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Neural computations underlying
psychedelic insight



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ABSTRACT

What happens in the brain as our minds change? This thesis investigates the phenomenon of insight from the perspectives of computational and cognitive neuroscience. Grounding insight using information and dynamical systems theories, the work integrates evidence from diverse fields to reveal insight as a core cognitive process. It presents progress towards a computational and neural framework of insight encompassing both mild and wild insights.

This disquisition looks at insight experiences utilizing the psychedelic state as a conceptual vehicle. Psychedelic substances reliably induce sudden and transformative insights that are accompanied by a strong sense of personal significance. This allows us to investigate the neural and computational mechanisms underlying powerful and profound realizations that are otherwise difficult to capture in controlled settings.

The thesis introduces *Psyrréal*, a novel virtual reality experience designed to replicate key elements of psychedelic phenomenology and induce therapeutically relevant insight, with preliminary results showing short-term reductions in depressive symptoms. Finally, the thesis proposes apical hypercontextualisation as a unifying cellular principle of serotonergic psychedelic action. Through 5-HT_{2A} receptor agonism primarily on the apical dendrites of layer V extratelencephalic pyramidal neurons, psychedelics amplify contextual modulation across cortical representations providing a candidate neural mechanism for both the characteristic phenomenology of the psychedelic state and the representational restructuring that underlies deep insight. Altogether, this dissertation contributes to our understanding of the computations underlying insight.

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LIST OF ORIGINAL PUBLICATIONS

Publications included in the thesis

- I Tulver, Kadi, Kaup, Karl Kristjan, Laukkonen, Ruben, and Aru, Jaan. “Restructuring insight: An integrative review of insight in problem-solving, meditation, psychotherapy, delusions and psychedelics”. In: *Consciousness and cognition* 110 (2023), p. 103494. DOI: <https://doi.org/10.1016/j.concog.2023.103494>.
- II Tulver, Kadi, Kaup, Karl Kristjan, and Aru, Jaan. “The road to Aha: A recipe for mental breakthroughs”. In: *Cognition* 257 (2025), p. 106081. DOI: <https://doi.org/10.1016/j.cognition.2025.106081>.
- III Kaup, Karl Kristjan, Vasser, Madis, Tulver, Kadi, Munk, Mari, Pikamäe, Juhan, and Aru, Jaan. “Psychedelic replications in virtual reality and their potential as a therapeutic instrument: an open-label feasibility study”. In: *Frontiers in Psychiatry* 14 (2023), p. 1088896. DOI: <https://doi.org/10.3389/fpsy.2023.1088896>.
- IV Kaup, Karl Kristjan, Hidalgo Jimenez, Javier, and Aru, Jaan. “Cellular mechanisms of serotonergic psychedelics - apical hypercontextualisation”. In: *review* (forthcoming).

Author’s contribution to the publications

- I Background research, reviewing and writing
- II Conceptualization, background research and writing
- III Conceptualization, VR design, experimental design, conducting experiments, data analysis and writing
- IV Conceptualization, background research, reviewing and writing

Publications not included in the thesis

- V Kim, Juensung J, Tulver, Kadi, Aru, Jaan, Kaup, Karl Kristjan, Pogliani, Ambra, and Laukkonen, Ruben E. “Realization experiences: a convergent account of insight and mystical experiences”. In: *Philosophical Psychology* (2026), pp. 1–30.
- VI Kase, Marten, Kaup, Karl Kristjan, and Aru, Jaan. “Effects of LSD, DMT and psilocybin on cognitive and psychological functions: A systematic review of the literature”. In: *Journal of Psychopharmacology* (Feb. 2026), p. 02698811251412012. DOI: 10.1177/02698811251412012.
- VII Jiménez, Javier Hidalgo, Kaup, Karl Kristjan, and Aru, Jaan. “Electrophysiological mechanisms of psychedelic drugs: A systematic review”. In: *Neuroscience & Biobehavioral Reviews* (2026), p. 106649.

1. INTRODUCTION

Sometimes something just *clicks* in our mind, things fall into place and begin to make sense in a moment of insight. Through implicit restructuring we suddenly come to a new understanding, feeling relief, warmth and clarity (Tulver et al., 2023). For most of us, these joyful (Canestrari et al., 2018; Hutchinson, 2014) experiences are rare and fleeting and much of our effort is directed at feeling them more often (Chesebrough et al., 2024). Some are willing, even in the busy and demanding times of modernity, to sit down, do nothing and wait for them to arise (Anālayo, 2010; Colzato et al., 2012, 2017; Dahl & Davidson, 2019; Eberth et al., 2019; Ireland, 2013; Ostafin & Kassman, 2012; Ren et al., 2011; Yates et al., 2015). Others look for quicker fixes such as various *pharmacological interventions*. Administration of psychedelic substances appears to be one of the more reliable pharmacological methods for inducing subjective experiences of insight (e.g., Kugel et al., 2025; Peill et al., 2022).

What happens when we *come to understand* a concept, when we find a novel association or realize the relevance of something - what happens when our mind changes and *when* does our mind change? This thesis attempts to progress towards the grounding of the phenomenon of insight using cognitive, computational and mathematical frameworks.

This is not an easy task, as strong insight moments are hard to capture in the laboratory. These are moments where the mind can undergo a sudden and powerful transformation. Not merely inducing changes in minute aspects of one's mind, but affecting personality, core beliefs, traits, and reflexive behaviours with broad and lasting consequences. Such are the incidents at the heart of this work. Understanding natural intelligence requires that we explain these big, transformative moments. As they are difficult to study directly in the laboratory, we can benefit from modelling them through computational frameworks. This is the main aim of this thesis.

The core of this thesis lies in four separate publications.

(I) (Tulver et al., 2023) indicates how insight is a core cognitive process common to many aspects of human mental activity. The review brings together evidence from separate fields which consider insight important. This review highlights the common characteristics of insight, thus laying the foundation for understanding the process computationally.

(II) (Tulver et al., 2025) proposes a novel framework for understanding the cognitive and computational mechanisms of insight highlighting tension, altered salience and flexibility as key. The iterative and interdependent cycling between these three properties of states of mind are suggested to underline various types of insight.

The first contributions describe how psychedelic substances frequently induce insight experiences and introduce a mechanistic description of insight aligned with the cognitive effects of psychedelics. This paves the way for using the

psychedelic state as a tool for investigating insight in the final two contributions.

(III) (Kaup et al., 2023) recreates psychedelic phenomenology in virtual reality and showcases how administering psychedelic virtual reality in a therapeutic intervention can induce therapeutically beneficial insight. This study introduces a novel therapeutic methodology using psychedelic virtual reality and also provides indirect support to the position that the alterations in subjective phenomenology are important for the mental changes evoked by psychedelics.

(IV) The final article (Kaup et al., forthcoming) reviews how psychedelics affect cellular neural activity and proposes a unifying framework for psychedelic action highlighting contextual computations to be primarily relevant for psychedelic activity. This framework also provides a potential neural explanation of how psychedelic substances could lead to insight experiences.

Together, these chapters contribute to our understanding of the cognitive, computational and neural mechanisms of insights. Although many questions will remain open, this inquiry hopefully helps to advance our understanding of the insight phenomenon at the core of natural intelligence.

2. BACKGROUND

2.1. What is insight?

The roots of our thoughts about insight lie largely within the soil of religion and philosophy. Hustling and aspiring towards changing our minds has been an important part of human culture likely for its whole existence. Perhaps the clearest surviving indications for such tendencies can be found in ancient religious and quasireligious approaches and especially within many of their practices (see also Van Der Braak, 2025). Practices such as Christian and Islamic prayer, and Taoist meditation can be, at least partially, conceived as aspiring towards greater self-understanding and a deeper, more reflexive grasp of specific fundamental concepts of the corresponding religion (e.g., Christian Epiphany or the Taoist concept of *wu wei*; Burbea, 2014; Dahl & Davidson, 2019; James 1902; Slingerland, 2003). Of all contemplative traditions, Buddhism contains arguably some of the most explicit frameworks for insight. For example, the Theravāda *vipassanā* tradition unpacks insight into a taxonomy of 'insight knowledges' (*ñāṇas*) - a sequence of distinct realizations that practitioners are said to gain in a relatively reliable order (Anālayo, 2010; Burbea, 2014). The Tibetan Dzogchen tradition offers another complementary perspective, emphasizing direct, non-conceptual recognition of the nature of mind. Many other cultural traditions, religions and philosophical approaches across history have held an important value in revelatory experiences and sudden transformations, and a considerable amount of theurgical and philosophical practices centrally intended to induce such moments of enlightenment (James, 1902). Such historical ubiquity also suggests that insight is a core cognitive process embedded deep in the machinery of a human organism (see contributions 1, 2 and 4 for more).

The perspicuous modern conceptualizations of insight have their beginnings in 19th and 20th century psychologists. Still holding onto religious discourse, William James was one of the first to make considerable steps towards a psychological conceptualization of insight, highlighting the noetic quality of mystical experiences (James, 1902; see also *Psychedelics and Insight*). But the first explicit conceptualizations of *insight* are generally associated with Gestalt psychologists. Karl Ludwig Bühler, a German psychologist from the Würzburg school, first used the term *Aha-Erlebnis* (Aha experience) at the dawn of the 20th century to denote sudden changes in understanding (Danek, 2023). Wolfgang Köhler, while studying the problem-solving behaviour of chimpanzees, noticed that sometimes when the primates were unable to fulfill some tasks, they realized the solution in a sudden manner¹ (Kohler, 2018). This led him to propose insight as a type of learning creating the first theoretical framework of insight (Vitello & Salvi, 2023). Many other prominent Gestalt psychologists, including Max Wertheimer and Kurt Kof-

¹ See for example <https://www.youtube.com/watch?v=6-YWrPzsmEE>.

fka, also considered insight as a vital cog of Gestalt psychology within their own works (Vitello & Salvi, 2023). After all, the holistic principles of Gestalt align well with the insight phenomenon (Danek, 2018) as the *whole* of the solution is revealed at once in an instance of insight.

Later on, the concept of insight has received the greatest amount of spotlight in the subfield of problem-solving. In this context, insight has been generally defined as a *way* of solving various puzzles or external tasks where the solution reveals itself in a sudden manner (e.g., Weisberg, 2013). This is antithetical to *analytical* problem-solving, where the solution is figured out step-by-step and gradually. There are various tasks that have been used to investigate insight problem-solving, generally such that are likely to induce an impasse - a (temporary) sustained period of lack of progress in solving the task. Such commonly utilized tasks include the 9-dot problem, Remote Associates Test (RAT; Mednick & Halpern, 1968), Compound Remote Associates task (CRA; Bowden & Jung-Beeman, 2003), anagram tasks (Kounios et al., 2008) and many others (see contribution I for a detailed overview on insight tasks).

Problem-solving insight experiences accompany shifts in specific external task representations (Kaplan & Simon, 1990), but insight can also denote changes in many other aspects of cognitive functioning. Beliefs and values, both implicit and explicit; dispositions and mindsets; reflexive and habitual behavioural patterns; emotional reactions and reactivity; as well as both propositional and procedural knowledge could be altered in an experience of insight (James, 1902; Miller & Baca, 2001). The phenomenon can therefore extend beyond task-specific restructuring, encompassing both propositional and non-propositional insights.

Recently, research into insight is going through a sort of a paradigm shift (e.g., Chesebrough et al., 2024; Laukkonen et al., 2023; Salvi & Bowden, 2024). Much of the research in the last decades has focused on the neural correlates of insight. Now, we are seeing an increasing emphasis on subjective and phenomenological aspects of insight, correlating the phenomenological aspects to the neural, cognitive and conceptual processes, using more immersive tasks and finding ways to investigate more naturalistic forms of insight (Chesebrough et al., 2024; Khajuria et al., 2022, 2025; R. E. Laukkonen et al., 2023). In light of this progress, the concept of insight has also gone through subtle changes. While keeping its more objectivistic/grounded property of change in mental and knowledge structures, its subjective and experiential characteristics have been (re)gaining salience (e.g., Chesebrough et al., 2024; Gick & Lockhart, 1995; Laukkonen et al., 2023; Shen et al., 2018). The field has thus converged on the currently dominant definition of insight as a sudden conscious experience accompanying a change (or awareness of change) in knowledge structures (e.g., Becker & Cabeza, 2025; Danek, 2018; Kounios & Beeman, 2014).

This has led many to describe insight as a two-part phenomenon (Danek, 2018; Gick & Lockhart, 1995). The division into two has taken several forms: on one side there is the informational process, sometimes also discussed as cognitive or

objective. On the other side there is the subjective phenomenology, also framed as affective or experiential, sometimes also denoted by the term ‘Aha! Experience’. The subjective dimension encompasses factors such as preceding tension, antecedent positive affect (joy, pleasure and relief), feelings of warmth, sense of fluency, certainty, importance and veracity, and perceptual alterations (e.g., altered salience, broadened attention). The informational dimension exhibits aspects such as restructuring; reframing; optimization and change in mental representations; abstraction and generalization; testing of various hypotheses, permutations and combinations; evaluative processes; heuristic and algorithmic approaches.

Such bipartite structure suggests that to understand insight, both sides are best taken into account simultaneously. Mapping the subjective dimension (contribution I, III and IV) and describing the informational dimension (contribution II and IV) as precisely as possible and investigating their relationship is likely a necessary approach in the quest for insight. Using computational and mathematical tools has been invaluable in understanding many cognitive phenomena (McClelland et al., 2010a) and could allow us to develop a more mechanistic grounding of the phenomenon of insight. In order to do that, we shall next briefly overview the current understanding of neural computations related to insight.

2.2. Neural correlates of insight

Research into the neural correlates of insight has been at the forefront of the science of insight for several decades (Chesebrough et al., 2024). Alas, as insight often happens suddenly and out of nowhere, it can be difficult to capture in a laboratory setting. Thus, most of the existing research on the neural correlates of insight involves using simple problem-solving tasks which can be administered concurrently with neuroimaging tools (e.g., electroencephalography [EEG] or functional magnetic resonance imaging [fMRI] Chesebrough et al., 2024; Kounios & Beeman, 2014). These approaches have led to revelations regarding neural processing related to insightful problem-solving implicating several structures within the brain.

Various regions of the temporal lobe have been found to be linked with insight (for a review see Shen et al., 2017). Temporal regions have been found responsible for multiple functions, with memory, language and auditory processing most often reported. One of the more consistently found regions related to insight has been the superior temporal gyrus (Chesebrough et al., 2024), which has been linked to semantic integration, binding and shuffling between various relevant representations (Kounios & Beeman, 2014; Shen, Tong, et al., 2018). The temporal lobe has been found to activate prior to insight as well as during the ‘moment’ of insight (Chesebrough et al., 2024) for several tasks such as anagrams, the CRA and riddles (Oh et al., 2020; Jung-Beeman et al., 2004; Huang et al., 2018). EEG studies corroborate the role of the temporal lobe in insight, finding increased gamma-band activity at the right temporal electrode at the moment of insight (Kounios

and Beeman, 2014). Regions implicated in cognitive control, such as the medial prefrontal cortex, have also been linked with insight (e.g., Chesebrough et al., 2024; Kizilirmak et al., 2016).

Another region which has been often linked to insight, is the anterior cingulate cortex (ACC; Chesebrough et al., 2024; Shen et al., 2018). The ACC is generally held responsible for discrepancy signals and internal attention (Chesebrough et al., 2024). It is generally activated prior to insight, potentially reflecting awareness of the unsolved problem (Kounios and Beeman, 2014; Shen et al., 2018). The ACC has been found to be linked with the CRA (e.g., Kizilirmak et al., 2016; Kounios et al., 2006) and various riddles (Shen et al., 2018; Salvi & Bowden, 2024). Inhibition of activity within the visual cortex is also sometimes seen immediately before an insight (Kounios and Beeman, 2014; Chesebrough et al., 2024). Increased alpha-band activity preceding insight in EEG studies supports this claim (Kounios and Beeman, 2014). This has been speculated to indicate direction of attention inwards and allocation of cognitive resources towards internal processing of the task (Chesebrough et al., 2024).

There is a heightened tendency for finding insight related neural activity in the right hemisphere (Kounios and Beeman, 2014). The right hemisphere is often linked with processing distant semantic associations, metaphors and abstract high-level meaning (E. Bowden et al., 2005). However, such hemispheric dominance could be task-dependent as such right-hemispheric bias is especially pronounced in verbal tasks relying on remote semantic associations (e.g., the CRA; Chesebrough et al., 2024). Moreover, enhanced activity in the left hemisphere has instead been reported on some spatial and visual insight tasks such as the 9-dot problem or geometric reasoning paradigms (Chesebrough et al., 2024; Oh et al., 2020).

While methodological issues have limited their investigation into the role of subcortical regions in insight, some studies do suggest that subcortical regions could influence insight. A recent meta-analysis (Shen, Tong, et al., 2018) indicated that the moment of insight is linked with increased activity in the hippocampus and amygdala. Regions of the reward network (e.g., ventral tegmental area and the nucleus accumbens) and the thalamus have also been implicated in insight (Tik et al., 2018). The relevance of evolutionarily more foundational regions of the brain being linked with insight suggests it to be a more basic component of cognition (Salvi & Bowden, 2024). Taken together, these findings suggest a tentative functional organization across the neural correlates of insight: the temporal cortex provides the semantic scaffolding most critical for verbal and associative insight tasks; prefrontal and cingulate regions govern conflict monitoring and attentional reorientation during impasse; and subcortical structures contribute more general and phenomenological aspects such as affective salience and motivational reinforcement of the solution (Chesebrough et al., 2024).

The investigation into the neural correlates of insight has been essentially limited to problem-solving as transformative and personally relevant insight has been

extremely difficult to reliably induce in a laboratory setting. However, recent advances in science have revealed the administration of psychedelic substances to frequently lead to insight and lasting psychological change. This could open up the possibility of systematically investigating deep and profound insight. Hence, we next turn to psychedelics.

2.3. Psychedelics

Psychedelics are a group of psychoactive compounds which have a wide range of effects on the contents of consciousness (see cognitive effects of psychedelics for more detail; Nichols, 2016). Historically, psychedelics have also been called hallucinogens or psychotomimetics, however, these terms are generally discouraged in modern science, due to their misleading and biased connotations (see also below on deliriant; Johnson et al., 2008). Psychedelics can induce various alterations in affect, mood, cognition and perception. Another distinct characteristic of psychedelic substances are various long-term effects that last beyond the acute phase of administration. These features have additionally led psychedelics to being referred to as **psychoplastogens** (Hatzipantelis & Olson, 2024). The following offers a general taxonomy of psychedelic substances.

Serotonergic psychedelics are psychedelic substances which exert their effects through binding at serotonergic (primarily 5-HT_{2A}) receptors. **Classical psychedelics** are a subset of serotonergic psychedelics, which have garnered a lot of cultural attention throughout history. Generally, these are considered to be 4-phosphoryloxy-N,N-dimethyltryptamine (psilocybin), N,N-dimethyltryptamine (DMT), lysergic acid diethylamide (LSD) and 3,4,5-trimethoxyphenethylamine (mescaline). **Non-classical (or atypical) psychedelics** are a diverse group of substances that have various psychoactive effects via primary mechanisms other than binding to serotonergic receptors, but can also have psychedelic or partially psychedelic effects. **Dissociative non-classical psychedelics** are psychoactive compounds that lead to dissociative states. The most common examples include ketamine, phencyclidine (PCP) and dextromethorphan (DXM). **Entactogenic (or empathogenic) non-classical psychedelics** are psychoactive substances that lead to empathic and euphoric states. The main examples include 3,4-methylenedioxymethamphetamine (MDMA) and 3,4-methylenedioxyamphetamine (MDA; Baggott et al., 2019). Several other substances are also sometimes considered among non-classical psychedelics. Some **cannabinoids** (including Δ -9-tetrahydrocannabinol) can have psychedelic effects at higher doses. Some **oneirogenic** substances (e.g., ibogaine) also induce similar alterations to psychedelic substances.

Deliriants are a related group of compounds which also lead to complex alterations in contents of consciousness and hallucinations. The terms hallucinogen and psychotomimetic are better suited for this class of substances as they are significantly more likely to induce auditory and true hallucinations, and dysphoric

alterations than serotonergic psychedelics. Deliriants are primarily anticholinergic substances like atropine, scopolamine and diphenhydramine (Volgin et al., 2019).

Neuroplastogens² are substances chemically similar to serotonergic (or dissociative) psychedelics, which, primarily through binding to 5-HT_{2A} (or NMDA) receptors, induce neuroplasticity and some long-term effects without the acute psychedelic effects (Agrawal et al., 2025). Many novel synthetic substances are suggested to be neuroplastogenic, such as tabernanthalog³ (Cameron et al., 2021), zalsupindole (Agrawal et al., 2025), 2-Br-LSD (Lewis et al., 2023), (+)-JRT (Tuck et al., 2025) and GM-1020 (Klein et al., 2024).

Chemically, psychedelic compounds are mainly indoleamines or phenethylamines (phenylalkylamines; Kwan et al., 2022). **Indoleamines** are constituted of an indole group (six-membered benzene ring fused with a pyrrole ring) and an amino group. Common indoleamines include endogenous compounds such as serotonin, melatonin and dimethyltryptamine as well as exogenous compounds like lysergic acid diethylamide, ibogaine, psilocybin and 4-hydroxy-N,N-dimethyltryptamine (psilocin). Indoleamines are sometimes further delineated into tryptamines (e.g., serotonin, psilocin and DMT), with a straightforward indole group structure, and ergolines, whose indole group is fused into a more complex cyclic structure (e.g., LSD, ergotamine, cabergoline). **Phenethylamines** (or substituted phenethylamines) are composed of a phenyl ring (benzene with one hydrogen replaced by some functional group) joined by an amino (-NH) group. There are many biologically and pharmacologically relevant phenethylamines. Examples include endogenous phenethylamines, such as dopamine, adrenaline, noradrenaline and tyramine, and exogenous compounds (many of which are used in medicine) like amphetamine, methamphetamine, pseudoephedrine, bupropion as well as the classical psychedelic mescaline and non-classical psychedelic MDMA. Only a subset of indoleamines and phenethylamines have psychedelic effects and the majority of psychedelic substances invoke their effects through serotonergic signalling. Here we offer a general taxonomy of various substances which can have psychedelic effects. As serotonergic psychedelics most clearly induce a distinct and characteristic ‘psychedelic’ effect, this thesis is primarily focused on these substances⁴.

²Sometimes used interchangeably with psychoplastogen, however based on (Agrawal et al., 2025) using neuroplastogen for substances which induce neuroplasticity and long-term change without the acute psychedelic effects, and psychoplastogen for substances which also (or only) cause acute effects, is recommended.

³However, some anecdotal reports suggest tabernanthalog to retain some psychedelic phenomenology in humans (e.g., <https://awjuliani.medium.com/a-phenomenological-report-on-the-novel-non-hallucinogenic-psychedelic-tabernanthalog-ed2fc601c1dc>, <https://psychedelicalpha.com/news/non-hallucinogenic-trip-reports-searching-for-the-tabernanthalog-tasters/>).

⁴Therefore, the thesis will generally use the term psychedelics to refer to serotonergic psychedelics, unless otherwise specified.

2.4. The effects of serotonergic psychedelics

All known serotonergic psychedelics affect a broad range of receptors within the human body and brain (Jain et al., 2025). However, the bulk of their signature effects have been narrowed down to dependence on the 5-HT_{2A} receptor (Kwan et al., 2022; see contribution 4 for a detailed overview).

2.4.1. The effects of serotonergic psychedelics on network activity

Psychedelics have been found to produce a range of effects on brain network activity. While psychedelics often lead to decreased within-network functional connectivity (FC; Carhart-Harris et al., 2012; Mason et al., 2021; Palhano-Fontes et al., 2015; Tagliazucchi et al., 2016; Timmermann et al., 2023), there is a marked and broad increase in between-network FC (e.g., Barrett et al., 2020; Carhart-Harris et al., 2016; Luppi et al., 2021; Madsen et al., 2021; Müller et al., 2018; Roseman et al., 2014), with these increases especially pronounced in associative regions of the cortex (Linguiti et al., 2023; Roseman et al., 2014; Tagliazucchi et al., 2016). Acute resting-state psychedelic fMRI studies generally find increased global brain connectivity (Erritzoe et al., 2024; Linguiti et al., 2023), decreased modularity (Daws et al., 2022; Girn et al., 2022), and an increased dynamical variability and repertoire of occupied brain states (Lord et al., 2019; Tagliazucchi et al., 2014). A recent study also found that the effect of global signal regression is especially high for LSD compared to d-amphetamine, MDMA or placebo, with controls for heart rate, blood pressure, temperature and head motion ruling out non-neuronal sources (Avram et al., 2025), suggesting that LSD makes neural activity more global. Psychedelics have also been found to broadly increase thalamocortical connectivity, with some evidence suggesting this effect may be dose-dependent across higher- and lower-order thalamic regions (Avram et al., 2025; Preller et al., 2018; Preller, Razi, et al., 2019; Siegel et al., 2024; Tagliazucchi et al., 2016).

The acute and long-term effects of psychedelics have also been found to relate to disruptions in default mode network activity (Carhart-Harris, Muthukumaraswamy, et al., 2016; Lebedev et al., 2015; Müller et al., 2018; Roseman et al., 2014; Siegel et al., 2024; Tagliazucchi et al., 2016; for a review see Gattuso et al., 2023), a network commonly linked with self-related processing and internal mentation. Similar disruptions have been reported for many other large-scale networks such as the dorsal attention, executive function, salience, visual and somatomotor networks (Carhart-Harris, Muthukumaraswamy, et al., 2016; Müller et al., 2018; Stoliker et al., 2024; for a review see Erritzoe et al., 2024), though with some variability across studies (e.g., Mason et al., 2021; Stoliker et al., 2024). All together, psychedelics seem to disrupt regular network activity leading the brain into a state of global processing (see contribution IV for more).

2.4.2. The cognitive effects of serotonergic psychedelics

Attempts to comprehensively list the cognitive effects of serotonergic psychedelics tend to end up with extremely long and dense lists (e.g., Grof, 2016; Kins, n.d.; Masters & Houston, 1966; Preller & Vollenweider, 2018). A useful generalization of their acute effects that sets psychedelics apart from other known psychoactive substances is that psychedelics affect basically *all kinds of contents of consciousness* (see Grof, 1980 for example). It is relevant to specify, however, that psychedelics might not lead to *all kinds of alterations* to all kinds of contents. That is, while seemingly all (or at least the vast majority) of contents of consciousness could be altered by psychedelics, the ways they are changed seem to be more constrained (e.g., visual alterations respect the compositionality of the visual scene and do not break the part-whole structure completely; Shanon, 2002).

In order to paint a picture of the cognitive effects of psychedelics without running out of ink, I shall highlight certain characteristics which are more common and deemed as especially important by many who come to experience them or study them. The most conspicuous effects of psychedelics are perceptual alterations. While altered perception can occur in various modalities, vision is predominantly affected (though mild alterations in audition are also common; Preller & Vollenweider, 2018). Examples of visual alteration include illusory perception, movement in static objects, changes in colours and overlays of geometrical patterning (Kins, n.d.; Preller & Vollenweider, 2018; Swanson, 2024). Contrary to common misconception, psychedelics generally do not induce ‘true hallucinations’ (hallucinatory percept indistinguishable from a real percept), but primarily induce illusions (altered processing of sensory information) and pseudohallucinations (hallucinatory percept accompanied by awareness of its hallucinatory nature; Preller & Vollenweider, 2018).

Psychedelics also commonly lead to altered cognition, visions and dream-like episodes (Girn et al., 2020; Kraehenmann, Pokorny, Vollenweider, et al., 2017). At its more basic levels this can just include perception of unusual objects or bizarre semantic associations (Kraehenmann, Pokorny, Aicher, et al., 2017). But in its full-blown form, this can include living out realistic and autobiographical scenarios, or completely imaginary symbolic and mythical stories (Preller and Vollenweider, 2018). There is also a considerable amount of research assessing the cognitive effects of psychedelics with various empirical tests common in cognitive science. In general, studies find psychedelics to impair performance on most cognitive tasks, measuring aspects such as attention, executive function, working memory, cognitive flexibility (for reviews see Kase et al., 2026; Basedow et al., 2024; Balaet, 2022; Yousefi et al., 2025). This empirical profile stands in apparent tension with phenomenological reports, which frequently portray psychedelic cognition as more dynamic, flexible, associative and immersive⁵ (Kins, n.d.; Masters & Houston, 1966; Preller & Vollenweider, 2018).

⁵However, states of various cognitive impairment are also possible due to psychedelics and

This discrepancy may be partly methodological: preliminary evidence suggests psychedelics impair speed- rather than accuracy-based measures (Basedow et al., 2024; Yousefi et al., 2025), pointing to impaired engagement with external stimuli rather than a wholesale degradation of cognition. Resources may instead be allocated inward, where the processing of internal imagery and sensations appears spared or even enhanced (Kase et al., 2026).

