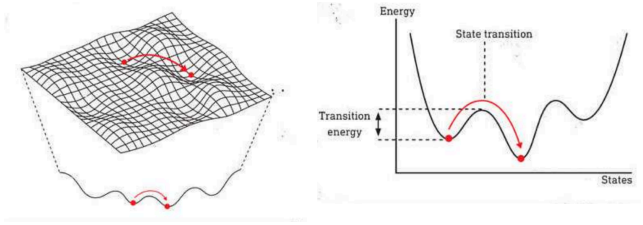

Figure 1. *Topological landscape representation of relative likelihoods for realizable cortical states (Gallimore, 2022).*

Computational Cognitive Linguistics

Cognitive linguistics deal with how latent patterns in linguistic expression can offer glances at mental construal, exposing the inner workings of cognition. Such patterns may serve as "[…] a lens on the mind" (Evans, 2012). Using computational Natural Language Processing (NLP) tools, large quantities of human-generated text can be leveraged to identify latent semantic patterns. Such techniques have proven fruitful in a variety of cognitive science domains, e.g., computational psychiatry (Al-Mosaiwi & Johnstone, 2018; Hansen et al., 2023; Kruse et al., 2024; Nour et al., 2023), epidemiological- and crowd psychology (Aiello et al., 2021; Horne & Adali, 2017) and political ideology (Zmigrod, 2020; Zmigrod et al., 2020).

The idea of applying NLP and computational linguistic approaches to psychedelics is not, in itself, novel. See for example Zamberlan et al. (2018) which explores the relationship between psychedelic molecules' neuropharmacological binding profiles to their subjective effects, Sanz et al. (2018) investigating the likeness of hallucinogenic experiences and dreams, Friedman & Ballentine (2024) surveying the unfolding of psychedelic experiences in terms of temporal dynamics over the duration of the experience as well as Qiu & Minda (2021) exploring the connection between encounters with mystical entities and ensuing impact on subjective well-being.

Semantic Embeddings

The core tenet, in the context of this study, is that textual semantics are, as a proxy, indicative of underlying cognitive/neurological states. In this vein, the areas of semantic space predominantly frequented under the influence of a psychedelic compound may point toward the distinct states of mind fostered and favored by that particular compound. The cognitive

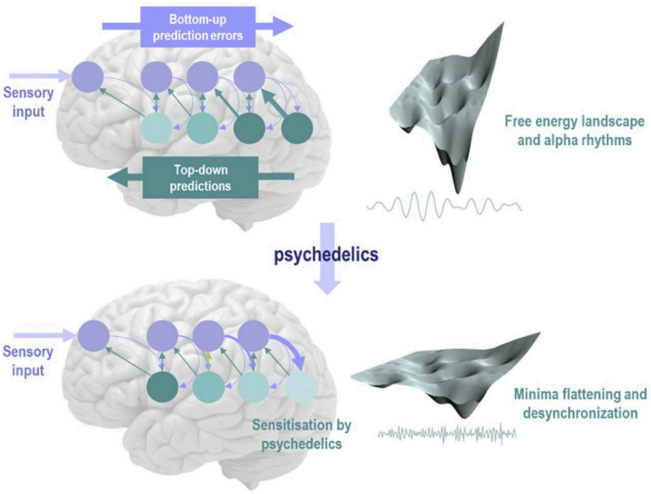

Figure 2. *REBUS (relaxed beliefs under psychedelics) conceptualization. (Carhart-Harris & Friston, 2019).*

linguistic aspect is operationalized through semantic vector-embedding, which refers to using pre-trained transformer models (large language models) to map a text to a vector that then numerically represents the semantics of its contents (Jurafsky & Martin, 2024; Vaswani et al., 2017). This can be thought of as a kind of compression — in the sense that texts of any length are reduced to and represented by an object of the same size — aiming to capture all the information in the text that pertains to its linguistic meaning while discarding anything extrasemantic. Semantic embeddings are an attempt at leveraging the concept of statistical semantics: "[that] statistical patterns of human word usage can be used to figure out what people mean" (Turney & Pantel, 2010; *SI People*, 2010). The endeavor of statistical semantics, in turn, hinges on the distributional hypothesis of semantics (Sahlgren, 2006) which proposes that "[…] a word is characterized by the company it keeps" (Firth J R et al., 1962). Essentially that words (or other lexical units) that frequently occur either together or in the same kinds of contexts, carry similar meanings and may be considered semantically alike (Lenci, 2008; McDonald & Ramscar, 2001).

The distributional hypothesis can be generalized to the sentence-, and even document-level, using so-called *sentence transformers* that modify pre-trained transformer models using Siamese- and triplet network structures to yield an aggregate embedding for whole text documents (Reimers & Gurevych, 2019). By de-

fault, transformer models compute embeddings at the *token* level, which tokens can take the form of words, subwords, n-grams or something more exotic depending on the tokenization algorithm employed (Yang, 2024). The models are also inherently limited in the amount of tokens they can take into consideration concurrently, the so-called context-window. Both of these issues are handled by sentence transformers to produce embeddings at the document level such that we can represent the semantic content of whole experience reports in a latent semantic space.

A useful feature of such embedding representations is the fact that they may be compared using similarity measures which aim to quantify their likeness. The canonical measure is that of cosine similarity, which denotes the degree to which two vectors *extend into the same general direction* of the embedding space. When dealing with semantic embeddings, cosine similarity can offer a useful measure of similarity between two documents in terms of their subject matter, even when the documents are of different length (McDonald & Ramscar, 2001; Singhal, 2001). Conceptually, adjacency in latent semantic space translates into how semantically related two texts are (Grand et al., 2022).

In the context of this study, the allure of semantic embeddings is the promise of placing first-hand reports of psychedelic experiences somewhere in a high-dimensional latent semantic space, then compare these embeddings to the embeddings for established phenomenological dimensions. If embeddings capture semantic variation pertaining to phenomenological concepts, we may be able to derive phenomenological profiles for a range of psychedelic compounds from free-form text reports by quantifying their likeness with certain established phenomenological dimensions.

Objectives

This article will grapple chiefly with the following:

- Is it feasible to quantify psychedelic compounds' respective dispositions toward phenomenological dimensions by means of semantically embedding narrative reports chronicling psychedelic experiences?
- Do phenomenological profiles obtained by relying on semantic embeddings replicate those observed in psychometric validation across psychedelic compounds?

Methodology

A computational approach is taken to quantify the semantics of text-based artifacts of psychedelic experiences as well as descriptions of phenomenological dimensions established in the literature on altered states of consciousness. This involves leveraging an LLM (large language model) to compute semantic vector representations in a latent semantic space, first for text paragraphs representative of established phenomenological dimensions and then for a corpus of experience reports across a range of psychedelic compounds. A generalized linear model is then employed to estimate each compound's affinity for each phenomenological dimension.

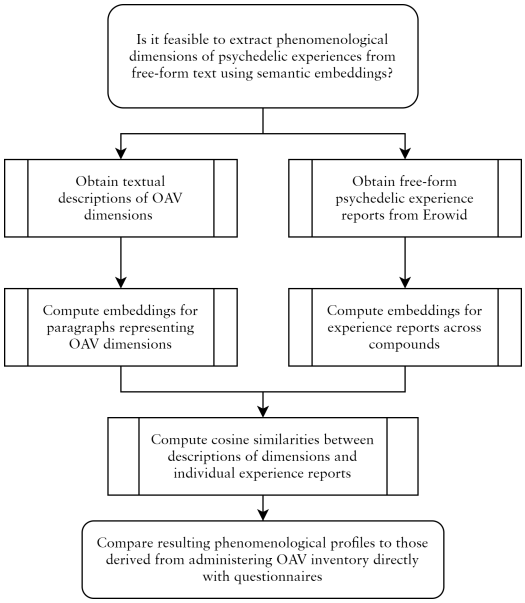

Figure 3. *Flowchart outlining conceptual steps of the approach taken to operationalize phenomenological dimensions using semantic embeddings.*

Target Metrics

Although Studerus et al. (2010) use structural equation modeling to argue that we can do better by furcating into 11 new lower-order, more granular dimensions, the three principal dimensions originally formulated in Dittrich's APZ scale, collectively referred to with the initialism *OAV* (Bodmer et al., 1994): *Oceanic Boundlessness (OBN), Anxious Ego-Dissolution (AED)* and *Visual Restructuralization (VIR)* seem well-suited for testing the proposed framework by virtue of their widespread, time-tested use as well as featuring comprehensive textual represen-

tations. An impression of the experiential qualities associated with- and defining of each of these dimensions may be gained from consulting Table 2. Studerus et al. (2010), by pooling data from 43 experimental studies, conducted a psychometric evaluation of the OAV dimensions across three compounds: Psilocybin, Ketamine and MDMA (see Figure 4), which will serve as the benchmark against which we compare results obtained from the semantic embedding approach.

