Review

Drug Science

Drug Science, Policy and Law
Volume 8: 1–16

DOI: 10.1177/20503245221097649
journals.sagepub.com/home/dsp
SAGE

Psychedelics as potential catalysts of scientific creativity and insight

Sam Gandy[1], Valérie Bonnelle[2], Edward Jacobs[3] and David Luke[4,5]

Abstract

Creativity, that is the creation of ideas or objects considered both novel and valuable, is among the most important and highly valued of human traits, and a fundamental aspect of the sciences. Dreams and hypnagogic states have been highly influential in promoting scientific creativity and insight, contributing to some important scientific breakthroughs. Phenomenologically, the latter states of consciousness share a great deal of overlap with the psychedelic state, which has also been associated with facilitating scientific creativity on occasion. The current article proposes that the dream, hypnagogic and psychedelic states share common features that make them conducive to supporting some aspects of scientific creativity and examines the putative underlying neurophenomenological and cognitive processes involved. In addition, some notable occurrences of scientific insights that have emerged from these types of altered states are reviewed and shared common features are presented, providing a ground for future research. The psychedelic state may have its own characteristic features making it amenable to creativity enhancement, such as brain hyperconnectivity, meta-cognitive awareness, access to a more dependable and sustained altered state experience, and potential for eliciting sustained shifts in trait openness. The contextual factors which may contribute to enhancement of scientific creativity and insight will be evaluated. While research in this area is limited, further work to elucidate how psychedelics may best contribute to scientific creativity enhancement is warranted.

Introduction

> *"The most beautiful experience we can have is the mysterious. It is the fundamental emotion that stands at the cradle of true art and true science. Whoever does not know it and can no longer wonder, no longer marvel, is as good as dead, and his eyes are dimmed."*
>
> - Albert Einstein

Aspects of creative thinking

Creativity is considered one of the most important and valued human traits (Andreasen, 2011). It is a ubiquitous and essential form of cognition linked to all areas of our everyday lives, allowing us to adapt to an ever-changing environment and come up with ways to solve problems (Kim & Pierce, 2013). While creativity is difficult to both define and measure (Barbot, 2019; Kaufman et al., 2012), it is considered a multidimensional domain (Chambers, 1969, Csikszentmihalyi, 1999), meaning a reliance on a single instrument or analytical approach will be unable to comprehensively capture its complex and multifaceted nature (Kerr & Gagliardi, 2003). It is a fundamental aspect of the sciences (Langley et al., 1987; McCrae, 1987), playing a pivotal role in important scientific discoveries (Li et al., 2015). Creativity has been defined as the "production of an idea, act or object that is both original and valued" (Csikszentmihalyi, 1999), with a number of different investigators converging on a definition of creativity as "the production of effective novelty" (see Aldous, 2007; Grosul & Feist, 2014; Plucker et al., 2004). This definition has also been applied to creativity in a scientific context (Diedrich et al., 2015; Runco & Jaeger, 2012). A creative idea cannot be generated by the generic rules applied to formulating a familiar idea, suggestive that creativity hinges on a conceptual shift in thinking (Boden, 2004), with novelty of ideas being particularly important (Diedrich et al., 2015). While scientific and artistic creativity overlap, scientific creativity tends to encompass the capacity to solve problems and formulate hypotheses, often involving an expansion of knowledge in a given domain,

[1]Synthesis Institute, The Netherlands
[2]The Beckley Foundation, UK
[3]Department of Psychiatry, University of Oxford, UK
[4]Centre for Mental Health, School of Human Sciences, University of Greenwich, UK
[5]Department of Brain Sciences, Centre for Psychedelic Research, Imperial College London, UK

Corresponding author:
Sam Gandy, Farndon Grange, Marston Lane, Market Harborough, Leicestershire, LE16 9SL, UK.
Email: greensam2512@hotmail.com

whereas artistic creativity tends to be more concerned with the generation of new representations of life or feelings (Aldous, 2007; Liang, 2002), or actions and ideas that seek to transform the thoughts, principals and materials of the artist and their audience (Lehmann & Gaskins, 2019). In addition, there is a tendency for scientific creativity to be more externally focussed and applied, whereas artistic creativity may be more introspectively orientated (Feist, 1999). Scientific creativity is broadly relevant across the sciences, being "not limited to the natural and biological sciences but included in the social sciences (i.e. anthropology, psychology, sociology), invention, engineering and mathematics" (Feist, 1998, p. 294).

Fluid and flexible cognitive processes are considered to be fundamental to problem solving and creative ability (Walker et al., 2002), and these may encompass features such as retrospective and forward thinking, while contemplating options in the present moment, or what those options might be under differing scenarios. Such a dynamic mind state that shifts between different modes of thought is a key aspect of creative thinking (Girn et al., 2020). These distinct modes of thought include divergent thinking (associated with the process of generating multiple potential solutions to a problem) and convergent thinking (associated with the process of coming up with a single concrete solution to a problem). Creative thought has also been conceptualised as analytical and synthetic thinking. Analytical thinking is associated with breaking down a concept into its component parts while systematically seeking a single viable solution to a problem, while rejecting inadequate ideas, with the thought process occurring in incremental stages (Ericsson & Simon, 1993; Kounios et al., 2008). Synthetic thinking is a more dynamic thought process, associated with combining multiple components into a coherent whole, and seeking patterns across these component parts. Analytical and synthetic thinking can be considered analogous to primary and secondary process thinking (Feist, 1991). Synthetic thinking has been associated with the occurrence of sudden *insight*, characterised by "a mental restructuring of acquired information, from which new explicit knowledge can be drawn" (Craig et al., 2018) and through which "previously unseen and unexpected connections suddenly reveal themselves to the mind" (Langley et al., 1987). A plastic mind state and a tension within knowledge structures have been proposed to be common prerequisites of insight generation (Tulver et al., 2021). Breakthroughs in science often occur when a novel connection is made between existing concepts previously perceived as being distinct or isolated (Scheffer et al., 2015). Examples include Albert Einstein's theory of general relativity, which demonstrated the intimate link between gravity, space and time (Einstein 1915a, 1915b), or James Clerk Maxwell's classical theory of electromagnetic radiation, which unified light, electricity and magnetism as manifestations of the same phenomenon (Maxwell, 1873).

The creative process has been defined as occurring in distinct phases, including preparation, incubation, illumination and verification (Wallas, 1926; see also Murphy, 1958). Imagination is considered an important aspect of creativity (Daniels-McGhee & Davis, 1994; French, 2020), considered vital for scientific inquiry and research by highly influential scientific figures such as Albert Einstein (Einstein, 1931, p. 46). Inspiration also constitutes an occasionally overlooked aspect of creativity (Oleynick et al., 2014). The creative process has been linked to accessing unconscious states rather than being limited to conscious thought, such as during reveries when the mind is more likely to wander freely and fluidly and without censorship (Andreasen, 2011). Physicist Arkady Migdal described the creative state as a liminal one "where consciousness and unconsciousness mix, when conscious reasoning continues in sleep, and subconscious work is done in waking" (Moss, 2014, p. 142). The use of mental visualisation and imagery is considered a key aspect of creativity by numerous scientific luminaries (LeBoutillier & Marks, 2003; Polland, 1996; Walkup, 1965). Imagery-based and visualisation approaches may confer benefits to the creative process, by transcending the limitations and structures imposed by language and traditional ways of thinking. The relation of imagery to external sources may also harbour interactions and interrelations not fully supported by language, and imagery may be more sensitive to intuition and manipulation (Intons-Peterson, 1993). The process of mind wandering has been associated with breaking fixation (the process of cycling back to old ideas when seeking new ones) (Chou & Tversky, 2020) and promoting insight generation (Zedelius & Schooler, 2016). Mind wandering has also been conceptualised as fluid thinking which has been associated with greater potential for creative problem solving during the incubation phase of the creative process (Baird et al., 2012). It has been argued that the sciences may benefit from greater application of this mind state creatively (Scheffer, 2014; Scheffer et al., 2015), and greater creativity more broadly (Craig, 1990), and that facilitating insight and generation of new ideas could aid scientific advancement (East & Ang, 2021).

Altered states and creativity

Increasing evidence suggests that altered states of consciousness are associated with both positive and negative effects on components of creative performance (Prochazkova & Hommel, 2020). A dosage of 50 ug LSD has been found to enhance mind wandering (Wießner et al., 2021a). Mind wandering is inversely correlated with mindful awareness, which tends to be associated with analytical thinking (Zedelius & Schooler, 2015, 2016). This suggests that while there may be gains in some forms of creative thinking under a psychedelic, there are likely to be accompanying deficits in analytical thinking. This suggests that the psychedelic state may contribute to aspects of creative generation, but not to creative evaluation (Girn et al., 2020; Wießner et al., 2021b). The illumination phase of the creative process is associated with loose, freely associative and non-logical thought and highly subjective ideation or primary process thinking, this being a shared feature of the psychedelic (Kraehenmann et al., 2017), dream (Livingston & Levin, 1991) and hypnagogic (Mavromatis, 1987) states. Mental imagery (Polland, 1996), dreams (Krippner & Hughes, 1970) and psychedelics (Harman et al., 1966) have all been associated with catalysing scientific insight at the illumination stage (also referred to as the 'eureka' phase, where creative ideas may spontaneously flash into vision).