For many the most important and influential effects are related to alterations in the sense of self. Many prominent psychedelic scientists and figures (e.g., Grof, 1980; Leary et al., 2017; Letheby, 2021; Preller & Vollenweider, 2018) have emphasized ego-dissolution and various alterations in self-related processing when discussing the effects of psychedelics. These effects can range from decreased self-related cognition and salience of self-related content, disrupted access to autobiographical memory, dissolution of a physical sense of self to a complete cessation of subject-object distinction within one's experience (Fink, 2020; Milliere, 2020; Millière et al., 2018). Many have speculated this to have an important therapeutic role (Grof, 1980; Letheby, 2021; Nour et al., 2016; Nour & Carhart-Harris, 2017; Stoliker et al., 2022), largely thanks to the alluring framework of linking various psychiatric conditions to a rigid and maladaptive self-model (e.g., Mason et al., 2019; Philippi & Koenigs, 2014).

Another central psychedelic phenomenon, the mystical (or mystical-type) experience, is also deeply entangled with self alterations. Some have even gone as far to suggest that an intense disruption of self-related processing is the main facet of a mystical experience (e.g., James, 1902; Stace, 1960; see also Nour et al., 2016). Indeed, an important aspect of mystical experiences does seem to be a profound loss of separate identity which could be reflected in a sense of unity and broad connectedness (e.g., MacLean et al., 2012; Stace, 1960). However, mystical experiences are often considered to have certain other characteristics as well. These experiences also tend to be sacred and profound (Stace, 1960). While debatable and subject to constructivistic controversies, these experiences often have religious undertones (e.g., Griffiths et al., 2025; Jylkkä et al., 2025). These experiences are often ineffable - hard or impossible to be described verbally -, yet have a noetic quality - feel as if new knowledge or understanding is gained through the experience (MacLean et al., 2012; Seragnoli et al., 2025; Stace, 1960).

These are mere scratches on the surface of the depths of the phenomenon of psychedelic experience. More details on the cognitive and phenomenological effects of psychedelics can be found in contribution I, Table 1 in Contribution III and Contribution IV. Here is also a modest list for further external reading (Kins, n.d.; Letheby, 2021; A. Lyon, 2023; Masters & Houston, 1966; Richards, 2016; Shanon, 2002).

occasionally reported.

2.4.3. Serotonergic psychedelics and insight

The most relevant effect of psychedelics for this thesis is their hallmark quality of inducing insight. There are various conceptualizations regarding psychedelics that stress the relevancy of insight.

Staying on the track set in the end of the previous section, we need not look beyond mystical experiences to find sight of insight (Kim et al., 2026). Noetic quality was highlighted as a frequent aspect of such experiences, already by William James (1902; see also Seragnoli et al., 2025). It has considerable and obvious overlap with insight such as a sense of knowing or gaining a new understanding. Furthermore, noetic quality is often described as having non-verbal and experiential characteristics, not merely intellectual and propositional understandings, highlighting the non-propositional nature of many psychedelic insights and aligning with recent trends in conceptualizing insight (e.g., Laukkonen et al., 2023; Osuna-Mascaró & Auersperg, 2021). A recent perspective has also suggested that insight and mystical experiences belong to a unified category (Kim et al., 2026).

There are several findings which indicate the occurrence of transformative insight in psychedelic states. Several prominent questionnaires used in psychedelic research (such as the Altered States of Consciousness questionnaire; 5D-ASC; Studerus et al., 2010; and the Revised Mystical Experience Questionnaire; MEQ30; MacLean et al., 2012) contain subscales or items regarding insight which are often found to correlate with or predict beneficial change (e.g., Carhart-Harris et al., 2018; Garcia-Romeu et al., 2019; Kugel et al., 2025; von Rotz et al., 2023). A recent review of studies implementing various measures for insight during psychedelics found the dose of psychedelic to correlate with increased insight (Kugel et al., 2025). Various forms of insight are also reported by people after participating in psychedelic therapy (Belser et al., 2017; Watts et al., 2017), ritual ceremonies (Wolff et al., 2019) or following uncategorized naturalistic use (e.g., Jylkkä et al., 2025). It is also common for participants to report various kinds of dispositional or behavioural change following high-dose psychedelic sessions (e.g., Griffiths et al., 2006, 2008; Johnson et al., 2017).

Psychedelic-induced alterations in cognition could also support insights. Psychedelic cognition is primarily characterized by unusual and bizarre content, amplified symbolic, associative and analogical thinking, and dream-like awareness of internal or usually ‘unconscious’ processing (M. Baggott, 2015; Kase et al., 2026; Kraehenmann, Pokorny, Aicher, et al., 2017; Kraehenmann, Pokorny, Vollenweider, et al., 2017; A. Lyon, 2023; Preller & Vollenweider, 2018; Wießner et al., 2022). Even a superficial analysis would suggest that all of these internal processes could promote the occurrence of insight (but for more detail, see contributions II and IV; see also Gandy et al., 2022; Girn et al., 2020). Furthermore, there is some indication that psychedelics can increase divergent thinking, although this could primarily reflect effects of microdosing or post-acute rather than acute effects of moderate-to-high doses (Kuypers et al., 2016; Mason et al.,

2019, 2021; Prochazkova et al., 2025).

Another important characteristic of psychedelics is their ability to lead to long-term changes in beliefs and traits. There is evidence for changes in philosophical and metaphysical beliefs following psychedelic use (Jylkkä et al., 2024, 2025; Nayak et al., 2023; Nayak & Griffiths, 2022; Timmermann et al., 2021) and their potential to increase well-being and decrease various psychopathologies could also be conceived as indication for their ability of inducing transformation (Grinspoon & Doblin, 2001; e.g., Carhart-Harris et al., 2016, 2021; Davis et al., 2021; Goodwin et al., 2022; Griffiths et al., 2016; Raison et al., 2023). Psychedelic-led changes in beliefs and traits might not always happen suddenly, but their relatively common occurrence and the long-lasting nature (with some evidence suggesting that some changes could last decades; e.g., Doblin, 1991) highlights the power of these substances to elicit change in mental structures.

Contribution IV provides a different take on the neural correlates of insight through looking at the neural activity of the psychedelic state as a proxy for a more profound and transformative state of insight (as opposed to task-dependent problem-solving insight). Furthermore, contribution 4 proposes a framework for how understanding the neural processes of the psychedelic state can also provide insight into insight.

2.5. Computational algorithms of insight and psychedelics

The general themes of representational restructuring and neural activity patterns hint at the promising but nascent avenue of research involving computational and algorithmic approaches to describing insight. Themes of representational shift, coding in artificial neural networks, and computational learning processes have been discussed in artificial intelligence and machine learning at length and breadth ever since the advent of computationalist approaches to cognition at the pivot of the 20th century (e.g., McCulloch & Pitts, 1943; Turing, 1950). However, there are only a few conceptualizations that incorporate the suddenness of insight into their algorithmic engine (Batchelder & Alexander, 2012). Here we shall briefly overview some computational frameworks which we shall use later to model and conceptualize insight.

Conceiving cognition as a dynamical system has been rather popular in cognitive science for decades (Beer, 2000; McClelland et al., 2010b; Port & Gelder, 1995; Thelen & Smith, 1994; Van Gelder, 1998). Beyond providing a useful framework to explicate dimensions and aspects of cognition, complex and dynamical systems theories could also support linking cognition to complex patterns of dynamical brain activity (e.g., Esteban et al., 2026).

Dynamical systems theory is a powerful and highly abstract mathematical framework used to describe the movement or evolution of a system (Brin & Stuck, 2002). While useful for describing the movement of physical systems in space, in its more general form it can be used to analyze the dynamics of an abstract system

in an arbitrary state-space. This makes it a powerful tool to model a broad range of changing phenomena. Dynamical systems theory is primarily interested in describing and analyzing the *structure of the trajectories* of the system in a given state-space.

Dynamical systems theory has led to several perspectives on insight. For example, insight has been suggested to be the ‘emergence’ of a new solution, non-incremental and non-linear change, a phase transition, or the appearance of a new attractor (Kelso, 1995; Stephen, Boncoddò, et al., 2009; Stephen, Dixon, et al., 2009).

Information Theory is also seeing increasing use in explaining various cognitive functions (Chater & Vitányi, 2003; Sayood, 2018). Information Theory is essentially a ‘mathematical theory of communication’ which deals with analyzing the structure of signals between a sender and a receiver in order to allow for reliable, robust and optimal signal transmission (Shannon, 1948).

There are also many approaches which have slightly weaker ties to formal aspects of Information Theory, but still attempt to describe insight in terms of information processing (e.g., Knoblich et al., 1999; Ohlsson, 1984a, 1984b). The majority of these approaches has focussed primarily on describing the structure of various insight problems (e.g., Knoblich et al., 1999; Korf, 1980; Ohlsson, 1984b). However, more direct information-theoretical approaches have been rather popular in psychedelic science (e.g., Carhart-Harris, 2018; Carhart-Harris et al., 2014; Carhart-Harris & Friston, 2019; see also Moses et al., 2026). In essence, the complex phenomenology of the psychedelic state is taken to imply an information-rich and, therefore, highly entropic neural configuration (Carhart-Harris et al., 2014).

The clearest use of information-theoretical approaches to insight can be found in the popular field of predictive processing (Friston et al., 2017; R. E. Laukkonen et al., 2023). Predictive processing essentially constitutes a solution to the shortcomings of direct realism by establishing prediction as the fundamental operation of cognitive and neural processes (e.g., Swanson, 2016). The brain and the mind work to guess upcoming sensory inputs and minimize the discrepancy between the prediction and subsequently received sensory data (Friston, 2010). The most prominent formalization of predictive processing utilizes Bayesian formalism and the free-energy principle (FEP; Friston, 2010).

The FEP describes the activity of physical autopoietic systems (that includes human organisms and their mental functioning) as minimizing information-theoretical free-energy. This can be considered as a proxy for surprise or prediction error. Basically, the optimization of free-energy leads to models of the external environment which are better suited to support the functional flourishing of the system (e.g., staying alive and getting food). Within this framework, the informational aspects of insight have been conceptualized as Bayesian model reduction or *fact-free learning* (Aragones et al., 2005; Carhart-Harris & Friston, 2019; Friston et al., 2017). Some experiential aspects of insight (e.g., confidence, pleasure

and salience) have been also conceptualized as increased precision-weighting of prediction errors (R. E. Laukkonen et al., 2023).

3. RESTRUCTURING INSIGHT: AN INTEGRATIVE REVIEW OF INSIGHT IN PROBLEM-SOLVING, MEDITATION, PSYCHOTHERAPY, DELUSIONS AND PSYCHEDELICS

3.1. Introduction

We begin by surveying insight across multiple domains of scientific inquiry. As a broad marker, we shall consider insight a sudden change (or awareness of change) in one's knowledge structures accompanied by a subjective feeling of understanding. The most systematic approaches to insight have been developed within the problem-solving subfield of cognitive science. However, insight and various other forms of understanding and sudden transformations are commonly discussed in many fields of scientific inquiry. Here, we bring together secluded scientific traditions highlighting the differences and similarities of how they discuss and conceptualize insightful phenomena.

3.2. Motivation

The problem-solving discourse on insight contains two primary schools of thought. The Business-As-Usual approach posits that there is no principal difference in informational processing between insight and analytical cognizing and the Special Process approach which considers insight as a distinct cognitive process (E. Bowden et al., 2005; Seifert et al., 1994; Weisberg, 2016). However, on top of being a cornerstone of problem-solving literature, insight and its adjacent phenomena are also important to many other fields. This work set out to compare and analyze sudden realizations across different fields in order to see how the Special Process and Business-As-Usual approaches fare outside of the domain of problem-solving. This delineation can help us shed light in the nature of insight.

Various contemplative and meditative traditions, such as Buddhism, discuss phenomena of sudden realization and profound transformations. Some such schools posit certain kinds of understandings as core to their teachings and their realization as one of the main goals of the practices. Psychotherapy similarly aspires to induce in its target population a shift towards more positive, balanced or adaptive perspectives which often occur out of the blue. The budding field of psychedelic science has also registered that psychedelic substances lead to Aha! Experiences and profound shifts in beliefs often with favorable therapeutic consequences. And somewhat akin to the psychedelic alterations of mind, psychotic states can also feature insights which can precipitate harmful delusional beliefs and other long-term debilitating consequences. This contribution reviews insight in these various fields helping us come to a more parsimonious conceptualization of the phenomenon.

3.3. Main ideas

The main goal of this work was to give a detailed overview of how insight is conceptualized in various fields allowing for a comprehensive comparison. The work also provides an overview of the methodology used in these fields to empirically measure insight.

3.3.1. Problem-solving insight

The most explicit approaches for describing insight can be found in problem-solving where insight is generally conceptualized in relation to various tasks. Insight solutions are more common for non-routine problems, such as riddles and puzzles, which are mainly used in problem-solving research (Mayer, 1995). One of the main features of insight in problem-solving is the “aha” moment - a sudden realization with a sense of certainty accompanied by an affective component of relief or pleasure (Beeman & Kounios, 2015; Danek et al., 2014). Insight solutions are generally underlined by a restructuring of the initial problem representation or developing new associations (Ohlsson, 1984b). Recent research has also started to indicate that the experiential “aha” moment could have important functional consequences, such as increased retention of the solution (Danek et al., 2013; Danek & Wiley, 2020; J. M. Kizilirmak et al., 2016; J. M. Kizilirmak, Galvao Gomes da Silva, et al., 2016) or enhanced entrenchment of new beliefs (Hedne et al., 2016; R. E. Laukkonen et al., 2018, 2020). As problem-solving insight forms the foundation for insight research this part is covered in higher detail in the Background subsection on Insight.

3.3.2. Psychotherapeutic insight

The primary goal of therapy is to elicit positive change in beliefs, feelings, thoughts and behaviour. While this can happen gradually, there are also occasions when such shifts occur suddenly (Carey et al., 2007; Castonguay & Hill, 2006; Miller & Baca, 2001). Insight is commonly considered a crucial mechanism in eliciting positive psychotherapeutic change (Castonguay & Hill, 2006; Jennissen et al., 2018; Kallestad et al., 2010; Lacewing, 2014).

Insight is not as clearly operationalized within the therapeutic discourse as in problem-solving, but it has broadly similar features. It is often studied qualitatively through transcripts or reflections with existing rating scales for therapeutic insight primarily focusing on the content of insight forgoing its experiential characteristics (e.g., Beck et al., 2004; Morgan et al., 1982). Most perspectives suggest therapeutic insight to align with many of the primary characteristics of problem-solving insight. This is well highlighted in one of the more commonly mentioned definitions of therapeutic insight: “A *client’s* expressing an understanding of something about him/herself and articulating patterns or reasons for behaviors, thoughts, or feelings; insight usually involves an “aha” experience in which the client perceives self or world in a new way.” (Hill et al., 1992 pp. 548-549).

The psychotherapeutic approaches to insight also emphasize the importance of distinguishing the intellectual component from the emotional. Emotional insight involves an additional affective and experiential component wherein the new connections are not only understood intellectually but experienced perceptually or somatically (Ellis, 1963). For example, psychotherapy can sometimes lead participants to have a visual experience of the change (Carey et al., 2007) or induce somatic experiences leading to a release of bodily tension which can accompany therapeutic change (e.g., Kuhfuß et al., 2021; Payne et al., 2015). Several researchers suggest that only such deeply felt insight can be considered as ‘true’ therapeutic insight (Ellis, 1963; Greenberg, 1990; Mahoney, 1974; Wachtel, 1997).

Therapeutic insights are generally preceded by tension, internal conflict or some unresolved issues. Some suggest that bringing awareness to the tension and trying to ‘understand’ the tension and its causes can support the occurrence of a therapeutic insight (Hayes et al., 2007; Timulak & McElvaney, 2013). Another aspect often offered to lead to insight is an open and relaxed state. Developing a state of openness and vulnerability combined with bringing the source of tension into mind could allow rigid thought structures and predispositions regarding the underlying issues to thaw and open up the possibility of their revision (Timulak & McElvaney, 2013).

3.3.3. Contemplative insight

While the discussion about insight in contemplative science is predominantly theoretical and has seen minimal empirical work, traditions employing contemplative practices have developed many mechanistic frameworks which either touch upon or directly describe insight. There are a small number of empirical studies which have found a positive relationship between meditation and insight (Colzato et al., 2017; Ren et al., 2011; Ostafin & Kassman, 2012; see also Ireland, 2013). Many meditative traditions highlight that one of the main goals of meditation is to achieve insight (Anālayo, 2010; Burbea, 2014; Yates et al., 2015). However, it must be noted, that, while ‘insight’ can sometimes specifically mean a sudden acquisition of a novel understanding, it is sometimes also used to indicate a ‘state of clear-seeing’ (Burbea, 2014). The former type of insight is more a quality of perception or of the state of cognition (as opposed to a specific experience or event), such that the content is apprehended ‘as is’ with minimal evaluation and recruitment of associations (R. E. Laukkonen & Slagter, 2021). But there are also approaches which conceive insight as an experience featuring a subjective sense of deep understanding along with perceptual, judgmental, and/or behavioral changes (Dahl et al., 2015; Eberth et al., 2019), similarly to how insight is defined in other fields.

One of the most-discussed cognitive abilities related to insight in the contemplative field is mindfulness. While the construct and precise definition of ‘mind-

fulness' is subject to considerable disagreement, our current needs are met by the popular definition of "self-regulation of attention to the conscious awareness

of one's immediate experiences while adopting an attitude of curiosity, openness, and acceptance" (Bishop et al., 2004; Lutz et al., 2015; Slagter et al., 2011). There is some indication that mindfulness can facilitate insight (Colzato et al., 2017; Ireland, 2013; Ostafin & Kassman, 2012; Ren et al., 2011; but see also Zedelius & Schooler, 2015). Mindfulness could support the ability to assess and analyze mental content and processes with more detail (Eberth et al., 2019), potentially leading to insights into the machinery of the mind (Dahl et al., 2015) or noticing previously missed associations between different mental contents (Dahl et al., 2015; Eberth et al., 2019).

3.3.4. Psychedelic insight

In psychedelic research, insights are essentially conceptualized similarly to 'aha moments' - sudden new understandings that feel meaningful. While empirical work on psychedelic insights is still in its infancy, there are several indications that psychedelics can induce powerful and long-lasting transformations in humans. Perhaps most clearly, a recent large study (n = 886) found that 99% of participants reported gaining insight following a psychedelic experience (Peill et al., 2022). A recent meta-analysis found a reliable relationship between psychedelic dose and insight, and of the 46 placebo-controlled studies included in the analysis, 93.5% reported a significantly higher degree of insight in the psychedelic condition (Kugel et al., 2025). Moreover, participants in psychedelic sessions often mention gaining novel understandings and new perspectives on existing issues (Gandy et al., 2022; Watts et al., 2017). Participants in psychedelic therapy also often report an experiential and ineffable feeling of insight (Belser et al., 2017; Garcia-Romeu et al., 2015; Katz et al., 1968) and emotional breakthroughs (Roseman et al., 2019), as opposed to mere declarations of novel propositions. In fact, insight has been found in multiple studies to be a good subjective predictor of the therapeutic effects of psychedelics (Kugel et al., 2025).

While many aspects of psychedelic cognitive alterations could be theoretically linked with insight (see *Psychedelics and Insight and Contribution IV*), there are some preliminary empirical findings. The insightfulness of a psychedelic experience has been found to correlate with some subexperiences such as experiences of unity (Pallavicini et al., 2021), oceanic boundlessness (Roseman et al., 2018), ego-dissolution (Kraehenmann, Pokorny, Vollenweider, et al., 2017) and mystical experiences (Liechti et al., 2017; Pallavicini et al., 2021). Certain aspects of psychedelic experiences have also been found to be linked with insight, such as positive mood (Kraehenmann, Pokorny, Vollenweider, et al., 2017; Liechti et al., 2017; Pallavicini et al., 2021), changed meaning of percepts (Kraehenmann, Pokorny, Vollenweider, et al., 2017) and non-judgmentality (Uthaug et al., 2020).

Psychedelic insights can seemingly be about a lot of different things, even ac-

companying trivial understandings which can feel ground-breaking in the moment are usually understood as arbitrary upon subsequent validation (e.g., Hartogsohn, 2018). That being said, psychedelic insights seem to often be of high personal relevance, likely to reflect the emotionally significant aspects of the participants' mindset going into the session (Belser et al., 2017; Davis, Barrett, So, et al., 2021; Jylkkä et al., 2025; Watts et al., 2017). Psychedelics also often lead to changes in philosophical and metaphysical beliefs highlighting their ability to lead to changes in abstract, complex and higher-order beliefs (Jylkkä et al., 2025; Nayak et al., 2023; Timmermann et al., 2021). Finally, while psychedelics often lead to lasting beneficial change, there are infrequent occurrences where psychedelics can exacerbate the symptoms of various psychiatric disorders or precipitate psychotic episodes and schizophrenia (Johnson et al., 2008).

3.3.5. Delusional insight

Increased propensity for insight is also sometimes linked with psychotic episodes and schizophrenia. Insightfulness has been reported especially in the formation of primary delusions (Arieti, 1955; Feyaerts et al., 2021; Jaspers, 1997), but there are also occurrences of salient and powerful Aha! moments during acute phases of psychosis. This is well illustrated by the following quote: "I had that a few times, especially during my first two psychoses, deep moments of the feeling of all-knowing, aha-moments. Incredible. It is an explosion of truth in your head, and that truth is so simple you can't explain" (Sips et al., 2021).

Psychotic insights often arise following a state of affective tension characterized by ambiguous feelings of conflict, distrust and discomfort lacking a clear cause (Bowers & Freedman, 1966; Gozé et al., 2017; Jaspers, 1997; Uhlhaas & Mishara, 2007). This is sometimes called delusional atmosphere or mood, or *trema* (Conrad, 1971; Jaspers, 1997). It is usually triggered by a traumatic event or a stressful period (Berner, 1991) and often leads to the formation of primary delusions (Uhlhaas and Mishara, 2007; Jaspers, 1997; Conrad, 1971). It is also often characterized by aberrant salience, where mundane, peripheral and background stimuli seem more vivid and important (Kapur, 2003; Mishara, 2010). It has been suggested that an insight can occur to ease the uncertainty and vagueness of the delusional atmosphere as well as reorganize the unusually salient stimuli into a meaningful narrative¹. On one hand, this brings a sense of relief and clarity, but it can also amplify the veracity of the novel delusional belief and 'set it into stone' (Hedne et al., 2016; Kiran & Chaudhury, 2009; Lyndon & Corlett, 2020; see also R. E. Laukkonen et al., 2018). Delusional beliefs are often resistant to revision and intrusive to a degree that their incessant replaying can further reinforce their felt validity (Mishara & Corlett, 2009).

¹In a classic and tragic example of the emergence of a delusional belief through aberrant salience, a man saw a red pickup truck parked on a bridge and suddenly understood that he was John the Baptist whose mission was to introduce the new Messiah to the world (Mellor, 1991).

3.3.6. Synthesis

Reviewing these distant fields yields several important clues about the nature of insight (see fig 1). For example, all fields indicate tension, internal mental conflict or awareness of conflict as generally preceding insight. In some sense, this could be considered tautological - insight is the resolution of discrepancy between mental structures. But this could also be taken to indicate a special role for insight: developing coherence between mental representations beyond striving towards solutions in contexts with predefined goal states.

There are also considerable phenomenological similarities in the experiences of insight and qualities of cognition preceding its rise. Therapeutic, psychedelic and delusional (and sometimes meditative) insight can often feel intense and engrossing and accompany change that is about personally important and foundational beliefs. These changes are often deeply meaningful, important and come with a heightened sense of truthfulness. However, problem-solving insights stand out from these as they are rarely given such personal value. Insight also seems to be more likely to arise in a state of openness and 'letting go' and when effort into finding a solution is relaxed. The relationship of psychedelic use and meditative practices with psychotic disorders could also be indicative of shared underlying mechanisms with psychotic insight.

There are also some differences of how insight is regarded in various fields. Psychedelic, meditative and psychotic insights can, at times, be prolonged as if a 'period of insightfulness'. However, in problem-solving, insight is generally a brief, momentary illumination. Also, problem-solving and therapeutic insight are usually linked to questions which have been intentionally tackled. Delusional, psychedelic and meditative insight, on the other hand, are quite frequently non-specific and regarding questions or ideas which one might not have been explicitly pondering on.

3.4. Summary and implications

This contribution reviews insight in many fields showing insight to be important in problem-solving, psychotherapeutic, psychotic, psychedelic and contemplative research. The relevance of insight across multiple domains suggests it to have a much broader functional role within cognition than solving puzzles. This could be taken as support that the business-as-usual approach does not quite cut it in describing insight. The high likelihood of insight solutions to be correct and the strong sense of veracity they are accompanied suggests these properties to be idiosyncratic to insight, but not to all kinds of cognitive problem-solving (Danek & Wiley, 2017; Salvi et al., 2016). All in all, the characteristics of insight across these fields support it being a special process of cognition. Insight is not merely a specific subprocess of problem-solving but the manifestation of a core process of cognition.

Insight also has important bearings on the field of creativity (Girn et al., 2020). However, it is rarely mechanistically integrated into frameworks of creativity and even when mentioned, stands somewhat separated as a subset (Becker & Cabeza, 2025; Carpenter, 2019; Fleck & Weisberg, 2013; Wallas, 1926), consequence or alternative (Shen, Yuan, et al., 2018) to mechanisms of creativity. With that being said, insight and its related mechanisms are also likely to have important roles in various creative processes. Not only can insight lead to solving puzzles, therapeutic benefits and deeper understanding of religious claims, but also progress in scientific, philosophical, artistic or professional endeavours (e.g., Gandy et al., 2022).

This contribution provides a useful comparative tool for interdisciplinary research. Bridging these divergent fields in one article can help structure interdisciplinary approaches to investigating insight. Taking into account the primary finding of this article indicating the relevance of insight in various fields, conducting more interdisciplinary research is likely to be crucial in developing a proper understanding of it. A key methodological priority for this effort is the operationalisation of the subjective dimension of insight, especially beyond problem-solving. There is plenty of room to lean into the measurement of subjective dimensions which has been left behind a bit methodologically. For example, instead of asking directly about some subjective factor, microphenomenological methods (Petitmengin, 2006) can be used to develop reliable proxy features that map onto broader phenomena. This could be particularly valuable for non-propositional insights, whose experiential and non-verbal character eludes simple and direct measurement methods. Training protocols (e.g., mindfulness) before self-report questionnaires or cognitive tasks could also help standardise how participants answer or perform. Extending such measures across domains, alongside characterising individual differences, could support a more unified empirical science of insight.

		Problem-solving	Psychotherapy	Meditation	Psychedelics	Delusions
Prerequisites	<i>Specific problem / goal</i>	•••	•••	••	••	•
	<i>Altered salience (external / internal)</i>	•	•	••	•••	•••
	<i>Tension / conflict / impasse</i>	•••	•••	••	••	•••
	<i>Increased metacognitive awareness</i>	•••	•••	•••	•••	••
	<i>Openness / relaxed constraints</i>	•••	•••	•••	•••	••
	<i>Enhanced associative thinking</i>	••	••	••	•••	•••
Event	<i>Restructuring / new associations</i>	•••	•••	•••	•••	•••
	<i>Sudden</i>	•••	•••	••	••	•••
	<i>Unexpected</i>	•••	••	••	•••	•••
	<i>Affective response / relief</i>	•••	•••	•••	•••	•••
	<i>Confidence in veracity</i>	•••	•••	••	•••	•••
Consequences	<i>Intersubjective accuracy</i>	••	••	••	••	•
	<i>Personal significance</i>	•	•••	••	••	•••
	<i>Rigid to change</i>	•••	••	••	••	•••
	<i>Long-term memory storage</i>	•••	••	•••	••	•••
	<i>Improved mental health</i>	N/A	•••	••	••	•

Figure 1. A summary comparison between the five reviewed domains where insight events are often considered. The first column lists the most relevant features of insight that we distilled from our review, sectioned into prerequisites (yellow), event (pink), and consequences (blue). There is some variance in which terms are preferred in different domains, but for the purpose of keeping the figure simple and comprehensive we have opted for the most broad and descriptive terminology that would encapsulate any subtle distinctions. For each domain, we provided an estimation on a three-point scale to propose a tentative assessment of how characteristic that aspect is in the conceptualization of insights in that field (three points represents a feature that is very relevant for insights in that field whereas one point refers to a feature that usually does not coincide with such insights). It is important to note that in many areas, insight events are not equally diligently researched and therefore some of these estimates are to some extent subjective rather than empirically proven, based on descriptive accounts in the literature. Moreover, since there is a high level of variability in individual insight events (especially during psychedelic experiences, but also during meditation) the listed features may apply in some cases, but not in others. Note that the goal of the figure is not to provide a definitive assessment but rather to give a broad overview of the topics covered in this review and better illustrate the commonalities and differences between the fields. We have marked “N/A” if there has been no mention of these aspects to the best of our knowledge.

4. THE ROAD TO AHA: A RECIPE FOR MENTAL BREAKTHROUGHS

4.1. Introduction

The previous contribution established that insight-like events are common across various fields. Such reframing of insight begs for fresh mechanistic descriptions that allow integrating the phenomenon between disparate domains. Thus, we now turn to investigate the cognitive intricacies of insight.