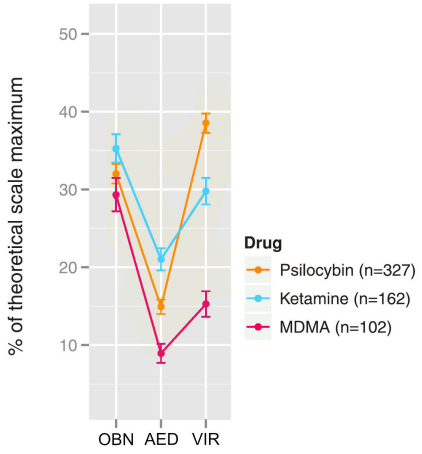

Figure 4. *OAV contrast across Psilocybin, Ketamine and MDMA. Adapted from Studerus et al. (2010, Figure 2).*

Data

The empirical underpinnings for this inquiry take the form of a corpus of curated first-person psychedelic experience reports submitted/contributed to *Erowid Experience Vaults* (Erowid Center, n.d.-a). The vaults constitute an online repository of such experience reports and are hosted by the non-profit *Erowid Center* (www.erowid.org). Erowid, founded in 1995, identify as "[…] a member-supported organization providing access to reliable, non-judgmental information about psychoactive plants, chemicals, and related issues" with a stated aim of fostering "[…] a world where people treat psychoactives with respect and awareness" (Erowid Center, 2003). Erowid's vaults have featured extensively in the literature on psychedelics and their therapeutic as well as recreational use (Friedman & Ballentine, 2024; Garcia-Romeu et al., 2019; Mooseder et al., 2022; Sanz et al., 2018; Valsecchi et al., 2023). As of October 2024, the vaults collectively comprised more than 39 000 curated experience reports across more than 700 psychoactive substances.

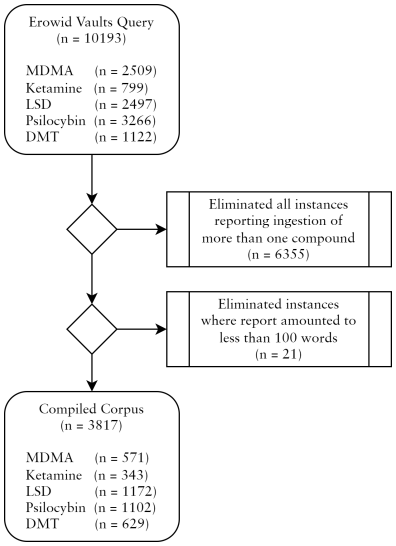

Figure 5. *Flowchart describing the data selection process from preliminary Erowid query to the final corpus.*

A subset of reports from Erowid's Experience Vaults were compiled from an initial query for five compounds deemed suitable to addressing the questions posed. These included three of the "classic" serotonergic hallucinogens, DMT (N,N-dimethyltryptamine), LSD (lysergic acid diethylamide) and Psilocybin (4-phosphoryloxy-N,N-dimethyltryptamine), as well as the dissociative anaesthetic, Ketamine (2-(2-chlorophenyl)- 2-(methylamino)-cyclohexanone), and the empathogen/entactogen, MDMA (3,4-Methylenedioxymethamphetamine). The latter two do not strictly belong to the pharmacological class of psychedelics but have been shown to have similar phenomenological properties and therapeutic applications (Gigliucci et al., 2013; Smith et al., 2022). While Psilocybin, Ketamine and MDMA were included by virtue of guaranteeing a concrete reference for comparison in Studerus et al. (2010), LSD and DMT were included in order to generate testable hypotheses across an even wider range of compounds. The five compounds are henceforth collectively referred to as *the psychedelic compounds*, although a more formally precise umbrella term when including MDMA and Ketamine would be *psychoplastogens* (Benko & Vranková, 2020; Olson, 2018). This initial collection of experience reports was then filtered according to predetermined inclusion criteria. Reports pertaining to ingestion of more than one compound were discarded to avoid or at least limit the confounding effects of

	Amount Reports	Unique Authors*	Sex Ratio	Mean Age (range)	Text Mass (median)
MDMA	571	545	37% female	23.3 (16-58)	479 564 words (641)
Ketamine	343	332	14% female	25.1 (15-65)	309 830 words (739)
LSD	1172	1091	20% female	22.9 (14-65)	1 657 821 words (1055)
Psilocybin	1102	1032	23% female	25.0 (12-59)	1 365 210 words (968)
DMT	629	591	12% female	24.5 (15-54)	654 127 words (818)
Combined	**3817**	**3407**	**22% female**	**24.0 (12-65)**	**4 466 552 words (895)**

Table 1. *Descriptive statistics for the compiled Erowid corpus. *Not counting cases of author anonymity (58 instances in total).*

potential pharmacological interactions. Also, experience reports shorter than 100 words were discarded. Substance labels were recoded to represent the constituent molecule producing the psychotropic effects (e.g., "Mushrooms" was recoded to Psilocybin).

From this emerges a rich corpus of 3817 experience reports across five compounds. These date from the year 2000 until 2024 and comprise more than 4 million words of visceral textual resource from which we may unearth insights into the comparative phenomenology of experiences elicited by a range of psychedelic compounds. Descriptive statistics for the corpus are listed in Table 1.

Text paragraphs representing each of three OAV dimensions (see Table 2) were procured from the "Supporting Information" section of Studerus et al. (2010).

Data Processing & Analysis

Seeing as experience reports generally take the form of flowing prosaic text, apart from the removal of non-alphanumeric and non-punctuation characters no comprehensive text cleaning or other preprocessing was carried out. Text bodies of experience reports were passed to a transformer embedding model which computed a semantic embedding vector for each report. Similarly, text paragraphs characterizing each of the three OAV dimensions were fed to the same embedding model, yielding embedding vectors for each of the three dimensions in the same latent space as the experience reports. Then, for each dimension of phenomenology, cosine similarity against the embedding of each experience report was computed, yielding a measure of how semantically aligned each experience report is to that dimension. See Figure 3 for a schematic overview of the conceptual steps involved.

The final step of the analysis involved fitting a multivariate multilevel generalized linear model (Bürkner,

Dimension	Textual Representation
OBN	I experienced an all-embracing love. It seemed to me that my environment and I were one. I experienced a touch of eternity. I experienced a profound peace in myself. Conflicts and contradictions seemed to dissolve. Everything seemed to unify into oneness. I felt totally free and released from all responsibilities. Everything around me seemed animated. Worries and anxieties of everyday life seemed unimportant to me. I enjoyed boundless pleasure. My experience had religious aspects. I felt unusual powers in myself. I experienced past, present, and future as oneness. I had the feeling of being connected to a superior power. Many things appeared to be breathtakingly beautiful. The world appeared to me beyond good and evil. I experienced a kind of awe. The boundaries between myself and my surroundings seemed to blur. I felt as though I were floating. I felt like I was in a fantastic other world. I felt I was being transformed forever in a marvelous way. I gained clarity into connections that puzzled me before. I felt very profound. It seemed to me as though I did not have a body anymore. I had the feeling of being outside of my body.
AED	I felt threatened. I was afraid without being able to say exactly why. I experienced my surroundings as strange and weird. I was afraid to lose my self-control. I experienced everything terrifyingly distorted. I had the feeling something horrible would happen. I felt tormented. I was afraid that the state I was in would last forever. I felt as though I were paralyzed. I felt like a marionette. I had the feeling that I no longer had a will of my own. I felt isolated from everything and everyone. My body seemed to me numb, dead, and weird. I felt surrendered to dark powers. I had difficulty making even the smallest decision. I experienced an unbearable emptiness. Time passed tormentingly slow. I had difficulty in distinguishing important from unimportant things. Everything around me was happening so fast that I no longer could follow what was going on. I stayed frozen in a very unnatural position for quite a long time. I was not able to complete a thought, my thought repeatedly became disconnected.
VIR	I saw colors before me in total darkness or with closed eyes. I saw regular patterns in complete darkness or with closed eyes. The shapes of things seemed to change by sounds and noises. The colors of things seemed to be changed by sounds and noises. I saw scenes rolling by in total darkness or with my eyes closed. Noises seemed to influence what I saw. I saw lights or flashes of light in total darkness or with closed eyes. I saw things that I knew were not real. I could see pictures from my past or fantasy extremely clearly. My imagination was extremely vivid. Many things seemed unbelievably funny to me.