While rigorous research on psychedelics and creativity is still scarce, the problem solving capacity of psychedelics has been used in traditional indigenous contexts (Rubel & Gettelfinger-Krejci, 1976; Winkelman, 2019). The problem solving potential of the dream state has been long recognised and cultivated via dream incubation practices by a variety of cultures for millenia (Nielsen, 1988), and acknowledged scientifically for over a century (Barrett, 2020). Dreams (Barrett, 1993; Schatzman, 1984; White & Taytroe, 2003) and lucid dreams (Stumbrys & Daniels, 2010) have been associated with enhancing problem solving ability through their ability to generate insights. Dream processes are more likely to be engaged to solve emotionally relevant problems as opposed to the abstract puzzle designs used in some studies (Barrett, 1993; Schatzman, 1984) and creative problem solving dreams tend to occur following extensive work on a problem while awake (Barrett, 2001a). Similarly, an early study assessing the effects of LSD on creative thinking concluded that it "would only be likely to enhance creative thought in those individuals who were meaningfully engaged in some specific interest or problem" (Zegans et al., 1967). While research examining the creativity enhancing potential of the hypnagogic state is lacking, one study found that hypnagogia almost tripled the chances of participants solving mathematical problems (administered without them knowing a hidden rule which would allow for them to be solved almost instantly) in comparison to the equivalent time period spent on the task while awake (Lacaux et al., 2021).

Overlap between psychedelic, dream and hypnagogic states

The neurophenomenological similarity shared by the dream and psychedelic state has long been acknowledged (Fischman, 1983; Jacobs, 1978), and supported by recent research (Carhart-Harris & Nutt, 2014; Kraehenmann, 2017; Sanz et al., 2018). This supports the notion that psychedelics acutely induce dreamlike subjective experiences (Kraehenmann, 2017), with both states featuring the emergence of unconscious material into consciousness (Carhart-Harris, 2007). Psychedelic states are considered particularly similar to lucid dreaming due to the clarity of consciousness (encompassing a clarity of emotional and intellectual capacities and a remembrance of current and past circumstances) and capacity for meta-cognitive awareness associated with both (Kraehenmann, 2017; Sanz et al., 2018), this being characterised by a mixed state of dreaming and waking consciousness (Voss et al., 2009). The dream, hypnagogic and psychedelic states are associated with enhanced capacity for mental imagery and visualisation (Kraehenmann, 2017; Mavromatis, 1987) and all are associated with more fluid, unconstrained, imagistic and hyper-associative states of consciousness (Girn et al., 2020; Kraehenmann, 2017; Mavromatis, 1987; Tagliazucchi et al., 2014). However, while recall of content from dream and hypnagogic states can be harnessed with practice or through the application of specific techniques (Lacaux et al., 2021; Nielsen, 1992; Purcell et al., 1986), amnesia is associated with both (Schacter, 1976; Waters et al., 2016), which may make recall of insights challenging. Amnesia may be less of an issue with low to medium doses of psychedelics (Fadiman, 2011, p. 142).

It has been postulated that an important benefit distinguishing hypnagogia over dreaming for problem solving is the capacity for hallucinatory images to be critically examined before the eyes (Barrett, 2001b). This is a quality shared with the psychedelic state, with the similarities in visual qualities of both states long recognised (Klüver, 1942; Mitchell, 1896; Ardis & Mckellar, 1956). Hypnagogia can be considered a hybrid semi-lucid state, where an individual's awareness is decoupled from their external environment, where the mind is liable to freely wander but logical ability to identify creative insight is retained (Horowitz, 2019). This shares overlap with the psychedelic state, which is typically associated with metacognitive awareness, where one is aware they are under the influence of a drug, and they are more grounded in the external world (Kraehenmann, 2017). However, psychedelics may provide access to a more reliable and sustained altered state than hypnagogia, which tends to be transient and fleeting (Lacaux et al., 2021; Waters et al., 2016). In the non-lucid dream state, the dreamer is cut off from reality (Waters et al., 2016) and there tends to be a lack of contextual awareness of where one is and what one is doing, with events and characters taken for real (Nir & Tononi, 2010), a feature shared by intoxication with deliriant tropane alkaloids (Sanz et al., 2018). Aside from dream and hypnagogic states, there is increasing evidence to demonstrate overlap between the phenomenology and neurophysiology of psychedelics with meditation practices (Millière et al., 2018), as well as synergy between them (Gandy, 2022). Meditation practices may be a worthwhile additional avenue to explore with regard to cultivation of creative thinking (Henriksen et al. 2020), potentially contributing to creative incubation and illumination (Horan, 2009). Mindfulness meditation practice has been demonstrated to reduce cognitive rigidity, reducing likelihood of being creatively blinded by prior preconceptions and experiences (Greenberg et al., 2012), while promoting divergent (Berkovich-Ohana et al., 2017; Colzato et al., 2012) and insight (Ostafin & Kassman, 2012) thinking.

Contribution of altered states to scientific creativity

Dreams and hypnagogic states (Barrett, 2001a; Polland, 1996; Mazzarello, 2000), and psychedelic experiences (Harman et al., 1966; Stafford & Golightly, 1967) have been associated with enhanced creative problem solving ability and catalysing scientific creativity and insight on occasion, contributing to some important scientific breakthroughs (see Table 1). Some scientists may be predisposed towards having dreams that catalyse insight. One survey study looking at exceptional human experiences among scientists and engineers in comparison to the general population found that scientists scored significantly higher on some items assessing aspects of their dream lives, including the item "*Received important information through your dreams*" (Wahbeh et al., 2018).

Dreams were highly influential to the thinking of René Descartes, and his insights contributed to the development of the natural sciences and the foundation of the modern scientific method (Davis & Hersh, 1986; Withers, 2008). A dream is thought to have been pivotal in Russian chemist Dmitri Mendeleev's conception of the periodic table of chemical elements; described as chemistry's most important breakthrough (Rouvray, 1994). According to his close friend A. A. Inostrantzev, he went three days and nights without sleep while working on it, before finally falling asleep with extreme fatigue. He was quoted by Inostrantzev as saying: "I saw in a dream a table where all the elements fell into place as required … only in one place did a correction later seem necessary." (Sharpe, 1967). Dreams also played a role in Nobel Prize winning chemist Alfred Werner's important contribution to the field of inorganic chemistry (Berl, 1942; Kauffman, 1968) and Nobel Prize winning pharmacologist and psychobiologist Otto Loewi's work (Loewi, 1960; McCoy & Tan, 2014) which would constitute a very important step towards establishing the field of neuroscience. Hypnagogic states have also been important sources of scientific insight. Chemist August Kekulé was struggling to ascertain the chemical structure of benzene and perceived a hypnagogic vision of atoms forming the image of a snake with a tail in its mouth. He strongly felt this vision was of the cyclic molecular structure of benzene (Rothenberg, 1995; Strunz, 1993) which was subsequently verified (Lonsdale, 1929; 1931). Within a generation Kekulé's theory had been described as the "most brilliant piece of scientific prediction to be found in the whole of organic chemistry", and that "three-fourths of modern organic chemistry is, directly or indirectly, the product of this theory" (Japp, 1898). It is noteworthy that in these aforementioned cases and others detailed in Table 1, the individuals in question tended to be deeply emotionally engaged with their respective subjects, in many cases having exerted extensive mental focus and effort on their subject or unable to make progress when their breakthrough insight experience occurred (Barrett, 2001a).

Contribution of psychedelics to scientific creativity, insight and inspiration

Psychedelics have contributed to catalysing scientific insight in a number of domains. British pharmacologist Sir John Gaddum self-experimented with LSD (having noted the similarity in chemical structure between it and serotonin) to study its effects in the first-person (Green, 2008). He postulated that the compound induced effects by blocking the stimulating effects of serotonin, and he was the first scientist to postulate that serotonin might play a role in mood regulation (Gaddum, 1953, 1957). This was an important contribution to the emerging field of psychopharmacology at the time. Psychedelics have also been credited with catalysing insights in the fields of neurology (Lees, 2019), mathematics (Abraham, 2008) and theoretical physics (Higgins, 2018). LSD was utilised as a creativity enhancing tool by the Berkley-based Fundamental Fysiks Group, who helped revive interest in Bell's theorem, which was neglected by mainstream physics at the time (Kaiser, 2012). Anthropologist Jeremy Narby accompanied three molecular biologists to the Amazon where they all participated in ayahuasca ceremonies supervised by an indigenous shaman, with all three scientists reporting that they felt they had obtained visionary insight relating to their work perceived as being useful and relevant, and all felt further research was warranted (Narby, 2001, p. 301–305). The chemist and pharmacologist Alexander Shulgin credits his first psychedelic experience with "unquestionably confirming the entire direction" of his life (Shulgin & Shulgin, 1991, p. 16). Self-experimentation with psychedelics by researchers likely played an important and largely undocumented role in the first wave of mainstream psychiatric research from the 1950′s to the early 1970′s (Nielson & Guss, 2018; Winkler & Csémy, 2014), and some modern researchers' credit self-experimentation as being helpful for the development of research questions pertaining to the psychological effects of the substances (Nielson & Guss, 2018; Forstmann & Sagioglou, 2021). While LSD has been credited with playing a role in the discovery of the structure of DNA through self-experimentation by Francis Crick, its

Table 1. Contributions of psychedelic, dream and hypnagogic states to catalysing scientific creativity and insight.