4.2. Motivation

Providing a computational framework for insight that unifies simple and mild insights arising from solving puzzles with radical and profound transformations during altered states of consciousness. Insight has thus been primarily linked with problem-solving contexts. However, with the advent of novel tools (e.g., psychedelics and transcranial stimulation) the time is nigh for empirical research into stronger insights. In order to guide empirical research, novel frameworks with a more comprehensive approach to insight that accept the ubiquity of the phenomenon are necessary. This contribution attempts to provide such a framework based on a theoretical computational approach.

While algorithmic and computational approaches to insight are slowly emerging (e.g., Laukkonen et al., 2023), we also offer a conceptualization of insight aligning with multiple perspectives from different computational approaches. There are only a few conceptualizations of insight which explicate computational or algorithmic details (e.g., Knoblich et al., 1999; Ohlsson, 1984). Such frameworks are vital for insight research as their explicit structure can support interpretation and detailed analytical discussion among scientific peers as well as provide a foundation allowing to conduct practical and quantitative research. Furthermore, they can help broadcast relevant ideas from insight research to adjacent fields, especially computational approaches to cognition (e.g., computational neuroscience, artificial intelligence or machine learning). As highlighted by contribution I, interdisciplinary methods are likely to be crucial if our attempt to understand insight pays due respect to its ubiquitous and nuanced nature.

4.3. Main ideas

Conceptualizing insight using complex dynamical systems theory and information theory allows us to expound its mechanisms in detail. Building upon these computational approaches this contribution advances several hypotheses regarding insight. First, we suggest the continuum hypothesis of insight. It proposes that insight can be conceptualized through three correlated factors: degree of subjectively experienced phenomenological intensity, degree of resolved uncertainty,

and the hierarchical depth of the restructured mental representation. All of these factors can be viewed as continua housing different insights of variable intensity and relevance. Second, the contribution highlights the potential of attractor dynamics to model insight. And third, we forward a mechanistic framework of insight, whereby an iterative cycle of tension, altered salience, and enhanced flexibility is necessary for insight to occur.

4.3.1. Continuum hypothesis of insight

Not all insights are made equal. Some feel strong, others weak; some infinitely meaningful, others trivial or pointless; some transform one for years, others are forgotten in minutes. The following attempts to unify these various forms of insight.

Relying on the common two-part arrangement of insight (see Background) often separating its experiential and functional aspects, we suggest that both of these parts share a fundamental structure (see also Danek & Kizilirmak, 2021). These parts can be unified by representing mental representations as an interconnected hierarchical network. On the one hand, insights can be viewed along an axis of experiential phenomenological intensity. On the other hand, they can also be conceptualized as affecting representations of differing degrees of hierarchical depth. Our contribution suggests that these two conceptualizations are essentially equivalent: a powerfully felt insight affects a mental representation of high hierarchical depth (fig 2).

4.3.2. Attracting insight

The concept of attractor landscapes in dynamical systems theory has extensive scientific utility and is seeing increasing use in cognitive neuroscience (Khona & Fiete, 2022). Thanks to their ease of interpretability and usefulness in describing non-linear systems, attractors exude promise for modelling insight. From the perspective of attractors, insights can be considered as sudden, non-linear transitions leading to changes in the structure of the landscape of mental representations (see also figure 3). An alternative way could be to model insight as “switching from one attractor to another” (e.g., Cui et al., 2024; Gelo & Salvatore, 2016).

Armed with these conceptual tools we now build upon contribution I by taking general aspects of insight and elucidating them through these mathematical frameworks.

4.3.3. Tension

One of the most common aspects of insight is a preceding state of tension. Tension can indicate conflict between internal representations (such as goals, beliefs or expectations) and initiate the process of looking for more suitable and coherent explanations (Parr & Friston, 2017). From the perspective of dynamical systems, tension can be seen as a period of destabilization indicating a breakdown in exist-

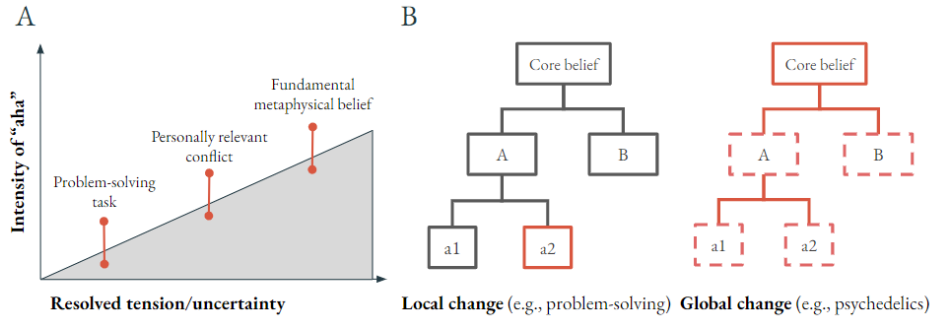


Figure 2. The continuum hypothesis of insight. A. We hypothesize that there is a direct correlation between the intensity of the experience, aha-moment and the amount of tension or uncertainty it resolves, which can reflect personal relevance and motivation to solve the conflict. B. The impact and experienced intensity of the breakthrough event can depend on the extent of the network of affected mental models. On the left side, a lower level model (“a2”) is affected which is not linked to an extensive network of other models, as for instance, in the case of reframing a simple task or problem, hence, only eliciting restructuring on a local level. On the right side, a core belief which is located much higher in the cognitive hierarchy is changed (for example, a belief about oneself or the world) which in turn will affect a wide range of other models and concepts resulting in an impactful and intensely experienced mental transformation, as may occur during the psychedelic experience.

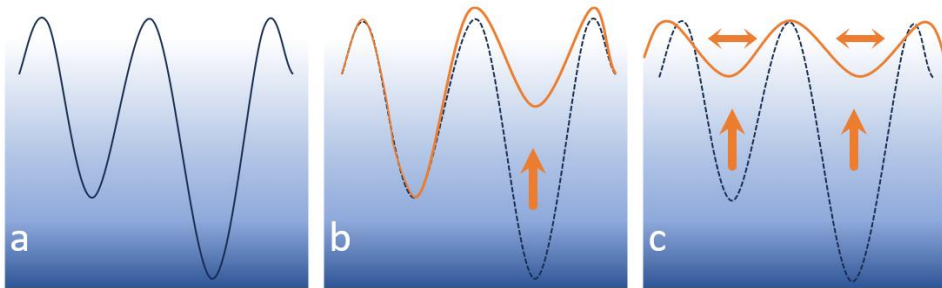


Figure 3. A simplified illustration of the energy landscape of mental representations. Deeper attractors have more pull and are more resistant to perturbation. Attractors whose peak is located in the darker area are in a stable state which is harder to change (a). When tension is introduced that challenges the reliability of a model, it can destabilise the attractor from a stable state towards more uncertainty until another explanation is found (b). In states of global plasticity and enhanced flexibility, the energy landscape is flattened more broadly, rendering the related attractors wider and more shallow which promotes more remote associations and switching between states (c).

ing structures while on the look out for novel, more adaptive configurations (Gelo & Salvatore, 2016). A stable state, which fails to account for the source of tension, begins to loosen, allowing the system to explore different trajectories within its state-space. This loosening is captured in the shoaling of the deep attractor (figure 3B). In problem-solving, the idea of ‘chunk decomposition’ also reflects

this idea. A mental representation is decomposed into different sets of smaller parts allowing testing for multiple ways of restructuring (Knoblich et al., 1999).

In predictive processing terms, tension can be conceptualized as unoptimized representations. The path to optimization requires informational exchange between representations, because optimization can only be achieved internally within the domain of the representational state-space (Ohlsson, 2009). In a slightly crude simplification, the spatiotemporal bandwidth limits of attention ‘isolate’ different representations from one another. It is clearest in the temporal sense, where a certain ‘content of consciousness’ can be experienced in an interactional relation to other contents in a limited temporal vicinity. Similarly, in the ‘spatial’ sense (however, spatial is not the most suitable analogy here), more distant parts at a single moment of consciousness have a weaker interaction than nearby parts. Such ‘separation’ of representations can lead to lack of coordination and contextualisation between them. Unoptimization can be considered in psychological or agential terms as being related to conflicting goals. The feeling of tension and unease arises from the individual holding several representations which have, due to limitations of attentional bandwidth, some kind of conflicting content.

Optimization can be conceived in information theoretical terms as a decrease in the entropy of a signal (Friston et al., 2017). A signal that is conveyed between two parts of one’s mind (i.e., functional neural representations) is high in entropy and information meaning that for the receiver, it resolves a high degree of uncertainty. In a related sense, a signal high in entropy can imply that, for the receiver, there is a large amount of different potential signals it could receive and the receiving signal clarifies the latent state of the sender with minimal ambiguity.

4.3.4. Altered salience

In cognitive terms, salience is often conceptualized as the relative relevance of a set of features or stimuli as determined by their intrinsic structure. As a more basic function that is generally linked to the structure of input (or at least the structure at a very low-level processing of input), it is usually taken to dictate the level of attention something shall be allocated (Parr & Friston, 2019). Altered salience can be thought of as a distortion to the standard order of relevance increasing the likelihood of noticing unusual stimuli. As tension motivates the search for novel ideas, altered salience can help looking for different stimuli and perspectives. It can direct attention away from existing, stagnant representations highlighting novel and different cues or internal models that could enable the updating of existing representations.

In predictive processing, salience is constructed as the confidence or certainty attributed to a belief or an input (Feldman & Friston, 2010). Decreasing the ‘strength’ of a belief or empowering an unusual feature can both help revising the original or developing new beliefs (Carhart-Harris & Friston, 2019). In dynamical systems terms, altered salience can be construed as “stochastic resonance” where

random fluctuations can amplify weak signals and lead the system to escaping a deep attractor (Kelso, 1995).

4.3.5. Enhanced flexibility

The third component of insight is enhanced flexibility. It can be expressed as psychological openness and vulnerability, increased plasticity (both neural and cognitive), cognitive flexibility and less rigid thought patterns. In the dynamical sense, enhanced flexibility can be conceived as a flattened attractor landscape (Carhart-Harris & Friston, 2019; Hipólito et al., 2023; Singleton et al., 2022). As the ‘energy’ requirements necessary to move from one attractor are decreased in the flattening of the landscape, explorative roaming and possibility of considering more remote associations are made easier. This can allow for testing novel and more adaptive hypotheses, increasing the likelihood of reaching a new understanding.

From a predictive processing perspective, enhanced flexibility can also constitute relaxation of so-called ‘hyperpriors’ - high-order priors which constrain cognition and perception and contain highly general and abstract beliefs about the structure of one’s experience and sensory data (e.g., Hohwy et al., 2008). This can lead to unusual perceptual experiences and altered salience of sensory input (Carhart-Harris & Friston, 2019). Relaxation of high-order priors can free the hyperpriors and also their lower-order constituents to be more amenable to change (see also fig 3B; Carhart-Harris & Friston, 2019).

4.4. Summary and implications

This contribution attempts to unify the mechanisms of insight across broad fields and move towards a framework of insight which makes it possible to bring together isolated approaches to the phenomenon.

It puts forward tension, altered salience and enhanced flexibility as primary cognitive mechanisms for insight. Furthermore, it suggests that insights can be seen as lying on a continuum of the hierarchical depth of the beliefs they affect.

We suggest the sequence of the components of this framework are not set and they generally operate in an iterative cycle. For example, a state of enhanced openness and mental exploration can lead to awareness of tension about something new or lead to a partial answer. Then another period of tension can lead to altered salience and flexibility again. Alternatively, the relaxation of ‘hyperpriors’ can also induce aberrant salience, such as during the prodromal phases of psychosis.

Crucially, this article also elaborates and explicates the findings of the first contribution in specific computational terms. Central characteristics of insight - tension, altered salience and enhanced flexibility - are described through dynamical systems theory, information theory and predictive processing approaches.

While this work predominantly employs these mathematical frameworks in a descriptive manner and offers a conceptual framework for insight, it constitutes a step towards quantitative and formal models of the phenomenon. This progression can be pursued through several avenues. One approach would be to model the dynamics of neural activity patterns directly, though this would require considerable technological and methodological advancement. A more immediately tractable route is to design experimental paradigms that measure multiple related dimensions of problem-solving, allowing for the empirical construction of state-spaces. Tasks that are more naturalistic and immersive, and that permit continuous automated measurements (e.g., skin conductance, movement), could be particularly well-suited to this purpose. Within such contexts, state-spaces and their associated dynamics could in principle be empirically characterised, although this would require substantial development of dedicated experimental designs. Network models grounded in longitudinal data (e.g., through multi-dimensional experience sampling; Briganti et al., 2024) offer another promising avenue for developing explicit dynamical models of insight. The centrality of a belief could be empirically operationalized through semantic network approaches such as free association or category fluency tasks. A more straightforward alternative is to use quantitative self-report ratings of the insight's personal relevance. This approach could be particularly practical in psychedelic and contemplative studies, where more elaborate assessment tools might interfere with the ongoing experience.

5. PSYCHEDELIC REPLICATIONS IN VIRTUAL REALITY AND THEIR POTENTIAL AS A THERAPEUTIC INSTRUMENT: AN OPEN-LABEL FEASIBILITY STUDY

5.1. Introduction

The aforementioned three components - tension, altered salience and enhanced flexibility - are all major elements of psychedelic phenomenology. The following study attempts to bring them to life in a reproducible manner using virtual reality.

5.2. Motivation

This study developed a novel methodology using virtual reality (VR) as a therapeutic tool. As the mental health crisis is looming ever-larger and existing methods used in psychiatry have limited efficacy, there is a dire need for new treatment modalities.

Using VR as a tool in cognitive science, psychology and psychiatry has been gaining ground in the last decades (Pan & Hamilton, 2018; Slater & Sanchez-Vives, 2016; Tarr & Warren, 2002). VR has many benefits in conducting various kinds of experiments. It allows the creation of immersive and interactive experiences of situations which are impossible or very difficult to create in reality (Parsons et al., 2017). This is also enhanced by recent technological advancements, which allow for increasingly complex and realistic scenarios to be modelled in virtual reality (Pan and Hamilton, 2018). Furthermore, it gives the researcher a high-degree of control over environmental factors allowing for highly standardized experimental conditions (Bohil et al., 2011).

VR-based methods are also seeing increasing use in therapy. They have been primarily used for anxiety disorders as useful tools to conduct fear exposure therapy (Freeman et al., 2017). There have been some niche attempts at employing VR against other disorders as well, such as schizophrenia, substance-related disorder, eating disorders and depression, showing promising preliminary results (Baghaei et al., 2021; Falconer et al., 2016; Freeman et al., 2017).

Recent developments suggest that it could be possible to induce mystical experiences and partially imitate the phenomenology of the psychedelic state (Glowacki et al., 2020; K. Suzuki et al., 2017). One attempt found that a specifically designed VR-experience, Isness, can lead to scores on a mystical experience questionnaire similar to moderate doses of psilocybin (Glowacki et al., 2020). Another venture developed the Hallucination Machine, using Deep Dream (a visualisation algorithm based on deep convolutional neural networks) to modify panoramic 360-degree videos to have a 'hallucinatory' quality (Suzuki et al., 2017). Hallucination Machine has been shown to induce phenomenology similar to psilocybin (Suzuki

et al., 2017). Related approaches using VR videos with DeepDream-based perceptual alterations have also been found to lead to increased neural flexibility during VR (Greco et al., 2021) and cognitive flexibility following VR (Rastelli et al., 2022). Similarly, neural activity has been found to be dynamic and flexible during the psychedelic state (Tagliazucchi et al., 2014; Lord et al., 2019) and increased cognitive flexibility has been reported post-acutely (Doss et al., 2021; Rossi et al., 2025). Given that certain features of psychedelic phenomenology are widely regarded as central to their therapeutic efficacy, the possibility of using virtual reality to recreate these features might hold valuable psychiatric benefits (Riva et al., 2026).

As reviewed in Background, recent research has indicated promising therapeutic effects for psychedelics (P. D. Harvey & Nemeroff, 2026). However, the mechanisms for these therapeutic benefits are yet to be clearly elucidated (Fonzo et al., 2025; Heifets & Olson, 2024; van Elk & Yaden, 2022). For example, the functional role of the subjective effects of psychedelics has been one of the more controversial and disputed questions in recent psychedelic science. On one hand, there is considerable evidence finding associations between subjective measures and therapeutic efficacy (Yaden & Griffiths, 2021). Scores on several questionnaires of subjective psychedelic alterations have been found correlated with long-term therapeutic benefits. For example, the intensity of insight (Kugel et al., 2025; Letheby, 2021) and mystical experiences (often measured with the Mystical Experience Questionnaire 30; MEQ30; MacLean et al., 2012; Yaden & Griffiths, 2020) are often strongly related to positive therapeutic change. On the other hand, there is some *in vitro* and preclinical evidence indicating that the therapeutic effects could be pharmacologically decoupled from the acute psychedelic effects (Olson, 2021; Rosenblat et al., 2023). As the 5-HT_{2A} receptor initiates multiple cellular pathways, it could be possible that the therapeutic and acute mind-altering effects are mediated by separate intracellular processes. Indeed, psychedelic-inspired drug development has revealed several substances which seem to have long-lasting positive consequences in animal models of various psychiatric illnesses (e.g., Cameron et al., 2021; see ‘Psychedelics’ for more). Administering strictly the subjective components of the psychedelic experience through virtual reality gives us another method to decouple the subjective and neuropharmacological mechanisms. This allows us to also investigate the therapeutic mechanisms of psychedelics and especially the role of their characteristic subjective alterations.

5.3. Main findings

This study created a novel psychedelic VR experience, Psyrrreal, and then used it in a brief 2-day therapeutic intervention to investigate its feasibility and therapeutic potential.

5.3.1. Development of Psyrreal

The quest to develop Psyrreal began with an in-depth and systematic analysis of the phenomenology of the psychedelic and related (e.g., spontaneous mystical, deep meditative and awe-inducing) experiences. Psychedelics can alter many facets of cognition and lead to a wide range of different subexperiences (Preller & Vollenweider, 2018). There are also significant idiosyncrasies between different individuals and even between different psychedelic sessions for an individual. These considerations led us to focus primarily on more salient and frequently reported psychedelic qualia, such as mystical and ego-dissolution experiences, various open-eye visual alterations and dream-like visions (Preller & Vollenweider, 2018). The experience also follows the temporal trajectory common to psychedelic experiences: an initial ramping up of intensity leading into a peak, self-transcendent experience followed by episodes of visions and reflection with milder periodic recurrences of the initial peak (Preller & Vollenweider, 2018; see also Brouwer et al., 2025). Both the intensity of the alterations as well as the ‘narrative’ intensity are also oscillatorily modulated. The majority of the visual effects were purposefully abstract and with minimal semantic content, to support the participant in projecting their own meaning to the experience.

Psyrreal contains a total of 19 distinct visual levels each lasting between 30 seconds to 2 minutes. The experience begins in a virtual ‘real world’ where the participants go through a brief introductory meditation. Mimicking the more gradual come-up phase of LSD and psilocybin, the ‘real’ environment begins to gain psychedelic qualities. The relative sizes of objects start to vacillate¹, their movements leave trails for 1-2 seconds² and their outlines gain a shifting rainbow-like colourfulness³. Colours become more intense and saturated⁴ and the colours of objects start to shift in time⁵. The alterations become increasingly apparent and, as they reach full intensity, the experience escapes the ‘real world’ into a phase of closed-eye visuals for the majority of the rest of the experience. This phase imitates the phenomenology of multiple core concepts of intense psychedelic states. Starting off with simpler two-dimensional geometrical patternings⁶ which then develop into more complex, spatial patterns akin to the ‘DMT hyperspaces’ (e.g., Cott & Rock, 2008; Wolff et al., 2019). The subsequent phases incorporate levels imitating peak mystical experiences (also sometimes referred to as ‘pure consciousness’ experiences; Richards, 2016; MacLean et al., 2012) and minimal phenomenal experiences (Gamma & Metzinger, 2021), various kinds of dream-like visions (Kraehenmann, Pokorny, Vollenweider, et al., 2017; Sanz et al., 2018), and self- and boundary-dissolution (Nour et al., 2016; Studerus et al., 2010, 2011).

¹ See for example <https://www.effectindex.com/effects/drifting?s=breathing>.

² <https://www.effectindex.com/effects/tracers>

³ <https://www.effectindex.com/effects/visual-auras>

⁴ <https://www.effectindex.com/effects/colour-enhancement>

⁵ <https://www.effectindex.com/effects/colour-shifting>

⁶ <https://www.effectindex.com/effects/geometry>

The psychedelic content of Psyrreal was also validated with a small ($n = 6$) additional study in participants with extensive prior experience with psychedelics. Five participants rated at least one scene in Psyrreal as visually very similar (4 out of 5) to their psychedelic experiences. Although the stimulus was exclusively audiovisual and involved no tactile input, six individuals nevertheless rated the bodily sensations evoked by Psyrreal as highly comparable to those typically induced by psychedelics.

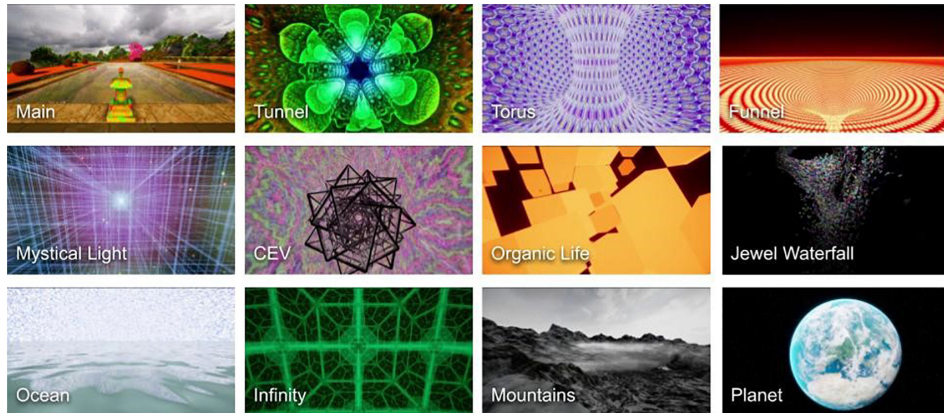


Figure 4. Screenshots of some of the environments in Psyrreal shown in sequence to exemplify the diversity of visuals presented to the user during the experience. The experience starts in a temple (top left), progresses through different levels of varying abstraction and intensity, and culminates in outer space (bottom right). See also Supplementary for more illustrations of the environments.

5.3.2. Therapeutic findings

A 2-day intervention implementing Psyrreal was found to significantly decrease depressive symptoms from $M = 15.20$ ($SD = 2.66$) at baseline to $M = 11.00$ ($SD = 3.47$) at the 2-week follow-up ($n = 10$, $p = 0.007$, Hedges' $g = 1.046$) as measured by the Emotional State Questionnaire (EST-Q2; Aluoja et al., 1999). The response rate (proportion of participants showing a decrease of at least 50% of baseline) of the treatment was 18% and remission rate (proportion of participants showing decrease to below clinical cut-off of ≥ 12) was 60%. While not the target of this study, responses on the anxiety scale of EST-Q2 also showed a similar pattern. Scores decreased from baseline $M = 10.10$ ($SD = 4.65$) to $M = 7.60$ ($SD = 4.14$) after 2 weeks ($p = 0.005$, $g = 0.459$).

5.3.3. Explorative mechanistic findings

Psychedelic subjective effects were assessed with multiple measures commonly used in psychedelic science. Insightfulness of the experience was measured with the Psychological Insight Questionnaire (PIQ; Davis et al., 2021). The degree of how mystical the experience is was evaluated with the Revised Mystical Ex-

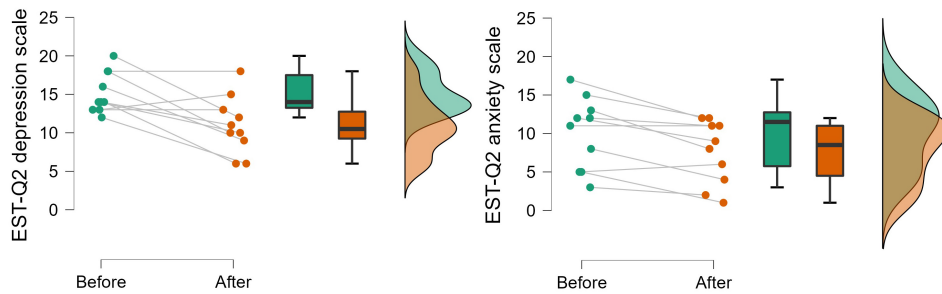


Figure 5. A raincloud plot of the EST-Q2 depression scale (A) and anxiety scale (B) scores as measured before the experiment and two weeks after. Depicted are individual scores, as well as boxplots and density distributions of the results (N = 11).

perience Questionnaire (MEQ30; MacLean et al., 2012). The degree of ego-dissolution was measured with the Ego-Dissolution Inventory (EDI; Nour et al., 2016). The scores on these measures were compared against a brief introductory session in virtual reality where participants were in a virtual living room for 5 minutes on the first day of the intervention. None of the measures showed significant change. However, two participants showed a large increase (>25 points) in EDI scores and one participant reported a complete mystical experience (all MEQ30 subscales over 60) on day two. Although another participant reported a complete mystical experience on the first day.

5.3.4. Qualitative findings

The participants also underwent a semi-structured interview about their experience with a clinical psychologist. These interviews were transcribed (with authorization from the participants) and thematically analyzed. All participants reported feeling some positive emotions during the experience. Over half (55%) of the participants reported calmness or peace and the same amount reported joy, pleasure or fun. 45% of the participants reported personally relevant thoughts during the experience, with five reporting changes in perspective: *“Like a shift in perspective - in the beginning, I was looking more at the details, afterward I was looking at the whole,”*. Three participants arrived at new insights, also highlighting a physical sense of insight: *“It was a different kind of insight, like a new insight. Like a physical insight,”*. Six participants experienced alterations in their sense of self, for example: *“[...] this novel understanding that I can reprogram myself, that this essence of myself doesn’t exist—it’s very liberating. It gives me, in some sense, a vitality that I’m looking for,”*.

5.4. Summary and implications

This study presents Psyrréal, a novel virtual reality experience that replicates many aspects of the psychedelic state. Psyrréal was used in a brief open-label ther-

apeutic intervention and was found to provide significant relief against depressive symptoms two weeks later. This work offers a novel way for using virtual reality in therapeutic contexts as well as in scientific research. It also advances our understanding of psychedelic phenomenology by creating detailed 3D audiovisual models of psychedelic alterations.

As this was an early-phase feasibility study there are important limitations to be considered. The small sample size and lack of a proper control condition limit the generalizability of these results. But the strong effect sizes, results of the thematic analysis and positive participant feedback suggest that more rigorous studies are warranted. A follow-up, double-blind, randomized and controlled study that utilizes Psyrreal in a more realistic clinical setting is also currently ongoing. For that, we have developed a specific, and adaptable general VR control condition, Routine Realms. Essentially it consists of a set of realistic VR environments (e.g., a living room, an office, a supermarket). Such a control condition allows us to investigate the ‘psychedelic content’ and not other factors intrinsic to VR.

While our explorative investigations did not reveal compelling evidence for specific therapeutic mechanisms of psychedelic virtual reality. Though the measures of subjective effects did not yield significant results, the high interindividual variance in responses and thematic analysis suggest that there could exist a subset of people who might be more susceptible to the mind-altering or therapeutic effects of psychedelic virtual reality. Larger samples could provide a better assessment of the function of these mechanisms. Furthermore, other constructs, such as awe (Yaden et al., 2019) or emotional breakthrough (Roseman et al., 2019) used in evaluating the therapeutic mechanisms of psychedelics could also prove fruitful to investigate. Virtual reality itself could have some psychedelic qualities. For example, the lack of or an altered self-avatar could lead to alterations in self-related processing (see for example the use of the virtual rubber hand illusion in treating phantom limb pain; e.g., Thøgersen et al., 2020). Experiencing a virtual world could lead to some affective and cognitive effects (e.g., awe, restructuring or an altered sense of reality) which might also occur in psychedelic states (Hendricks, 2018).

Although the PIQ showed no significant group-level effect, the observed therapeutic benefits together with qualitative reports of insight suggest that Psyrreal could serve as a tool for investigating insight more directly. In a pilot study with creative individuals working on a personally significant problem, Psyrreal outperformed a matched control condition (Routine Realms) in facilitating resolution of their creative troubles (Siimon et al., 2023). Larger studies in creative populations and studies employing established insight problems, could be a useful direction for future research and help develop psychedelic virtual reality into a more reliable method for inducing insight.

6. CELLULAR MECHANISMS OF SEROTONERGIC PSYCHEDELICS - APICAL HYPERCONTEXTUALISATION

6.1. Introduction

So far, we've seen how insight is a core process of human cognition relevant for a broad set of scientific disciplines. Moreover, the previous contribution suggests that there could be something about the consciously experienced part of the effects of psychedelics in mediating deep transformations. Therefore we will now investigate the acute psychedelic effects in order to gain a deeper look into the mechanisms of insight.