Table 2. *Textual representations of the three OAV scale dimensions: OBN (Oceanic Boundlessness), AED (Anxious Ego-Dissolution) and VIR (Visual Restructuralization). Derived from Studerus et al. (2010, Supplementary Table S6).*

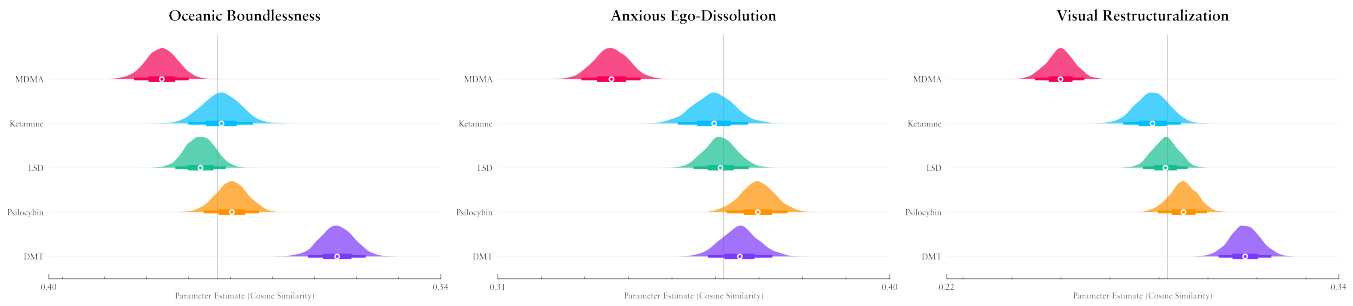

Figure 6. *Parameter estimate distributions for compounds' cosine similarity with OAV dimensions. Vertical lines denote grand median within each dimension.*

2018) to distributions of cosine similarity with each phenomenological dimension across compounds. The statistical model posed cosine similarity for each dimension as Gaussian distributions centered around a mean resulting from a linear combination of terms. Terms of this linear combination included the main effect, which was the particular compound which elicited the experience, as well as predictors to control for age at the time of the experience (in years, if provided) and the stated (binary) sex (if provided). In mathematical notation, this would correspond to $\texttt{CosineSimilarity} \sim \mathcal{N}(\texttt{Compound + Age + Sex})$. The model also incorporated varying intercepts across authors to enable proper discounted weighting of data points which stemmed from multi-report authors and were thus not independent. Global intercept terms were not fitted, facilitating intuitive interpretation of the absolute cosine similarity values associated with each respective compound. Prior distributions were set permissively, serving only the purpose of constraining parameter estimates to valid domains.

Software

Semantic embeddings were generated using NVIDIA's flagship generalist embedding model available to consumers, `NV-Embed-v2` (Lee et al., 2024), which, as of December 2024, had been the world-leading model on the MTEB (Massive Text Embedding Benchmark) task (Muennighoff et al., 2022) for four months running. Based on the Mistral-7B-v0.1 architecture, the model features a latent-attention pooling layer and yields high-resolution embeddings in 4096-dimensional latent semantic space. Unlike generative AI models, this model is not equipped to output text in the form of natural language. Instead, it emits only document-level vectorized embeddings and is optimized exclusively for the task of semantic feature extraction.

Text embedding and cosine similarity calculations were facilitated by the `sentence-transformers` library for interfacing with transformer embedding models (Reimers & Gurevych, 2019). `pandas` (McKinney, 2010; The pandas development team, 2020) was used for data structures, `matplotlib` (Hunter, 2007) for data visualization, `SciPy` (Virtanen et al., 2020) for statistical models, and `Scikit-learn` (Pedregosa et al., 2011) for machine learning algorithms. Bayesian model-fitting was achieved through the `brms` interface (Bürkner, 2017) using `cmdstanr` (Gabry et al., 2024) as the link to the probabilistic programming language, `stan` (Carpenter et al., 2017).

Results

Results of multivariate multilevel modeling are summarized in Table 3. Posterior distributions for parameter estimates are visualized in Figure 6.

We find MDMA unambiguously associated with the lowest propensity for both Oceanic Boundlessness, Anxious Ego-Dissolution and Visual Restructuralization. DMT stood out as associated with the greatest degree of both Oceanic Boundlessness and Visual Restructuralization. Anxious Ego-Dissolution was found to be most pronounced in Psilocybin, although there was substantial uncertainty in the parameter estimate which was only partly separated from the from the overlapping distributions of DMT, LSD and Ketamine, respectively.

The two predictors added to control for unbalanced group demographics yielded non-zero yet small esti-

	Predictor Term	Estimate	89% Cred. Int.
OBN	substanceMDMA	0.440	[0.429, 0.451]
	substanceKetamine	0.462	[0.448, 0.475]
	substanceLSD	0.454	[0.444, 0.464]
	substancePsilocybin	0.465	[0.454, 0.476]
	substanceDMT	0.503	[0.491, 0.515]
	sexMale	-0.008	[-0.014, -0.002]
	ageYears	-0.001	[-0.002, -0.001]
AED	substanceMDMA	0.336	[0.328, 0.344]
	substanceKetamine	0.360	[0.350, 0.369]
	substanceLSD	0.361	[0.354, 0.368]
	substancePsilocybin	0.370	[0.362, 0.377]
	substanceDMT	0.366	[0.357, 0.374]
	sexMale	-0.014	[-0.018, -0.009]
	ageYears	-0.001	[-0.002, -0.001]
VIR	substanceMDMA	0.255	[0.246, 0.263]
	substanceKetamine	0.283	[0.273, 0.293]
	substanceLSD	0.287	[0.279, 0.294]
	substancePsilocybin	0.292	[0.284, 0.300]
	substanceDMT	0.311	[0.302, 0.320]
	sexMale	-0.007	[-0.012, -0.002]
	ageYears	-0.001	[-0.001, -0.001]

Table 3. *Summary of posterior estimates obtained from the generalized linear model. Values are in cosine similarity units.*

mates. Each year lived up until the experience took place was found to be associated with a slight negative influence on the propensity for each phenomenological dimension. However, considering that the largest inter-compound gap in age distribution was on the order of 2.2 years (25.1 years mean for Ketamine and 22.9 years mean for LSD; see Table 1), age effects were of minimal scope in terms of comparing the compounds.

Meanwhile, the effect associated with reported sex tended decidedly towards reduced expression for males in all three phenomenological dimensions, though with substantial uncertainty of magnitude. The effect of maleness was estimated to be twice as large for Anxious Ego-Dissolution as for Oceanic Boundlessness and Visual Restructuralization, respectively. However, ut should be noted that because the largest imbalance in sex distribution between any two compounds was a 25% shift between MDMA (63% male) to DMT (88% male), the magnitude of any inter-compound confounding due to sex — had it not been controlled for — would have been limited to 25% of the parameter estimate.

Discussion

Results obtained indicated that the semantic embedding approach did seem to pick on latent semantic signals pertaining to phenomenological dimensions of psychedelic experiences. Additionally, the inter-compound relationships seemed broadly in concordance with existing literature on the topic, albeit with one notable discrepancy.

Consistent with the findings of Studerus et al. (2010) — see Figure 4 — MDMA stood out as having the lowest propensity across the board for all three of the OAV dimensions. DMT distinguished itself as occasioning the largest degree of both Oceanic Boundlessness as well as Visual Restructuralization. For Anxious Ego-Dissolution, there is significant overlap between parameter estimates for Ketamine, LSD and DMT while Psilocybin separates itself as ostensibly engendering this aspect to the greatest extent. Dissenting from Studerus et al. (2010), we find that Psilocybin is estimated to be associated with Oceanic Boundlessness to a greater extent than Ketamine. In Studerus et al. (2010), Ketamine also scored higher on Anxious Ego-Dissolution, whereas, as mentioned, we find Psilocybin winning out. In terms of Visual Restructuralization, the pattern observed in Studerus et al. (2010) was replicated, though with less clear separation between Ketamine and Psilocybin.

An explanation for the inversion of the relative ranking of Psilocybin and Ketamine — particularly in terms of Anxious Ego-Dissolution where the modeled relationship differs markedly from that observed by Studerus et al. (2010) — may be found in Ketamine's complex dose-response dynamics (Li & Mashour, 2019; Nicol & Morton, 2020). This means the experience can differ dramatically in phenomenological expression depending on the exact dosage. At very large doses, so-called *K-hole* phenomena, experienced as an intense detachment from reality, may arise (Gallimore, 2022). These are associated with experiences of melting into one's surroundings and out-of-body experiences, what may correspond to the dimension of Oceanic Boundlessness (Muetzelfeldt et al., 2008), but also with near-death experiences (Stirling & McCoy, 2010), which would presumably contribute to Anxious Ego-Dissolution. If the samples for Ketamine included in Studerus et al. (2010) pertained to higher

doses than is the case for naturalistic use (represented by the Erowid sample), this may explain why the present investigation found Ketamine to be less prominent in these two dimensions. This hypothesis finds some support since it appears that *all* samples for Ketamine in Studerus et al. (2010) stemmed from "medium" or "high" doses, whereas dose-distributions for MDMA and Psilocybin were centered around "medium" doses (Studerus et al., 2010, Table 1). This is just one possible explanation for what may have precipitated the discrepancy between results obtained in this study and results observed in existing literature.