State	Individual	Scientific field and insight	References
Dream	Alfred Werner	*Chemistry*; contributed to conception of coordination theory	Berl, 1942; Ernst & Berke, 2011
Dream	Dmitri Mendeleev	*Chemistry*; development of Periodic Table of the Elements	Barrett, 2001a; Sharpe, 1967
Dream	Steven Barker	*Chemistry/Neurochemistry;* childhood lucid dreams inspired career pursuing research into psychedelic DMT	Crockett, 2012
Dream	Alan Huang	*Computing (design);* insight into lasers that assisted in design of laser computers	Barrett, 2001c
Dream	Stephen Bailey	*Computing (programming);* assisted in creation of program allocating computer memory for working with complex mathematical matrices	Barrett, 2001c
Dream	Larry Page	*Computing (software development);* contributed to the conception of Google search engine	McPherson, 2010, p. 27
Dream	Paul Horowitz	*Engineering (optical);* dreams assisted in optic and circuit assembly during radio-telescope construction projects	Barrett, 2001c
Dream	Don Newman	*Mathematics*; overcoming a mathematical problem, which led to a publication	Barrett, 2011, p. 27
Dream	Srinivasa Ramanujan	*Mathematics*; various, unspecified	Kanigel, 1991, p. 281
Dream	Otto Loewi	*Neuroscience*; inspired experiment demonstrating primary language of cell communication was chemical rather than electrical	Loewi, 1953, 1960; Mazzarello, 2000
Hypnagogic & Dream	Louis Agassiz	*Paleontology*; assisted in revealing the fossilised morphology of a fish	Agassiz, 1855
Hypnagogic	August Kekulé	*Chemistry*; insights into carbon bonding in chemical structures and conception of cyclic structure of benzene	Dayan, 2006; Rothenberg, 1995; Strunz, 1993
Hypnagogic	Thomas Edison	*Electrical engineering*; creative inspiration and insight on inventions, unspecified	Porterfield, 1941, p. 94
Psychedelic	John P. Allen	*Architecture (ecological)*; insights contributed to conception and construction of Biosphere 2	Allen, 2009
Psychedelic	Mark Van Thillo	*Architecture (ecological)*; insights into ecotechnology inspired work as manager of the technical systems of Biosphere 2	Thillo, 2009
Psychedelic	Kiyo Izumi	*Architecture (psychiatric)*; architectural redesign of a psychiatric hospital	Izumi, 1970, pp. 381–397; Stafford & Golightly, 1967, pp. 207–209
Psychedelic	Kary Mullis	*Biochemistry*; development of PCR	Doyle, 2002; Mullis, 1997
Psychedelic	Alexander Shulgin	*Chemistry/Pharmacology*; self-experimentation inspired career involving creation of 230 novel psychedelic and entactogenic compounds	Shulgin & Shulgin, 1991, p. 16
Psychedelic	Steve Jobs	*Computing (design)*; inspired shift in creative focus (prioritising quality over revenue generation)	Dormehl, 2012; Markoff, 2005
Psychedelic	Dennis Wier	*Computing (programming)*; assisted in development of compiler for an application language known as MARLAN	Wier, 2008
Psychedelic	Kevin Herbert	*Computing (programming)*; overcoming creative blocks and complex problems, aiding in finding technical solutions	Reitman, 2008
Psychedelic	Adam Wiggins	*Computing (software development)*; assisting in development of a cloud platform service supporting several programming languages	Christiansen, 2017
Psychedelic	John Busby	*Electrical engineering*; helped overcome problem in pattern recognition developing intelligence equipment for US Navy	Rosenfeld, 1966, p. 30D
Psychedelic	Ralph Abraham	*Mathematics*; insights on understanding of chaos theory	Abraham, 2008
Psychedelic	Andrew Lees	*Neurology*; insights into Parkinson's disease research	Lees, 2019
Psychedelic	Kenneth Ring	*Psychology;* insights led to research of near-death experiences	Blackmore, 2020
Psychedelic	John Gaddum	*Psychopharmacology*; self-experimentation contributed to hypothesis that serotonin might play a role in mood regulation	Green, 2008
Psychedelic	Carlo Rovelli	*Theoretical physics*; inspired career in physics, due to insights on the nature of time: works in field of quantum gravity and a founder of loop quantum gravity theory	Higgins, 2018

role in the latter discovery was neither confirmed nor denied by him, with it taking place in 1953, at a time when LSD was rare and little known (Roberts, 2008).

American biochemist Kary Mullis considers his use of LSD to have played an important role in his discovery of a means to automate the polymerase chain reaction (PCR) (Doyle, 2002), a breakthrough for which he was awarded the Nobel Prize in Chemistry in 1993 (Shampo & Kyle, 2002). Notably, Mullis's breakthrough came not while under the influence of LSD, but subsequent to its usage, suggesting a more enduring change in cognition or creativity, as suggested by some studies (Frecska et al., 2012; Harman et al., 1966; Mason et al., 2019, 2021; Uthaug et al., 2018).

In his own words:

> "*PCR's another place where I was down there with the molecules when I discovered it and I wasn't stoned on LSD, but my mind by then had learned how to get down there. I could sit on a DNA molecule and watch the polymerase go by…I've learned that partially I would think, and this is again my opinion, through psychedelic drugs…if I had not taken LSD ever would I have still been in PCR? I don't know, I doubt it, I seriously doubt it.*" (Mullis, 1997).

Psychedelics appear to have had a notable influence on computing, credited with enhancing creativity and contributing to computer programming (Reitman, 2008; Wier, 2008) and software development (Christiansen, 2017). Noteworthy computing pioneer Douglas Engelbart was administered LSD as part of a study conducted by the International Foundation of Advanced Study (IFAS) investigating how psychedelics might influence creativity. He went on to introduce a score of major technical innovations, including the computer mouse (Markoff, 2005). LSD has been credited with contributing to the design of computer circuit chips by early Silicon Valley computer engineers before they could be designed on computers (Pollan, 2018, p. 182) and to the formation of quantum encryption, helping ignite the multi-billion dollar research field of quantum information science (Kaiser, 2012). Apple founder Steve Jobs felt that LSD had played a pivotal and transformative role in his life and work (Dormehl, 2012), describing taking LSD "as one of the two or three most important things he had done in his life" (Markoff, 2005). It is possible that psychedelics have had more influence on the field of computing than is currently publicly known (Abraham, 2008; Reitman, 2008)

Although these anecdotes are not evidence that psychedelics systematically induce a state of heightened creativity conducive to scientific insight, they seem to indicate that, under certain circumstances, they can. In light of this, it is important to acknowledge the selection bias inherent in these accounts, through selecting cases where these altered states contributed to creative scientific insight. However it should be noted that dreams often go unreported (Nir & Tononi, 2010), and it is possible that psychedelic usage by scientists is underreported, due to valid concerns over potential repercussions to personal and professional lives if illicit usage is revealed (Fadiman, 2011, p. 117; Love, 2019; Nutt, 2012, p. 258). Certainly this applies within the psychedelic research field itself (Forstmann & Sagioglou, 2021).

Research on psychedelics and scientific creativity

A noteworthy seminal pilot study conducted by Harman and colleagues looked at the effect of a psychedelic on creative problem solving. The researchers took care to select 27 individuals engaged in creative work (including engineering, physics, theoretical mathematics, architecture, commercial art and furniture design). This study is notable in that participants were not solely assessed via psychometric tests, but also worked on genuine work-related creative issues they were trying to solve. They had a pre-drug session where they were encouraged to select problems of professional concern where creative solutions were needed (with a number of participants having worked for weeks or months on problems without a satisfactory solution). They were positively primed for the experience by being instructed that the drug would help enhance their creativity and assist them in their work and that they would experience few if any distractions or personal emotional states, and that the experience could be directed as desired.

Participants were administered 200 mg of mescaline sulphate (a relatively low dose, similar to 50 µg LSD; Baggot, 2015) and were encouraged to work in groups and as individuals to engage with their creative problem task. Psychometric tests assessing creativity were used pre, during and post session, and qualitative assessments performed at one week post session, with a follow up conducted with 16 participants 6–8 weeks post experience. All study participants displayed enhanced abilities on all tests during the session, and around half subjectively reported that their creative ability to solve professional problems had been enhanced and that they had accomplished more than on a typical workday. Around 20% of participants reported being unable to concentrate on their creative problem due to being distracted by personal concerns. Of the subsample of 16 participants surveyed 6–8 weeks post experience, around half continued to attribute a range of benefits to the experience relating to their creative ability and work performance, with no deficits reported. Assessment of qualitative accounts revealed that all participants felt the drug had subjectively enhanced their creative process, and revealed 11 core themes pertaining to 'Strategies of Enhanced Functioning'. These included an enhanced fluency and flexibility to ideas, superior visualising capacity, heightened motivation, empathy, concentration and access to the subconscious, reduced inhibition and anxiety and an improved association of dissimilar ideas and capacity to restructure problems in a wider context (Harman et al., 1966; Fadiman, 2011). Many participants attempted to find a creative solution to more than one problem, and follow up assessments revealed that 6 solutions were accepted for production or construction, 10 partial solutions were being developed or further applied, and 20 new avenues for investigation were opened up, with 4 reports of no solution obtained (Fadiman, 2011, p. 132).

While this study's findings are compelling and warrant further research, it should be noted that this study was severely limited through a lack of double blinding or placebo control, and a lack of independent assessment of creativity by experts. Given that psychedelics enhance suggestibility (Carhart-Harris et al., 2015), it is unclear to what extent the positive priming contributed to the results. In addition, 8 participants had prior experience with psychedelics, and methamphetamine was also administered during the psychedelic session day (Baggot, 2015). This was one of the last legally sanctioned psychedelic studies of the 1960′s, before all psychedelic research was shut down by the US Food and Drug Administration (Fadiman, 2011, p. 185), halting all scientific progress in this area for decades.

Effects of psychedelics on cognitive processes relevant to creativity

Numerous early studies on psychedelics and creativity suffered from methodological limitations (Iszáj et al., 2017; Krippner, 1985), but tended to show a discrepancy between subjective feelings of enhanced creativity and external assessment of creative ability (Baggott, 2015). This is possibly due to changes in affect and meaning attribution associated with their effects (Girn et al., 2020; Griffiths et al., 2008; Hartogsohn, 2018). Research suggests that psychedelics can alter aspects of cognition and subjective experience that may modulate some aspects of creative thinking rather than playing a generalised role in enhancing creativity (Girn et al., 2020). They have been associated with eliciting a state of 'unconstrained' cognition (Girn et al., 2020) and generating 'loosened cognition' in the mid to long term (Carhart-Harris et al., 2016a).