We review electrophysiological and cognitive findings regarding serotonergic psychedelics to arrive at a computational principle that underlines how psychedelics affect neural processing and encoding of 'contents of consciousness'. This principle - apical hypercontextualisation - allows us also to further understand the nature of profound and deep insights.

6.2. Motivation

The primary pharmacological target of psychedelics - the 5-HT_{2A} receptor - is most abundantly expressed on cortical layer V pyramidal neurons and their apical dendrites (Chiu et al., 2023; Weber & Andrade, 2010). However, existing approaches and theories rarely incorporate the role of the apical dendrites. This contribution reviews the cellular anatomy of the 5-HT_{2A} receptor, the dendritic electrophysiological studies on psychedelics and integrates them with the current understanding of the apical dendrites of the layer V pyramidal neurons. Beyond providing detailed review about the effects of psychedelics from various perspectives, it also proposes a mechanistic framework to explain the action of psychedelics from a dendritic lens.

Emerging research into the cognitive, psychological and phenomenological effects of psychedelics is also starting to converge on the idea that their effects could be underlined by enhanced contextual modulation (Aqil et al., 2025; Michael et al., 2019; Schallmo et al., 2025; Swanson, 2024; Swanson et al., 2024). Many psychedelic effects, especially the visual effects (see Aqil & Roseman, 2022), have been suggested to be best described by alterations in contextual processing as opposed to direct object or feature processing (Swanson, 2024). Here we also provide a brief overview of cognitive, psychological and neural effects of psychedelics indicating how they are likely to arise from hypercontextualisation.

6.3. Main ideas

While human and primate data on the localization of the 5-HT_{2A} receptor is rather limited (but do see Mengod et al., 2015), there is considerable existing research in rodents. Broadly speaking, 5-HT_{2A} receptors can be found in many regions of the brain (both cortical and subcortical), in various types of cells (in pyramidal- and interneurons) and in different cortical lamina. However, modern studies have revealed the 5-HT_{2A} receptor to primarily inhabit the cortex with an especially prominent presence in postsynaptic regions of layer V pyramidal neurons (Fig 1A; Chiu et al., 2023; Jensen et al., 2020; Weber & Andrade, 2010; see also Xu & Pandey, 2000). On these cells, the 5-HT_{2A} receptors have been mainly found perched on the apical dendrites (Chiu et al., 2023; Jakab & Goldman-Rakic, 1998; Miner et al., 2003; Willins et al., 1997; T. Xu & Pandey, 2000). However, they are likely to also occupy oblique and basal dendrites (Chiu et al., 2023; Jakab & Goldman-Rakic, 1998; Willins et al., 1997; however, see Weber & Andrade, 2010), but this has been difficult to confirm due to technical limitations.

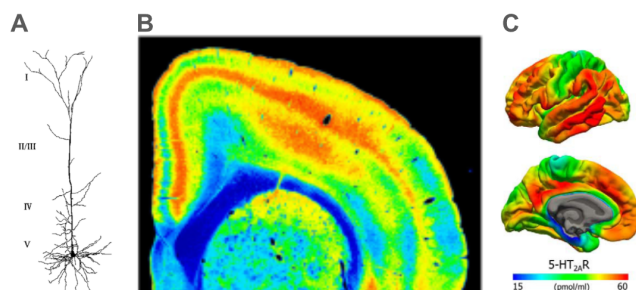


Figure 6. Layer V pyramidal neurons and the localization of the 5-HT_{2A} receptor. (A) The general morphology of a layer V pyramidal neuron. (B) The primary localization of the 5-HT_{2A} receptor in the rodent brain is within layer V pyramidal neurons and also their apical dendrites (Chiu et al., 2023; Weber & Andrade, 2010). (C) The cortical localization of the 5-HT_{2A} receptor within the human brain (Beliveau et al., 2017).

Our review converges on two central mechanisms of psychedelic action. **Mechanism 1: Psychedelics increase the sensitivity of the apical compartment in a subset of extratelencephalic (ET) layer V pyramidal neurons.** The primary cell type affected by psychedelics seems to be ET layer V pyramidal neurons which project outside of the cortex (González-Maeso et al., 2007; Martin & Nichols, 2016; Muir et al., 2024; Schmitz et al., 2025; Shao et al., 2025). Increased amplitude of evoked EPSCs/EPSPs (Aghajanian & Marek, 1997; Zhai et al., 2003) and calcium signaling within apical dendrites of ET layer V pyramidal neurons (Shao et al., 2025) suggest that apical signals could be amplified in these cells. **Mechanism 2: Psychedelics increase thalamocortical glutamatergic signals through presynaptic 5-HT_{2A} receptors.** Even though most 5-HT_{2A} receptors are cortical and postsynaptic, one of the clearest electrophysiological findings of psychedelic action seems to actually be presynaptically-driven 5-HT_{2A}-receptor-dependent

increase in apical glutamate levels (Aghajanian, 2009; Hidalgo Jiménez et al., 2025; Lambe & Aghajanian, 2007; Marek, 2017; Marek & Schoepp, 2021). These mechanisms suggest that the effect of psychedelics is mainly situated in the apical thalamocortical loop.

Pinpointing the effect of psychedelics at the apical thalamocortical loop also indicates the relevance of contextual processing (Larkum, 2013; Phillips et al., 2025). Indeed, a considerable range of evidence suggests the apical compartment to be responsible for contextual processing. For example, the apical compartment of layer V pyramidal neurons has highly branched structure receiving input from both nearby and distant cortical (Cauller et al., 1998) as well as subcortical regions (Roth et al., 2016; Rubio-Garrido et al., 2009). This broadly distributed input has been suggested to provide context for active processing (Aru et al., 2020; Bachmann et al., 2020; Larkum, 2013; Phillips, 2023; Phillips et al., 2018; Spratling, 2002). Furthermore, apical calcium signals have been found to be linked with context (Takahashi et al., 2020). Conditioned response learning (Benezra et al., 2024; Godenzini et al., 2022) and cross-modal integration (N. Xu et al., 2012) have also been linked with apical activity.

This prompts us to suggest that an important general mechanism for serotonergic psychedelics is *increased contextualisation of internal representations* via activity at the 5-HT_{2A} receptor. This is in alignment with psychedelics leading to a more relational and associative processing (intercolumnar, -cortical and corticocortical; Muckli et al., 2015; Roth et al., 2016; for a recent review see Huang et al., 2024) and disrupting direct object/stimulus/feature processing (intracolumnar; see also Aru et al., 2020). Equivalently, the action of psychedelics could also be conceptualized as altering the *boundaries between representations* (see Aghajanian, 2009; Bayne & Carter, 2018).

Furthermore, many cognitive, psychological and phenomenological effects of psychedelics are also best generalized by amplified contextualisation. The contribution provides an in-depth overview of how many common effects of psychedelics are best described via enhanced contextualisation. Emerging evidence is starting to directly show how the visual perceptual effects of psychedelics are reliant on ‘surround effects’ (Aqil et al., 2025; Swanson, 2024; Swanson et al., 2024; Vemola et al., 2025; Michael et al., 2019). For example, a recent study found that psilocybin dose-dependently enhances the Ebbinghaus illusion, a context-dependent perceptual effect (Aqil et al., 2025). In general, psychedelics do not alter perceptual stimuli directly, but rather the relations between objects and features. At high doses it might seem that individual stimuli are directly affected, however, we suggest that this could be caused by hierarchical dose-dependence (i.e., increasingly ‘minute’ relations are dose-dependently affected). Neuroimaging studies have also found increasingly global processing across the cortex following psychedelic administration. Broad increases in between-network functional connectivity (e.g., Barrett et al., 2020; Carhart-Harris, Muthukumaraswamy, et al., 2016; Luppi et al., 2021; Madsen et al., 2021; N. L. Mason et al., 2021;

Müller et al., 2018; Roseman et al., 2014; Tagliazucchi et al., 2016) and increased global functional connectivity (Erritzoe et al., 2024; Linguiti et al., 2023) are robustly reported during psychedelic states. A range of animal studies also indicates that the 5-HT_{2A} receptor is specifically responsible for associative and conditioned learning (Barre et al., 2016; J. A. Harvey, 2003; J. A. Harvey et al., 1988; see also Caulfield et al., 2025), and cross-modal plasticity (e.g., Jitsuki et al., 2011; Lombaert et al., 2018) further supporting hypercontextualisation.

6.4. Summary and implications

This contribution provides a comprehensive overview of the cellular anatomy and dendritic electrophysiology related to serotonergic psychedelics. The review suggests that the effect of psychedelic substances is likely to be strongly underlined by the function and activity of the apical compartment. Moreover, the theory posits thalamocortical connectivity as vital in psychedelic action clarifying the role of the thalamus.

Serotonergic psychedelics target anatomically and functionally the apical compartment, which has been found to be linked with contextual processing (e.g., Phillips et al., 2025; Phillips, 2023). Based on this we propose apical hypercontextualisation as a framework of psychedelic action in alignment with emerging proposals of amplified contextual modulation as a general mechanism of psychedelics (e.g., Swanson, 2024; Aqil et al., 2025). In its essence, apical hypercontextualisation suggests that by their primary activity at apical dendrites of extratelencephalic layer V pyramidal neurons, psychedelics lead to hyperamplified contextual processing. We further review a broad range of psychedelic studies indicating how crucial findings in neuroimaging, cognitive and psychological provide support for this general mechanism (see also Swanson, 2024).

Apical hypercontextualisation complements existing frameworks of psychedelics by providing a cellular and anatomical description of their activity. It shares common ground with RELaxed/ALtered Beliefs Under pSychedelics (REBUS/ALBUS) in suggesting that psychedelic-induced changes in mental representations arise through a form of relaxation (Carhart-Harris & Friston, 2019; Safron et al., 2025), though we emphasize relaxation of contextual factors rather than higher-order priors, with dose-dependence reflecting the hierarchical complexity of affected representations rather than prior strength. The framework further aligns with REBUS in highlighting the main relevance of associative regions such as the default mode network and hippocampal/parahippocampal areas (Carhart-Harris & Friston, 2019), which may exhibit pronounced psychedelic effects as a consequence of higher 5-HT_{2A} receptor distribution. Our proposal also connects to the cortico-striato-thalamo-cortical (CSTC) model through its shared emphasis on thalamo-cortical circuits, while offering a complementary cellular-level account centred on dendritic compartments and altered contextual processing rather than network connectivity (Vollenweider & Smallridge, 2022). In this sense, apical hypercon-

textualisation can be viewed as providing a physical and mechanistic substrate that can be integrated with many existing circuit-level and computational theories of psychedelic action (Carhart-Harris & Friston, 2019; Vollenweider & Smallridge, 2022; see also Corlett et al., 2019; Doss et al., 2022).

We suggest that apical hypercontextualisation is a neural mechanism for insight. In essence, the enhanced contextual and relational processing allows communication between internal representations and can lead to their restructuring. Usually, cortical representations are isolated from one another. Attentional bandwidth, columnar segregation and hierarchical ordering all limit how freely representations can interact. Contextual signals from distant cortical regions and higher-order thalamic nuclei arrive at the apical compartment. By amplifying apical activity, psychedelic 5-HT_{2A} agonism lowers the threshold for contextual signals to modulate local activity. Representations that would otherwise remain segregated are brought into informational contact, their usual boundaries start to disintegrate. Associations that are normally suppressed gain the opportunity to shape processing. This opens a cellular route to the restructuring at the heart of insight - new relations can form, old structures can reorganise, and the result can settle into a more coherent whole.

The framework of apical hypercontextualisation builds on the dynamical systems account of insight proposed in contribution II, grounding its key components: tension, altered salience and enhanced flexibility. Psychedelics often induce challenging and tense experiences, and bringing awareness to this tension can at times be supportive of insight (e.g., Carbonaro et al., 2016). Altered salience arises from increased sensitivity to associative signals that would normally remain below threshold, while enhanced flexibility follows from the amplified global processing and the reduced precision of the mental representations that constitute the 'normal' state of consciousness. In dynamical terms, these map onto a destabilisation of existing attractors, a shifted pattern of salience and a flattening of the attractor landscape - all hallmarks commonly linked to psychedelic states (e.g., Erritzoe et al., 2024; Tagliazucchi et al., 2014).

7. DISCUSSION

This thesis has examined the phenomenon of insight from a broad range of perspectives to develop a better understanding of the phenomenon in terms of neural computations. The first contribution reviewed research into insight in multiple fields and highlighted how insight is a core process of cognition. The second contribution distilled the results of the review into a novel mechanistic framework of insight and grounded them in various computational approaches. The third contribution created a psychedelic virtual reality experience in order to induce the mechanisms necessary for insight and positive therapeutic change. The fourth contribution offered a novel perspective on the neural computations underlying the psychedelic state while also providing a glimpse into the neural mechanisms underlying radical mental transformations.

In the second contribution, we relied on attractor dynamics to describe insight. When using attractor dynamics to describe insight, there is a tendency to construct insight as a phase transition - a system moves from one region of the phase space to another region which denotes a different qualitative behaviour of the system (e.g., Reed & Vallacher, 2020; Stephen, Dixon, et al., 2009). In other words, a system leaves its first attracting region for another region, where it shall stably abide in until another insight, or some other gradual process, shifts it somewhere else. However, it might be preferable to conceptualize that upon insight, the phase space instead goes through a bifurcation (Kelso, 1995). Not only does the position of the system change, but the whole structure of phases within the phase space can change from insight. So that after the insightful shake-up of its phase space the system leaves a certain stable trajectory and proceeds to travel on a different trajectory. After a positive insight, for example, the trajectory could become more extensive and the system able to explore a larger portion of its phase space. Or it might learn to avoid some regions representing less adaptive and narrower repertoire of states of mind.

In essence the apical hypercontextualisation framework aligns the phenomenon of insight with fact-free learning, model reduction, optimization and increased coherence between representations (Aragones et al., 2005; Friston et al., 2017). This also aligns with the fluency account of insight which describes insight as leading to increased processing fluency (Topolinski and Reber, 2010; Skaar and Reber, 2020). More fluent mental processing and a sense of ease could be a corollary of more optimized and coherent mental representation. Describing insight through coherence and optimization also comes with implications related to its epistemic profile. These views emphasize that insights (at least ones induced by psychedelics) shift a representation to fit more snugly with other parts of the mental domain. While this usually leads to accurate solutions and can induce a feeling of truthfulness and certainty, its actual correspondence depends on the quality of other pieces of knowledge. This implies two important epistemic claims regarding psychedelic insights. Firstly, it is vital to validate the content of any insight

- the feeling of truthfulness it comes with is only an indicator of its relationship with other internal knowledge structures. This emphasizes the importance of integration and subsequent analysis and validation of an insight (psychedelic or otherwise), and supports a careful disposition towards them (Timmermann et al., 2020). And secondly, the more knowledge one has on a certain topic, the less likely one is to experience a ‘false’ insight. This would suggest that preparation and effort spent on a topic can make beneficial and useful insights more likely to arise from a psychedelic session.

Relatedly, apical hypercontextualisation and aspects of the second contribution could also indicate that insight can arise from shifts in the modularity of representational structure. Using the example of psychedelics, they could make brain activity more ‘shallow’ (M. Suzuki et al., 2023) by disrupting the usual hierarchical structure and emphasizing ‘lateral’ processing whereby relational processing comes to the fore (Girn et al., 2022; see also Carhart-Harris and Friston, 2019). As the usual hierarchical and modular constraints are disintegrated, processing can occur in a more associative and integrative mode through unconstrained shifting between different hierarchical or modular degrees. This could support the restructuring associated with insight (Carhart-Harris and Friston, 2019).

Apical hypercontextualisation allows us to make another generalization regarding insight - it requires a representational domain exceeding the content of insight. It requires other representations which allow for information exchange, relational processing, comparison and collective optimization. In this sense, insight is a consequence of attentional mechanisms and of representational resource limitations (see also Ohlsson, 2009). As learning the patterns of sensory data is always bottlenecked by attention, there is a need for subsequent reanalysis and reevaluation of the learned patterns to fit with the rest of the knowledge structure. This could be an important function of insight. As proposed in contribution IV, psychedelics could specifically support this process through hypercontextualisation - by increased information processing between different representations.

Psychedelics are commonly said to lead to an altered state of consciousness (ASC). However, this wording might be potentially misleading in a technical sense. While one could consider the psychedelic state to be a specific state of altered contents of consciousness, the term ‘state of consciousness’ is generally used to distinguish between a state of wakefulness from a state of unconsciousness. It is technically more precise and preferable to retain the term ‘state of consciousness’ to denote the binary characteristic of whether there is phenomenal consciousness or not. One could extend the term ‘state of consciousness’ to also contain anesthetized, vegetative, minimally conscious and comatose states (see also Bayne and Hohwy, 2016). However, these seem to differ from states of wakefulness and unconsciousness primarily by the contents of consciousness or various measures of verbal or motoric responsiveness, not by any kind of change in the state of phenomenal consciousness. In this vein, it is preferable to conceptualize psychedelics as not really altering one’s state of consciousness, but

rather primarily affecting the contents of consciousness (see also Bayne et al., 2016). With this being said, some psychedelic effects (e.g., mood, arousal, clarity) might not be clearly captured as alterations of content, but rather seem to be related to state-level phenomena. Such ‘states’, however, are content-dependent (i.e., they denote a higher-order structure of contents of consciousness) and for clarity’s sake, might require a distinct term such as a ‘phase of consciousness’.

Psychedelics induce these effects on contents of consciousness primarily by targeting the 5-HT_{2A} receptors which are eminently located on layer V pyramidal neurons (Nichols, 2016). Taken together, these constitute evidence of a significant role for layer V pyramidal neurons in consciousness and especially ‘contents of consciousness’ (e.g., Aru et al., 2019). This also suggests that researching the effect of 5-HT_{2A} receptor activity, subsequent intracellular processing and psychedelic agonism more generally can provide vital insights into the cellular and neural mechanisms of consciousness (e.g., Yaden et al., 2021).

Similarly to how psychedelic neuroplasticity (Jiang et al., 2026) and their direct neural effects are modulatory (Hidalgo Jiménez et al., 2025), this work suggests modulation to be a more general property of psychedelics also applicable to the psychological and cognitive levels. This implies, in alignment with various psychedelic traditions, that in order to reap the insightful benefits of psychedelics, preparation, priming and prior effort is vital. Setting clear intentions for the psychedelic experience, having a question and trying to frame it as clearly as possible beforehand could also make it more likely for the psychedelic experience to induce insight into the intended issues. Similar aspects are also considered to increase the likelihood of psychotherapeutic insight (contribution II; Timulak and McElvaney, 2013). Attempts to solve the question or represent it in different ways beforehand could also support the incidence of a related insight (Hayes et al., 2007). Furthermore, more embodied and multi-modal preparative approaches or activities during the acute psychedelic experience (e.g., ritual ceremonies) could also be utilized to direct or amplify the long-term consequences (e.g., Laird et al., 2026). In essence, the more modalities of cognition that can be concurrently utilized both in preparation or during the acute phase, the more effective the priming. This is also inferred by the continuum hypothesis proposed in contribution II. As more aspects and different perspectives are brought to bear upon the question, this could increase the likelihood of transformative insight related to the intended question.

Apical hypercontextualisation and the modulatory nature of psychedelic effects can be further leveraged to explain their strong dependence on ‘set and setting’. The effects of psychedelic substances are especially sensitive to environmental (i.e., physical and sociocultural ‘setting’) and psychological (i.e., prior experiences and proximate mindset) factors. In a sense, this might be counter-intuitive, as psychedelics seem to lead to dose-dependent disengagement with the external environment (e.g., Hirschfeld and Schmidt, 2021; see also Mediano et al., 2024). However, apical hypercontextualisation suggests that the effect of

psychedelics targets relationships between internal representations. Psychedelics do not enhance external sensory information, but can rather boost the associations of the impression it makes. In other words, they can affect the relationships of an internal representation after it has been activated by corresponding sensory activity. This is highlighted by psychedelics increasing suggestibility (Carhart-Harris et al., 2015) towards views that are similar to one's own, but not towards dissimilar views (Duerler et al., 2020; Preller, Schilbach, et al., 2019). Similarly, psychedelics increase neural activity linked with familiar stimuli, but decrease it when presented with novel stimuli (Timmermann et al., 2018; see also Horrocks et al., 2025). This boost can also extend to various aspects of the mindset, such as recent experiences, thoughts and feelings if they are activated. In essence, the strong influence of set and setting arises from psychedelics amplifying the associations of a representation - whatever is currently salient in one's mind or surroundings will shape the trajectory of the experience.

An important implication of this thesis is to narrow down the possibility of neural computational mechanisms which are affected by psychedelics. Basic point-neuron models might not contain the relevant level of detail to model and explain how neural processing is affected by psychedelics. To diligently capture their effects in computational models it could be necessary to use dual compartmental models or even more complex neuronal models. Dual-compartment models could yield considerable benefit for modelling psychedelic-affected brain circuits for a minimal increase in computational cost compared to point-neuron models. Dual-compartment models have two functionally distinct dendritic sections. This allows for two separate flows of input which can then be integrated in a single cell. This mechanism has been proposed as important for combining top-down and bottom-up information (e.g., Aru et al., 2019; Pastorelli et al., 2025; Phillips et al., 2018) which is also prominently thought to be affected by psychedelics (Kwan et al., 2022).

If the neural mechanisms of psychedelic activity, which are likely to induce insight, are anything to go by, it is likely that the thalamus and other subcortical regions are relevant for insight. This is in alignment with emerging evidence on the neural correlates of insight which are increasingly finding activity in the regions like the thalamus, hippocampus and amygdala related to insight experiences (e.g., Shen et al., 2018; Tik et al., 2018). Cognitive functions can be seen in much simpler organisms, which might lack not even just the cortex, but even the nervous system itself (Baluška & Levin, 2016; P. Lyon et al., 2021). Thereby the complex form of insight in humans and primates could have differentiated from a more basic form already evident in simpler life forms. This could imply that there could be relevant correlates at biochemical or biophysical levels (e.g., proteins and messengers related to structural plasticity or intracellular reorganization) to the processes underlying insight (Salvi and Bowden, 2023).

Furthermore, this work suggests that utilizing divisive normalization models in describing or modeling neural populations during psychedelic administration

could be useful (see also Swanson et al., 2024; Aqil et al., 2025). Divisive normalization is a mathematical modelling approach of neuronal firing where the activity of a single neuron (or neural population) adapts to the activity of neurons responsible for encoding adjacent parts of the receptive field (Carandini & Heeger, 2012). It was first used to explain activity in the visual cortex, but has since been adapted to the brain more broadly and has even been suggested to be a highly general form of neural computation (Carandini & Heeger, 2011). Based on the prominent contextual effects of psychedelics, normalization could be a type of neural computation especially susceptible to these compounds.

There is plenty of room for future research on these topics. Research into insight could benefit from increasingly interdisciplinary approaches. For example, investigating the effect of meditation or psychedelic administration on insight problem solving (e.g., Ren et al., 2012) or measuring the suddenness of psychotherapeutic, psychedelic and meditative insights. Empirical testing of the continuum hypothesis of insight also constitutes an important future goal. Using the proposed insight and apical hypercontextualisation frameworks in further conjunction with mathematical approaches could help develop more quantitative approaches. For example, on the subjective axis, felt intensity and personal relevance could be useful quantitative measurements. The objective dimension could benefit from using multiple tasks with varying difficulty or using the psychedelic state as a proxy. Linking metrics of brain activity globalization (e.g., global functional connectivity or between-network functional connectivity) to ratings or questionnaires of insight (e.g., PIS and PIQ). Developing novel tools for assessing psychedelic phenomenology which have better temporal resolution and take into account the idiosyncrasies of the psychedelic state can be vital for future research (Kase et al., 2026).

Another important line of research is to conduct further research into psychedelic virtual reality and its use in therapy. Our research provides a first step in understanding the potential utility of psychedelic virtual reality. Studies with a larger sample size, a suitable control condition and a more realistic therapeutic implementation (i.e., in a clinic as opposed to a laboratory) can provide important progress. We are currently conducting one such follow-up study¹. Moreover, ongoing advancements in virtual reality technologies enable increasingly precise and detailed replications of psychedelic experiences. Although Psyrrreal incorporates many of the complex audiovisual features characteristic of psychedelic states, there remain several avenues for substantial improvement. For instance, hallucinations could be coded to respect the perspectival compositionality of the scene, rather than being overlaid uniformly across the visual field as some effects are currently implemented. For ease and robustness of use, our current version employs simple body avatars; however, higher-quality cameras combined with advanced visual processing models could enable seamless integration of avatars

¹<https://clinicaltrials.gov/study/NCT06174285>

with the user's real body. This improvement would also enhance interactivity, which could be further boosted by gaze-tracking and gamified scenarios (Vasser & Aru, 2020). Moreover, higher-quality cameras also support the incorporation of augmented reality features.

At this stage, many aspects of the hypercontextualisation framework are rather speculative or based on a small number of poorly-powered studies. There are many experimental approaches that can be taken to evaluate the framework. The most straightforward approach is to conduct psychophysical research on contextual processing during the psychedelic state in humans (e.g., Swanson et al., 2024; Schallmo et al., 2025; Aqil et al., 2025). This can allow us to directly link psychedelic agonism with alterations in contextual modulation. Using other experimental paradigms of contextual processing could also help in elucidating psychedelic effects. Contextual disambiguation, selective attention, Gestalt grouping, associative learning, priming effects as well as context-based illusions could be promising paradigms for future psychedelic research (Family et al., 2016; Phillips et al., 2015; Swanson, 2024).

There is a necessity for more direct empirical research regarding the functionality of psychedelics relative to various dendritic compartments. There are many important lines of research. One of the more obvious ones would be to investigate the occurrence and effect of 5-HT_{2A} receptors on the basal compartment of layer V pyramidal neurons. While technically even more challenging, it could also be beneficial to localize the 5-HT_{2A} receptors more precisely on the apical compartment (e.g., on the tuft, the oblique dendrites or on the trunk) and investigate the effect of variously localized 5-HT_{2A} receptors. Furthermore, it could be beneficial to decouple the effect of outer plasma membrane receptors from functionally active intracellular receptors and the effect of the intracellular receptors on affecting incoming dendritic input (especially from the apical compartment; see for example Vargas et al., 2023). Understanding the precise role of the thalamus and its nuclei in psychedelic activity is also important to address in more detail (Avram et al., 2022; Delli Pizzi et al., 2023; Inserra et al., 2021). And while this may be ethically and methodologically complicated, there is also much room to progress from animal models into more specific human data regarding psychedelic neural electrophysiology. The use of high-resolution neuroimaging tools such as high-density EEG (e.g., Farnes et al., 2020; Ip et al., 2026) and laminar fMRI (Lawrence et al., 2019), dense longitudinal neuroimaging (e.g., Vinci-Booher et al., 2025), and human cortical slices (e.g., Cohen et al., 2002; Schwarz et al., 2019) and induced pluripotent stem cells (Eiraku et al., 2008) for electrophysiological research can be especially promising future directions.

8. CONCLUSION

Insight is a complex and fundamental process of human cognition underlying both radical and mundane mental changes. We have made a step towards a unification of insights of varying intensity and conceptualizations of insight in secluded fields of research. By looking at the neural and computational mechanisms related to the psychedelic state we have also progressed our understanding of transformative insights.

The way to insight lies in confronting the conflicts between the contents of our mind, opening ourselves to feel the tension and allowing it to unfold. This opens up streams between one's mental representations, letting them reach out and communicate with one another. Ultimately, insights serve to optimize the mental domain, helping us progress towards greater coherence, unison and harmony.