Variation in age at the time of having the experience did not seem to significantly impact propensity for any of the OAV dimensions. In terms of sex differences, the model fit indicated that being male was associated with reduced expression in each of three phenomenological dimensions, more so for Anxious Ego-Dissolution than Oceanic Boundlessness and Visual Restructuralization. Sensitivity analyses indicating that these aspects had minimal scope for confounding somewhat tempered concerns of unbalanced contributor demographics driving the phenomenological differentiation.

However, more work is needed to verify and validate these results — particularly for the inter-compound contrasts where no suitable reference was found — in a more controlled setting. Also, for MDMA, Ketamine and DMT which were markedly less well-represented in the corpus than LSD and Psilocybin (see Table 1), the reliability of the analysis would certainly have benefitted from larger sample sizes. This is particularly true for Ketamine and DMT, where sex ratios were highly unbalanced.

A literature review did reveal one study due to Gouzoulis-Mayfrank et al. (2005) which might have served as a reference for the contrast between DMT and Ketamine. The study even compares the respective phenomenological profiles factorially across two levels of dosage. However, the study in question dealt specifically with (S)-Ketamine (the purified S-enantiomer of Ketamine; also referred to as "Esketamine"), which is, strictly speaking, a distinct chemical compound from racemic Ketamine. This fact may give it different phenomenological properties. Because of this, comparison of the presented results pertaining to Ketamine, and those of Gouzoulis-Mayfrank et al. relating to (S)-Ketamine, were considered fallacious and refrained from.

There are multiple legitimate objections to both the methodology, construct operationalization and the empirical data relied upon in this investigation, each of which append caveats and demand certain reservations when considering the findings.

Empirical Merit

Firstly, there's the issue relating to the origins and dependability of the data retrieved from Erowid. While featuring in journals such as *Frontiers in Neuroscience* (e.g., Sanz et al., 2018) and *Journal of Psychopharmacology* (e.g., Garcia-Romeu et al., 2019) has lent Erowid's Experience Vaults some academic legitimacy, it cannot be ignored that the veracity of these self-reports being anecdotal and non-verifiable, constraining the trustworthiness of the data and spawning some skepticism as to its credibility. A slight mitigation of this worry may be found in Erowid's stewardship practices of curating material on their site. As of January 2023, more than 117 000 reports had been submitted to Erowid (Erowid Center, n.d.-b), but "only" 39 000 had passed the extensive review process and been listed in the Experience Vaults (Erowid Center, 2023). This review process includes a two-reviewer triage and averages six months from submission until acceptance and publication (Erowid Center, 2005). While this does not directly address the issue of reports' veracity, it does go some way in ensuring that they are relevant and have value as data.

Another apposite consideration relates to Erowid's contributors, what would be considered *subjects* in the vernacular of research design. By using the Erowid corpus, we have effectively pre-selected for a segment of the general population that 1) on their own initiative, engages in administration of what is, in most parts of the world, illegal or controlled substances and 2) are inclined to chronicle and share their personal experiences publicly on the internet where it is available to anyone. The resulting demographic will arguably be quite unrepresentative of the broader population, which may severely restrict the external validity and generalizability of any patterns identified in this study. It must be noted, however, that (many) clinical trials on psychedelics also suffer from this, so this is not a qualification that is exclusive to the Erowid corpus.

It can also not be easily ascertained whether an experience report concerns use of a psychedelic compound for self-medication of a mental or physical affliction, or simply for recreational purposes. This is consequential due to the fact that extra-pharmacological factors can mediate and pivotally shape the phenomenology of a psychedelic experience (Haijen et al., 2018). In the culture of psychedelics, these external factors are often explained in terms of *set and setting* (Hartogsohn, 2016; Zinberg, 1984), meaning the intention set for the trip and the environment in which the trip is carried out, respectively (e.g., what emotional state the individual was in; what was the intention behind the trip; whether an experienced guide was present; whether the substance was ingested in a quiet environment or in a loud party setting). Since the experiences in the Erowid corpus effectively represent a non-coordinated effort of self-experimentation, it can be reasonably be assumed that these experiences took place across a wider gamut of contexts than would be the case in clinical trials (where strict, tightly controlled, regimens would be followed) (Glynos et al., 2023). In this way, the Erowid dataset can be thought of as a window into uncompromisingly naturalistic use of the psychedelics. This may, incidentally, turn out to be advantageous in divulging the full range of psychedelic phenomenology by spanning a greater diversity of contexts than would be expected in highly constrained therapeutic environments. There are sound arguments for why clinical practices go to great lengths in controlling and constraining sets and settings to avoid so-called *bad trips* which may, counterproductively, traumatize the patient and compromise the trajectory of recovery (Evans et al., 2023). However, far from eliminating it, this just emphasizes the importance of grasping the full spectrum of phenomenological expressions these substances can engender, so we can gain a better understanding of how to employ them constructively.

A related constraint is tied to the narrative free-form format of the reports. Because the report text bodies are monolithic — in the sense that a single text body covers the full recollection of the experience and any context provided along with it — there's no way to easily dissociate parts of reports pertaining to the content of the experience (the phenomenological description of the actual trip) from the context of a experience (the individual's personal history, e.g., what has led them to ingest this substance, what they hope to achieve from it, how they've felt during the time between the experience and writing up the report). This means only some of the text mass relates to the phenomenological experience, which will inevitably reduce the signal-to-noise ratio with of relevant phenomenological constructs. When looking for rather subtle variations in lexical choice that may not present themselves but for a minority of critical sentences, massive amounts of text are needed to reliably pick up on such a signal without being overwhelmed by extensive noise not related to the construct of interest. Considering this, the size the compiled corpus may be called into question as being of insufficient scale to reliably quantify the subtle patterns of phenomenology sought for. One worry of insufficient sample size would be that the if we were dealing with tiny effect sizes, the signal would not be separable from noise, which does not seem to be the case. Another would be spurious relations arising due to small subsets of data having large amounts of leverage. Such an effect may be mitigated simply by increasing sample size, courtesy of the law of large numbers.

Finally, all but a few reports list, alongside the date at which the report was published to the Erowid Vaults (as in listed for public access, not the date at which it was submitted to Erowid by the contributor), the year in which the psychedelic experience took place. Approximately a third of reports were published more than a year after the experience took place, while two thirds were published more than five years after the experience ostensibly took place. Calling into mind the lead time of around six months associated with Erowid's triage (Erowid Center, 2005) may explain some of this disparity, but it certainly does not explain the significant proportion of reports listed more than five years after the experience took place. Digging into this issue by looking at how lead time has varied across the years, we find that since the early 2000s, the mean lead time has ballooned such that in 2018 it exceeded 11 years on average. It's not clear whether this is simply a case of Erowid's backlog snowballing during those years, or whether it is a case of large groups of people discovering the Erowid platform in the late 2010s and deciding to contribute by retrospectively relating experiences they have had multiple years past.

This segues into the issue of cognitive biases accompanying retrospective accounts of experienced events. Disregarding the question of relative proportions attributable to Erowid's triage lead time and the time elapsed between an individual having the actual experience to submitting the report to Erowid, it seems likely that an appreciable share of reports were not penned immediately following the experience, let alone on the day thereof. This opens the door for a number of memory-related cognitive biases to seep in, which may distort recollection away from what would have been reported had the data been collected at the earliest opportunity. One such example may be what Kahneman (2003) termed *the peak/end rule*: "[e]xtended episodes are represented in memory by a typical moment — and the desirability or aversiveness of the episode is dominated by the remembered utility of that moment." As memories are consolidated overnight, details may get lost, distilling the experience to a point where only highly salient aspects remain.

In sum, the Erowid corpus comes "with strings attached". The legal landscape surrounding psychedelics means large-scale experiments are hard to come by, and raw data generated by such experiments are unlikely to be publicly available due to the sensitive nature of their contents. Thus, seeing as comparable data generated under controlled circumstances are currently out of reach, these data represent a fallible, yet valuable, resource.

Methodological Considerations

The fact that this was a wholly post-hoc observational study with no randomization or experimental control dictates caution and care when inferring from the data, particularly as it relates to causality. One of the major perils of relying on exclusively observational data is that confounding may seep in in all sorts of ways.