The hyperassociative nature of the psychedelic state is likely an important aspect of its creativity enhancing potential, and this shift in mind state is supported by a number of studies, one demonstrating that psilocybin can affect semantic processing, leading to an increased availability of free associations (Spitzer et al., 1996), where a thought or image may spontaneously suggest another despite lacking a logical connection. LSD can also increase semantic network activation and enhance associative thinking, fostering unusual and unconstrained forms of thought (Family et al., 2016; Wießner et al., 2021a). A further study with ayahuasca adds further support for the enhancement of associative thinking associated with the psychedelic state, with an enhancement in divergent thinking and a decrease in convergent thinking during the acute effects of the brew reported (Kuypers et al., 2016). Further research with LSD has suggested it can enhance primary process thinking (Kraehenmann et al., 2017). Consumption of psilocybin truffles has been found to yield distinct effects on measures of creativity as part of the acute and persisting effects of the substance, increasing ratings of divergent thinking the morning following usage, and enhancing convergent thinking a week following usage (Mason et al., 2019). A moderate dose of psilocybin has been associated with spontaneous creative insights, while decreasing deliberate task-based creativity during the acute experience, with an increase in the number of novel ideas at seven days post experience reported (Mason et al., 2021), while a moderate (50 μg) dose of LSD has also been found to increase originality and novelty in thinking (Wießner et al., 2021b). One study reported an enhancement of convergent thinking sustained for four weeks following an ayahuasca experience (Uthaug et al., 2018) while another assessed participants engaging in several ayahuasca sessions in a ritual setting, and found that ayahuasca users exhibited increased originality on a standardised test of creative thinking, sustained at two week follow-up post experience (Frecska et al., 2012). Naturalistic psychedelic usage has been shown to have a robust association with greater creative problem-solving ability (Sweat et al., 2016).

Preliminary research on psilocybin microdosing has suggested that it may be associated with improvements in convergent and divergent thinking performance, with one study combining data from three double-blind placebo-controlled longitudinal trials (controlling for expectation and demographic biases on psilocybin microdosing) reporting that it increased originality and fluency of thinking, indicating a higher quality of divergent answers than sober controls (Prochazkova et al., 2021). Findings of a preliminary study were suggestive that analytical thinking was unaffected by psilocybin microdosing (Bălăeţ, 2022; Prochazkova et al., 2018). Assorted scientific creatives including software engineers, biologists and mathematicians have claimed psychedelic microdosing can aid in lateral thinking and accessing flow states (Solon, 2016). A flow state is associated with full immersion and involvement in an activity, with intense concentration and an energised focus and accompanying feelings of enjoyment. It shares some phenomenological overlap with the psychedelic state, including states of heightened absorption, reduction in ego and time distortion (Nakamura & Csikszentmihalyi, 2014). Individuals who enjoy creative activities or those deemed to be highly creative show a proclivity for seeking out flow states (Gardner, 1988), and many scientists mention flow as being important to their work, linking it to performance enhancement (Csikszentmihalyi, 1990).

Psychedelics and the mystical-type experiences they can elicit have been associated with paradoxicality, where individuals report the experience or co-existence of normally mutually exclusive states, concepts or feelings (Barrett & Griffiths, 2018; Katz et al., 1968). This break down in divisions and tendency to embrace oppositions may contribute to creativity, it having been argued that the conception of two or more opposites or antitheses or 'janusian thinking' can contribute to creative scientific thinking (Rothenberg, 1988). This has been linked to scientific thinking among a range of Nobel Prize winning scientists (Rothenberg, 1996). Accounts by scientists who have undergone psychedelic sessions suggest that psychedelics can enhance pluralistic perspectivism, where the scientist may become their object of study, or seemingly perceive from its perspective during the experience (Harman et al., 1966; Narby, 2001, pp. 301–305; Sheldrake, 2021, p. 23), and in one notable case, following it (Mullis, 1997). Such a shift in epistemological perspective is more aligned to a shamanic approach, which emphasises subjectivity through subjectively becoming that you wish to learn from, in contrast to the scientific approach which is centered on a perspective of detached objectivity (Luna, 2021, p. 5). By providing the potential for a plurality of perspectives, the psychedelic state may yield a fertile ground for the generation of new insights or the perception of problems from new angles.

It is important to acknowledge that while there may be gains in some aspects of creative thinking in the acute phase of an altered state experience, there may also be accompanying deficits indicated by a general decrease in psychological performance when assessed by objective performance measures (Prochazkova & Hommel, 2020; Spitzer et al., 1996; Wießner et al., 2021b). Furthermore, it should be highlighted that psychometric measures assessing modes of creative thinking alone may be too specific to accurately and comprehensively characterize the putatively beneficial cognitive changes associated with psychedelic usage (Baggot, 2015). In addition, it has been argued that psychometric measures of divergent thinking fail to correlate effectively with real-world performance (Okuda et al., 1991).

Putative neurobiological mechanisms

Psychedelics appear to act by altering activity of the thalamus in the brain, which has been implicated in sensory gating both internal and external information entering the cortex, so the brain's ability to filter or inhibit information is impaired (Preller et al., 2019). This reduced thalamic censorship may provide a rich ground for new insights and perspectives, allowing greater access to unconscious material that is more unprocessed, uncensored and unconstrained (Girn et al., 2020). Psychedelics also elicit a brain state of higher entropy, characterised by enhanced dynamic brain activity that is more random and less predictable, and make a greater repertoire of brain states available. This more anarchic brain state, which has been conceptualised as reduced reliance on prior beliefs and expectations and increased richness of conscious experience in the 'REBUS' model (Relaxed beliefs under psychedelics - Carhart-Harris & Friston, 2019), may be part of the mechanism underpinning changes in creative thought (Atasoy et al., 2017; Carhart-Harris et al., 2014, Carhart-Harris & Friston, 2019; Tagliazucchi et al., 2014). Preconceptions may be a barrier to the creative process (Leski, 2015), including in the sciences (Gell-Mann, 1995). It has been argued that an open mind can come through a process of unlearning, which eliminates preconceptions (Leski, 2015, p. 14), which in turn may liberate creative thinking from the tendency to perceive more obvious associations, a quality that psychedelics may amplify. However, the loosening of prior assumptions and beliefs may also result in a reduced ability to weigh the validity of an idea against existing theories or concepts. Building on the 'REBUS' model, another model has been proposed to account for the difference between the effects of large and small doses (ALBUS: Altered beliefs under psychedelics). According to this theory, the relaxation of prior beliefs may be more likely to occur with medium to high doses of psychedelics, while low to medium doses of psychedelics may strengthen rather than relax beliefs (SEBUS: Strengthened beliefs under psychedelics). Such an intensification of beliefs under psychedelics has been proposed to potentially aid in overcoming barriers to traditional thinking and facilitate access to novel streams of imagination and territories of inference space (Safron, 2022).

Another defining characteristic of the psychedelic brain state is an increase in global connectivity, with enhanced communication between different brain networks or regions with a concomitant decrease of communication within networks (Carhart-Harris et al., 2016b; Müller et al., 2018; Tagliazucchi et al., 2016). Individuals possessing high levels of scientific and artistic creativity have been found to express higher whole-brain functional connectivity between different brain networks (Beaty et al., 2018). Changes in brain connectivity may partly underpin the shifts in perspective and the less rigid and more unconstrained changes in creative thinking associated with the psychedelic state (Sweat et al., 2016; Tagliazucchi et al., 2014). An account of computer programmer Kevin Herbert who found LSD to be a useful adjunct to his work alludes to this:

> "*It must be changing something about the internal communication in my brain. Whatever my inner process is that lets me solve problems, it works differently, or maybe different parts of my brain are used*" (Wired, 2006).

Post-acute effects of psychedelics on personality and implications for creativity and cognition

Psychedelics may yield more enduring effects to creativity and cognition. They have been shown to increase the personality traits *openness to experience* and *absorption* in an enduring way (Barrett et al., 2020; Erritzoe et al., 2018; Lebedev et al., 2016; Madsen et al., 2020; MacLean et al., 2011; Netzband et al., 2020). Openness has a positive association with cognitive ability, fluid intelligence (associated with the ability to think abstractly and solve problems) and permeability to new ideas and experiences (Austin et al., 2002; DeYoung et al., 2005; Moutafi et al., 2003; Rammstedt et al. 2016; Zeidner & Matthews, 2000). It has been associated with 'need for cognition' (Fleischhauer et al., 2010), a motivational tendency to think about ideas, scrutinize information and enjoy solving puzzles, which is tied to intellectual engagement (Rocklin, 1994). It is also related to imagination, intellectual curiosity and increased hunger for knowledge (McCrae & Costa, 1987), and it has been positively associated with giftedness, distinct from the other major personality traits (Ogurlu & Özbey, 2021). Openness has been linked to an interest in science (Feist, 2006), with previous studies reporting that scientists tend to rate higher in openness than non-scientists (Lounsbury et al., 2012; McCrae, 1987). It is strongly associated with creativity (Li et al., 2015; Silvia et al., 2009), being a better predictor of creative performance, creative achievement or creative self-beliefs than the other personality traits (Vartanian et al., 2018) and is the personality trait most strongly associated with scientific creativity (Feist, 1998; Grosul & Feist, 2014). Related to openness is absorption (Radtke & Stam, 1991), which is also linked to creativity (Manmiller et al., 2005; Tanggaard, 2019), and associated with flow states (Csikszentmihalyi, 1990; Nakamura & Csikszentmihalyi, 2009).