BIBLIOGRAPHY

1. Aghajanian, G. K. (2009). Modeling “psychosis” in vitro by inducing disordered neuronal network activity in cortical brain slices. *Psychopharmacology*, 206(4), 575–585. <https://doi.org/10.1007/s00213-009-1484-9>
2. Aghajanian, G. K., & Marek, G. J. (1997). Serotonin Induces Excitatory Postsynaptic Potentials in Apical Dendrites of Neocortical Pyramidal Cells. *Neuropharmacology*, 36(4), 589–599. [https://doi.org/10.1016/S0028-3908\(97\)00051-8](https://doi.org/10.1016/S0028-3908(97)00051-8)
3. Agrawal, R., Gillie, D., Mungenast, A., Chytil, M., Engel, S., Wu, M. C., Rasmussen, K., Salinas, E., & Olson, D. E. (2025). Zalsupindole is a Nondissociative, Nonhallucinogenic Neuroplastogen with Therapeutic Effects Comparable to Ketamine and Psychedelics. *ACS Chemical Neuroscience*, 16(22), 4388–4399. <https://doi.org/10.1021/acscchemneuro.5c00667>
4. Aluoja, A., Shlik, J., Vasar, V., Luuk, K., & Leinsalu, M. (1999). Development and psychometric properties of the Emotional State Questionnaire, a self-report questionnaire for depression and anxiety. *Nordic Journal of Psychiatry*. <https://doi.org/10.1080/080394899427692>
5. Anālayo. (2010). *The Dynamics of Theravāda Insight Meditation*. Dharma Drum Journal of Buddhist Studies.
6. Aqil, M., de Hollander, G., Vreugdenhil, N., Knapen, T., & Dumoulin, S. O. (2025). Psilocybin alters visual contextual computations. *Nature Communications*, 16(1), 10271. <https://doi.org/10.1038/s41467-025-65150-y>
7. Aqil, M., & Roseman, L. (2022). More than meets the eye: The role of sensory dimensions in psychedelic brain dynamics, experience, and therapeutics. *Neuropharmacology*. <https://doi.org/10.1016/j.neuropharm.2022.109300>
8. Aragones, E., Gilboa, I., Postlewaite, A., & Schmeidler, D. (2005). Fact-Free Learning. *American Economic Review*, 95(5), 1355–1368. <https://doi.org/10.1257/000282805775014308>
9. Arieti, S. (1955). Interpretation of schizophrenia (pp. xviii, 522). Robert Brunner.
10. Aru, J., Suzuki, M., & Larkum, M. E. (2020). Cellular Mechanisms of Conscious Processing. *Trends in Cognitive Sciences*, 24(10), 814–825. <https://doi.org/10.1016/j.tics.2020.07.006>
11. Aru, J., Suzuki, M., Rutiku, R., Larkum, M. E., & Bachmann, T. (2019). Coupling the State and Contents of Consciousness. *Frontiers in Systems Neuroscience*, 13, 43. <https://doi.org/10.3389/fnsys.2019.00043>

12. Avram, M., Fortea, L., Wollner, L., Coenen, R., Korda, A., Rogg, H., Holze, F., Vizeli, P., Ley, L., Radua, J., Müller, F., Liechti, M. E., & Borgwardt, S. (2025). Large-scale brain connectivity changes following the administration of lysergic acid diethylamide, d-amphetamine, and 3,4-methylenedioxyamphetamine. *Molecular Psychiatry*, 30(4), 1297–1307. <https://doi.org/10.1038/s41380-024-02734-y>
13. Avram, M., Müller, F., Rogg, H., Korda, A., Andreou, C., Holze, F., Vizeli, P., Ley, L., Liechti, M. E., & Borgwardt, S. (2022). Characterizing Thalamo-cortical (Dys)connectivity Following D-Amphetamine, LSD, and MDMA Administration. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, 7(9), 885–894. <https://doi.org/10.1016/j.bpsc.2022.04.003>
14. Bachmann, T., Suzuki, M., & Aru, J. (2020). Dendritic integration theory: A thalamo-cortical theory of state and content of consciousness. *Philosophy and the Mind Sciences*, 1(II). <https://doi.org/10.33735/phimisci.2020.II.52>
15. Baggott, M. (2015). Psychedelics and creativity: A review of the quantitative literature. <https://doi.org/10.7287/peerj.preprints.1202>
16. Baggott, M. J., Garrison, K. J., Coyle, J. R., Galloway, G. P., Barnes, A. J., Huestis, M. A., & Mendelson, J. E. (2019). Effects of the Psychedelic Amphetamine MDA (3,4-Methylenedioxyamphetamine) in Healthy Volunteers. *Journal of Psychoactive Drugs*, 51(2), 108–117. <https://doi.org/10.1080/02791072.2019.1593560>
17. Baghaei, N., Chitale, V., Hlasnik, A., Stemmet, L., Liang, H. N., & Porter, R. (2021). Virtual reality for supporting the treatment of depression and anxiety: Scoping review. *JMIR Mental Health*. <https://doi.org/10.2196/29681>
18. Baluška, F., & Levin, M. (2016). On Having No Head: Cognition throughout Biological Systems. *Frontiers in Psychology*, 7. <https://doi.org/10.3389/fpsyg.2016.00902>
19. Barre, A., Berthoux, C., De Bundel, D., Valjent, E., Bockaert, J., Marin, P., & Bécamel, C. (2016). Presynaptic serotonin 2A receptors modulate thalamocortical plasticity and associative learning. *Proceedings of the National Academy of Sciences*, 113(10). <https://doi.org/10.1073/pnas.1525586113>
20. Barrett, F. S., Doss, M. K., Sepeda, N. D., Pekar, J. J., & Griffiths, R. R. (2020). Emotions and brain function are altered up to one month after a single high dose of psilocybin. *Scientific Reports*, 10(1), 2214. <https://doi.org/10.1038/s41598-020-59282-y>
21. Batchelder, W. H., & Alexander, G. E. (2012). Insight Problem Solving: A Critical Examination of the Possibility of Formal Theory. *The Journal of Problem Solving*, 5(1). <https://doi.org/10.7771/1932-6246.1143>

22. Bayne, T., & Carter, O. (2018). Dimensions of consciousness and the psychedelic state. *Neuroscience of Consciousness*, 2018(1), 1–8. <https://doi.org/10.1093/nc/niy008>
23. Beck, A. T., Baruch, E., Balter, J. M., Steer, R. A., & Warman, D. M. (2004). A new instrument for measuring insight: The Beck Cognitive Insight Scale. *Schizophrenia Research*, 68(2), 319–329. [https://doi.org/10.1016/S0920-9964\(03\)00189-0](https://doi.org/10.1016/S0920-9964(03)00189-0)
24. Becker, M., & Cabeza, R. (2025). The neural basis of the insight memory advantage. *Trends in Cognitive Sciences*, 29(3), 255–268. <https://doi.org/10.1016/j.tics.2025.01.001>
25. Beeman, M., & Kounios, J. (2015). The Eureka factor: Creative insights and the brain. Cornerstone Digital. <https://researchdiscovery.drexel.edu/esploro/outputs/book/The-Eureka-factor-creative-insights-and/991020548384004721>
26. Beer, R. D. (2000). Dynamical approaches to cognitive science. *Trends in Cognitive Sciences*, 4(3), 91–99. [https://doi.org/10.1016/S1364-6613\(99\)01440-0](https://doi.org/10.1016/S1364-6613(99)01440-0)
27. Beliveau, V., Ganz, M., Feng, L., Ozenne, B., Højgaard, L., Fisher, P. M., Svarer, C., Greve, D. N., & Knudsen, G. M. (2017). A high-resolution in vivo atlas of the human brain's serotonin system. *Journal of Neuroscience*, 37(1), 120–128. <https://doi.org/10.1523/JNEUROSCI.2830-16.2016>
28. Belser, A. B., Agin-Liebes, G., Swift, T. C., Terrana, S., Devenot, N., Friedman, H. L., Guss, J., Bossis, A., & Ross, S. (2017). Patient Experiences of Psilocybin-Assisted Psychotherapy: An Interpretative Phenomenological Analysis. *Journal of Humanistic Psychology*, 57(4), 354–388. <https://doi.org/10.1177/0022167817706884>
29. Benezra, S. E., Patel, K. B., Perez Campos, C., Hillman, E. M., & Bruno, R. M. (2024). Learning enhances behaviorally relevant representations in apical dendrites. *eLife*, 13, RP98349. <https://doi.org/10.7554/eLife.98349>
30. Berner, P. (1991). Delusional Atmosphere. *The British Journal of Psychiatry*, 159(S14), 88–93. <https://doi.org/10.1192/S0007125000296554>
31. Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., Carmody, J., Segal, Z. V., Abbey, S., Specia, M., Velting, D., & Devins, G. (2004). Mindfulness: A proposed operational definition. *Clinical Psychology: Science and Practice*. <https://doi.org/10.1093/clipsy/bph077>
32. Bohil, C. J., Alicea, B., & Biocca, F. A. (2011). Virtual reality in neuroscience research and therapy. *Nature Reviews Neuroscience*, 12(12), 752–762. <https://doi.org/10.1038/nrn3122>

33. Bowden, E., Jungbeeman, M., Fleck, J., & Kounios, J. (2005). New approaches to demystifying insight. *Trends in Cognitive Sciences*, 9(7), 322–328. <https://doi.org/10.1016/j.tics.2005.05.012>
34. Bowden, E. M., & Jung-Beeman, M. (2003). Normative data for 144 compound remote associate problems. *Behavior Research Methods, Instruments, & Computers*, 35(4), 634–639. <https://doi.org/10.3758/BF03195543>
35. Bowers, M., & Freedman, D. (1966). " Psychedelic " Experiences in Acute Psychoses chotherapy. He describes a mystic or " cryptic state ". *Arch Gen Psychiatry*, 15, 240–248.
36. Briganti, G., Scutari, M., Epskamp, S., Borsboom, D., Hoekstra, R. H. A., Golino, H. F., Christensen, A. P., Morvan, Y., Ebrahimi, O. V., Costantini, G., Heeren, A., de Ron, J., Bringmann, L. F., Huth, K., Haslbeck, J. M. B., Isvoranu, A., Marsman, M., Blanken, T., Gilbert, A., ... McNally, R. J. (2024). Network analysis: An overview for mental health research. *International Journal of Methods in Psychiatric Research*, 33(4), e2034. <https://doi.org/10.1002/mpr.2034>
37. Brin, M., & Stuck, G. (2002). *Introduction to Dynamical Systems*. Cambridge University Press.
38. Brouwer, A., Brown, J. K., Erowid, E., Erowid, F., Thyssen, S., Raison, C. L., & Carhart-Harris, R. L. (2025). A qualitative analysis of the psychedelic mushroom come-up and come-down. *Npj Mental Health Research*, 4(1), 6. <https://doi.org/10.1038/s44184-024-00095-6>
39. Burbea, R. (2014). *Seeing That Frees: Meditations on Emptiness and Dependent Arising*. Troubador Publishing Limited.
40. Cameron, L. P., Tombari, R. J., Lu, J., Pell, A. J., Hurley, Z. Q., Ehinger, Y., Vargas, M. V., McCarroll, M. N., Taylor, J. C., Myers-Turnbull, D., Liu, T., Yaghoobi, B., Laskowski, L. J., Anderson, E. I., Zhang, G., Viswanathan, J., Brown, B. M., Tjia, M., Dunlap, L. E., ... Olson, D. E. (2021). A non-hallucinogenic psychedelic analogue with therapeutic potential. *Nature*. <https://doi.org/10.1038/s41586-020-3008-z>
41. Canestrari, C., Branchini, E., Bianchi, I., Savardi, U., & Burro, R. (2018). Pleasures of the Mind: What Makes Jokes and Insight Problems Enjoyable. *Frontiers in Psychology*, 8, 2297. <https://doi.org/10.3389/fpsyg.2017.02297>
42. Carandini, M., & Heeger, D. J. (2012). Normalization as a canonical neural computation. *Nature Reviews Neuroscience*, 13(1), 51–62. <https://doi.org/10.1038/nrn3136>
43. Carbonaro, T. M., Bradstreet, M. P., Barrett, F. S., MacLean, K. A., Jesse, R., Johnson, M. W., & Griffiths, R. R. (2016). Survey study of challenging experiences after ingesting psilocybin mushrooms: Acute and enduring positive and negative consequences. *Journal of Psychopharmacology*.

<https://doi.org/10.1177/0269881116662634>

44. Carey, T. A., Carey, M., Stalker, K., Mullan, R. J., Murray, L. K., & Spratt, M. B. (2007). Psychological change from the inside looking out: A qualitative investigation. *Counselling and Psychotherapy Research*, 7(3), 178–187. <https://doi.org/10.1080/14733140701514613>
45. Carhart-Harris, R. L. (2018). The entropic brain—Revisited. *Neuropharmacology*, 142, 167–178. <https://doi.org/10.1016/j.neuropharm.2018.03.010>
46. Carhart-Harris, R. L., Bolstridge, M., Day, C. M. J., Rucker, J., Watts, R., Erritzoe, D. E., Kaelen, M., Giribaldi, B., Bloomfield, M., Pilling, S., Rickard, J. A., Forbes, B., Feilding, A., Taylor, D., Curran, H. V., & Nutt, D. J. (2018). Psilocybin with psychological support for treatment-resistant depression: Six-month follow-up. *Psychopharmacology*. <https://doi.org/10.1007/s00213-017-4771-x>
47. Carhart-Harris, R. L., Bolstridge, M., Rucker, J., Day, C. M. J., Erritzoe, D., Kaelen, M., Bloomfield, M., Rickard, J. A., Forbes, B., Feilding, A., Taylor, D., Pilling, S., Curran, V. H., & Nutt, D. J. (2016). Psilocybin with psychological support for treatment-resistant depression: An open-label feasibility study. *The Lancet Psychiatry*, 3(7), 619–627. [https://doi.org/10.1016/S2215-0366\(16\)30065-7](https://doi.org/10.1016/S2215-0366(16)30065-7)
48. Carhart-Harris, R. L., Erritzoe, D., Williams, T., Stone, J. M., Reed, L. J., Colasanti, A., Tyacke, R. J., Leech, R., Malizia, A. L., Murphy, K., Hobden, P., Evans, J., Feilding, A., Wise, R. G., & Nutt, D. J. (2012). Neural correlates of the psychedelic state as determined by fMRI studies with psilocybin. *Proceedings of the National Academy of Sciences of the United States of America*, 109(6), 2138–2143. <https://doi.org/10.1073/pnas.1119598109>
49. 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, 316–344. <https://doi.org/10.1124/pr.118.017160>
50. Carhart-Harris, R. L., Giribaldi, B., Watts, R., Baker-Jones, M., Murphy-Beiner, A., Murphy, R., Martell, J., Blemings, A., Erritzoe, D., & Nutt, D. J. (2021). Trial of Psilocybin versus Escitalopram for Depression. *New England Journal of Medicine*, 384(15), 1402–1411. <https://doi.org/10.1056/nejmoa2032994>
51. Carhart-Harris, R. L., Kaelen, M., Whalley, M. G., Bolstridge, M., Feilding, A., & Nutt, D. J. (2015). LSD enhances suggestibility in healthy volunteers. *Psychopharmacology*, 232(4), 785–794. <https://doi.org/10.1007/s00213-014-3714-z>
52. Carhart-Harris, R. L., Leech, R., Hellyer, P. J., Shanahan, M., Feilding, A., Tagliazucchi, E., Chialvo, D. R., & Nutt, D. (2014). The entropic

- brain: A theory of conscious states informed by neuroimaging research with psychedelic drugs. *Frontiers in Human Neuroscience*, 8. <https://doi.org/10.3389/fnhum.2014.00020>
53. Carhart-Harris, R. L., Muthukumaraswamy, S., Roseman, L., Kaelen, M., Droog, W., Murphy, K., Tagliazucchi, E., Schenberg, E. E., Nest, T., Orban, C., Leech, R., Williams, L. T., Williams, T. M., Bolstridge, M., Sessa, B., McGonigle, J., Sereno, M. I., Nichols, D., Hellyer, P. J., ... Nutt, D. J. (2016). Neural correlates of the LSD experience revealed by multimodal neuroimaging. *Proceedings of the National Academy of Sciences of the United States of America*, 113(17), 4853–4858. <https://doi.org/10.1073/pnas.1518377113>
 54. Carpenter, W. (2019). The Aha! Moment: The Science Behind Creative Insights. In *Toward Super-Creativity—Improving Creativity in Humans, Machines, and Human—Machine Collaborations*. IntechOpen. <https://doi.org/10.5772/intechopen.84973>
 55. Castonguay, L. G., & Hill, C. E. (2006). *Insight in Psychotherapy*. American Psychological Association.
 56. Caulfield, A., Li, L., Askari, F., Belessiotis-Richards, C., Young, A. H., & Mehta, M. (2025). The effect of psychedelics on associative learning: A systematic review. *bioRxiv*. <https://doi.org/10.1101/2025.07.21.665870>
 57. Cauller, L. J., Clancy, B., & Connors, B. W. (1998). Backward cortical projections to primary somatosensory cortex in rats extend long horizontal axons in layer I. *The Journal of Comparative Neurology*, 390(2), 297–310. [https://doi.org/10.1002/\(SICI\)1096-9861\(19980112\)390:2%3C297::AID-CNE11%3E3.0.CO;2-V](https://doi.org/10.1002/(SICI)1096-9861(19980112)390:2%3C297::AID-CNE11%3E3.0.CO;2-V)
 58. Chater, N., & Vitányi, P. (2003). Simplicity: A unifying principle in cognitive science? *Trends in Cognitive Sciences*, 7(1), 19–22. [https://doi.org/10.1016/S1364-6613\(02\)00005-0](https://doi.org/10.1016/S1364-6613(02)00005-0)
 59. Chesebrough, C., Salvi, C., Beeman, M., Oh, Y., & Kounios, J. (2024). Waves of Insight: A Historical Overview of the Neuroscience of Insight. In C. Salvi, J. Wiley, & S. M. Smith (Eds.), *The Emergence of Insight* (1st ed., pp. 223–250). Cambridge University Press. <https://doi.org/10.1017/9781009244244.011>
 60. Chiu, Y.-T., Deutch, A. Y., Wang, W., Schmitz, G. P., Huang, K. L., Kocak, D. D., Llorach, P., Bowyer, K., Liu, B., Sciaky, N., Hua, K., Chen, C., Mott, S. E., Niehaus, J., DiBerto, J. F., English, J., Walsh, J. J., Scherrer, G., Herman, M. A., ... Roth, B. L. (2023). A suite of engineered mice for interrogating psychedelic drug actions. *Neuroscience*. <https://doi.org/10.1101/2023.09.25.559347>
 61. Cohen, I., Navarro, V., Clemenceau, S., Baulac, M., & Miles, R. (2002). On the Origin of Interictal Activity in Human Temporal Lobe Epilepsy in Vitro.

- Science, 298(5597), 1418–1421. <https://doi.org/10.1126/science.1076510>
62. Colzato, L. S., Ozturk, A., & Hommel, B. (2012). Meditate to create: The impact of focused-attention and open-monitoring training on convergent and divergent thinking. *Frontiers in Psychology*, 3(APR), 1–5. <https://doi.org/10.3389/fpsyg.2012.00116>
 63. Colzato, L. S., Szapora, A., Lippelt, D., & Hommel, B. (2017). Prior Meditation Practice Modulates Performance and Strategy Use in Convergent- and Divergent-Thinking Problems. *Mindfulness*. <https://doi.org/10.1007/s12671-014-0352-9>
 64. Conrad, K. (1971). Die beginnende Schizophrenie. Versuch Einer Gestaltanalyse Des Wahns. <https://cir.nii.ac.jp/crid/1572261549553557504>
 65. Corlett, P. R., Horga, G., Fletcher, P. C., Alderson-Day, B., Schmack, K., & Powers, A. R. (2019). Hallucinations and Strong Priors. *Trends in Cognitive Sciences*, 23(2), 114–127. <https://doi.org/10.1016/j.tics.2018.12.001>
 66. Cott, C., & Rock, A. (2008). Phenomenology of N,N-dimethyltryptamine use: A thematic analysis. *Journal of Scientific Exploration*.
 67. Cui, J., Olthof, M., Hasselman, F., & Lichtwarck, A. (2024). Specifying Transition Types and Scales of Interest in Understanding Clinical Change.
 68. Dahl, C. J., & Davidson, R. J. (2019). Mindfulness and the contemplative life: Pathways to connection, insight, and purpose. *Current Opinion in Psychology*, 28, 60–64. <https://doi.org/10.1016/j.copsyc.2018.11.007>
 69. Dahl, C. J., Lutz, A., & Davidson, R. J. (2015). Reconstructing and deconstructing the self: Cognitive mechanisms in meditation practice. *Trends in Cognitive Sciences*. <https://doi.org/10.1016/j.tics.2015.07.001>
 70. Danek, A. H. (2018). Magic tricks, sudden restructuring, and the Aha! experience: A new model of nonmonotonic problem solving. In *Insight*. Routledge.
 71. Danek, A. H. (2023). The Phenomenology of Insight: The Aha! Experience. In *The Routledge International Handbook of Creative Cognition*. Routledge.
 72. Danek, A. H., Fraps, T., von Müller, A., Grothe, B., & Öllinger, M. (2013). Aha! experiences leave a mark: Facilitated recall of insight solutions. *Psychological Research*, 77(5), 659–669. <https://doi.org/10.1007/s00426-012-0454-8>
 73. Danek, A. H., Fraps, T., von Müller, A., Grothe, B., & Öllinger, M. (2014). It's a kind of magic—What self-reports can reveal about the phenomenology of insight problem solving. *Frontiers in Psychology*, 5.

<https://doi.org/10.3389/fpsyg.2014.01408>

74. Danek, A. H., & Kizilirmak, J. M. (2021). The whole is more than the sum of its parts – addressing insight problem solving concurrently from a cognitive and an affective perspective. *Journal of Cognitive Psychology*, 33(6–7), 609–615. <https://doi.org/10.1080/20445911.2021.1967962>
75. Danek, A. H., & Wiley, J. (2017). What about False Insights? Deconstructing the Aha! Experience along Its Multiple Dimensions for Correct and Incorrect Solutions Separately. *Frontiers in Psychology*, 7. <https://doi.org/10.3389/fpsyg.2016.02077>
76. Danek, A. H., & Wiley, J. (2020). What causes the insight memory advantage? *Cognition*, 205, 104411. <https://doi.org/10.1016/j.cognition.2020.104411>
77. Davis, A. K., Barrett, F. S., May, D. G., Cosimano, M. P., Sepeda, N. D., Johnson, M. W., Finan, P. H., & Griffiths, R. R. (2021). Effects of Psilocybin-Assisted Therapy on Major Depressive Disorder: A Randomized Clinical Trial. *JAMA Psychiatry*, 78(5), 481–489. <https://doi.org/10.1001/jamapsychiatry.2020.3285>
78. Davis, A. K., Barrett, F. S., So, S., Gukasyan, N., Swift, T. C., & Griffiths, R. R. (2021). Development of the Psychological Insight Questionnaire among a sample of people who have consumed psilocybin or LSD. *Journal of Psychopharmacology*, 35(4), 437–446. <https://doi.org/10.1177/02698881120967878>
79. Daws, R. E., Timmermann, C., Giribaldi, B., Sexton, J. D., Wall, M. B., Erritzoe, D., Roseman, L., Nutt, D., & Carhart-Harris, R. (2022). Increased global integration in the brain after psilocybin therapy for depression. *Nature Medicine*, 28(4), 844–851. <https://doi.org/10.1038/s41591-022-01744-z>
80. Delli Pizzi, S., Chiacchiaretta, P., Sestieri, C., Ferretti, A., Tullo, M. G., Della Penna, S., Martinotti, G., Onofri, M., Roseman, L., Timmermann, C., Nutt, D. J., Carhart-Harris, R. L., & Sensi, S. L. (2023). LSD-induced changes in the functional connectivity of distinct thalamic nuclei. *NeuroImage*, 283, 120414. <https://doi.org/10.1016/j.neuroimage.2023.120414>
81. Doblin, R. (1991). PAHNKE'S "GOOD FRIDAY EXPERIMENT": A LONG-TERM FOLLOW-UP AND METHODOLOGICAL CRITIQUE.
82. Doss, M. K., Madden, M. B., Gaddis, A., Nebel, M. B., Griffiths, R. R., Mathur, B. N., & Barrett, F. S. (2022). Models of psychedelic drug action: Modulation of cortical-subcortical circuits. *Brain*, 145(2), 441–456. <https://doi.org/10.1093/brain/awab406>
83. Doss, M. K., Považan, M., Rosenberg, M. D., Sepeda, N. D., Davis, A. K., Finan, P. H., Smith, G. S., Pekar, J. J., Barker, P. B., Griffiths, R. R., &

- Barrett, F. S. (2021). Psilocybin therapy increases cognitive and neural flexibility in patients with major depressive disorder. *Translational Psychiatry*, 11(1), 574. <https://doi.org/10.1038/s41398-021-01706-y>
84. Duerler, P., Schilbach, L., Stämpfli, P., Vollenweider, F. X., & Preller, K. H. (2020). LSD-induced increases in social adaptation to opinions similar to one's own are associated with stimulation of serotonin receptors. *Scientific Reports*, 10(1), 12181. <https://doi.org/10.1038/s41598-020-68899-y>
 85. Eberth, J., Sedlmeier, P., & Schäfer, T. (2019). Promise: A model of insight and equanimity as the key effects of mindfulness meditation. *Frontiers in Psychology*. <https://doi.org/10.3389/fpsyg.2019.02389>
 86. Eiraku, M., Watanabe, K., Matsuo-Takasaki, M., Kawada, M., Yonemura, S., Matsumura, M., Wataya, T., Nishiyama, A., Muguruma, K., & Sasai, Y. (2008). Self-Organized Formation of Polarized Cortical Tissues from ESCs and Its Active Manipulation by Extrinsic Signals. *Cell Stem Cell*, 3(5), 519–532. <https://doi.org/10.1016/j.stem.2008.09.002>
 87. Ellis, A. (1963). Toward a More Precise Definition of “Emotional” and “Intellectual” Insight. *Psychological Reports*, 13(1), 125–126. <https://doi.org/10.2466/pr0.1963.13.1.125>
 88. Erritzoe, D., Timmermann, C., Godfrey, K., Castro-Rodrigues, P., Peill, J., Carhart-Harris, R. L., Nutt, D. J., & Wall, M. B. (2024). Exploring mechanisms of psychedelic action using neuroimaging. *Nature Mental Health*, 2(2), 141–153. <https://doi.org/10.1038/s44220-023-00172-3>
 89. Esteban, F. J., Vargas, E., Langa, J. A., & Soler-Toscano, F. (2026). Synchronization, Information, and Brain Dynamics in Consciousness Research. *Applied Sciences*, 16(2), 1056. <https://doi.org/10.3390/app16021056>
 90. Falconer, C. J., Rovira, A., King, J. A., Gilbert, P., Antley, A., Fearon, P., Ralph, N., Slater, M., & Brewin, C. R. (2016). Embodying self-compassion within virtual reality and its effects on patients with depression. *BJPsych Open*. <https://doi.org/10.1192/bjpo.bp.115.002147>
 91. Family, N., Vinson, D., Vigliocco, G., Kaelen, M., Bolstridge, M., Nutt, D. J., & Carhart-Harris, R. L. (2016). Semantic activation in LSD: Evidence from picture naming. *Language, Cognition and Neuroscience*, 31(10), 1320–1327. <https://doi.org/10.1080/23273798.2016.1217030>
 92. Farnes, N., Juel, B. E., Nilsen, A. S., Romundstad, L. G., & Storm, J. F. (2020). Increased signal diversity/complexity of spontaneous EEG, but not evoked EEG responses, in ketamine-induced psychedelic state in humans. *PLOS ONE*, 15(11), e0242056. <https://doi.org/10.1371/journal.pone.0242056>
 93. Feldman, H., & Friston, K. (2010). Attention, Uncertainty, and Free-Energy. *Frontiers in Human Neuroscience*, 4. <https://doi.org/10.>

94. Feyaerts, J., Henriksen, M. G., Vanheule, S., Myin-Germeys, I., & Sass, L. A. (2021). Delusions beyond beliefs: A critical overview of diagnostic, aetiological, and therapeutic schizophrenia research from a clinical-phenomenological perspective. *The Lancet Psychiatry*, 8(3), 237–249. [https://doi.org/10.1016/S2215-0366\(20\)30460-0](https://doi.org/10.1016/S2215-0366(20)30460-0)
95. Fink, S. B. (2020). Look who's talking! Varieties of ego-dissolution without paradox. *Philosophy and the Mind Sciences*, 1(I), 1–36. <https://doi.org/10.33735/phimisci.2020.I.40>
96. Fleck, J. I., & Weisberg, R. W. (2013). Insight versus analysis: Evidence for diverse methods in problem solving. *Journal of Cognitive Psychology*, 25(4), 436–463. <https://doi.org/10.1080/20445911.2013.779248>
97. Fonzo, G. A., Wolfgang, A. S., Barksdale, B. R., Krystal, J. H., Carpenter, L. L., Kraguljac, N. V., Grzenda, A., McDonald, W. M., Widge, A. S., Rodriguez, C. I., & Nemeroff, C. B. (2025). Psilocybin: From Psychiatric Pariah to Perceived Panacea. *American Journal of Psychiatry*, 182(1), 54–78. <https://doi.org/10.1176/appi.ajp.20230682>
98. Freeman, D., Reeve, S., Robinson, A., Ehlers, A., Clark, D., Spanlang, B., & Slater, M. (2017). Virtual reality in the assessment, understanding, and treatment of mental health disorders. *Psychological Medicine*. <https://doi.org/10.1017/S003329171700040X>
99. Friston, K. J. (2010). The free-energy principle: A unified brain theory? *Nature Reviews Neuroscience*. <https://doi.org/10.1038/nrn2787>
100. Friston, K. J., Lin, M., Frith, C. D., Pezzulo, G., Hobson, J. A., & Onodoba, S. (2017). Active Inference, Curiosity and Insight. *Neural Computation*, 29(10), 2633–2683. https://doi.org/10.1162/neco_a_00999
101. Gamma, A., & Metzinger, T. (2021). The Minimal Phenomenal Experience questionnaire (MPE-92M): Towards a phenomenological profile of “pure awareness” experiences in meditators. *PLoS ONE*. <https://doi.org/10.1371/journal.pone.0253694>
102. Gandy, S., Bonnelle, V., Jacobs, E., & Luke, D. (2022). Psychedelics as potential catalysts of scientific creativity and insight. *Drug Science, Policy and Law*, 8. <https://doi.org/10.1177/20503245221097649>
103. 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>
104. Garcia-Romeu, A., Himmelstein, S. P., & Kaminker, J. (2015). Self-transcendent experience: A grounded theory study. *Qualitative Research*, 15(5), 633–654. <https://doi.org/10.1177/1468794114550679>
105. Gattuso, J. J., Perkins, D., Ruffell, S., Lawrence, A. J., Hoyer, D., Ja-