Not having experimental control is particularly treacherous when dealing with a between-subjects design, as we have no way of knowing whether people engaging in one compound are just different in meaningful ways from those engaging in other compounds and whether that drives the semantic patterns differentiating the compounds in the analysis. The demography of contributors may have simply been different in such ways that (some of) the differentiation we see could be manifestations of inherent differences in psychological make-up of these demographies, independent of the actions of the respective psychoactive compound. This is in addition to the basic inconvenience that the data may not be address in the most direct manner possible the conceptual construct that we may be interested in, as is the case with Erowid's free-form format prohibiting the dissociation of context surrounding the experience and phenomenological content of the experience itself.

In addition to the methodological concerns relating to research design, there are also questions to be asked of the tools employed, both in terms of reliability, validity and interpretability. Although modern iterations of large language models (and neural networks in general) have reached impressive levels of performances on a number of tasks in diverse domains, they have also been extensively criticized for failing sporadically in curious and unexpected ways, often on tasks that would seem, to a human, no different and no harder than cases which the models handle with ease (Alemohammad et al., 2023; Berglund et al., 2024; Wu et al., 2024; Xu et al., 2024). This points to one of the major disadvantages associated with neural network-based tools as it relates to epistemology: the "black box problem" of AI. This refers to the opaque nature of neural architectures which have made it notoriously difficult to intuitively explain how these models arrive at the result they spit, to understand exactly *why* that was the result in a given instance; it appears that much of their behavior are emergent phenomena (Castelvecchi, 2016; Eschenbach, 2021). The corollary is that when things go awry, we cannot account for the etiology and, more worryingly, it can be very difficult to tell *whether* the model is behaving in the manner expected. This is particularly true for domains where the model outputs are voluminous and hard to validate, e.g., semantic embeddings for thousands of documents. In this vein, we cannot be sure whether the semantic signal we are picking up on is in fact related to the phenomenological dimension we are interested in. Rather, it is possible that computed similarities are, to some degree, driven by semantic variation entirely unrelated to phenomenology, e.g., simply valence or some other property that is not balanced in the descriptions of the OAV dimensions.

Furthermore, it stands to reason that the distributional semantics hypothesis — i.e., that words used in the

same contexts tend to carry similar meanings — applies only *on aggregate*, not at arbitrarily granular levels (Lenci, 2008). Transformer models may exhibit errant behavior particularly on short segments of text in domains that are not well-represented in the pretraining data (Geffet & Dagan, 2005), or they may simply struggle with the thorny issues of homonomy (words spelled identically but having different meanings) and polysemy (a single word having multiple meanings), which constitute an eternal challenge for these tools (Li & Jurafsky, 2015). Finally, there are reasons to treat with caution the concept of cosine similarity and to not naïvely equate it with semantic similarity (Steck et al., 2024). Cosine similarity is just one way to quantify the general notion of similitude in a vector space. There are no guarantees that applying this operation on semantic embeddings in such a vector space corresponds to our intuitive understanding of semantic likeness, and there are also no guarantees that there is not another mathematical operation out there which does more closely align with our anthropocentric notion of being semantically similar. It seems simply a case of cosine similarity being a well-known, computationally efficient operation with convenient properties which, as it turned out, made it well-suited as a starting point for the task of determining similarity of text embedded in a vector space (Singhal, 2001).

Another proviso is that a similarity measure like cosine similarity cannot account for variation not present in the embedding representation it is fed. It cannot transcend the information it is given, meaning that it is limited by the resolution and degree to which the embeddings constitute a meaningful representation of the latent semantic space. Finally, seeing as the Erowid corpus data stretches over more than two decades, it is worth considering that the meaning of words may diachronically change (Hamilton et al., 2016), adding to the list of reservations tied to semantic embeddings.

With these considerations in hand, the validity and reliability of using semantic embeddings in concert with cosine similarity to operationalize correspondence with scantly defined phenomenological dimensions should be treated with a certain degree of skepticism.

Future Directions

There are a number of ways to build upon this venture of leveraging semantic embeddings to quantitatively investigate (psychedelic) phenomenology.

An obvious next step would be to expand to the 11D-ASC scale proposed by Studerus et al. (2010). As alluded to supra, Studerus et al. contest Dittrich's claim that his "[…] original hypotheses on ASC have survived considerable falsification testing not only in experimental but also in field studies and that the APZ questionnaire has become a psychometrically well-validated instrument for the assessment of 'aetiology-independent' features of ASC in a 'aetiology-independent' three-dimensional space […]." They cite "serious methodological limitations, [of] which only few have been recognized in the existing literature" (Studerus et al., 2010). They ultimately assert that "OBN, DED[1], and VRS scales are multidimensional constructs that can be split into many reliable and valid subscales. Although the use of the OBN, DED, and VRS scales — due to their relatively strong general factor saturations — might be justified for predicting complex criteria, we believe that our newly constructed subscales should be preferred for most applications, because they are only slightly less reliable but much more homogeneous" (Studerus et al., 2010). The immediate obstacle to this path lies in the scarcity of textual definition Studerus et al. provide. A full eight of their 11 dimensions are defined and delineated by just three short sentences Studerus et al. (2010, Figure 1). Notwithstanding the potency of today's transformer models, a textual foundation that scant is likely to be insufficient for reliable results. This remains an unknown as such an endeavor was not exhaustively pursued in the course of the present investigation. Over time, these challenges may be mitigated from two sides: transformer models continuing to develop and becoming increasingly sensitive to subtler semantic patterns could go some way, but it will arguably also require the 11D-ASC being elaborated to have more comprehensive textual bases.

Going in another direction, the semantic embedding approach could be leveraged in a more exploratory data-mining capacity, e.g., to derive from latent se-

[1]Studerus et al. refer to Anxious Ego-Dissolution (AED) as Dread of Ego-Dissolution (DED) and use VRS instead of VIR to abbreviate Visual Restructuralization.

mantic patterns new phenomenological dimensions that have not yet found their way into the literature. A questionnaire, no matter how sophisticated and carefully designed, cannot pick up on aspects not addressed by the questions or statements it puts forth. Because of this, there may exist important and useful phenomenological dimensions not yet identified or described, simply for a lack of imagination or necessary conceptual constructs to envisage such dimensions on the part of those designing such questionnaires. Machine learning algorithms, e.g., topic-modelling approaches, may be a way toward identifying such latent constructs with unsupervised learning to yield novel axes of phenomenology which can add to our understanding of how psychedelic compounds relate to each other phenomenologically.

A further opportunity for generalizing the approach would be expanding into languages other than English. Ideally, it would be generalized to the point of being panlingual, such that contributors could recount their experiences in their mother tongue. Being constrained by having to translate one's thoughts into a non-native language is a lossy process that can easily diminish, if not eliminate, the subtle lexical variations conveying phenomenological experience. Dittrich's original formulation of the OAV scale was in German, promptly translated into English and subsequently to an array of other languages in order to make it an internationally applicable tool (Studerus et al., 2010). At first glance, making the OAV panlingual would require the scale's questionnaire to be carefully translated into any and all languages while preserving the linguistic coupling with latent phenomenological constructs. However, transformer models may here present another possibility, owing to the emergence of multilingual (also referred to as language-agnostic) models that can compute semantic embeddings in the same latent space for text sources written in a variety of languages (Artetxe & Schwenk, 2019; Duquenne et al., 2021). This would, theoretically, allow for computing semantic embeddings for experience reports written by people in their respective languages into a common semantic space, paving the way for a broader understanding of the psychedelic phenomenology in more global, non-WEIRD (Western, Educated, Industrialized, Rich and Democratic) demographics.

Concluding Remarks

The findings presented suggest that semantic embeddings hold promise as a tool for quantifying the phenomenology of psychedelic experiences. However, the employed methodology is exposed to serious pitfalls which may limit its validity. This means results should not be considered in isolation or without reservations. These concerns notwithstanding, reported results may yet contribute to the accruing knowledge base on psychedelics and their experiential aspects, adding to the toolbox of researchers in this and related fields.

Studying mind-altering substances and their phenomenology is an inherently challenging endeavor. And it is complicated even further by the unfortunate reality that pertinent data is scant, particularly the high-quality sort with experimental control baked in. This means empirical data of the observational kind, with the limited inference this affords us, may be the best we can do; at least for now. In time, access to large-scale experience report corpora generated with experimental control may pave the way for novel tools — such as the one proposed in this study — to help us reach a more comprehensive understanding of psychedelics and their phenomenological intricacies. ■

Data Availability & Supplementary Material

Erowid Experience Vaults ⤴ host all included experience reports. The compiled subset may be replicated by executing the query and observing the inclusion criteria described supra.