The conditions under which psychedelics experiences may be conducive of scientific creativity

Careful attention given to the set and setting is important to cultivate the characteristics which may contribute to positive effects of psychedelics when used in an applied context with the intent to enhance scientific creativity, while minimising those characteristics which may hinder such positive effects when used in this capacity (Harman et al., 1966). The appropriate mental set may be a particularly important factor when using psychedelics in a problem-solving capacity (Fadiman, 2011, p. 137). Inferring from the Harman et al. (1966) study, and cases of dream and hypnagogic-inspired scientific insight (Barrett, 2001a), psychedelics are likely to be best used in the context of meaningful and emotional engagement and involvement with creative tasks and when prior in-depth focus and effort has already been exerted on the subject in question, or when a creative block is hampering progress. Intent has been found to be a key determinant of the outcomes of psychedelic experiences (Carhart-Harris et al., 2018; Haijen et al., 2018; Metzner & Leary, 1967), and entering into the experience with the prior motivation and intent to harness the creativity enhancing potential of the psychedelic state is likely an important aspect of their successful application. Participants in the latter study were encouraged to relax and quietly listen to music for the first three hours of their psychedelic session and to "turn off" their analytical faculties and allow the experience to unfold as it will without attempting to control it. The setting should be comfortable and non-clinical to facilitate an atmosphere of psychological safety and freedom, and various means for participants to record notes or sketches should be provided (Fadiman, 2011, p. 139; Harman et al., 1966). Facilitators present can help ensure feelings of safety and promote focus among session participants (Fadiman, 2011, p. 140–141). Dosage of psychedelic is also likely an important factor. Low to moderate doses may promote an advantageous loosening of higher order cognitive functions and inhibitions, enhancement of visualisation skills, and access to the subconscious, coupled with some level of cognitive control where the ability to judge the validity and usefulness of novel ideas is retained. According to the recently proposed ALBUS model, this dosage range may allow for "overcoming barriers to breaking typical frames and engaging in non-traditional divergent thinking, so allowing novel streams of imagination to be considered" (Safron, 2022, p. 22). While more conducive of the generation of deep existential insights, the higher dosages used in modern clinical studies may impair cognitive processing (Wießner et al., 2021b) and yield effects likely to be too distracting for this applied context.

Future research avenues

The multidimensional nature of creativity and the qualitative study findings by Harman et al. (1966) indicate that relying on psychometric measures or quantitative scales alone for assessing the contribution of psychedelics to scientific creativity is likely to yield highly limited resolution into how they may impart benefits to the creative process, and so fail to provide a fully comprehensive overview of their potential. It is more likely, as suggested by the aforementioned study, that there are a number of potentially synergistic effects occurring concurrently that likely contribute to this process beyond changes in creative thinking alone. Inferring from the latter study's findings, and the various accounts of scientific dream-inspired insights, future controlled research studies should seek to recruit scientists, engineers and other scientific creatives who are actively engaged with working on applied creative tasks, particularly those they might be struggling with. Independent assessment of creativity by experts in the relevant domains may enhance the strength of the findings, helping safeguard against what has been referred to as the 'illusion of insight' (Love, 2019). Modern research has picked up where Harman et al. (1966) left off, with a study recently conducted assessing the effects of LSD on the problem-solving abilities of scientists, engineers and mathematicians (Sheldrake, 2021, p. 22), with results forthcoming (Family et al., 2022; Hendricks et al., 2022). Future studies could employ different dosing protocols and potentially different psychedelics to examine their effects on creative thinking in greater depth.

Conclusion

Humanity is likely to face immense challenges in the decades to come (Bradshaw et al., 2021). Scientific creativity, innovation and problem solving will play a vital role in ensuring we can meet these societal challenges (Ossola, 2014). Given the centrality of science to human progress and well-being, developing a scientific culture that consciously facilitates methods to catalyse creativity could potentially yield wide-scale societal benefits. Ethnobotanist and psychedelic advocate Terrence McKenna once said of the psychedelic experience that "…the greatest good you can do is to bring back a new idea, because our world is endangered by the absence of good ideas" (Monteith, 2016), with psychedelics having been proposed to act as *ideagens* (Roberts, 2019, p. 24). Investigation of any potential avenues that may be able to contribute to flexible thinking and help generate creative insight and new ideas should be considered a matter of great importance. It has been argued that modern science has systematically underestimated and neglected adventurous and associative modes of thinking with an over emphasis on analytical thinking (Scheffer, 2014). At a gathering of his fellow scientists, reflecting on his seminal hypnagogic insight, chemist August Kekulé is reputed to have said: "Let us learn to dream, gentlemen, and then perhaps we shall learn the truth … but let us beware of publishing our dreams before they have been put to the proof by the waking understanding." (Japp, 1898). Kekule calls on his fellow scientists to make better use of the dream and hypnagogic states, while highlighting the integral role analytical thinking plays in vetting the quality of insights generated through the more fluid and unconstrained thinking associated with these altered states. The psychedelic state may yield some of the same benefits as the dream and hypnagogic states, but provide a more reliable way to access an altered state, while also contributing distinct and unique qualities to cognition and creative thinking. When used in an applied context, with prior focus and emotional engagement on a creative task, psychedelics may help stimulate some aspects of scientific creativity and insight at the 'illumination' stage of the creative process, and further research to elucidate this is warranted.

With the recent success of various local psychedelic decriminalisation initiatives – including in Denver, Washington D.C., and Seattle – as well as the progression of psychedelic clinical trials into their latter phases, now is the time for increased national and international policy deliberations about the best way to regulate access to psychedelics. Currently, national laws crudely schedule drugs solely according to (often-outdated) perception of their medical utility and harm. Under this framework, many of the insights outlined in Table 1, including the Nobel Prize-winning discovery of PCR, were partially if not wholly dependent on criminalised activity. Alongside their sincere use within a number of spiritual and religious traditions, the potential of psychedelics as agents to support creative thinking demonstrates the restrictiveness of a 'health-only' classification that fails to holistically consider the breadth of risks and benefits of drug use.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

Abraham R (2008) Mathematics and the psychedelic revolution. *MAPS* 18(1): 6–8.

Agassiz EC (1855) *Louis Agassiz: His Life and Correspondence*. 3rd edition. Boston and New York, Houghton: Mifflin and company.

Aldous CR (2007) Creativity, problem solving and innovative science: insights from history, cognitive psychology and neuroscience. *International Education Journal* 8(2): 176–186.

Allen J (2009) Huicole peyote dance & the inspiration for biosphere 2. *MAPS* 19(1): 50–52.

Andreasen NC (2011) A journey into chaos: Creativity and the unconscious. *Mens Sana Monographs* 9(1): 42–5310.4103/0973-1229.77424

Ardis JA and Mckellar P (1956) Hypnagogic imagery and mescaline. *Journal of Mental Science* 102(426): 22–29.

Atasoy S, Roseman L, Kaelen M, et al. (2017) Connectome-harmonic decomposition of human brain activity reveals dynamical repertoire re-organization under LSD. *Scientific Reports* 7: 17661.

Austin EJ, Deary IJ, Whiteman MC, et al. (2002) Relationships between ability and personality: does intelligence contribute positively to personal and social adjustment? *Personality and Individual Differences* 32(8): 1391–1411.

Baggott MJ (2015) Psychedelics and creativity: A review of the quantitative literature. *PeerJ PrePrints* 3: e1202v1.

Baird B, Smallwood J, Mrazek MD, et al. (2012) Inspired by distraction: mind wandering facilitates creative incubation. *Psychological Science* 23(10): 1117–1122.

Balaet M (2022) Psychedelic cognition—the unreached frontier of psychedelic science. *Frontiers in Neuroscience* 16: DOI: 10.3389/fnins.2022.832375

Barbot B (2019) Measuring creativity change and development. *Psychology of Aesthetics, Creativity, and the Arts* 13(2): 203–210.

Barrett D (1993) The "committee of sleep": A study of dream incubation for problem solving. *Dreaming* 3(2): 115–122.

Barrett D (2020) When the answer Comes in a dream. *American Scientist* 108(4): 00.

Barrett D (2001a) *The Committee of Sleep: How Artists, Scientists, and Athletes Use Dreams for Creative Problem-Solving-- and How You Can Too*. New York: Crown.

Barrett D (2001b) Comment on baylor: A note about dreams of scientific problem solving. *Dreaming* 11: 93–95.

Barrett D (2001c) In dreams begin technologies: How innovations can come during sleep. *Invention & Technology* 17(2). Available from: https://www.inventionandtech.com/content/dreams-begin-technologies-1?page=full (accessed 15 May 2021).

Barrett D (2011) Answers in your dreams. *Scientific American Mind* 22(5): 26–33.

Barrett FS, Doss MK, Sepeda ND, et al. (2020) Emotions and brain function are altered up to one month after a single high dose of psilocybin. *Scientific Reports* 10: 2214.

Barrett FS and Griffiths RR (2018) Classic hallucinogens and mystical experiences: phenomenology and neural correlates. *Current Topics in Behavioral Neurosciences* 36: 393–430.

Beaty RE, Kenett YN, Christensen AP, et al. (2018) Robust prediction of individual creative ability from brain functional connectivity. *Proceedings of the National Academy of Sciences of the United States of America* 115(5): 1087−1092.

Berkovich-Ohana A, Glicksohn J, Ben-Soussan TD, et al. (2017) Creativity is enhanced by long-term mindfulness training and is negatively correlated with trait default-mode-related low-gamma inter-hemispheric connectivity. *Mindfulness* 8: 717–727.

Berl E (1942) Some personal recollections of alfred werner. *Journal of Chemical Education* 19(4): 153–154.

Blackmore S (2020) In praise of psychedelics: how LSD changed one psychologist's life. *Psychology Today*. Available from: https://www.psychologytoday.com/gb/blog/ten-zen-questions/202001/in-praise-psychedelics

Boden MA (2004) *The Creative Mind: Myths and Mechanisms* (2nd ed.) London: Routledge.

Bradshaw CJA, Ehrlich PR, Beattie A, et al. (2021) Underestimating the challenges of avoiding a ghastly future. *Frontiers in Conservation Science* 1: 615419.

Carhart-Harris R (2007) Waves of the unconscious: the neurophysiology of dreamlike phenomena and its implications for the psychodynamic model of the mind. *Neuro-Psychoanalysis* 9(2): 183–211.

Carhart-Harris RL and Friston KJ (2019) REBUS And the anarchic brain: toward a unified model of the brain action of psychedelics. *Pharmacological Reviews* 71(3): 316–344.

Carhart-Harris RL, Kaelen M, Bolstridge M, et al. (2016a) The paradoxical psychological effects of lysergic acid diethylamide (LSD). *Psychological Medicine* 46(7): 1379–1390.