- cobson, L. H., Timmermann, C., Castle, D., Rossell, S. L., Downey, L. A., Pagni, B. A., Galvão-Coelho, N. L., Nutt, D., & Sarris, J. (2023). Default Mode Network Modulation by Psychedelics: A Systematic Review. *International Journal of Neuropsychopharmacology*, 26(3). <https://doi.org/10.1093/ijnp/pyac074>
106. Gelo, O. C. G., & Salvatore, S. (2016). A dynamic systems approach to psychotherapy: A meta-theoretical framework for explaining psychotherapy change processes. *Journal of Counseling Psychology*, 63(4), 379–395. <https://doi.org/10.1037/cou0000150>
 107. Gick, M. L., & Lockhart, R. S. (1995). Cognitive and affective components of insight. In *The nature of insight* (pp. 197–228). The MIT Press.
 108. Girn, M., Mills, C., Roseman, L., Carhart-Harris, R. L., & Christoff, K. (2020). Updating the dynamic framework of thought: Creativity and psychedelics. *NeuroImage*. <https://doi.org/10.1016/j.neuroimage.2020.116726>
 109. Girn, M., Roseman, L., Bernhardt, B., Smallwood, J., Carhart-Harris, R., & Nathan Spreng, R. (2022). Serotonergic psychedelic drugs LSD and psilocybin reduce the hierarchical differentiation of unimodal and transmodal cortex. *NeuroImage*, 256, 119220. <https://doi.org/10.1016/j.neuroimage.2022.119220>
 110. Glowacki, D. R., Wonnacott, M. D., Freire, R., Glowacki, B. R., Gale, E. M., Pike, J. E., De Haan, T., Chatziapostolou, M., & Metatla, O. (2020). Isness: Using Multi-Person VR to Design Peak Mystical Type Experiences Comparable to Psychedelics. *Conference on Human Factors in Computing Systems - Proceedings*. <https://doi.org/10.1145/3313831.3376649>
 111. Godenzini, L., Shai, A. S., & Palmer, L. M. (2022). Dendritic Compartmentalization of Learning-Related Plasticity. *Eneuro*, 9(3), ENEURO.0060-22.2022. <https://doi.org/10.1523/ENEURO.0060-22.2022>
 112. González-Maeso, J., Weisstaub, N. V., Zhou, M., Chan, P., Ivic, L., Ang, R., Lira, A., Bradley-Moore, M., Ge, Y., Zhou, Q., Sealfon, S. C., & Gingrich, J. A. (2007). Hallucinogens Recruit Specific Cortical 5-HT_{2A} Receptor-Mediated Signaling Pathways to Affect Behavior. *Neuron*, 53(3), 439–452. <https://doi.org/10.1016/j.neuron.2007.01.008>
 113. Goodwin, G. M., Aaronson, S. T., Alvarez, O., Arden, P. C., Baker, A., Bennett, J. C., Bird, C., Blom, R. E., Brennan, C., Bruschi, 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*. <https://doi.org/10.1056/nejmoa2206443>
 114. Gozé, T., Grohmann, T., Naudin, J., & Cermolacce, M. (2017). New Insight into Affectivity in Schizophrenia: From the Phenomenology of Marc

- Richir. *Psychopathology*, 50(6), 401–407. <https://doi.org/10.1159/000481516>
115. Greco, A., Gallitto, G., D'alessandro, M., & Rastelli, C. (2021). Increased entropic brain dynamics during deepdream-induced altered perceptual phenomenology. *Entropy*. <https://doi.org/10.3390/e23070839>
 116. Greenberg, L. S. (1990). *Emotion in Psychotherapy*. Guilford Press.
 117. Griffiths, R. R., Jesse, R., Richards, W. A., Johnson, M. W., Sepeda, N. D., Bossis, A. P., & Ross, S. (2025). Effects of Psilocybin on Religious and Spiritual Attitudes and Behaviors in Clergy from Various Major World Religions. *Psychedelic Medicine*, 3(4), 172–191. <https://doi.org/10.1089/psymed.2023.0044>
 118. Griffiths, R. R., Johnson, M. W., Carducci, M. A., Umbricht, A., Richards, W. A., Richards, B. D., Cosimano, M. P., & Klinedinst, M. A. (2016). Psilocybin produces substantial and sustained decreases in depression and anxiety in patients with life-threatening cancer: A randomized double-blind trial. *Journal of Psychopharmacology*. <https://doi.org/10.1177/0269881116675513>
 119. Griffiths, R. R., Richards, W. A., Johnson, M. W., McCann, U. D., & Jesse, R. (2008). Mystical-type experiences occasioned by psilocybin mediate the attribution of personal meaning and spiritual significance 14 months later. *Journal of Psychopharmacology*, 22(6), 621–632. <https://doi.org/10.1177/0269881108094300>
 120. 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>
 121. Grinspoon, L., & Doblin, R. (2001). *Psychedelics as catalysts of insight-oriented psychotherapy*. Social Research.
 122. Grof, S. (1980). *LSD Psychotherapy*. Hunter House.
 123. Grof, S. (2016). *Realms of the Human Unconscious: Observations from LSD Research (Vol. 15)*. Souvenir Press. <https://doi.org/10.2307/1385643> (Original work published The Viking Press)
 124. Hartogsohn, I. (2018). The meaning-enhancing properties of psychedelics and their mediator role in psychedelic therapy, spirituality, and creativity. *Frontiers in Neuroscience*, 12, 129. <https://doi.org/10.3389/fnins.2018.00129>
 125. Harvey, J. A. (2003). Role of the Serotonin 5-HT_{2A} Receptor in Learning. *Learning & Memory*, 10(5), 355–362. <https://doi.org/10.1101/lm.60803>
 126. Harvey, J. A., Gormezano, I., Cool-Hauser, V. A., & Schindler, C. W. (1988). Effects of LSD on classical conditioning as a function of CS-

- UCS interval: Relationship to reflex facilitation. *Pharmacology Biochemistry and Behavior*, 30(2), 433–441. [https://doi.org/10.1016/0091-3057\(88\)90477-7](https://doi.org/10.1016/0091-3057(88)90477-7)
127. Harvey, P. D., & Nemeroff, C. B. (2026). Psychedelic therapeutics in psychiatric conditions. *Neuropsychopharmacology*. <https://doi.org/10.1038/s41386-026-02335-z>
 128. Hatzipantelis, C. J., & Olson, D. E. (2024). The Effects of Psychedelics on Neuronal Physiology. *Annual Review of Physiology*, 86(1), 27–47. <https://doi.org/10.1146/annurev-physiol-042022-020923>
 129. Hayes, A. M., Feldman, G. C., & Goldfried, M. R. (2007). The Change and Growth Experiences Scale: A Measure of Insight and Emotional Processing. In *Insight in psychotherapy* (pp. 231–253). American Psychological Association. <https://doi.org/10.1037/11532-011>
 130. Hedne, M. R., Norman, E., & Metcalfe, J. (2016). Intuitive Feelings of Warmth and Confidence in Insight and Noninsight Problem Solving of Magic Tricks. *Frontiers in Psychology*, 7. <https://doi.org/10.3389/fpsyg.2016.01314>
 131. Heifets, B. D., & Olson, D. E. (2024). Therapeutic mechanisms of psychedelics and entactogens. *Neuropsychopharmacology*, 49(1), 104–118. <https://doi.org/10.1038/s41386-023-01666-5>
 132. Hendricks, P. S. (2018). Awe: A putative mechanism underlying the effects of classic psychedelic-assisted psychotherapy. *International Review of Psychiatry*, 30(4), 331–342. <https://doi.org/10.1080/09540261.2018.1474185>
 133. Hidalgo Jiménez, J., Kaup, K., & Aru, J. (2025). Electrophysiological Mechanisms of Psychedelic Drugs: A Systematic Review (p. 2025.07.05.663289). *bioRxiv*. <https://doi.org/10.1101/2025.07.05.663289>
 134. Hill, C. E., Corbett, M. M., Kanitz, B., Rios, P., Lightsey, R., & Gomez, M. (1992). Client behavior in counseling and therapy sessions: Development of a pantheoretical measure. *Journal of Counseling Psychology*, 39(4), 539–549. <https://doi.org/10.1037/0022-0167.39.4.539>
 135. Hipólito, I., Mago, J., Rosas, F. E., & Carhart-Harris, R. (2023). Pattern breaking: A complex systems approach to psychedelic medicine. *Neuroscience of Consciousness*, 2023(1), niad017. <https://doi.org/10.1093/nc/niad017>
 136. Hirschfeld, T., & Schmidt, T. T. (2021). Dose–response relationships of psilocybin-induced subjective experiences in humans. *Journal of Psychopharmacology*, 35(4), 384–397. <https://doi.org/10.1177/0269881121992676>
 137. Hohwy, J., Roepstorff, A., & Friston, K. (2008). Predictive coding explains

- binocular rivalry: An epistemological review. *Cognition*, 108(3), 687–701. <https://doi.org/10.1016/j.cognition.2008.05.010>
138. Horrocks, M., Mohn, J. L., & Jaramillo, S. (2025). The serotonergic psychedelic DOI impairs deviance detection in the auditory cortex. *Journal of Neurophysiology*, 133(2), 388–398. <https://doi.org/10.1152/jn.00411.2024>
 139. Huang, F., Tang, S., Sun, P., & Luo, J. (2018). Neural correlates of novelty and appropriateness processing in externally induced constraint relaxation. *NeuroImage*, 172, 381–389. <https://doi.org/10.1016/j.neuroimage.2018.01.070>
 140. Huang, S., Wu, S. J., Sansone, G., Ibrahim, L. A., & Fishell, G. (2024). Layer 1 neocortex: Gating and integrating multidimensional signals. *Neuron*, 112(2), 184–200. <https://doi.org/10.1016/j.neuron.2023.09.041>
 141. Hutchinson, E. D. (2014). The Nature of Insight. *Psychiatry: Interpersonal and Biological Processes*, 77(3), 215–229. <https://doi.org/10.1521/psyc.2014.77.3.215>
 142. Inserra, A., De Gregorio, D., Rezai, T., Lopez-Canul, M. G., Comai, S., & Gobbi, G. (2021). Lysergic acid diethylamide differentially modulates the reticular thalamus, mediodorsal thalamus, and infralimbic prefrontal cortex: An in vivo electrophysiology study in male mice. *Journal of Psychopharmacology*, 35(4), 469–482. <https://doi.org/10.1177/0269881121991569>
 143. Ip, C.-T., Olbrich, S., De Bardeci, M., Monn, A., Ort, A., Smallridge, J. W., & Vollenweider, F. (2026). Psilocybin-induced alterations in EEG power, connectivity and network dynamics in healthy subjects: Correlations with subjective experience and implications for therapeutic applications. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, 111626. <https://doi.org/10.1016/j.pnpbp.2026.111626>
 144. Ireland, M. J. (2013). Meditative insight: Conceptual and measurement development. *Mental Health, Religion and Culture*. <https://doi.org/10.1080/13674676.2011.645225>
 145. Jain, M. K., Gumpfer, R. H., Slocum, S. T., Schmitz, G. P., Madsen, J. S., Tummino, T. A., Suomivuori, C.-M., Huang, X.-P., Shub, L., DiBerio, J. F., Kim, K., DeLeon, C., Krumm, B. E., Fay, J. F., Keiser, M., Hauser, A. S., Dror, R. O., Shoichet, B., Gloriam, D. E., ... Roth, B. L. (2025). The polypharmacology of psychedelics reveals multiple targets for potential therapeutics. *Neuron*, 113(19), 3129–3142.e9. <https://doi.org/10.1016/j.neuron.2025.06.012>
 146. Jakab, R. L., & Goldman-Rakic, P. S. (1998). 5-Hydroxytryptamine_{2A} serotonin receptors in the primate cerebral cortex: Possible site of action of hallucinogenic and antipsychotic drugs in pyramidal cell apical dendrites.

- Proceedings of the National Academy of Sciences, 95(2), 735–740. <https://doi.org/10.1073/pnas.95.2.735>
147. James, W. (1902). *The varieties of religious experience: A study in human nature: Being the Gifford Lectures on natural religion delivered at Edinburgh in 1901-1902*. Modern Library.
 148. Jaspers, K. (1997). *General Psychopathology*. JHU Press.
 149. Jennissen, S., Huber, J., Ehrental, J. C., Schauenburg, H., & Dinger, U. (2018). Association between insight and outcome of psychotherapy: Systematic review and meta-analysis. *American Journal of Psychiatry*, 175(10), 961–969. <https://doi.org/10.1176/appi.ajp.2018.17080847>
 150. Jensen, A. A., Halberstadt, A. L., Märcher-Rørsted, E., Odland, A. U., Chatha, M., Speth, N., Liebscher, G., Hansen, M., Bräuner-Osborne, H., Palner, M., Andreasen, J. T., & Kristensen, J. L. (2020). The selective 5-HT_{2A} receptor agonist 25CN-NBOH: Structure-activity relationship, in vivo pharmacology, and in vitro and ex vivo binding characteristics of [3H]25CN-NBOH. *Biochemical Pharmacology*, 177, 113979. <https://doi.org/10.1016/j.bcp.2020.113979>
 151. Jiang, Q., Shao, L.-X., Yao, S., Savalia, N. K., Gilbert, A. D., Davoudian, P. A., Nothnagel, J. D., Tian, G., Hung, T. S., Lai, H. M., Beier, K. T., Zeng, H., & Kwan, A. C. (2026). Psilocybin triggers an activity-dependent rewiring of large-scale cortical networks. *Cell*, 189(2), 659–675.e22. <https://doi.org/10.1016/j.cell.2025.11.009>
 152. Jitsuki, S., Takemoto, K., Kawasaki, T., Tada, H., Takahashi, A., Becamel, C., Sano, A., Yuzaki, M., Zukin, R. S., Ziff, E. B., Kessels, H. W., & Takahashi, T. (2011). Serotonin Mediates Cross-Modal Reorganization of Cortical Circuits. *Neuron*, 69(4), 780–792. <https://doi.org/10.1016/j.neuron.2011.01.016>
 153. Johnson, M. W., Garcia-Romeu, A., & Griffiths, R. R. (2017). Long-term follow-up of psilocybin-facilitated smoking cessation. *American Journal of Drug and Alcohol Abuse*, 43(1), 55–60. <https://doi.org/10.3109/00952990.2016.1170135>
 154. Johnson, M. W., Richards, W. A., & Griffiths, R. R. (2008). Human hallucinogen research: Guidelines for safety. *Journal of Psychopharmacology*. <https://doi.org/10.1177/0269881108093587>
 155. Jung-Beeman, M., Bowden, E. M., Haberman, J., Frymiare, J. L., Arambel-Liu, S., Greenblatt, R., Reber, P. J., & Kounios, J. (2004). Neural Activity When People Solve Verbal Problems with Insight. *PLOS Biology*, 2(4), e97. <https://doi.org/10.1371/journal.pbio.0020097>
 156. Jylkkä, J., Krabbe, A., & Jern, P. (2024). Endorsement of metaphysical idealism mediates a link between past use of psychedelics and well-being. *Scientific Reports*, 14(1), 13276. <https://doi.org/10.1038/>

157. Jylkkä, J., Väyrynen, H., Lin, E., Wallden, C., Krabbe, A., Kähönen, J., & Sikka, P. (2025). Meditation and psychedelics facilitate similar types of mystical, psychological, and philosophical-existential insights predictive of wellbeing: A qualitative-quantitative approach. *Consciousness and Cognition*. https://doi.org/10.31234/osf.io/ugr69_v1
158. Kallestad, H., Valen, J., McCullough, L., Svartberg, M., Høglend, P., & Stiles, T. C. (2010). The relationship between insight gained during therapy and long-term outcome in short-term dynamic psychotherapy and cognitive therapy for cluster C personality disorders. *Psychotherapy Research*, 20(5), 526–534. <https://doi.org/10.1080/10503307.2010.492807>
159. Kaplan, C. A., & Simon, H. A. (1990). In search of insight. *Cognitive Psychology*, 22(3), 374–419. [https://doi.org/10.1016/0010-0285\(90\)90008-R](https://doi.org/10.1016/0010-0285(90)90008-R)
160. Kapur, S. (2003). Psychosis as a State of Aberrant Salience: A Framework Linking Biology, Phenomenology, and Pharmacology in Schizophrenia. *American Journal of Psychiatry*. <https://psychiatryonline.org/doi/10.1176/appi.ajp.160.1.13>
161. Kase, M., Kaup, K. K., & Aru, J. (forthcoming). Effects of LSD, DMT and psilocybin on cognitive and psychological functions: A systematic review of the literature.
162. Katz, M. M., Waskow, I. E., & Olsson, J. (1968). Characterizing the Psychological State Produced By LSD. *Journal of Abnormal Psychology*, 73(1), 1. <https://doi.org/10.1037/h0020114>
163. Kaup, K. K., Hidalgo Jiménez, J., & Aru, J. (forthcoming). Cellular mechanisms of serotonergic psychedelics—Apical hypercontextualisation.
164. Kaup, K. K., Vasser, M., Tulver, K., Pikamäe, J., & Aru, J. (2023). Psychedelic replications in virtual reality and their potential as a therapeutic instrument: An open-label feasibility study. *Frontiers in Psychiatry*, 14. <https://doi.org/10.3389/fpsy.2023.1088896>
165. Kelso, J. A. S. (1995). *Dynamic Patterns: The Self-organization of Brain and Behavior*. MIT Press.
166. Khajuria, T., Tulver, K., & Aru, J. (2025). Comparing a computational model of visual problem solving with human vision on a difficult vision task. *PLOS Computational Biology*, 21(12), e1012968. <https://doi.org/10.1371/journal.pcbi.1012968>
167. Khajuria, T., Tulver, K., Luik, T., & Aru, J. (2022). Constellations: A Novel Dataset for Studying Iterative Inference in Humans and AI. *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) Workshops*, 5142–5152.
168. Khona, M., & Fiete, I. R. (2022). Attractor and integrator networks in the

- brain. *Nature Reviews Neuroscience*, 23(12), 744–766. <https://doi.org/10.1038/s41583-022-00642-0>
169. Kim, J. J., Tulver, K., Aru, J., Kaup, K. K., Pogliani, A., & Laukkonen, R. E. (2026). Realization experiences: A convergent account of insight and mystical experiences. *Philosophical Psychology*, 0(0), 1–30. <https://doi.org/10.1080/09515089.2026.2613030>
170. Kins, J. (n.d.). Subjective Effect Index. Retrieved March 29, 2021, from <https://effectindex.com/>
171. Kiran, C., & Chaudhury, S. (2009). Understanding delusions. *Industrial Psychiatry Journal*, 18(1), 3. <https://doi.org/10.4103/0972-6748.57851>
172. Kizilirmak, J. M., Galvao Gomes da Silva, J., Imamoglu, F., & Richardson-Klavehn, A. (2016). Generation and the subjective feeling of “aha!” are independently related to learning from insight. *Psychological Research*, 80(6), 1059–1074. <https://doi.org/10.1007/s00426-015-0697-2>
173. Kizilirmak, J. M., Thuerich, H., Folta-Schoofs, K., Schott, B. H., & Richardson-Klavehn, A. (2016). Neural Correlates of Learning from Induced Insight: A Case for Reward-Based Episodic Encoding. *Frontiers in Psychology*, 7. <https://doi.org/10.3389/fpsyg.2016.01693>
174. Kizilirmak, J. M., Wiegmann, B., & Richardson-Klavehn, A. (2016). Problem Solving as an Encoding Task: A Special Case of the Generation Effect. *The Journal of Problem Solving*, 9(1). <https://doi.org/10.7771/1932-6246.1182>
175. Klein, A. K., Austin, E. W., Cunningham, M. J., Dvorak, D., Gatti, S., Hulls, S. K., Kiss, L., Kruegel, A. C., Marek, G. J., Papp, M., Sporn, J., & Hughes, Z. A. (2024). GM-1020: A novel, orally bioavailable NMDA receptor antagonist with rapid and robust antidepressant-like effects at well-tolerated doses in rodents. *Neuropsychopharmacology*, 49(6), 905–914. <https://doi.org/10.1038/s41386-023-01783-1>
176. Knoblich, G., Haider, H., & Rhenius, D. (1999). Constraint Relaxation and Chunk Decomposition in Insight Problem Solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 25(6).
177. Kohler, W. (2018). *The Mentality of Apes*. Routledge. <https://doi.org/10.4324/9781351294966>
178. Korf, R. E. (1980). Toward a model of representation changes. *Artificial Intelligence*, 14(1), 41–78. [https://doi.org/10.1016/0004-3702\(80\)90033-8](https://doi.org/10.1016/0004-3702(80)90033-8)
179. Kounios, J., & Beeman, M. (2014). The Cognitive Neuroscience of Insight. *Annual Review of Psychology*, 65(1), 71–93. <https://doi.org/10.1146/annurev-psych-010213-115154>
180. Kounios, J., Fleck, J. I., Green, D. L., Payne, L., Stevenson, J. L., Bowden,

- E. M., & Jung-Beeman, M. (2008). The origins of insight in resting-state brain activity. *Neuropsychologia*, 46(1), 281–291. <https://doi.org/10.1016/j.neuropsychologia.2007.07.013>
181. Kounios, J., Frymiare, J. L., Bowden, E. M., Fleck, J. I., Subramaniam, K., Parrish, T. B., & Jung-Beeman, M. (2006). The Prepared Mind: Neural Activity Prior to Problem Presentation Predicts Subsequent Solution by Sudden Insight. *Psychological Science*, 17(10), 882–890.
 182. Kraehenmann, R., Pokorny, D., Aicher, H., Preller, K. H., Pokorny, T., Bosch, O. G., Seifritz, E., & Vollenweider, F. X. (2017). LSD increases primary process thinking via serotonin 2A receptor activation. *Frontiers in Pharmacology*, 8, 814. <https://doi.org/10.3389/fphar.2017.00814>
 183. Kraehenmann, R., Pokorny, D., Vollenweider, L., Preller, K. H., Pokorny, T., Seifritz, E., & Vollenweider, F. X. (2017). Dreamlike effects of LSD on waking imagery in humans depend on serotonin 2A receptor activation. *Psychopharmacology*, 234(13), 2031–2046. <https://doi.org/10.1007/s00213-017-4610-0>
 184. Kugel, J., Laukkonen, R. E., Yaden, D. B., Yücel, M., & Liknaitzky, P. (2025). Insights on psychedelics: A systematic review of therapeutic effects. *Neuroscience & Biobehavioral Reviews*, 173, 106117. <https://doi.org/10.1016/j.neubiorev.2025.106117>
 185. Kuhfuß, M., Maldei, T., Hetmanek, A., & Baumann, N. (2021). Somatic experiencing—effectiveness and key factors of a body-oriented trauma therapy: a scoping literature review. *European journal of psychotraumatology*, 12(1), 1929023.
 186. Kuypers, K. P. C., Riba, J., de la Fuente Revenga, M., Barker, S., Theunissen, E. L., & Ramaekers, J. G. (2016). Ayahuasca enhances creative divergent thinking while decreasing conventional convergent thinking. *Psychopharmacology*, 233(18), 3395–3403. <https://doi.org/10.1007/s00213-016-4377-8>
 187. Kwan, A. C., Olson, D. E., Preller, K. H., & Roth, B. L. (2022). The neural basis of psychedelic action. *Nature Neuroscience*. <https://doi.org/10.1038/s41593-022-01177-4>
 188. Lacewing, M. (2014). Psychodynamic psychotherapy, insight, and therapeutic action. *Clinical Psychology: Science and Practice*, 21(2), 154–171. <https://doi.org/10.1111/cpsp.12065>
 189. Laird, K. T., Siddarth, P., Ramos, A., Rich, R., Youssef, B., Schwartz, G. M., Sergi, K., Linton, M., Schwartzberg, L., Kelly, D. F., & Heinzlerling, K. G. (2026). Intentions, Spirituality, Set, and Setting Are Associated with Mystical Experiences in Psilocybin-Assisted Therapy. *Psychedelic Medicine*, 28314425251413425. <https://doi.org/10.1177/28314425251413425>

190. Lambe, E. K., & Aghajanian, G. K. (2007). Prefrontal cortical network activity: Opposite effects of psychedelic hallucinogens and D1/D5 dopamine receptor activation. *Neuroscience*, 145(3), 900–910. <https://doi.org/10.1016/j.neuroscience.2006.12.048>
191. Larkum, M. E. (2013). A cellular mechanism for cortical associations: An organizing principle for the cerebral cortex. *Trends in Neurosciences*, 36(3), 141–151. <https://doi.org/10.1016/j.tins.2012.11.006>
192. Laukkonen, R. E., Kaveladze, B. T., Tangen, J. M., & Schooler, J. W. (2020). The dark side of Eureka: Artificially induced Aha moments make facts feel true. *Cognition*, 196, 104122. <https://doi.org/10.1016/j.cognition.2019.104122>
193. Laukkonen, R. E., & Slagter, H. A. (2021). From many to (n)one: Meditation and the plasticity of the predictive mind. *Neuroscience and Biobehavioral Reviews*, 128, 199–217. <https://doi.org/10.1016/j.neubiorev.2021.06.021>
194. Laukkonen, R. E., Webb, M., Salvi, C., Tangen, J. M., & Schooler, J. (2018). Eureka Heuristic: How feelings of insight signal the quality of a new idea. 1–37.
195. Laukkonen, R. E., Webb, M., Salvi, C., Tangen, J. M., Slagter, H. A., & Schooler, J. W. (2023). Insight and the selection of ideas. *Neuroscience & Biobehavioral Reviews*, 153, 105363. <https://doi.org/10.1016/j.neubiorev.2023.105363>
196. Lawrence, S. J. D., Formisano, E., Muckli, L., & De Lange, F. P. (2019). Laminar fMRI: Applications for cognitive neuroscience. *NeuroImage*, 197, 785–791. <https://doi.org/10.1016/j.neuroimage.2017.07.004>
197. Leary, T., Alpert, R., & Metzner, R. (2017). *The Psychedelic Experience: A Manual Based on The Tibetan Book of the Dead*. Citadel.
198. Lebedev, A. V., Kaelen, M., Lövdén, M., Nilsson, J., Feilding, A., Nutt, D. J., & Carhart-Harris, R. L. (2016). LSD-induced entropic brain activity predicts subsequent personality change. *Human Brain Mapping*, 37(9), 3203–3213. <https://doi.org/10.1002/hbm.23234>
199. Letheby, C. (2021). *Philosophy of Psychedelics*. In *Philosophy of Psychedelics*. Oxford University Press. <https://doi.org/10.1093/med/9780198843122.001.0001>
200. Lewis, V., Bonniwell, E. M., Lanham, J. K., Ghaffari, A., Sheshbaradaran, H., Cao, A. B., Calkins, M. M., Bautista-Carro, M. A., Arsenault, E., Telfer, A., Taghavi-Abkuh, F.-F., Malcolm, N. J., El Sayegh, F., Abizaid, A., Schmid, Y., Morton, K., Halberstadt, A. L., Aguilar-Valles, A., & McCorvy, J. D. (2023). A non-hallucinogenic LSD analog with therapeutic potential for mood disorders. *Cell Reports*, 42(3), 112203. <https://doi.org/10.1016/j.celrep.2023.112203>