Any and all sensitive data were stored and handled in compliance with regional GDPR requirements using the UCloud HPC platform, which is managed by eScience Center at University of Southern Denmark. The transformer embedding model was run locally to ensure that no sensitive data were transmitted to any third party.

Source code used for analysis and data visualization are available on GitHub at `dlundgaard/quantitative-phenomenology` ⤴.

References

Aghajanian, G. K., & Marek, G. J. (1999). Serotonin and Hallucinogens. *Neuropsychopharmacology*, *21*(1), 16–23. https://doi.org/10.1016/S0893-133X(98)00135-3

Aiello, L. M., Quercia, D., Zhou, K., Constantinides, M., Šćepanović, S., & Joglekar, S. (2021). How epidemic psychology works on Twitter: evolution of responses to the COVID-19 pandemic in the U.S. *Humanities and Social Sciences Communications*, *8*(1), 1–15. https://doi.org/10.1057/s41599-021-00861-3

Al-Mosaiwi, M., & Johnstone, T. (2018). In an Absolute State: Elevated Use of Absolutist Words Is a Marker

Specific to Anxiety, Depression, and Suicidal Ideation. *Clinical Psychological Science*, *6*(4), 529–542. https://doi.org/10.1177/2167702617747074

Alemohammad, S., Casco-Rodriguez, J., Luzi, L., Humayun, A. I., Babaei, H., LeJeune, D., Siahkoohi, A., & Baraniuk, R. G. (2023, July 4). *Self-Consuming Generative Models Go MAD*. arXiv. https://doi.org/10.48550/arXiv.2307.01850

Artetxe, M., & Schwenk, H. (2019, September 25). *Massively Multilingual Sentence Embeddings for Zero-Shot Cross-Lingual Transfer and Beyond*. arXiv. https://doi.org/10.48550/arXiv.1812.10464

Benko, J., & Vranková, S. (2020). Natural Psychoplastogens As Antidepressant Agents. *Molecules*, *25*(5), 1172. https://doi.org/10.3390/molecules25051172

Berglund, L., Tong, M., Kaufmann, M., Balesni, M., Stickland, A. C., Korbak, T., & Evans, O. (2024, April 4). *The Reversal Curse: LLMs trained on "A is B" fail to learn "B is A"*. arXiv. https://doi.org/10.48550/arXiv.2309.12288

Bodmer, I., Dittrich, A., & Lamparter, D. (1994). Außergewöhnliche Bewusstseinszustände - Ihre gemeinsame Struktur und Messung [Altered states of consciousness - Their common structure and assessment]. In A. Hofmann & H. Leuner (Eds.), *Welten des bewusstseins: Vol. 3. Welten des bewusstseins* (pp. 45–58). VWB.

Brouwer, A., & Carhart-Harris, R. L. (2021). Pivotal mental states. *Journal of Psychopharmacology*, *35*(4), 319–352. https://doi.org/10.1177/0269881120959637

Bürkner, P.-C. (2017). brms: An R Package for Bayesian Multilevel Models Using Stan. *Journal of Statistical Software*, *80*, 1–28. https://doi.org/10.18637/jss.v080.i01

Bürkner, P.-C. (2018). Advanced Bayesian Multilevel Modeling with the R Package brms. *The R Journal*, *10*(1), 395–411. https://doi.org/10.32614/RJ-2018-017

Carhart-Harris, R. L., & Friston, K. J. (2019). REBUS and the Anarchic Brain: Toward a Unified Model of the Brain Action of Psychedelics. *Pharmacological Reviews*, *71*(3), 316–344. https://doi.org/10.1124/pr.118.017160

Carpenter, B., Gelman, A., Hoffman, M. D., Lee, D., Goodrich, B., Betancourt, M., Brubaker, M., Guo, J., Li, P., & Riddell, A. (2017). Stan: A Probabilistic Programming Language. *Journal of Statistical Software*, *76*, 1–32. https://doi.org/10.18637/jss.v076.i01

Castelvecchi, D. (2016). Can we open the black box of AI?. *Nature News*, *538*(7623), 20. https://doi.org/10.1038/538020a

Dittrich, A. (1998). The Standardized Psychometric Assessment of Altered States of Consciousness (ASCs) in Humans. *Pharmacopsychiatry*, *31*, 80–84. https://doi.org/10.1055/s-2007-979351

Duquenne, P.-A., Gong, H., & Schwenk, H. (2021). Multimodal and Multilingual Embeddings for Large-Scale Speech Mining. *Advances in Neural Information Processing Systems*, *34*, 15748–15761. https://papers.nips.cc/paper/2021/hash/8466f9ace6a9acbe71f75762ffc890f1-Abstract.html

Erowid Center. (n.d.-b). *About the Experience Vaults*. Retrieved November 8, 2024, from https://www.erowid.org/experiences/exp_about.cgi

Erowid Center. (n.d.-a). *Erowid Experience Vaults*. Retrieved October 19, 2024, from https://erowid.org/experiences/

Erowid Center. (2003, May). *Clarifying Erowid's Vision*. https://erowid.org/general/about/about_faq_vision1.shtml

Erowid Center. (2005, July). *A brief overview of the Erowid Experience Report Reviewing Process*. https://www.erowid.org/experiences/exp_info2.shtml

Erowid Center. (2023, January 1). *Erowid Experience Vaults Search Results As of Jan 2023*. https://web.archive.org/web/20230101184447/https://erowid.org/experiences/exp.cgi

Erritzoe, D., Barba, T., Greenway, K. T., Murphy, R., Martell, J., Giribaldi, B., Timmermann, C., Murphy-Beiner, A., Jones, M. B., Nutt, D., Weiss, B., & Carhart-Harris, R. (2024). Effect of psilocybin versus escitalopram on depression symptom severity in patients with moderate-to-severe major depressive disorder: observational 6-month follow-up of a phase 2, double-blind, randomised, controlled trial. *eClinicalMedicine*, *0*(0). https://doi.org/10.1016/j.eclinm.2024.102799

Eschenbach, W. J. von. (2021). Transparency and the Black Box Problem: Why We Do Not Trust AI. *Philosophy & Technology*, *34*(4), 1607–1622. https://doi.org/10.1007/s13347-021-00477-0

Evans, J., Robinson, O. C., Argyri, E. K., Suseelan, S., Murphy-Beiner, A., McAlpine, R., Luke, D., Michelle, K., & Prideaux, E. (2023). Extended difficulties following the use of psychedelic drugs: A mixed methods study. *PLOS ONE*, *18*(10), e293349. https://doi.org/10.1371/journal.pone.0293349

Evans, V. (2012). Cognitive linguistics. *WIREs Cognitive Science*, *3*(2), 129–141. https://doi.org/10.1002/wcs.1163

Firth J R, Haas W, Halliday M A K, Allen W S, Robins R H, #prigg R K, Palmer F R, Carnochan J, & Mitchell T F. (1962). *Studies in linguistic analysis*. Blackwell.

Friedman, S. F., & Ballentine, G. (2024). Trajectories of sentiment in 11,816 psychoactive narratives. *Human Psychopharmacology: Clinical and Experimental*, *39*(1), e2889. https://doi.org/10.1002/hup.2889

Gabry, J., Češnovar, R., Johnson, A., & Bronder, S. (2024). *cmdstanr: R Interface to 'CmdStan'*. https://mc-stan.org/cmdstanr/

Gallimore, A. (2014). *DMT And The Topology of Reality*.

Gallimore, A. (2022). *Reality Switch Technologies: Psychedelics as Tools for the Discovery and Exploration of New Worlds*. Strange Worlds Press. https://www.whsmith.co.uk/Product/Andrew-R-Gallimore/Reality-Switch-Technologies%E2%80%93Psychedelics-as-Tools-for-the-Discovery-and-Exploration-of-New-Worlds/13018039

Garcia-Romeu, A., Davis, A. K., Erowid, F., Erowid, E., Griffiths, R. R., & Johnson, M. W. (2019). Cessation and reduction in alcohol consumption and misuse after psychedelic use. *Journal of Psychopharmacology*, *33*(9), 1088–1101. https://doi.org/10.1177/0269881119845793

Geffet, M., & Dagan, I. (2005). The Distributional Inclusion Hypotheses and Lexical Entailment. In K. Knight, H. T. Ng, & K. Oflazer (Eds.), *Proceedings of the 43rd Annual Meeting of the Association for Computational Linguistics (ACL'05): Proceedings of the 43rd Annual Meeting of the Association for Computational Linguistics (ACL'05)*. https://doi.org/10.3115/1219840.1219854

Gigliucci, V., O'Dowd, G., Casey, S., Egan, D., Gibney, S., & Harkin, A. (2013). Ketamine elicits sustained antidepressant-like activity via a serotonin-dependent mechanism. *Psychopharmacology*, *228*(1), 157–166. https://doi.org/10.1007/s00213-013-3024-x