Carhart-Harris RL, Kaelen M, Whalley MG, et al. (2015) LSD Enhances suggestibility in healthy volunteers. *Psychopharmacology (Berl)* 232(4): 785–794.

Carhart-Harris RL, Leech R, Hellyer PJ, et al. (2014) The entropic brain: A theory of conscious states informed by neuroimaging research with psychedelic drugs. *Frontiers in Human Neuroscience* 8: 20.

Carhart-Harris RL, Muthukumaraswamy S, Roseman L, et al. (2016b) 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.

Carhart-Harris RL and Nutt D (2014) Was it a vision or a waking dream? *Frontiers in Psychology* 5: 255.

Carhart-Harris RL, Roseman L, Haijen E, et al. (2018) Psychedelics and the essential importance of context. *Journal of Psychopharmacology* 32(7): 725–731.

Chambers JA (1969) Beginning a multidimensional theory of creativity. *Psychological Reports* 25(3): 779–799.

Chou YJ and Tversky B (2020) Changing perspective: building creative mindsets. *Cognitive Science* 44(4): e12820.

Christiansen M (2017) Technology, creativity, and psychedelics: an interview with adam wiggins. *MAPS Bulletin Winter* 27(3): 53.

Colzato LS, Ozturk A and Hommel B (2012) Meditate to create: The impact of focused-attention and open-monitoring training on convergent and divergent thinking. *Frontiers in Psychology* 3: 116.

Craig L (1990) A guide to increased creativity in research-–inspiration or perspiration? *Bioscience* 40(2): 123–129.

Craig M, Ottaway G and Dewar M (2018) Rest on it: awake quiescence facilitates insight. *Cortex: A Journal Devoted to the Study of the Nervous System and Behavior* 109: 205–214.

Crockett C (2012) Professor talks DMT research, its effects on you — and possibly your faith. *LSU News from the Reveille*. Available from: https://www.lsureveille.com/legacy/article_4a851c42-036d-11e2-b3fb-0019bb30f31a.html

Csikszentmihalyi M (1990) *Flow: The Psychology of Optimal Experience* (1st ed.) New York: HarperPerennial.

Csikszentmihalyi M (1999) *Creativity: Flow and the Psychology of Discovery and Invention*. New York: HarperCollins.

Daniels-McGhee S and Davis GA (1994) The imagery-creativity connection. *The Journal of Creative Behavior* 28(3): 151–176.

Davis PJ and Hersh R (1986) *Descartes' Dream: The World According to Mathematics*. Cambridge, MA: Harcourt Brace Jovanovich.

Dayan AD (2006) The circumstances of Kekule's "molecular dream" in London in 1854. *Bulletin for the History of Chemistry* 31(1): 28–30.

DeYoung CG, Peterson JB and Higgins DM (2005) Sources of openness/intellect: Cognitive and neuropsychological correlates of the fifth factor of personality. *Journal of Personality* 73(4): 825–858.

Diedrich J, Benedek M, Jauk E, et al. (2015) Are creative ideas novel and useful? *Psychology of Aesthetics*, *Creativity, and the Arts* 9(1): 35–40.

Dormehl L (2012) *The Apple Revolution: Steve Jobs, the Counter Culture and how the Crazy Ones Took Over the World*. London: Virgin Books.

Doyle R (2002) LSDNA: rhetoric, consciousness expansion, and the emergence of biotechnology. *Philosophy & Rhetoric* 35: 153–174.

East R and Ang L (2021) Insight: the key to faster progress in science. *Foundations of Science* 26: 503–514.

Einstein A (1915a) Zur allgemeinen relativitätstheorie. Königlich preuüische, akademie der wissenschaften (Berlin). *Sitzungsberichte* 778–786.

Einstein A (1915b) Zur allgemeinen relativitätstheorie. (nachtrag). königlich preuüische akademie der wissenschaften (Berlin). *Sitzungsberichte* 799–801.

Einstein A (1931) *On Cosmic Religion: With Other Opinions and Aphorisms*. New York: Covici-Friede, Inc., 49.

Ericsson KA and Simon HA (1998) How to study thinking in everyday life: Contrasting think-aloud protocols with descriptions and explanations of thinking. *Mind, Culture, and Activity* 5(3):178–186.

Ernst KH and Berke H (2011) Optical activity and alfred werner's coordination chemistry. *Chirality* 23(3):187–189.

Erritzoe D, Roseman L, Nour MM, et al. (2018) Effects of psilocybin therapy on personality structure. *Acta Psychiatrica Scandinavica* 138(5): 368–378.

Fadiman J (2011) *Psychedelic Explorer's Guide: Safe, Therapeutic, and Sacred Journeys*. Vermont: Park Street Press.

Family N, Hendricks P, Williams L, et al. (2022) Safety, tolerability, pharmacokinetics, and subjective effects of 50 μg, 75 μg, and 100 μg LSD in healthy participants within a novel intervention paradigm: A proof-of-concept study. *Journal of Psychopharmacology* 36(3): 321–336.

Family N, Vinson D, Vigliocco G, et al. (2016) Semantic activation in LSD: Evidence from picture naming. *Language, Cognition and Neuroscience* 31(10): 1320–1327.

Feist GJ (1998) A meta-analysis of the impact of personality on scientific and artistic creativity. *Personality and Social Psychological Review* 2: 290–309.

Feist GJ (1991) Synthetic and analytic thought: similarities and differences among art and science students. *Creativity Research Journal* 4(2): 145–155.

Feist GJ (1999) Influence of personality on artistic and scientific creativity. In Sternberg RJ (Ed.), *Handbook of Creativity*. New York: Cambridge University Press, 272−296.

Feist GJ (2006) The psychology of science: development and personality in scientific thought, interest and achievement. *Review of General Psychology* 10: 163–182.

Fleischhauer M, Enge S, Brocke B, Ullrich J, Strobel A (2010) Same or different? Clarifying the relationship of need for cognition to personality and intelligence. *Personality and Social Psychology Bulletin* 36(1): 82–96.

Fischman LG (1983) Dreams, hallucinogenic drug states, and schizophrenia: A psychological and biological comparison. *Schizophrenia Bulletin* 9(1): 73–94.

Forstmann M and Sagioglou C (2021) How psychedelic researchers' self-admitted substance use and their association with psychedelic culture affect people's perceptions of their scientific integrity and the quality of their research. *Public Understanding of Science* 30(3): 302–318.

Frecska E, Móré CE and Vargha A (2012) Enhancement of creative expression and entoptic phenomena as after-effects of repeated ayahuasca ceremonies. *Journal of Psychoactive Drugs* 44(3): 191–199.

French S (2020) Imagination in scientific practice. *European Journal for Philosophy of Science* 10: 27.

Gaddum JH (1953) Antagonism between lysergic acid diethylamide and 5-hydroxytryptamine. *Journal of Physiology (London)* 121: 15.

Gaddum JH (1957) Serotonin-LSD interactions. *Annals of the New York Academy of Sciences* 66(3): 643–648.

Gandy S (2022) Predictors and potentiators of psychedelic-occasioned mystical experiences. *Journal of Psychedelic Studies*: In Press. DOI: 10.1177/2055102920978123.

Gardner H (1988) Creativity: an interdisciplinary perspective. *Creativity Research Journal* 1: 8–26.

Gell-Mann M (1995) *The Quark and the Jaguar: Adventures in the Simple and the Complex*. London: Abacus Publishing.

Girn M, Mills C, Roseman L, et al. (2020) Updating the dynamic framework of thought: creativity and psychedelics. *Neuroimage* 213: 116726.

Green AR (2008) Gaddum and LSD: The birth and growth of experimental and clinical neuropharmacology research on 5-HT in the UK. *British Journal of Pharmacology* 154: 1583–1599.

Greenberg J, Reiner K and Meiran N (2012) "Mind the trap": mindfulness practice reduces cognitive rigidity. *PLoS ONE* 7(5): e36206.

Griffiths RR, Richards WA, Johnson MW, et al. (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.

Grosul M and Feist GJ (2014) The creative person in science. *Psychology of Aesthetics, Creativity, and the Arts* 8(1): 30–43.

Haijen ECHM, Kaelen M, Roseman L, et al. (2018) Predicting responses to psychedelics: A prospective study. *Frontiers in Pharmacology* 9: 97.

Harman WW, McKim RH, Mogar RE, et al. (1966) Psychedelic agents in creative problem-solving: A pilot study. *Psychological Reports* 19(1): 211–227.

Hartogsohn I (2018) The meaning-enhancing properties of psychedelics and their mediator role in psychedelic therapy, spirituality, and creativity. *Frontiers in Neuroscience* 12: 29.

Hendricks P, Copes H, Family N, et al. (2022) Perceptions of safety, subjective effects, and beliefs about the clinical utility of lysergic acid diethylamide (LSD) in healthy participants within a novel intervention paradigm: qualitative results from a proof-of-concept study. *Journal of Psychopharmacology* 36(3):337–347.

Henriksen D, Richardson C and Shack K (2020). Mindfulness and creativity: implications for thinking and learning. *Thinking Skills and Creativity* 37: 100689.

Higgins C (2018) 'There is no such thing as past or future': Physicist carlo rovelli on changing how we think about time. *The Guardian*. Available from: https://www.theguardian.com/books/2018/apr/14/carlo-rovelli-exploding-commonsense-notions-order-of-time-interview

Horan R (2009) The neuropsychological connection between creativity and meditation, *Creativity Research Journal* 21(2-3): 199–222.

Horowitz AJH (2019) Incubating Dreams, Awakening Creativity. Masters thesis, Massachusetts Institute of Technology.

Intons-Peterson MJ (1993) Chapter 1. Imagery's role in creativity and discovery. In Roskos-Ewoldsen B, Intons-Peterson MJ and Anderson RE (Eds.) *Advances in Psychology*. Amsterdam: North-Holland, 98: 1−37.