201. Liechti, M. E., Dolder, P. C., & Schmid, Y. (2017). Alterations of consciousness and mystical-type experiences after acute LSD in humans. *Psychopharmacology*, 234(9–10), 1499–1510. <https://doi.org/10.1007/s00213-016-4453-0>
202. Linguiti, S., Vogel, J. W., Sydnor, V. J., Pines, A., Wellman, N., Basbaum, A., Eickhoff, C. R., Eickhoff, S. B., Edwards, R. R., Larsen, B., McKinstry-Wu, A., Scott, J. C., Roalf, D. R., Sharma, V., Strain, E. C., Corder, G., Dworkin, R. H., & Satterthwaite, T. D. (2023). Functional imaging studies of acute administration of classic psychedelics, ketamine, and MDMA: Methodological limitations and convergent results. *Neuroscience & Biobehavioral Reviews*, 154, 105421. <https://doi.org/10.1016/j.neubiorev.2023.105421>
203. Lombaert, N., Hennes, M., Gilissen, S., Schevenels, G., Aerts, L., Vanlaer, R., Geenen, L., Van Eeckhaut, A., Smolders, I., Nys, J., & Arckens, L. (2018). 5-HTR2A and 5-HTR3A but not 5-HTR1A antagonism impairs the cross-modal reactivation of deprived visual cortex in adulthood. *Molecular Brain*, 11(1), 65. <https://doi.org/10.1186/s13041-018-0404-5>
204. Lord, L. D., Expert, P., Atasoy, S., Roseman, L., Rapuano, K., Lambiotte, R., Nutt, D. J., Deco, G., Carhart-Harris, R. L., Kringelbach, M. L., & Cabral, J. (2019). Dynamical exploration of the repertoire of brain networks at rest is modulated by psilocybin. *NeuroImage*, 199(May), 127–142. <https://doi.org/10.1016/j.neuroimage.2019.05.060>
205. Luppi, A. I., Carhart-Harris, R. L., Roseman, L., Pappas, I., Menon, D. K., & Stamatakis, E. A. (2021). LSD alters dynamic integration and segregation in the human brain. *NeuroImage*, 227(December 2020), 117653. <https://doi.org/10.1016/j.neuroimage.2020.117653>
206. Lutz, A., Jha, A. P., Dunne, J. D., & Saron, C. D. (2015). Investigating the phenomenological matrix of mindfulness-related practices from a neurocognitive perspective. *American Psychologist*, 70(7), 632–658. <https://doi.org/10.1037/a0039585>
207. Lyndon, S., & Corlett, P. R. (2020). Hallucinations in posttraumatic stress disorder: Insights from predictive coding. *Journal of Abnormal Psychology*, 129(6), 534–543. <https://doi.org/10.1037/abn0000531>
208. Lyon, A. (2023). *Psychedelic Experience: Revealing the Mind*. Oxford University Press. <https://doi.org/10.1093/oso/9780198843757.001.0001>
209. Lyon, P., Keijzer, F., Arendt, D., & Levin, M. (2021). Reframing cognition: Getting down to biological basics. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 376(1820), 20190750. <https://doi.org/10.1098/rstb.2019.0750>
210. MacLean, K. A., Leoutsakos, J. M. S., Johnson, M. W., & Griffiths, R. R. (2012). Factor Analysis of the Mystical Experience Questionnaire: A

- Study of Experiences Occasioned by the Hallucinogen Psilocybin. *Journal for the Scientific Study of Religion*, 51(4), 721–737. <https://doi.org/10.1111/j.1468-5906.2012.01685.x>
211. Madsen, M. K., Stenbæk, Dea S., Arvidsson, Albin, Armand, Sophia, Marstrand-Joergens, Maja R.en, Johansen, Sys S., Linnet, Kristian, Ozenne, Brice, Knudsen, Gitte M., & Fishera, Patrick M. (2021). Psilocybin-induced changes in brain network integrity and segregation correlate with plasma psilocin level and psychedelic experience. *European Neuropsychopharmacology*, 50, 121–132.
 212. Mahoney, M. J. (1974). *Cognition and behavior modification* (pp. xv, 351). Ballinger.
 213. Marek, G. J. (2017). Interactions of Hallucinogens with the Glutamatergic System: Permissive Network Effects Mediated Through Cortical Layer V Pyramidal Neurons. In A. L. Halberstadt, F. X. Vollenweider, & D. E. Nichols (Eds.), *Behavioral Neurobiology of Psychedelic Drugs* (Vol. 36, pp. 107–135). Springer Berlin Heidelberg. https://doi.org/10.1007/7854_2017_480
 214. Marek, G. J., & Schoepp, D. D. (2021). Cortical influences of serotonin and glutamate on layer V pyramidal neurons. In *Progress in Brain Research* (Vol. 261, pp. 341–378). Elsevier. <https://doi.org/10.1016/bs.pbr.2020.11.002>
 215. Martin, D. A., & Nichols, C. D. (2016). Psychedelics Recruit Multiple Cellular Types and Produce Complex Transcriptional Responses Within the Brain. *EBioMedicine*, 11, 262–277. <https://doi.org/10.1016/j.ebiom.2016.08.049>
 216. Mason, N. L., Kuypers, K. P. C., Reckweg, J. T., Müller, F., Tse, D. H. Y., Da Rios, B., Toennes, S. W., Stiers, P., Feilding, A., & Ramaekers, J. G. (2021). Spontaneous and deliberate creative cognition during and after psilocybin exposure. *Translational Psychiatry*, 11(1), 209. <https://doi.org/10.1038/s41398-021-01335-5>
 217. Mason, N. L., Mischler, E., Uthaug, M. V., & Kuypers, K. P. C. (2019). Sub-Acute Effects of Psilocybin on Empathy, Creative Thinking, and Subjective Well-Being. *Journal of Psychoactive Drugs*, 51(2), 123–134. <https://doi.org/10.1080/02791072.2019.1580804>
 218. Mason, T. B., Smith, K. E., Engwall, A., Lass, A., Mead, M., Sorby, M., Bjorlie, K., Strauman, T. J., & Wonderlich, S. (2019). Self-discrepancy theory as a transdiagnostic framework: A meta-analysis of self-discrepancy and psychopathology. *Psychological Bulletin*, 145(4), 372–389. <https://doi.org/10.1037/bul0000186>
 219. Masters, R. E. L., & Houston, J. (1966). *The Varieties of psychedelic experience*. Dell Publishing.

220. Mayer, R. E. (1995). The search for insight: Grappling with Gestalt psychology's unanswered questions. In *The nature of insight* (pp. 3–32). The MIT Press.
221. McClelland, J. L., Botvinick, M. M., Noelle, D. C., Plaut, D. C., Rogers, T. T., Seidenberg, M. S., & Smith, L. B. (2010a). Letting structure emerge: Connectionist and dynamical systems approaches to cognition. *Trends in Cognitive Sciences*, 14(8), 348–356. <https://doi.org/10.1016/j.tics.2010.06.002>
222. McClelland, J. L., Botvinick, M. M., Noelle, D. C., Plaut, D. C., Rogers, T. T., Seidenberg, M. S., & Smith, L. B. (2010b). Letting structure emerge: Connectionist and dynamical systems approaches to cognition. *Trends in Cognitive Sciences*, 14(8), 348–356. <https://doi.org/10.1016/j.tics.2010.06.002>
223. McCulloch, W. S., & Pitts, W. (1943). A logical calculus of the ideas immanent in nervous activity. *The Bulletin of Mathematical Biophysics*, 5(4), 115–133. <https://doi.org/10.1007/BF02478259>
224. Mediano, P. A. M., Rosas, F. E., Timmermann, C., Roseman, L., Nutt, D. J., Feilding, A., Kaelen, M., Kringelbach, M. L., Barrett, A. B., Seth, A. K., Muthukumaraswamy, S., Bor, D., & Carhart-Harris, R. L. (2024). Effects of External Stimulation on Psychedelic State Neurodynamics. *ACS Chemical Neuroscience*, 15(3), 462–471. <https://doi.org/10.1021/acscchemneuro.3c00289>
225. Mednick, M. T., & Halpern, S. (1968). Remote associates test. *Psychological Review*.
226. Mellor, C. S. (1991). Delusional Perception. *The British Journal of Psychiatry*, 159(S14), 104–107. <https://doi.org/10.1192/S0007125000296578>
227. Mengod, G., Palacios, J. M., & Cortés, R. (2015). Cartography of 5-HT1A and 5-HT2A Receptor Subtypes in Prefrontal Cortex and Its Projections. *ACS Chemical Neuroscience*, 6(7), 1089–1098. <https://doi.org/10.1021/acscchemneuro.5b00023>
228. Michaiel, A. M., Parker, P. R. L., & Niell, C. M. (2019). A Hallucinogenic Serotonin-2A Receptor Agonist Reduces Visual Response Gain and Alters Temporal Dynamics in Mouse V1. *Cell Reports*, 26(13), 3475–3483.e4. <https://doi.org/10.1016/j.celrep.2019.02.104>
229. Miller, W. R., & Baca, J. C. (2001). *Quantum Change: When Epiphanies and Sudden Insights Transform Ordinary Lives*. The Guilford Press.
230. Milliere, R. (2020). Varieties of Selflessness. *Philosophy and the Mind Sciences*, 1(I), 1–41. <https://doi.org/10.33735/phimisci.2020.i.48>
231. Millière, R., Carhart-Harris, R. L., Roseman, L., Trautwein, F.-M.,

- & Berkovich-Ohana, A. (2018). Psychedelics, Meditation, and Self-Consciousness. *Frontiers in Psychology*, 9, 1475. <https://doi.org/10.3389/fpsyg.2018.01475>
232. Miner, L. A. H., Backstrom, J. R., Sanders-Bush, E., & Sesack, S. R. (2003). Ultrastructural localization of serotonin_{2A} receptors in the middle layers of the rat prelimbic prefrontal cortex. *Neuroscience*, 116(1), 107–117. [https://doi.org/10.1016/S0306-4522\(02\)00580-8](https://doi.org/10.1016/S0306-4522(02)00580-8)
 233. Mishara, A. L. (2010). Klaus Conrad (1905-1961): Delusional mood, psychosis, and beginning schizophrenia. *Schizophrenia Bulletin*, 36(1), 9–13. <https://doi.org/10.1093/schbul/sbp144>
 234. Mishara, A. L., & Corlett, P. (2009). Are delusions biologically adaptive? Salvaging the doxastic shear pin. *Behavioral and Brain Sciences*, 32(6), 530–531. <https://doi.org/10.1017/S0140525X09991464>
 235. Morgan, R., Luborsky, L., Crits-Christoph, P., Curtis, H., & Solomon, J. (1982). Predicting the Outcomes of Psychotherapy by the Penn Helping Alliance Rating Method. *Archives of General Psychiatry*, 39(4), 397–402. <https://doi.org/10.1001/archpsyc.1982.04290040013002>
 236. Moses, B., Doss, M., & Tagliazucchi, E. (2026). A critical review of brain entropy as a biomarker of the psychedelic state.
 237. Muckli, L., De Martino, F., Vizioli, L., Petro, L. S., Smith, F. W., Ugurbil, K., Goebel, R., & Yacoub, E. (2015). Contextual Feedback to Superficial Layers of V1. *Current Biology*, 25(20), 2690–2695. <https://doi.org/10.1016/j.cub.2015.08.057>
 238. Muir, J., Lin, S., Aarrestad, I. K., Daniels, H. R., Ma, J., Tian, L., Olson, D. E., & Kim, C. K. (2024). Isolation of psychedelic-responsive neurons underlying anxiolytic behavioral states. *Science*, 386(6723), 802–810. <https://doi.org/10.1126/science.adl0666>
 239. Müller, F., Dolder, P. C., Schmidt, A., Liechti, M. E., & Borgwardt, S. (2018). Altered network hub connectivity after acute LSD administration. *NeuroImage: Clinical*, 18(March), 694–701. <https://doi.org/10.1016/j.nicl.2018.03.005>
 240. Nayak, S. M., & Griffiths, R. R. (2022). A Single Belief-Changing Psychedelic Experience Is Associated With Increased Attribution of Consciousness to Living and Non-living Entities. *Frontiers in Psychology*, 13(March), 1–8. <https://doi.org/10.3389/fpsyg.2022.852248>
 241. Nayak, S. M., Singh, M., Yaden, D. B., & Griffiths, R. R. (2023). Belief changes associated with psychedelic use. *Journal of Psychopharmacology*, 37(1), 80–92. <https://doi.org/10.1177/02698811221131989>
 242. Nichols, D. E. (2016). Psychedelics. *Pharmacological Reviews*, 68(2), 264–355. <https://doi.org/10.1124/pr.115.011478>
 243. Nour, M. M., & Carhart-Harris, R. L. (2017). Psychedelics and the science

- of self-experience. *British Journal of Psychiatry*, 210(3), 177–179. <https://doi.org/10.1192/bjp.bp.116.194738>
244. Nour, M. M., Evans, L., Nutt, D., & Carhart-Harris, R. L. (2016). Ego-dissolution and psychedelics: Validation of the ego-dissolution inventory (EDI). *Frontiers in Human Neuroscience*, 10, 190474. <https://doi.org/10.3389/fnhum.2016.00269>
 245. Oh, Y., Chesebrough, C., Erickson, B., Zhang, F., & Kounios, J. (2020). An insight-related neural reward signal. *NeuroImage*, 214, 116757. <https://doi.org/10.1016/j.neuroimage.2020.116757>
 246. Ohlsson, S. (1984a). Restructuring revisited. *Scandinavian Journal of Psychology*, 25(1), 65–78. <https://doi.org/10.1111/j.1467-9450.1984.tb01001.x>
 247. Ohlsson, S. (1984b). Restructuring revisited. *Scandinavian Journal of Psychology*, 25(2), 117–129. <https://doi.org/10.1111/j.1467-9450.1984.tb01005.x>
 248. Ohlsson, S. (2009). Resubsumption: A Possible Mechanism for Conceptual Change and Belief Revision. *Educational Psychologist*, 44(1), 20–40. <https://doi.org/10.1080/00461520802616267>
 249. Olson, D. E. (2021). The Subjective Effects of Psychedelics May Not Be Necessary for Their Enduring Therapeutic Effects. *ACS Pharmacology and Translational Science*. <https://doi.org/10.1021/acsptsci.0c00192>
 250. Ostafin, B. D., & Kassman, K. T. (2012). Stepping out of history: Mindfulness improves insight problem solving. *Consciousness and Cognition*. <https://doi.org/10.1016/j.concog.2012.02.014>
 251. Osuna-Mascaró, A. J., & Auersperg, A. M. I. (2021). Current Understanding of the “Insight” Phenomenon Across Disciplines. *Frontiers in Psychology*, 12, 791398. <https://doi.org/10.3389/fpsyg.2021.791398>
 252. Palhano-Fontes, F., Andrade, K. C., Tofoli, L. F., Santos, A. C., Crippa, J. A. S., Hallak, J. E. C., Ribeiro, S., & De Araujo, D. B. (2015). The Psychedelic State Induced by Ayahuasca Modulates the Activity and Connectivity of the Default Mode Network. *PLOS ONE*, 10(2), e0118143. <https://doi.org/10.1371/journal.pone.0118143>
 253. Pallavicini, C., Cavanna, F., Zamberlan, F., de la Fuente, L. A., Ilksoy, Y., Perl, Y. S., Arias, M., Romero, C., Carhart-Harris, R., Timmermann, C., & Tagliazucchi, E. (2021). Neural and subjective effects of inhaled N,N-dimethyltryptamine in natural settings. *Journal of Psychopharmacology*. <https://doi.org/10.1177/0269881120981384>
 254. Pan, X., & Hamilton, A. F. de C. (2018). Why and how to use virtual reality to study human social interaction: The challenges of exploring a new research landscape. *British Journal of Psychology*. <https://doi.org/10.1111/bjop.12290>

255. Parr, T., & Friston, K. J. (2017). Uncertainty, epistemics and active inference. *Journal of The Royal Society Interface*, 14(136), 20170376. <https://doi.org/10.1098/rsif.2017.0376>
256. Parr, T., & Friston, K. J. (2019). Attention or salience? *Current Opinion in Psychology, Attention & Perception*, 29, 1–5. <https://doi.org/10.1016/j.copsyc.2018.10.006>
257. Parsons, T. D., Gaggioli, A., & Riva, G. (2017). Virtual Reality for Research in Social Neuroscience. *Brain Sciences*, 7(4). <https://doi.org/10.3390/brainsci7040042>
258. Pastorelli, E., Yegenoglu, A., Kolodziej, N., Wybo, W., Simula, F., Diaz-Pier, S., Storm, J. F., & Paolucci, P. S. (2025). Simplified two-compartment neuron with calcium dynamics capturing brain-state specific apical-amplification, -isolation and -drive. *Frontiers in Computational Neuroscience*, 19, 1566196. <https://doi.org/10.3389/fncom.2025.1566196>
259. Payne, P., Levine, P. A., & Crane-Godreau, M. A. (2015). Somatic experiencing: Using interoception and proprioception as core elements of trauma therapy. *Frontiers in psychology*, 6, 124489.
260. Peill, J. M., Trinci, K. E., Kettner, H., Mertens, L. J., Roseman, L., Timmermann, C., Rosas, F. E., Lyons, T., & Carhart-Harris, R. L. (2022). Validation of the Psychological Insight Scale: A new scale to assess psychological insight following a psychedelic experience. *Journal of Psychopharmacology*, 36(1), 31–45. <https://doi.org/10.1177/02698811211066709>
261. Petitmengin, C. (2006). Describing one's subjective experience in the second person: An interview method for the science of consciousness. *Phenomenology and the Cognitive Sciences*, 5(3), 229–269. <https://doi.org/10.1007/s11097-006-9022-2>
262. Philippi, C. L., & Koenigs, M. (2014). The neuropsychology of self-reflection in psychiatric illness. *Journal of Psychiatric Research*, 54, 55–63. <https://doi.org/10.1016/j.jpsychires.2014.03.004>
263. Phillips, W. A. (2023). *The cooperative neuron: Cellular foundations of mental life*. Oxford university press.
264. Phillips, W. A., Bachmann, T., Spratling, M. W., Muckli, L., Petro, L. S., & Zolnik, T. (2025). Cellular psychology: Relating cognition to context-sensitive pyramidal cells. *Trends in Cognitive Sciences*, 29(1), 28–40. <https://doi.org/10.1016/j.tics.2024.09.002>
265. Phillips, W. A., Bachmann, T., & Storm, J. F. (2018). Apical Function in Neocortical Pyramidal Cells: A Common Pathway by Which General Anesthetics Can Affect Mental State. *Frontiers in Neural Circuits*, 12, 50. <https://doi.org/10.3389/fncir.2018.00050>
266. Phillips, W. A., Clark, A., & Silverstein, S. M. (2015). On the functions,

- mechanisms, and malfunctions of intracortical contextual modulation. *Neuroscience & Biobehavioral Reviews*, 52, 1–20. <https://doi.org/10.1016/j.neubiorev.2015.02.010>
267. Port, R. F., & Gelder, T. V. (1995). *Mind as Motion: Explorations in the Dynamics of Cognition*. MIT Press.
 268. Preller, K. H., Burt, J. B., Ji, J. L., Schleifer, C. H., Adkinson, B. D., Stämpfli, P., Seifritz, E., Repovs, G., Krystal, J. H., Murray, J. D., Vollenweider, F. X., & Anticevic, A. (2018). Changes in global and thalamic brain connectivity in LSD-induced altered states of consciousness are attributable to the 5-HT_{2A} receptor. *eLife*, 7, 1–31. <https://doi.org/10.7554/eLife.35082>
 269. Preller, K. H., Razi, A., Zeidman, P., Stämpfli, P., Friston, K. J., & Vollenweider, F. X. (2019). Effective connectivity changes in LSD-induced altered states of consciousness in humans. *Proceedings of the National Academy of Sciences of the United States of America*, 116(7), 2743–2748. <https://doi.org/10.1073/pnas.1815129116>
 270. Preller, K. H., Schilbach, L., Dürler, P., Pokorny, T., & Vollenweider, F. X. (2019). LSD increases social adaptation to opinions similar to one's own. *European Neuropsychopharmacology*, 29, S226–S227. <https://doi.org/10.1016/j.euroneuro.2018.11.368>
 271. Preller, K. H., & Vollenweider, F. X. (2018). Phenomenology, structure, and dynamic of psychedelic states. In *Current Topics in Behavioral Neurosciences* (Vol. 36, pp. 221–256). https://doi.org/10.1007/7854_2016_459
 272. Raison, C. L., Sanacora, G., Woolley, J., Heinzerling, K., Dunlop, B. W., Brown, R. T., Kakar, R., Hassman, M., Trivedi, R. P., Robison, R., & others. (2023). Single-Dose Psilocybin Treatment for Major Depressive Disorder: A Randomized Clinical Trial. *JAMA*, 330(9), 843–853.
 273. Rastelli, C., Greco, A., Kenett, Y. N., Finocchiaro, C., & De Pisapia, N. (2022). Simulated visual hallucinations in virtual reality enhance cognitive flexibility. *Scientific Reports*. <https://doi.org/10.1038/s41598-022-08047-w>
 274. Reed, S. K., & Vallacher, R. R. (2020). A comparison of information processing and dynamical systems perspectives on problem solving. *Thinking & Reasoning*, 26(2), 254–290. <https://doi.org/10.1080/13546783.2019.1605930>
 275. Ren, J., Huang, Z. H., Luo, J., Wei, G. X., Ying, X. P., Ding, Z. G., Wu, Y. B., & Luo, F. (2011). Meditation promotes insightful problem-solving by keeping people in a mindful and alert conscious state. *Science China Life Sciences*, 54(10), 961–965. <https://doi.org/10.1007/s11427-011-4233-3>

276. Richards, W. A. (2016). *Sacred Knowledge: Psychedelics and Religious Experiences*. Columbia University Press. <http://www.jstor.org/stable/10.7312/rich17406>
277. Riva, G., Brizzi, G., Rastelli, C., & Greco, A. (2026). AI-generated virtual psychedelics bridge digital and therapeutic frontiers in mental health research. *Nature Mental Health*, 4(2), 183–185. <https://doi.org/10.1038/s44220-025-00576-3>
278. Roseman, L., Haijen, E., Idialu-Ikato, K., Kaelen, M., Watts, R., & Carhart-Harris, R. (2019). Emotional breakthrough and psychedelics: Validation of the Emotional Breakthrough Inventory. *Journal of Psychopharmacology*, 33(9), 1076–1087. <https://doi.org/10.1177/0269881119855974>
279. Roseman, L., Leech, R., Feilding, A., Nutt, D. J., & Carhart-Harris, R. L. (2014). The effects of psilocybin and MDMA on between-network resting state functional connectivity in healthy volunteers. *Frontiers in Human Neuroscience*, 8. <https://doi.org/10.3389/fnhum.2014.00204>
280. Roseman, L., Nutt, D. J., & Carhart-Harris, R. L. (2018). Quality of acute psychedelic experience predicts therapeutic efficacy of psilocybin for treatment-resistant depression. *Frontiers in Pharmacology*. <https://doi.org/10.3389/fphar.2017.00974>
281. Rosenblat, J. D., Leon-Carlyle, M., Ali, S., Husain, M. I., & McIntyre, R. S. (2023). Antidepressant Effects of Psilocybin in the Absence of Psychedelic Effects. *American Journal of Psychiatry*, 180(5), 395–396. <https://doi.org/10.1176/appi.ajp.20220835>
282. Rossi, G. N., Khubsing, R. S. I., Haijen, E. C. H. M., Mason, N. L., Van Leerdam, M., Dos Santos, R. G., Hallak, J. E. C., & Kuypers, K. P. C. (2025). Comparative effects of ayahuasca and breathwork on self-reported cognitive flexibility, emotion regulation, positive affect, and sleep quality. *Journal of Psychedelic Studies*. <https://doi.org/10.1556/2054.2025.00440>
283. Roth, M. M., Dahmen, J. C., Muir, D. R., Imhof, F., Martini, F. J., & Hofer, S. B. (2016). Thalamic nuclei convey diverse contextual information to layer 1 of visual cortex. *Nature Neuroscience*, 19(2), 299–307. <https://doi.org/10.1038/nn.4197>
284. Rubio-Garrido, P., Pérez-de-Manzo, F., Porrero, C., Galazo, M. J., & Clascá, F. (2009). Thalamic Input to Distal Apical Dendrites in Neocortical Layer 1 Is Massive and Highly Convergent. *Cerebral Cortex*, 19(10), 2380–2395. <https://doi.org/10.1093/cercor/bhn259>
285. Safron, A., Juliani, A., Reggente, N., Klimaj, V., & Johnson, M. (2025). On the varieties of conscious experiences: Altered Beliefs Under Psychedelics (ALBUS). *Neuroscience of Consciousness*, 2025(1), niae038. <https://doi.org/10.1093/nc/naie038>

286. Salvi, C., & Bowden, E. (2024). Insight: What Happens Backstage? In C. Salvi, J. Wiley, & S. M. Smith (Eds.), *The Emergence of Insight* (1st ed., pp. 280–308). Cambridge University Press. <https://doi.org/10.1017/9781009244244.013>
287. Salvi, C., Bricolo, E., Kounios, J., Bowden, E., & Beeman, M. (2016). Insight solutions are correct more often than analytic solutions. *Thinking & Reasoning*, 22(4), 443–460. <https://doi.org/10.1080/13546783.2016.1141798>
288. 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>
289. Sayood, K. (2018). Information Theory and Cognition: A Review. *Entropy*, 20(9), 706. <https://doi.org/10.3390/e20090706>
290. Schallmo, M.-P., Jungers, S., Varghese, R., Cullen, K., Evans, M., Nielson, J., & Swanson, L. (2025). Stronger visual surround suppression under psilocybin: A psychophysical and EEG pilot study. *Journal of Vision*, 25(9), 2091. <https://doi.org/10.1167/jov.25.9.2091>
291. Schmitz, G. P., Chiu, Y.-T., Foglesong, M. L., Magee, S. N., MacKinnon, M., König, G. M., Kostenis, E., Hsu, L.-M., Shih, Y.-Y. I., Roth, B. L., & Herman, M. A. (2025). Psychedelic compounds directly excite 5-HT2A layer V medial prefrontal cortex neurons through 5-HT2A Gq activation. *Translational Psychiatry*, 15(1), 381. <https://doi.org/10.1038/s41398-025-03611-0>
292. Schwarz, N., Uysal, B., Welzer, M., Bahr, J. C., Layer, N., Löffler, H., Stanaitis, K., Pa, H., Weber, Y. G., Hedrich, U. B., Honegger, J. B., Skodras, A., Becker, A. J., Wuttke, T. V., & Koch, H. (2019). Long-term adult human brain slice cultures as a model system to study human CNS circuitry and disease. *eLife*, 8, e48417. <https://doi.org/10.7554/eLife.48417>
293. Seifert, C. M., Meyer, D. E., Davidson, N., Patalano, A. L., & Yaniv, I. (1994). Demystification of cognitive insight: Opportunistic assimilation and the prepared-mind hypothesis.
294. Seneca. (n.d.). *Letters to Lucilius*. Retrieved February 15, 2026, from http://archive.org/details/seneca-letters-to-lucilius_202406
295. Seragnoli, F., Picard, F., Thorens, G., Buchard, A., Geyer, M., Abatista, A., Ponomarenko, P., Petignat, C., Riccardi, M., Bisson, M., Rochat, L., Penzestadler, L., Zullino, D., & Billieux, J. (2025). Metacognitive Feelings of Epistemic Gain are Central to the Understanding of Psychedelic-Induced Mystical-Type Experiences. *Cognitive Therapy and Research*, 49(5), 873–901. <https://doi.org/10.1007/s10608-025-10588-z>

296. Shannon, C. E. (1948). A mathematical theory of communication. *The Bell System Technical Journal*, 27(3), 379–423. <https://doi.org/10.1002/j.1538-7305.1948.tb01338.x>
297. Shanon, B. (2002). *The antipodes of the mind: Charting the phenomenology of the Ayahuasca experience*. Oxford University Press.
298. Shao, L.-X., Liao, C., Davoudian, P. A., Savalia, N. K., Jiang, Q., Wojtasiewicz, C., Tan, D., Nothnagel, J. D., Liu, R.-J., Woodburn, S. C., Bilash, O. M., Kim, H., Che, A., & Kwan, A. C. (2025). Psilocybin's lasting action requires pyramidal cell types and 5-HT_{2A} receptors. *Nature*, 642(8067), 411–420. <https://doi.org/10.1038/s41586-025-08813-6>
299. Shen, W., Tong, Y., Li, F., Yuan, Y., Hommel, B., Liu, C., & Luo, J. (2018). Tracking the neurodynamics of insight: A meta-analysis of neuroimaging studies. *Biological Psychology*, 138, 189–198. <https://doi.org/10.1016/j.biopsycho.2018.08.018>
300. Shen, W., Yuan, Y., Liu, C., & Luo, J. (2017). The roles of the temporal lobe in creative insight: An integrated review. *Thinking and Reasoning*, 23(4), 321–375. <https://doi.org/10.1080/13546783.2017.1308885>
301. Shen, W., Yuan, Y., Zhao, Y., Zhang, X., Liu, C., Luo, J., Li, J., & Fan, L. (2018). Defining insight: A study examining implicit theories of insight experience. *Psychology of Aesthetics, Creativity, and the Arts*, 12(3), 317–327. <https://doi.org/10.1037/aca0000138>
302. Siegel, J. S., Subramanian, S., Perry, D., Kay, B. P., Gordon, E. M., Lauermann, T. O., Reneau, T. R., Metcalf, N. V., Chacko, R. V., Gratton, C., Horan, C., Samuel R. Krimmel, J. S. S., Schweiger, J. A., De Nicol, G. E., & Dosenbach, N. U. F. (2024). Psilocybin desynchronizes the human brain. *Nature*, 632, 131–138.
303. 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). Receptor-informed network control theory links LSD and psilocybin to a flattening of the brain's control energy landscape. *Nature Communications*, 13(1), 5812. <https://doi.org/10.1038/s41467-022-33578-1>
304. Sips, R., Van Duppen, Z., Kasanova, Z., De Thurah, L., Teixeira, A., Feyaerts, J., & Myin-Germeys, I. (2021). Psychosis as a dialectic of aha- and anti-aha-experiences: A qualitative study. *Psychosis*, 13(1), 47–57. <https://doi.org/10.1080/17522439.2020.1798492>
305. Skaar, Ø. O., & Reber, R. (2020). The phenomenology of Aha-experiences. *Motivation Science*, 6(1), 49–60. <https://doi.org/10.1037/mot0000138>
306. Slagter, H. A., Davidson, R. J., & Lutz, A. (2011). Mental Training as a Tool in the Neuroscientific Study of Brain and Cognitive Plasticity. *Frontiers in Human Neuroscience*, 5. <https://doi.org/10.3389/fnhum>.