Glynos, N. G., Fields, C. W., Barron, J., Herberholz, M., Kruger, D. J., & Boehnke, K. F. (2023). Naturalistic Psychedelic Use: A World Apart from Clinical Care. *Journal of Psychoactive Drugs*, *55*(4), 379–388. https://doi.org/10.1080/02791072.2022.2108356

Goodwin, G. M., Aaronson, S. T., Alvarez, O., Arden, P. C., Baker, A., Bennett, J. C., Bird, C., Blom, R. E., Brennan, C., Brusch, D., Burke, L., Campbell-Coker, K., Carhart-Harris, R., Cattell, J., Daniel, A., DeBattista, C., Dunlop, B. W., Eisen, K., Feifel, D., … Malievskaia, E. (2022). Single-Dose Psilocybin for a Treatment-Resistant Episode of Major Depression. *New England Journal of Medicine*, *387*(18), 1637–1648. https://doi.org/10.1056/NEJMoa2206443

Gouzoulis-Mayfrank, E., Heekeren, K., Neukirch, A., Stoll, M., Stock, C., Obradovic, M., & Kovar, K.-A. (2005). Psychological Effects of (S)-Ketamine and N,N-Dimethyltryptamine (DMT): A Double-Blind, Cross-Over Study in Healthy Volunteers. *Pharmacopsychiatry*, *38*, 301–311. https://doi.org/10.1055/s-2005-916185

Grand, G., Blank, I. A., Pereira, F., & Fedorenko, E. (2022). Semantic projection recovers rich human knowledge of multiple object features from word embeddings. *Nature Human Behaviour*, *6*(7), 975–987. https://doi.org/10.1038/s41562-022-01316-8

Griffiths, R. R., Richards, W. A., McCann, U., & Jesse, R. (2006). Psilocybin can occasion mystical-type experiences having substantial and sustained personal meaning and spiritual significance. *Psychopharmacology*, *187*(3), 268–283. https://doi.org/10.1007/s00213-006-0457-5

Hadar, A., David, J., Shalit, N., Roseman, L., Gross, R., Sessa, B., & Lev-Ran, S. (2023). The Psychedelic Renaissance in Clinical Research: A Bibliometric Analysis of Three Decades of Human Studies with Psychedelics. *Journal of Psychoactive Drugs*, *55*(1), 1–10. https://doi.org/10.1080/02791072.2021.2022254

Haijen, E. C. H. M., Kaelen, M., Roseman, L., Timmermann, C., Kettner, H., Russ, S., Nutt, D., Daws, R. E., Hampshire, A. D. G., Lorenz, R., & Carhart-Harris, R. L. (2018). Predicting Responses to Psychedelics: A Prospective Study. *Frontiers in Pharmacology*, *9*. https://doi.org/10.3389/fphar.2018.00897

Hamilton, W. L., Leskovec, J., & Jurafsky, D. (2016). Diachronic Word Embeddings Reveal Statistical Laws of Semantic Change. In K. Erk & N. A. Smith (Eds.), *Proceedings of the 54th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers): Proceedings of the 54th Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*. https://doi.org/10.18653/v1/P16-1141

Hansen, L., Rocca, R., Simonsen, A., Olsen, L., Parola, A., Bliksted, V., Ladegaard, N., Bang, D., Tylén, K., Weed, E., Østergaard, S. D., & Fusaroli, R. (2023). Speech- and text-based classification of neuropsychiatric conditions in a multidiagnostic setting. *Nature Mental Health*, *1*(12), 971–981. https://doi.org/10.1038/s44220-023-00152-7

Hartogsohn, I. (2016). Set and setting, psychedelics and the placebo response: An extra-pharmacological perspective on psychopharmacology. *Journal of Psychopharmacology*, *30*(12), 1259–1267. https://doi.org/10.1177/0269881116677852

Horne, B., & Adali, S. (2017). The Impact of Crowds On News Engagement: A Reddit Case Study. *Proceedings of the International AAAI Conference on Web and Social Media*, *11*(1), 751–758. https://doi.org/10.1609/icwsm.v11i1.14977

Hunter, J. D. (2007). Matplotlib: A 2D graphics environment. *Computing in Science & Engineering*, *9*(3), 90–95. https://doi.org/10.1109/MCSE.2007.55

Jurafsky, D., & Martin, J. H. (2024). Vector Semantics and Embeddings. In *Speech and language processing: an introduction to natural language processing, computational linguistics, and speech recognition: Speech and language processing: an introduction to natural language processing, computational linguistics, and speech recognition* (3. ed. [Nachdr.]). Prentice Hall.

Kahneman, D. (2003). Maps of Bounded Rationality: Psychology for Behavioral Economics. *The American Economic Review*, *93*(5), 1449–1475. https://www.jstor.org/stable/3132137

Kruse, L., Rocca, R., & Wallentin, M. (2024). Inferring Depression and Its Semantic Underpinnings from Simple Lexical Choices. *Depression and Anxiety*, *2024*, e3010831. https://doi.org/10.1155/2024/3010831

Lee, C., Roy, R., Xu, M., Raiman, J., Shoeybi, M., Catanzaro, B., & Ping, W. (2024). NV-embed: Improved techniques for training llms as generalist embedding models. *arXiv Preprint arXiv:2405.17428*.

Lenci, A. (2008). *Distributional semantics in linguistic and cognitive research*.

Li, D., & Mashour, G. A. (2019). Cortical dynamics during psychedelic and anesthetized states induced by ketamine. *NeuroImage*, *196*, 32–40. https://doi.org/10.1016/j.neuroimage.2019.03.076

Li, J., & Jurafsky, D. (2015). Do Multi-Sense Embeddings Improve Natural Language Understanding?. In L. Màrquez, C. Callison-Burch, & J. Su (Eds.), *Proceedings of the 2015 Conference on Empirical Methods in Natural Language Processing: Proceedings of the 2015 Conference on Empirical Methods in Natural Language Processing*. https://doi.org/10.18653/v1/D15-1200

Lu, D. (2021). 'Psychedelics renaissance': new wave of research puts hallucinogenics forward to treat mental health. *The Guardian*. https://www.theguardian.com/society/2021/sep/26/psychedelics-renaissance-new-wave-of-research-puts-hallucinogenics-forward-to-treat-mental-health

Ly, C., Greb, A. C., Cameron, L. P., Wong, J. M., Barragan, E. V., Wilson, P. C., Burbach, K. F., Zarandi, S. S., Sood, A., Paddy, M. R., Duim, W. C., Dennis, M. Y., McAllister, A. K., Ori-McKenney, K. M., Gray, J. A., & Olson, D. E. (2018). Psychedelics Promote Structural and Functional Neural Plasticity. *Cell Reports*, *23*(11), 3170–3182. https://doi.org/10.1016/j.celrep.2018.05.022

Marks, M., & Cohen, I. G. (2021). Psychedelic therapy: a roadmap for wider acceptance and utilization. *Nature Medicine*, *27*(10), 1669–1671. https://doi.org/10.1038/s41591-021-01530-3

McDonald, S., & Ramscar, M. (2001). *Testing the Distributional Hypothesis: The Influence of Context on Judgements of Semantic Similarity*.

McKinney, W. (2010). *Data Structures for Statistical Computing in Python*. 56–61. https://doi.org/10.25080/Majora-92bf1922-00a

Mooseder, A., Malik, M. M., Lamba, H., Erowid, E., Thyssen, S., & Pfeffer, J. (2022, January 31). *Glowing Experience or Bad Trip? A Quantitative Analysis of User Reported Drug Experiences on Erowid.org*. arXiv. https://doi.org/10.48550/arXiv.2201.13064

Muennighoff, N., Tazi, N., Magne, L., & Reimers, N. (2022). MTEB: Massive text embedding benchmark. *arXiv Preprint arXiv:2210.07316*. https://doi.org/10.48550/ARXIV.2210.07316

Muetzelfeldt, L., Kamboj, S. K., Rees, H., Taylor, J., Morgan, C. J. A., & Curran, H. V. (2008). Journey through the K-hole: Phenomenological aspects of ketamine use. *Drug and Alcohol Dependence*, *95*(3), 219–229. https://doi.org/10.1016/j.drugalcdep.2008.01.024

Nichols, D. E. (2018). Chemistry and Structure–Activity Relationships of Psychedelics. In A. L. Halberstadt, F. X. Vollenweider, & D. E. Nichols (Eds.), *Behavioral Neurobiology of Psychedelic Drugs: Behavioral Neurobiology of Psychedelic Drugs* (pp. 1–43). Springer. https://doi.org/10.1007/7854_2017_475

Nicol, A. U., & Morton, A. J. (2020). Characteristic patterns of EEG oscillations in sheep (Ovis aries) induced by ketamine may explain the psychotropic effects seen in humans. *Scientific Reports*, *10*(1), 9440. https://doi.org/10.1038/s41598-020-66023-8

Nour, M. M., McNamee, D. C., Liu, Y., & Dolan, R. J. (2023). Trajectories through semantic spaces in schizophrenia and the relationship to ripple bursts. *Proceedings of the National Academy of Sciences*, *120*(42), e2305290120. https://doi.org/10.1073/pnas.2305290120

Olson, D. E. (2018). Psychoplastogens: A Promising Class of Plasticity-Promoting Neurotherapeutics. *Journal of Experimental Neuroscience*, *12*, 1179069518800508. https://doi.org/10.1177/1179069518800508

The pandas development team. (2020, February). *pandas-dev/pandas: Pandas*. Zenodo. https://doi.org/10.5281/zenodo.3509134

Pedregosa, F., Varoquaux, G., Gramfort, A., Michel, V., Thirion, B., Grisel, O., Blondel, M., Prettenhofer, P., Weiss, R., Dubourg, V., Vanderplas, J., Passos, A., Cournapeau, D., Brucher, M., Perrot, M., & Duchesnay, E.