Iszáj F, Griffiths MD and Demetrovics Z (2017) Creativity and psychoactive substance use: A systematic review. *International Journal of Mental Health and Addiction* 15(5): 1135–1149.

Izumi K (1970) LSD And architectural design. In Aaronson B and Osmond H (Eds.) *Psychedelics: The Uses and Implications of Hallucinogenic Drugs*. Garden City, New York: Anchor/Doubleday, pp.381–397.

Jacobs BL (1978) Dreams and hallucinations: A common neurochemical mechanism mediating their phenomenological similarities. *Neuroscience & Biobehavioral Reviews* 2(1): 59–69.

Japp FR (1898) Kekule memorial lecture. *Journal of the Chemical Society* 73: 97–108.

Kaiser D (2012) *How the Hippies Saved Physics: Science, Counterculture and the Quantum Revival*. New York: W. W. Norton.

Kanigel R (1991) *The Man Who Knew Infinity: A Life of the Genius Ramanujan*. New York: Charles Scribner's Sons, 281.

Katz MM, Waskow IE and Olsson J (1968) Characterizing the psychological state produced by LSD. *Journal of Abnormal Psychology* 73: 1–14.

Kauffman GB (1968) *Classics in Coordination Chemistry, Part I: The Selected Papers of Alfred Werner*. New York: Dover, 5.

Kaufman JC, Plucker JA and Russell CM (2012) Identifying and assessing creativity as a component of giftedness. *Journal of Psychoeducational Assessment* 30(1): 60–73.

Kerr B and Gagliardi C (2003) Measuring creativity in research and practice. In Lopez SJ and Snyder CR (Eds.), *Positive Psychological Assessment: A Handbook of Models and Measures*. Washington, DC: American Psychological Association, pp.155–169.

Kim KH and Pierce RA (2013) Adaptive creativity and innovative creativity. In: Carayannis EG (Eds.) *Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship*. New York: Springer. Available at: https://doi.org/10.1007/978-1-4614-3858-8_21

Klüver H (1942) Mechanisms of hallucinations. In McNemar Q and Merrill MA (Eds.) *Studies in Personality*. New York: McGraw-Hill, pp.175–207.

Kounios J, Fleck JI, Green DL, et al. (2008) The origins of insight in resting-state brain activity. *Neuropsychologia* 46(1): 281–291.

Kraehenmann R (2017) Dreams and psychedelics: neurophenomenological comparison and therapeutic implications. *Current Neuropharmacology* 15(7): 1032–1042.

Kraehenmann R, Pokorny D, Aicher H, et al., (2017) LSD Increases primary process thinking via serotonin 2A receptor activation. *Frontiers in Pharmacology* 8: 14.

Krippner S (1985) Psychedelic drugs and creativity. *Journal of Psychoactive Drugs* 17(4): 235–246.

Krippner S and Hughes W (1970) Dreams and human potential. *Journal of Humanistic Psychology* 10(1): 1–20.

Kuypers KPC, Riba J, de la Fuente Revenga M, et al. (2016) Ayahuasca enhances creative divergent thinking while decreasing conventional convergent thinking. *Psychopharmacology* 233: 3395–3403.

Langley PW, Simon HA, Bradshaw GF, et al. (1987) *Scientific Discovery: Computational Explorations of the Creative Processes*. Cambridge, MA: Cambridge, MA: MIT Press.

Lacaux C, Andrillon T, Bastoul C et al. (2021) Sleep onset is a creative sweet spot. *Science Advances* 7(50): eabj5866.

Lebedev AV, Kaelen M, Lövdén M, et al. (2016) LSD-induced entropic brain activity predicts subsequent personality change. *Human Brain Mapping* 37(9): 3203–3213.

LeBoutillier N and Marks DF (2003) Mental imagery and creativity: A meta-analytic review study. *British Journal of Psychology* 94(Pt 1): 29–44.

Lees AJ (2019) *Mentored by a Madman: The William Burroughs Experiment*. Kendal: Notting Hill Editions.

Lehmann J and Gaskins B (2019) Learning scientific creativity from the arts. *Palgrave Communications* 5: 96.

Leski K (2015) *The Storm of Creativity (Simplicity: Design, Technology, Business, Life)*. Cambridge, MA: MIT Press.

Liang J (2002) Exploring Scientific Creativity of Eleventh Grade Students in Taiwan, (PhD Thesis). The University of Texas, Austin.

Li W, Li X, Huang L, et al. (2015) Brain structure links trait creativity to openness to experience. *Social Cognitive and Affective Neuroscience* 10(2): 191–198.

Livingston G and Levin R (1991) The effects of dream length on the relationship between primary process in dreams and creativity. *Dreaming* 1(4): 301–309.

Loewi O (1953) *From the Workshop of Discoveries*. Lawrence, KS: University of Kansas Press.

Loewi O (1960) *An Autobiographical Sketch. Perspectives in Biology and Medicine 4: 17*. London & Sydney: Simon & Schuster.

Lonsdale K (1929) The structure of the benzene ring in hexamethylbenzene. *Proceedings of the Royal Society* 123A(792): 494–515.

Lonsdale K (1931) An X-ray analysis of the structure of hexachlorobenzene, using the Fourier method. *Proceedings of the Royal Society* 133A(822): 536–553.

Lounsbury JW, Foster N, Patel H, et al. (2012) An investigation of the personality traits of scientists versus nonscientists and their relationship with career satisfaction. *R&D Management* 42(1): 47–59.

Love S (2019) The ethics of taking the drugs you study. *VICE*. Available from: https://www.vice.com/en/article/qv7jkx/the-ethics-of-taking-the-drugs-you-study

Luna LE (2021) On encounters with entities in the ayahuasca realm. In Luke D and Spowers R (Eds.) *DMT entity Encounters: Dialogues on the Spirit Molecule*. Rochester, VA: Park Street Press, 5.

MacLean KA, Johnson MW and Griffiths RR (2011) Mystical experiences occasioned by the hallucinogen psilocybin lead to increases in the personality domain of openness. *Journal of Psychopharmacology* 25: 1453–1461.

Madsen MK, Fisher PM, Stenbæk DS, et al. (2020) A single psilocybin dose is associated with long-term increased mindfulness, preceded by a proportional change in neocortical 5-HT2A receptor binding. *European Neuropsychopharmacology* 33: 71–80.

Manmiller JL, Kumar VK and Pekala RJ (2005) Hypnotizability, creative capacity, creativity styles, absorption, and phenomenological experience during hypnosis. *Creativity Research Journal* 17(1): 9–24.

Markoff J (2005) *What the Dormouse Said: How the Sixties Counterculture Shaped the Personal Computer Industry*. New York: Viking Books.

Mason NL, Kuypers KPC, Reckweg JT, et al. (2021) Spontaneous and deliberate creative cognition during and after psilocybin exposure. *Translational Psychiatry* 11: 09.

Mason NL, Mischler E, Uthaug MV, et al. (2019) Sub-Acute effects of psilocybin on empathy, creative thinking, and subjective well-being. *Journal of Psychoactive Drugs* 51(2): 123–134.

Mavromatis A (1987) *Hypnagogia: The Unique State of Consciousness Between Wakefulness and Sleep*. London: Routledge & Kegan Paul Ltd

Mazzarello P (2000) What dreams may come? *Nature* 408: 23.

Maxwell JC (1873) *A Treatise on Electricity and Magnetism*. Oxford: Oxford University Press.

McCoy AN and Tan SY (2014) Otto loewi (1873–1961): dreamer and nobel laureate. *Singapore Medical Journal* 55(1): –4.

McCrae RR (1987) Creativity, divergent thinking, and openness to experience. *Journal of Personality and Social Psychology* 52(6): 1258–1265.

McCrae RR and Costa PT (1987) Validation of the five-factor model of personality across instruments and observers. *Journal of Personality and Social Psychology* 52(1): 81–90.

McPherson SS (2010) *Sergey Grin and Larry Page: Founders of Google*. Minneapolis, MN: *Twenty-First Century Books*, p. 27.

Metzner R and Leary T (1967) On programming psychedelic experiences. *Psychedelic Review* 9: 5–19.

Millière R, Carhart-Harris RL, Roseman L, et al. (2018) Psychedelics, meditation, and self-consciousness. *Frontiers in Psychology* 9: 1475.

Mitchell SW (1896) The effects of Anhalonium Lewinii (the mescal button). *British Medical Journal* 2: 1625–1628.

Monteith A (2016) "The words of McKenna": healing, political critique, and the evolution of psychonaut religion since the 1960s counterculture. *Journal of the American Academy of Religion* 84(4): 1081–1109.

Moss R (2014) *The Secret History of Dreaming*. Novato, California: New World Library.

Moutafi J, Furnham A and Crump J (2003) Demographic and personality predictors of intelligence: A study using the neo personality inventory and the myers-briggs type indicator. *European Journal of Personality* 17(1): 79–94.

Müller F, Dolder PC, Schmidt A, et al. (2018) Altered network hub connectivity after acute LSD administration. *NeuroImage: Clinical* 18: 694–701.

Mullis (1997) Horizon: psychedelic science. [TV Programme]. BBC, 27th February 1997.

Murphy G (1958) *Human Potentialities*. New York: Basic Books.

Narby J (2001) Shamans and scientists. In Narby J and Huxley F. (Eds.) *Shamans Through Time: 500 Years on the Path to Knowledge*. New York: TarcherPerigee, 301–305.

Nakamura J and Csikszentmihalyi M (2009) Flow theory and research. In Snyder CR and Lopez SJ (Eds.) *Oxford Handbook of Positive Psychology*. (2nd ed.). Oxford, UK: Oxford University Press, 195–206.

Nakamura J and Csikszentmihalyi M (2014) The concept of flow. In: Csikszentmihalyi M (Ed.) *Flow and the Foundations of Positive Psychology: The Collected Works of Mihaly Csikszentmihalyi*. Dordrecht: Springer Netherlands, 239–263.