2011.00017

307. Slater, M., & Sanchez-Vives, M. V. (2016). Enhancing Our Lives with Immersive Virtual Reality. *Frontiers in Robotics and AI*, 3. <https://doi.org/10.3389/frobt.2016.00074>
308. Slingerland, E. (2007). *Effortless Action: Wu-wei As Conceptual Metaphor and Spiritual Ideal in Early China*. Oxford University Press.
309. Spratling, M. W. (2002). Cortical Region Interactions and the Functional Role of Apical Dendrites. *Behavioral and Cognitive Neuroscience Reviews*, 1(3), 219–228. <https://doi.org/10.1177/1534582302001003003>
310. Stace, W. T. (1960). *Mysticism and Philosophy*. Macmillan Pub Ltd.
311. Stephen, D. G., Boncoddio, R. A., Magnuson, J. S., & Dixon, J. A. (2009). The dynamics of insight: Mathematical discovery as a phase transition. *Memory & Cognition*, 37(8), 1132–1149. <https://doi.org/10.3758/MC.37.8.1132>
312. Stephen, D. G., Dixon, J. A., & Isenhower, R. W. (2009). Dynamics of representational change: Entropy, action, and cognition. *Journal of Experimental Psychology: Human Perception and Performance*, 35(6), 1811–1832. <https://doi.org/10.1037/a0014510>
313. Stoliker, D., Egan, G. F., Friston, K. J., & Razi, A. (2022). Neural Mechanisms and Psychology of Psychedelic Ego Dissolution. *Pharmacological Reviews*, 74(4), 876–917. <https://doi.org/10.1124/pharmrev.121.000508>
314. Stoliker, D., Novelli, L., Vollenweider, F. X., Egan, G. F., Preller, K. H., & Razi, A. (2024). Neural Mechanisms of Resting-State Networks and the Amygdala Underlying the Cognitive and Emotional Effects of Psilocybin. *Biological Psychiatry*, 96(1), 57–66. <https://doi.org/10.1016/j.biopsych.2024.01.002>
315. Studerus, E., Gamma, A., & Vollenweider, F. X. (2010). Psychometric evaluation of the altered states of consciousness rating scale (OAV). *PLoS ONE*, 5(8). <https://doi.org/10.1371/journal.pone.0012412>
316. Studerus, E., Komater, M., Hasler, F., & Vollenweider, F. X. (2011). Acute, subacute and long-term subjective effects of psilocybin in healthy humans: A pooled analysis of experimental studies. *Journal of Psychopharmacology*, 25(11), 1434–1452. <https://doi.org/10.1177/02698811110382466>
317. Suzuki, K., Roseboom, W., Schwartzman, D. J., & Seth, A. K. (2017). A Deep-Dream Virtual Reality Platform for Studying Altered Perceptual Phenomenology. *Scientific Reports*. <https://doi.org/10.1038/s41598-017-16316-2>
318. Suzuki, M., Pennartz, C. M. A., & Aru, J. (2023). How deep is the brain? The shallow brain hypothesis. *Nature Reviews Neuroscience*, 24(12), 778–791. <https://doi.org/10.1038/s41583-023-00756-z>

319. Swanson, L. R. (2016). The Predictive Processing Paradigm Has Roots in Kant. *Frontiers in Systems Neuroscience*, 10. <https://doi.org/10.3389/fnsys.2016.00079>
320. Swanson, L. R. (2024). Psychedelic visuals in context. In *Philosophical Perspectives on Psychedelic Psychiatry* (pp. 116–138).
321. Swanson, L. R., Jungers, S., Varghese, R., Cullen, K. R., Evans, M. D., Nielson, J. L., & Schallmo, M.-P. (2024). Enhanced visual contrast suppression during peak psilocybin effects: Psychophysical results from a pilot randomized controlled trial. *Journal of Vision*, 24(12), 5. <https://doi.org/10.1167/jov.24.12.5>
322. Tagliazucchi, E., Carhart-Harris, R., Leech, R., Nutt, D., & Chialvo, D. R. (2014). Enhanced repertoire of brain dynamical states during the psychedelic experience. *Human Brain Mapping*. <https://doi.org/10.1002/hbm.22562>
323. Tagliazucchi, E., Roseman, L., Kaelen, M., Orban, C., Muthukumaraswamy, S. D., Murphy, K., Laufs, H., Leech, R., McGonigle, J., Crossley, N., Bullmore, E., Williams, T., Bolstridge, M., Feilding, A., Nutt, D. J., & Carhart-Harris, R. (2016). Increased Global Functional Connectivity Correlates with LSD-Induced Ego Dissolution. *Current Biology*. <https://doi.org/10.1016/j.cub.2016.02.010>
324. Takahashi, N., Ebner, C., Sigl-Glöckner, J., Moberg, S., Nierwetberg, S., & Larkum, M. E. (2020). Active dendritic currents gate descending cortical outputs in perception. *Nature Neuroscience*, 23(10), 1277–1285. <https://doi.org/10.1038/s41593-020-0677-8>
325. Tarr, M. J., & Warren, W. H. (2002). Virtual reality in behavioral neuroscience and beyond. *Nature Neuroscience*, 5(11), 1089–1092. <https://doi.org/10.1038/nn948>
326. Thelen, E., & Smith, L. B. (1994). *A Dynamic Systems Approach to the Development of Cognition and Action*. MIT Press.
327. Thøgersen, M., Andoh, J., Milde, C., Graven-Nielsen, T., Flor, H., & Petrini, L. (2020). Individualized Augmented Reality Training Reduces Phantom Pain and Cortical Reorganization in Amputees: A Proof of Concept Study. *The Journal of Pain*, 21(11–12), 1257–1269. <https://doi.org/10.1016/j.jpain.2020.06.002>
328. Tik, M., Sladky, R., Luft, C. D. B., Willinger, D., Hoffmann, A., Banissy, M. J., Bhattacharya, J., & Windischberger, C. (2018). Ultra-high-field fMRI insights on insight: Neural correlates of the Aha!-moment. *Human Brain Mapping*, 39(8), 3241–3252. <https://doi.org/10.1002/hbm.24073>
329. Timmermann, C., Kettner, H., Letheby, C., Roseman, L., Rosas, F., & Carhart-Harris, R. (2021). Psychedelics alter metaphysical beliefs. *Scientific Reports*, 11(1), 22166. <https://doi.org/10.31234/osf.io/f6sjk>

330. Timmermann, C., Roseman, L., Haridas, S., Rosas, F. E., Luan, L., Kettner, H., Martell, J., Erritzoe, D., Tagliazucchi, E., Pallavicini, C., Girn, M., Alamia, A., Leech, R., Nutt, D. J., & Carhart-Harris, R. L. (2023). Human brain effects of DMT assessed via EEG-fMRI. *Proceedings of the National Academy of Sciences of the United States of America*, 120(13), e2218949120. <https://doi.org/10.1073/pnas.2218949120>
331. Timmermann, C., Spriggs, M. J., Kaelen, M., Leech, R., Nutt, D. J., Moran, R. J., Carhart-Harris, R. L., & Muthukumaraswamy, S. D. (2018). LSD modulates effective connectivity and neural adaptation mechanisms in an auditory oddball paradigm. *Neuropharmacology*, 142, 251–262. <https://doi.org/10.1016/j.neuropharm.2017.10.039>
332. Timmermann, C., Watts, R., & Dupuis, D. (2020). Towards psychedelic apprenticeship: Developing a gentle touch for the mediation and validation of psychedelic-induced insights and revelations. *Transcultural Psychiatry*.
333. Timulak, L., & McElvaney, R. (2013). Qualitative meta-analysis of insight events in psychotherapy. *Counselling Psychology Quarterly*, 26(2), 131–150. <https://doi.org/10.1080/09515070.2013.792997>
334. Topolinski, S., & Reber, R. (2010). Gaining Insight Into the “Aha” Experience. *Current Directions in Psychological Science*, 19(6), 402–405. <https://doi.org/10.1177/0963721410388803>
335. Tuck, J. R., Dunlap, L. E., Khatib, Y. A., Hatzipantelis, C. J., Weiser Novak, S., Rahn, R. M., Davis, A. R., Mosswood, A., Vernier, A. M. M., Fenton, E. M., Aarrestad, I. K., Tombari, R. J., Carter, S. J., Deane, Z., Wang, Y., Sheridan, A., Gonzalez, M. A., Avanes, A. A., Powell, N. A., ... Olson, D. E. (2025). Molecular design of a therapeutic LSD analogue with reduced hallucinogenic potential. *Proceedings of the National Academy of Sciences*, 122(16), e2416106122. <https://doi.org/10.1073/pnas.2416106122>
336. Tulver, K., Kaup, K. K., & Aru, J. (2025). The road to Aha: A recipe for mental breakthroughs. *Cognition*, 257, 106081. <https://doi.org/10.1016/j.cognition.2025.106081>
337. Tulver, K., Kaup, K. K., Laukkonen, R., & Aru, J. (2023). Restructuring insight: An integrative review of insight in problem-solving, meditation, psychotherapy, delusions and psychedelics. *Consciousness and Cognition*, 110, 103494. <https://doi.org/10.1016/j.concog.2023.103494>
338. Turing, A. M. (1950). Computing Machinery and Intelligence. *Mind*, 59(236), 433–460.
339. Uhlhaas, P. J., & Mishara, A. L. (2007). Perceptual anomalies in schizophrenia: Integrating phenomenology and cognitive neuroscience. *Schizophrenia Bulletin*, 33(1), 142–156. <https://doi.org/10.1093/schbul/sbl047>
340. Uthaug, M. V., Lancelotta, R., Szabo, A., Davis, A. K., Riba, J., & Ramaekers, J. G. (2020). Prospective examination of synthetic 5-methoxy-

- N,N-dimethyltryptamine inhalation: Effects on salivary IL-6, cortisol levels, affect, and non-judgment. *Psychopharmacology*. <https://doi.org/10.1007/s00213-019-05414-w>
341. Van Der Braak, A. (2025). Beyond the Mystical Experience Model: Theurgy as a Framework for Ritual Learning with Psychedelics. *Religions*, 16(11), 1430. <https://doi.org/10.3390/rel16111430>
 342. van Elk, M., & Yaden, D. B. (2022). Pharmacological, neural, and psychological mechanisms underlying psychedelics: A critical review. *Neuroscience and Biobehavioral Reviews*, 140. <https://doi.org/10.1016/j.neubiorev.2022.104793>
 343. Van Gelder, T. (1998). The dynamical hypothesis in cognitive science. *Behavioral and Brain Sciences*, 21(5), 615–628. <https://doi.org/10.1017/S0140525X98001733>
 344. 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-HT_{2A} receptors. *Science*, 379(6633), 700–706. <https://doi.org/10.1126/science.adf0435>
 345. Vejmla, Č., Šíchová, K., Syrová, K., Janečková, L., Koudelka, V., Tesař, M., Nikolič, M., Viktorinová, M., Tylš, F., Korčák, J., Viktorin, V., Kelemen, E., Nekovářová, T., Brunovský, M., Horáček, J., Kuchař, M., & Páleníček, T. (2025). Cross-Species Evidence for Psilocin-Induced Visual Distortions: Apparent Motion Is Perceived by Both Humans and Rats. *Biological Psychiatry Global Open Science*, 5(5), 100524. <https://doi.org/10.1016/j.bpsgos.2025.100524>
 346. Vinci-Booher, S., Ren, X., Kay, K., Yu, C., Pestilli, F., & Booth, J. R. (2025). Dense longitudinal neuroimaging reveals individual brain change trajectories. *Trends in Cognitive Sciences*, 0(0). <https://doi.org/10.1016/j.tics.2025.09.005>
 347. Vitello, M., & Salvi, C. (2023). Gestalt's Perspective on Insight, a Recap Based on Recent Behavioral and Neuroscientific Evidence. *Social Sciences*. <https://doi.org/10.20944/preprints202309.1198.v1>
 348. Volgin, A. D., Yakovlev, O. A., Demin, K. A., Alekseeva, P. A., Kyzar, E. J., Collins, C., Nichols, D. E., & Kalueff, A. V. (2019). Understanding Central Nervous System Effects of Deliriant Hallucinogenic Drugs through Experimental Animal Models. *ACS Chemical Neuroscience*, 10(1), 143–154. <https://doi.org/10.1021/acschemneuro.8b00433>
 349. Vollenweider, F. X., & Smallridge, J. W. (2022). Classic Psychedelic Drugs: Update on Biological Mechanisms. *Pharmacopsychiatry*, 55(03), 121–138. <https://doi.org/10.1055/a-1721-2914>

350. von Rotz, R., Schindowski, E. M., Jungwirth, J., Schuld, A., Rieser, N. M., Zahoranszky, K., Seifritz, E., Nowak, A., Nowak, P., Jäncke, L., Preller, K. H., & Vollenweider, F. X. (2023). Single-dose psilocybin-assisted therapy in major depressive disorder: A placebo-controlled, double-blind, randomised clinical trial. *eClinicalMedicine*, 56. <https://doi.org/10.1016/j.eclinm.2022.101809>
351. Wachtel, P. L. (1997). Psychoanalysis, behavior therapy, and the relational world (pp. xxiv, 484). American Psychological Association. <https://doi.org/10.1037/10383-000>
352. Wallas, G. (1926). *The art of thought*. Harcourt, Brace.
353. Watts, R., Day, C., Krzanowski, J., Nutt, D., & Carhart-Harris, R. (2017). Patients' Accounts of Increased "Connectedness" and "Acceptance" After Psilocybin for Treatment-Resistant Depression. *Journal of Humanistic Psychology*, 57(5), 520–564. <https://doi.org/10.1177/0022167817709585>
354. Weber, & Andrade, R. (2010). Htr2a gene and 5-HT2A receptor expression in the cerebral cortex studied using genetically modified mice. *Frontiers in Neuroscience*, 4, 36. <https://doi.org/10.3389/fnins.2010.00036>
355. Weisberg, R. W. (2013). On the "Demystification" of Insight: A Critique of Neuroimaging Studies of Insight. *Creativity Research Journal*, 25(1), 1–14. <https://doi.org/10.1080/10400419.2013.752178>
356. Weisberg, R. W. (2016). *Creativity: Understanding Innovation in Problem Solving, Science, Invention, and the Arts*. John Wiley & Sons.
357. Wießner, I., Falchi, M., Maia, L. O., Daldegan-Bueno, D., Palhano-Fontes, F., Mason, N. L., Ramaekers, J. G., Gross, M. E., Schooler, J. W., Feilding, A., Ribeiro, S., Araujo, D. B., & Tófoli, L. F. (2022). LSD and creativity: Increased novelty and symbolic thinking, decreased utility and convergent thinking. *Journal of Psychopharmacology*, 36(3), 348–359. <https://doi.org/10.1177/02698811211069113>
358. Willins, D. L., Deutch, A. Y., & Roth, B. L. (1997). Serotonin 5-HT2A receptors are expressed on pyramidal cells and interneurons in the rat cortex. *Synapse*, 27(1), 79–82. [https://doi.org/10.1002/\(SICI\)1098-2396\(199709\)27:1%3C79::AID-SYN8%3E3.0.CO;2-A](https://doi.org/10.1002/(SICI)1098-2396(199709)27:1%3C79::AID-SYN8%3E3.0.CO;2-A)
359. Wolff, T. J., Ruffell, S., Netzband, N., & Passie, T. (2019). A phenomenology of subjectively relevant experiences induced by ayahuasca in Upper Amazon vegetalismo tourism. *Journal of Psychedelic Studies*, 3(3), 295–307. <https://doi.org/10.1556/2054.2019.007>
360. Xu, N., Harnett, M. T., Williams, S. R., Huber, D., O'Connor, D. H., Svoboda, K., & Magee, J. C. (2012). Nonlinear dendritic integration of sensory and motor input during an active sensing task. *Nature*, 492(7428), 247–251. <https://doi.org/10.1038/nature11601>

361. Xu, T., & Pandey, S. C. (2000). Cellular localization of serotonin_{2A} (5HT_{2A}) receptors in the rat brain. *Brain Research Bulletin*, 51(6), 499–505. [https://doi.org/10.1016/S0361-9230\(99\)00278-6](https://doi.org/10.1016/S0361-9230(99)00278-6)
362. Yaden, D. B., & Griffiths, R. R. (2021). The Subjective Effects of Psychedelics Are Necessary for Their Enduring Therapeutic Effects. *ACS Pharmacology and Translational Science*. <https://doi.org/10.1021/acspsci.0c00194>
363. Yaden, D. B., Johnson, M. W., Griffiths, R. R., Doss, M. K., Garcia-Romeu, A., Nayak, S., Gukasyan, N., Mathur, B. N., & Barrett, F. S. (2021). Psychedelics and Consciousness: Distinctions, Demarcations, and Opportunities. *International Journal of Neuropsychopharmacology*, 24(8), 615–623. <https://doi.org/10.1093/ijnp/pyab026>
364. Yaden, D. B., Kaufman, S. B., Hyde, E., Chirico, A., Gaggioli, A., Zhang, J. W., & Keltner, D. (2019). The development of the Awe Experience Scale (AWE-S): A multifactorial measure for a complex emotion. *The Journal of Positive Psychology*, 14(4), 474–488. <https://doi.org/10.1080/17439760.2018.1484940>
365. Yates, J., Immergut, M., & Graves, J. (2015). *The Mind Illuminated: A Complete Meditation Guide Integrating Buddhist Wisdom and Brain Science*. Dharma Treasure Press. <https://books.google.ee/books?id=u0yIrgEACAAJ>
366. Zedelius, C. M., & Schooler, J. W. (2015). Mind wandering “Ahas” versus mindful reasoning: Alternative routes to creative solutions. *Frontiers in Psychology*, 6(June), 1–13. <https://doi.org/10.3389/fpsyg.2015.00834>
367. Zhai, Y., George, C. A., Zhai, J., Nisenbaum, E. S., Johnson, M. P., & Nisenbaum, L. K. (2003). Group II Metabotropic Glutamate Receptor Modulation of DOI-induced c-fos mRNA and Excitatory Responses in the Cerebral Cortex. *Neuropsychopharmacology*, 28(1), 45–52. <https://doi.org/10.1038/sj.npp.1300013>

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Victoria Concordia Crescit

SISUKOKKUVÕTE

Psühhedeelse taipamisega seotud arvutused ajus

Mis toimub meie ajus, kui me millestki järsku aru saame? Selles väitekirjas uuritakse võimsaid ja tähendusrikkaid taipamiselamusi, mis tekitavad pikaajalisi ja põhjalikke muutuseid inimese meeletegevuses. Selliseid taipamisi on väga raske kontrollitud keskkonnas esile kutsuda, mistõttu on nende teaduslik uurimine olnud äärmiselt piiratud. Viimaste aastakümnete uuringud annavad aga lootust ägedate taipamiste süstemaatilisele uurimisele, kasutades nende tekitamiseks psühhedeelikume. Selle alusel keskendutakse siin psühhedeelse seisundi uurimisele.

Kõigepealt aga annab väitekiri põhjaliku ülevaate taipamisest eri valdkondades: probleemilahenduses, psühhoterapias, meditatsioonis, psühhedeelse teaduse ja psühhootiliste seisundite uuringutes. Ülevaateartikkel toob välja sarnasused ja erinevused, kuidas nendes valdkondades taipamist mõtestatakse ning uuritakse. Vaatamata sellele, et need valdkonnad on üksteisest suhteliselt eraldatud, on taipamist käsitletud võrdlemisi sarnaselt. Taipamisele eelneb tihti pingetunne või konfliktiseisund. Mitmes valdkonnas on täheldatud, et uus mõistmine saabub pigem just siis, kui pingutus vastuse leidmiseks peatatakse ning ollakse avatud ja vastuvõtlik. Taipamiskogemused on tihti tähendusrikkad ja tunduvad tõesed. Nähtuse käigus võivad muutuda erinevad meeletegevuse objektid, näiteks uskumused, mõtted või teadmised. Taipamise keskne tähtsus kõikides nendes eripärastes valdkondades illustreerib tema fundamentaalsust inimese mõtetegevuses.

Seejärel kasutatakse väitekirjas arvutuslikke raamistikke, näiteks informatsioonteooriat ja dünaamiliste süsteemide teooriat, et taipamist täpsemalt kirjeldada. Nendele toetudes pakutakse välja taipamise uus käsitlus, mis on üles ehitatud eelmainitud ülevaateartiklis leitud põhilistele taipamisega seotud mehhanismidele. Toetudes meesisude ja uskumuste informatsioonilisele hierarhilisele struktuurile, pakutakse välja, et taipamise intensiivsus on märk muutunud uskumuse hierarhilisest sügavusest: väga võimas taipamiskogemus, mis muudab inimese käitumist aastateks, on seotud fundamentaalse ja sügava uskumuse mõjutamisega, leebe taipamine, näiteks mõne mõistatuse lahendamine, mõjutab aga ainult pinnapealset uskumust. Lisaks tuuakse välja taipamise peamised mehhanismid: konflikt sismiste kujutiste vahel, muutunud salientsus ning võimendunud kognitiivne paindlikkus. Nende mehhanismide täpsema ja selgema mõistmise huvides kirjeldatakse neid erinevate arvutuslike raamistike abil. Uus käsitlus toob kokku malbed ja met-sikud taipamised ning võimaldab luua paremaid kvantitatiivseid lähenemisi.

Taipamise tekitamiseks loodi virtuaalreaalsuskogemus Psyrreal, mis imiteerib psühhedeelse seisundi võtmelemente. Palju muu seas võib Psyrrealis leida mitmekülgseid nägemistaju moonutusi ning füüsilise egolahustumisega tihti seotud tajulisi ilminguid. Psühhedeelse seisundi kogemuslike aspektide terapeutilise toime uurimiseks rakendati Psyrreali lühikeses, kahepäevases terapeutilises sekumises. Esialgsed tulemused näitasid, et Psyrrealiga toetatud teraapia tagajärjel

vähenesid patsientide depressioonisümptomid. Uuring toetab virtuaalreaalsuse ja psühhedeelsete ainete subjektiivse mõju potentsiaali psühhiaatrilises ravis.

Väitekirja võtab kokku viimane artikkel, kus selgitatakse psühhedeelse seisundi ajal ajus toimuvaid arvutuslikke protsesse. Serotonergilised psühhedeelikumid toimivad läbi serotoniinireseptori 2A alamtüübi, mis paiknevad eeskätt ajukoore viienda rakukihi apikaalsetel dendriitidel. Sellele vaatamata ei ole psühhedeelses neuroteaduses seni pööratud erilist tähelepanu apikaalsete dendriitide funktsioonile ja anatoomiale. Siinses töös antakse ülevaate viienda kihi püramidaalneuronite apikaalsetest dendriitidest seoses serotonergiliste psühhedeelikumide toimega. Lühidalt öeldes suunavad serotonergilised psühhedeelikumid ajukoore infotöötamise raskuskeset viienda rakukihi närvirakkude apikaalsetele dendriitidele. Selle tulemusena võimendub ajukoore ja ajukoorealuse taalamuse koostöö ning ajusignaali jaotatakse laiali mööda kogu ajukoort. See neurobioloogiline protsess on aluseks psühhedeelikumide kesksele mehhanismile, hüperkontekstualiseerimisele, mis seisneb meeleisude omavahelise suhtlemise võimendumises. Seejärel antakse artiklis ülevaade serotonergiliste psühhedeelikumide toimest meele- ja ajutegevusele, näidates, et nende mõju saab kokku võtta kui võimendunud kontekstuaalset informatsioonitöötlust.

Väitekirjas pakutakse uusi meetodeid taipamise ja psühhedeelsete ainete toime uurimiseks ning uusi raamistikke nende protsessidega seotud arvutuste paremaks mõistmiseks.

PUBLICATIONS

CURRICULUM VITAE

Personal data

Full name: Karl Kristjan Kaup
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Education

2021 – 2026 Ph.D. in Computer Science, University of Tartu
2017 – 2019 Researcher, National Institute of Chemical and Biophysics
2017 – 2019 MSc in Physics (*cum laude*), University of Tartu
2012 – 2017 BSc in Physics, University of Tartu

Employment

2021 – Junior Research Fellow, University of Tartu
2020 - 2021 Engineer, National Institute of Chemical and Biophysics
2019 - 2020 Data Analyst, Lemeks Group AS

Supervision

2025, MSc thesis Marten Kase, 2025, (juh) Jaan Aru¹; Karl Kristjan Kaup, *"Effects of LSD, DMT and psilocybin on cognitive and psychological functions: a systematic review of the literature"*, Tartu Ülikool, Sotsiaalteaduste valdkond, psühholoogia instituut

2024, MSc thesis Ares Hubel, magistrikraad (juh) Karl Kristjan Kaup¹ *"Exploring Entropy and Signal Diversity in Neural Networks Using the AdEx Model"*

2026, BSc thesis Sandra Schihalejev, (juh) Jaan Aru¹; Karl Kristjan Kaup *"The Possibility of Simulating Psychedelic Experiences in Virtual Reality Using Psyrreal "*

2026, BSc thesis Kristofer Robin Kütt, (juh) Karl Kristjan Kaup¹ *"Alterations of Consciousness Associated with a Psychedelic Virtual Reality Experience"*

Teaching

Spring 2023, 2026 Natural and Artificial Intelligence Seminar
Fall 2021 Computational Neuroscience (teaching assistant)

¹Supervisor in charge

Administrative and professional activities

- Conference participation and presentation: INSIGHT 2021, 2023, ASSC 2022, ICPR 2022, Mystical Entropy Workshop 2023, ESISyNC 2025, SA TAIP seminar "Psychedelic-assisted therapy in Estonia and Europe"
- Collaborations: SA TAIP
- Additional training: NeuroMatch Academy Computational Neuroscience course 2023
- Radio and podcast appearances: "Labor", "Tähenduse Teejuhid", and SA TAIP's "Taipamised"

ELULOOKIRJELDUS

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Haridus

2021 – 2026 Arvutiteaduse doktoriõpe, Tartu Ülikool
2017 – 2019 Keemilise ja Bioloogilise Füüsika Instituut, uurija
2017 – 2019 Füüsika magistrantuur (*cum laude*), Tartu Ülikool
2012 – 2017 Füüsika bakalaureus, Tartu Ülikool

Teenistuskäik

2021 – Nooremteadur, Tartu Ülikool
2020 - 2021 Insener, Keemilise ja Bioloogilise Füüsika Instituut
2019 - 2020 Andmeanalüütik, Lemeks Grupp AS

Juhendamine

2025, MSc lõputöö Marten Kase, magistrikraad, 2025, (juh) Jaan Aru¹; Karl Kristjan Kaup, LSD, DMT ja psilotsübiini mõju kognitiivsetele ja psühholoogilistele funktsioonidele: süstemaatilise ülevaade kirjandusest), Tartu Ülikool, Sotsiaalteaduste valdkond, psühholoogia instituut
2024, MSc lõputöö Ares Hubel, magistrikraad (juh) Karl Kristjan Kaup¹ "*Entroopia ja signaali mitmekesisuse uurimine AdEx närvivõrkudes*"
2026, BSc lõputöö Sandra Schihalejev, (juh) Jaan Aru¹; Karl Kristjan Kaup "*Psühhedeeset kogemust jälgendava virtuaalreaalsuse valideerimine ja andmestiku analüüs*"
2026, BSc lõputöö Kristofer Robin Kütt, (juh) Karl Kristjan Kaup¹ "*Psühheedelse virtuaalreaalsuskogemusega seotud tajumuutused*"

Õppetöö

Kevad 2023, 2026 Tehisliku ja loomuliku mõistuse seminar
Sügis 2021 Arvutuslik neuroteadus (õppeassistent)

¹ Vastutav juhendaja

Administratiivsed ja professionaalsed tegevused

- Osalemine ja ettekanded konverentsidel: INSIGHT 2021, 2023, ASSC 2022, ICPR 2022, Mystical Entropy Workshop 2023, ESISyNC 2025, SA TAIP seminar "Psühhedeelikumidega toetatud teraapia Eestis ja Euroopas"
- Populaarteaduslik koostöö muude asutustega: SA TAIP
- Lisaõpe: NeuroMatch Academy arvutusliku neuroteaduse kursus 2023
- Raadio ja taskuhäälingu esinemised: "Labor", "Tähenduse Teejuhid", and SA TAIPi "Taipamised"

**DISSERTATIONES INFORMATICAЕ
PREVIOUSLY PUBLISHED IN
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UNIVERSITATIS TARTUENSIS**

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