(2011). Scikit-learn: Machine learning in Python. *Journal of Machine Learning Research*, *12*, 2825–2830.

Qiu, T. (., & Minda, J. P. (2021, November 29). *Recreational Psychedelic Users Frequently Encounter Complete Mystical Experiences: Trip Content and Implications for Wellbeing*. OSF. https://doi.org/10.31234/osf.io/xrbzs

Reiff, C. M., Richman, E. E., Nemeroff, C. B., Carpenter, L. L., Widge, A. S., Rodriguez, C. I., Kalin, N. H., McDonald, W. M., & and the Work Group on Biomarkers and Novel Treatments, a Division of the American Psychiatric Association Council of Research. (2020). Psychedelics and Psychedelic-Assisted Psychotherapy. *American Journal of Psychiatry*, *177*(5), 391–410. https://doi.org/10.1176/appi.ajp.2019.19010035

Reimers, N., & Gurevych, I. (2019, November). Sentence-BERT: Sentence embeddings using siamese BERT-networks. *Proceedings of the 2019 Conference on Empirical Methods in Natural Language Processing*. https://arxiv.org/abs/1908.10084

Sahlgren, M. (2006). *The distributional hypothesis*.

Sanz, C., Zamberlan, F., Erowid, E., Erowid, F., & Tagliazucchi, E. (2018). The Experience Elicited by Hallucinogens Presents the Highest Similarity to Dreaming within a Large Database of Psychoactive Substance Reports. *Frontiers in Neuroscience*, *12*. https://doi.org/10.3389/fnins.2018.00007

Singhal, A. (2001). *Modern Information Retrieval: A Brief Overview*.

Singleton, S. P., Luppi, A. I., Carhart-Harris, R. L., Cruzat, J., Roseman, L., Nutt, D. J., Deco, G., Kringelbach, M. L., Stamatakis, E. A., & Kuceyeski, A. (2022, May 4). *LSD and psilocybin flatten the brain's energy landscape: insights from receptor-informed network control theory*. bioRxiv. https://doi.org/10.1101/2021.05.14.444193

Smith, K. W., Sicignano, D. J., Hernandez, A. V., & White, C. M. (2022). MDMA-Assisted Psychotherapy for Treatment of Posttraumatic Stress Disorder: A Systematic Review With Meta-Analysis. *The Journal of Clinical Pharmacology*, *62*(4), 463–471. https://doi.org/10.1002/jcph.1995

Steck, H., Ekanadham, C., & Kallus, N. (2024, March 8). *Is Cosine-Similarity of Embeddings Really About Similarity?*. arXiv. https://doi.org/10.48550/arXiv.2403.05440

Stirling, J., & McCoy, L. (2010). Quantifying the Psychological Effects of Ketamine: From Euphoria to the k-Hole. *Substance Use & Misuse*, *45*(14), 2428–2443. https://doi.org/10.3109/10826081003793912

Studerus, E., Gamma, A., & Vollenweider, F. X. (2010). Psychometric Evaluation of the Altered States of Consciousness Rating Scale (OAV). *PLOS ONE*, *5*(8), e12412. https://doi.org/10.1371/journal.pone.0012412

Turney, P. D., & Pantel, P. (2010, March 4). *From Frequency to Meaning: Vector Space Models of Semantics*. arXiv. https://doi.org/10.48550/arXiv.1003.1141

University of Michigan - SI Faculty Profile: George Furnas. (2010, June 7). https://web.archive.org/web/20100607082845/http://www.si.umich.edu/people/faculty-detail.htm?sid=41

Valsecchi, F., Pfaender, F., & Erowid, F. (2023). Substantiated Spaces: The Invisible Geographies of Erowid's Vaults. In *Substantiated Spaces: The Invisible Geographies of Erowid's Vaults: Substantiated Spaces: The Invisible Geographies of Erowid's Vaults* (pp. 182–193). JOVIS. https://doi.org/10.1515/9783986120184-017

Vargas, M. V., Dunlap, L. E., Dong, C., Carter, S. J., Tombari, R. J., Jami, S. A., Cameron, L. P., Patel, S. D., Hennessey, J. J., Saeger, H. N., McCorvy, J. D., Gray, J. A., Tian, L., & Olson, D. E. (2023). Psychedelics promote neuroplasticity through the activation of intracellular 5-HT2A receptors. *Science*, *379*(6633), 700–706. https://doi.org/10.1126/science.adf0435

Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., Kaiser, L., & Polosukhin, I. (2017,). *Attention Is All You Need*. arXiv. https://doi.org/10.48550/arXiv.1706.03762

Virtanen, P., Gommers, R., Oliphant, T. E., Haberland, M., Reddy, T., Cournapeau, D., Burovski, E., Peterson, P., Weckesser, W., Bright, J., Walt, S. J. van der, Brett, M., Wilson, J., Millman, K. J., Mayorov, N., Nelson, A. R. J., Jones, E., Kern, R., Larson, E., … SciPy 1.0 Contributors. (2020). SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python. *Nature Methods*, *17*, 261–272. https://doi.org/10.1038/s41592-019-0686-2

Vollenweider, F. X., & Preller, K. H. (2020). Psychedelic drugs: neurobiology and potential for treatment of psychiatric disorders. *Nature Reviews Neuroscience*, *21*(11), 611–624. https://doi.org/10.1038/s41583-020-0367-2

Vollenweider, F. X., & Smallridge, J. W. (2022). Classic Psychedelic Drugs: Update on Biological Mechanisms. *Pharmacopsychiatry*, *55*, 121–138. https://doi.org/10.1055/a-1721-2914

Wu, Z., Qiu, L., Ross, A., Akyürek, E., Chen, B., Wang, B., Kim, N., Andreas, J., & Kim, Y. (2024, March 28). *Reasoning or Reciting? Exploring the Capabilities and Limitations of Language Models Through Counterfactual Tasks*. arXiv. https://doi.org/10.48550/arXiv.2307.02477

Xu, Z., Jain, S., & Kankanhalli, M. (2024, January 22). *Hallucination is Inevitable: An Innate Limitation of Large Language Models*. arXiv. https://doi.org/10.48550/arXiv.2401.11817

Yang, J. (2024, March 1). *Rethinking Tokenization: Crafting Better Tokenizers for Large Language Models*. arXiv. https://doi.org/10.48550/arXiv.2403.00417

Zamberlan, F., Sanz, C., Martínez Vivot, R., Pallavicini, C., Erowid, F., Erowid, E., & Tagliazucchi, E. (2018). The Varieties of the Psychedelic Experience: A Preliminary Study of the Association Between the Reported Subjective Effects and the Binding Affinity Profiles of Substituted Phenethylamines and Tryptamines. *Frontiers in Integrative Neuroscience*, *12*. https://doi.org/10.3389/fnint.2018.00054

Zinberg, N. E. (1984). *Drug, set, and setting: the basis for controlled intoxicant use*. Yale Univ. Press.

Zmigrod, L. (2020). The role of cognitive rigidity in political ideologies: theory, evidence, and future directions. *Current Opinion in Behavioral Sciences*, *34*, 34–39. https://doi.org/10.1016/j.cobeha.2019.10.016

Zmigrod, L., Robbins, T. W., & Rentfrow, P. J. (2020). The partisan mind: Is extreme political partisanship related to cognitive inflexibility?. *Journal of Experimental Psychology: General*, *149*(3), 407–418. https://doi.org/10.1037/xge0000661