Netzband N, Ruffell S, Linton S, et al. (2020) Modulatory effects of ayahuasca on personality structure in a traditional framework. *Psychopharmacology* 237: 3161–3171.

Nielsen TA (1992) A self-observational study of spontaneous hypnagogic imagery using the upright napping procedure. *Imagination, Cognition and Personality* 11(4): 353–366.

Nielsen T (1988) Ancient methods of dream incubation: bodily methods of inducing spiritual presence. *Bulletin of the Montreal Center for the Study of Dreams* 3(3–4): 6–10.

Nielson EM and Guss J (2018) The influence of therapists' first-hand experience with psychedelics on psychedelic-assisted psychotherapy research and therapist training. *Journal of Psychedelic Studies* 2(2): 64–73.

Nir Y and Tononi G (2010) Dreaming and the brain: From phenomenology to neurophysiology. *Trends in Cognitive Sciences* 14(2): 88–100.

Nutt D (2012) *Drugs Without the hot air: Making Sense of Legal and Illegal Drugs*. (2nd ed.). Cambridge: UIT Cambridge LTD.

Okuda SM, Runco MA and Berger DE (1991) Creativity and the finding and solving of real-world problems. *Journal of Psychoeducational Assessment* 9(1): 45–53.

Oleynick VC, Thrash TM, LeFew MC, et al. (2014) The scientific study of inspiration in the creative process: Challenges and opportunities. *Frontiers in Human Neuroscience* 8: 36.

Ogurlu U and Özbey A (2021) Personality differences in gifted versus non-gifted individuals: A three-level meta-analysis. *High Ability Studies* 1–25. DOI: 10.1080/13598139.2021.1985438.

Ossola A (2014) Scientists are more creative than you might imagine. *The Atlantic.* Available from: https://www.theatlantic.com/education/archive/2014/11/the-creative-scientist/382633/

Ostafin BD and Kassman KT (2012) Stepping out of history: Mindfulness improves insight problem solving. *Consciousness and Cognition* 21(2): 1031–1036.

Plucker JA, Beghetto RA and Dow GT (2004) Why isn’t creativity more important to educational psychologists? Potentials, pitfalls and future directions in creativity research. *Educational Psychology* 39: 83–96.

Pollan M (2018) *How to Change Your Mind: What the new Science of Psychedelics Teaches us About Consciousness, Dying, Addiction, Depression, and Transcendence*. London: Penguin Books Ltd, 182.

Polland MJ (1996) Mental Imagery in Creative Problem Solving. PhD thesis, Claremont Graduate School.

Porterfield AL (1941) *Creative Factors in Scientific Research*. Durham, NC: Duke University Press, 94.

Preller KH, Razi A, Zeidman P, et al. (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.

Prochazkova L and Hommel B (2020) Chapter 6 - altered states of consciousness and creativity. In Preiss DD, Cosmelli D and Kaufman JC (Eds.) *Creativity and the Wandering Mind: Spontaneous and Controlled Cognition*. Cambridge, MA: Academic Press, 121−158.

Prochazkova L, Lippelt DP, Colzato LS, et al. (2018) Exploring the effect of microdosing psychedelics on creativity in an open-label natural setting. *Psychopharmacology* 235: 3401–3413.

Prochazkova L, van Elk M, Marschall J, et al. (2021) Microdosing psychedelics and its effect on creativity: lessons learned from three double-blind placebo controlled longitudinal trials. *PsyArXiv Preprints.* DOI: 10.31234/osf.io/emcxw

Purcell S, Mullington J, Moffitt A, et al. (1986) Dream self-reflectiveness as a learned cognitive skill. *Sleep* 9(3): 423–437.

Radtke HL and Stam HJ (1991) The relationship between absorption, openness to experience, anhedonia, and susceptibility. *International Journal of Clinical and Experimental Hypnosis* 39: 39–56.

Rammstedt B, Danner D and Martin S (2016) The association between personality and cognitive ability: going beyond simple effects. *Journal of Research in Personality* 62: 39–44.

Reitman L (2008) An interview with kevin herbert. *MAPS* 18(1): 19–21.

Roberts A (2008) *Albion Dreaming: A Popular History of LSD in Britain (Revised Edition with a New Foreword by Dr Sue*

Blackmore). Singapore: Marshall Cavendish International (Asia) Ptd Limited.

Roberts T (2019) *Mindapps: Multistate Theory and Tools for Mind Design*. Vermont: Park Street Press.

Rocklin T (1994) Relation between typical intellectual engagement and openness: comment on goff and ackerman (1992). *Journal of Educational Psychology* 86(1): 145–149.

Rosenfeld A (1966) The vital facts about the drug and its effects. *Life (Chicago, Ill* 60(12) March 25th, 30D.

Rothenberg A (1988) Creativity and the homospatial process. *Experimental Studies. Psychiatric Clinics of North America* 11: 443–459.

Rothenberg A (1995) Creative cognitive processes in kekulé’s discovery of the structure of the benzene molecule. *The American Journal of Psychology* 108(3): 419–438.

Rothenberg A (1996) The janusian process in scientific creativity. *Creativity Research Journal* 9:(2-3): 207–231.

Rouvray D (1994) The periodic table was chemistry’s most important breakthrough. *New Scientist* Available from: https://www.newscientistcom/article/mg14119123-900-the-periodic-table-was-chemistrys-most-important-breakthrough/&hash;:~:text=So&per;20convinced&per;20was&per;20he&per;20of, confirmed&per;20his&per;20predictions&per;20almost&per;20exactly.

Rubel AJ and Gettelfinger-Krejci J (1976) The use of hallucinogenic mushrooms for diagnostic purposes among some highland chinantecs. *Economic Botany* 30(3): 235–248.

Runco MA and Jaeger GJ (2012) The standard definition of creativity. *Creativity Research Journal* 24(1): 92–96.

Safron A (2022) On the varieties of conscious experiences: altered beliefs under psychedelics (ALBUS). *PsyArXiv Preprints* 22. DOI: 10.31234/osf.io/zqh4b.

Sanz C, Zamberlan F, Erowid E, et al. (2018) The experience elicited by hallucinogens presents the highest similarity to dreaming within a large database of psychoactive substance reports. *Frontiers in Neuroscience* 12: 7.

Schacter DL (1976) The hypnagogic state: A critical review of the literature. *Psychological Bulletin* 83(3): 452–481.

Schatzman M (1984) Dreams and problem solving. *International Medicine* 4: 6–9.

Scheffer M (2014) The forgotten half of scientific thinking. *Proceedings of the National Academy of Sciences of the United States of America* 111(17): 6119.

Scheffer M, Bascompte J, Bjordam TK, et al. (2015) Dual thinking for scientists. *Ecology and Society* 20(2): 3.

Shampo MA and Kyle RA, Kary B. (2002) Mullis-Nobel laureate for procedure to replicate DNA. Mayo Clinic Proceedings 77(7): 606. DOI:10.4065/77.7.606

Sharpe ME (1967) The soviet review translations VIII(2) incorporated*,* 38.

Shulgin A and Shulgin A (1991) *PiHKAL*. California, USA: Transform Press, 16.

Sheldrake M (2021) *Entangled Life*. New York: Vintage Books.

Silvia PJ, Nusbaum EC, Berg C, et al. (2009) Openness to experience, plasticity, and creativity: Exploring lowerorder, higher-order, and interactive effects. *Journal of Research in Personality* 43: 1087–1090.

Solon O (2016) Under pressure, silicon valley workers turn to LSD microdosing. *Wired*. Available from: https://www.wired.co.uk/article/lsd-microdosing-drugs-silicon-valley

Spitzer M, Thimm M, Hermle L, et al. (1996) Increased activation of indirect semantic associations under psilocybin. *Biological Psychiatry* 39: 1055–1057.

Stafford PG and Golightly BH (1967) *LSD – the Problem-Solving Psychedelic, Chapter VII*. London: Tandom Books, 207–209.

Strunz F (1993) Preconscious mental activity and scientific problem-solving: A critique of the kekulé dream controversy. *Dreaming* 3(4): 281–294.

Stumbrys T and Daniels M (2010) An exploratory study of creative problem solving in lucid dreams: preliminary findings and methodological considerations. *International Journal of Dream Research* 3(2): 121–129.

Sweat NW, Bates LW and Hendricks PS (2016) The associations of naturalistic classic psychedelic use, mystical experience, and creative problem solving. *Journal of Psychoactive Drugs* 48(5): 344–350.

Tagliazucchi E, Carhart-Harris R, Leech R, et al. (2014) Enhanced repertoire of brain dynamical states during the psychedelic experience. *Human Brain Mapping* 35(11): 5442–5456.

Tagliazucchi E, Roseman L, Kaelen M, et al. (2016) Increased global functional connectivity correlates with LSD-induced ego dissolution. *Current Biology* 26(8):1043–1050.

Tanggaard L (2019) Content-Driven pedagogy: on passion, absorption and immersion as dynamic drivers of creativity. In: Beghetto R and Corazza G. (eds) *Dynamic Perspectives on Creativity. Creativity Theory and Action in Education*, vol 4. Cham: Springer, pp.165–177.

Thillo MP (2009) Ecology, technology, and biosphere 2. *MAPS* 19(1): 48–49.

Tulver K, Kaup KK, Laukkonen R, et al. (2021) Restructuring insight: An integrative review of insight in problem-solving, meditation, psychotherapy, delusions and psychedelics. *PsyArXiv* 1–88. DOI: 10.31234/osf.io/8fbt9.

Uthaug MVK, van Oorsouw KPC, Kuypers M, et al. (2018) Sub-acute and long-term effects of ayahuasca on affect and cognitive thinking style and their association with ego dissolution. *Psychopharmacology* 235(10): 2979–2989.

Vartanian O, Wertz CJ, Flores RA, et al. (2018) Structural correlates of openness and intellect: implications for the contribution of personality to creativity. *Human Brain Mapping* 39(7): 2987–2996.

Voss U, Holzmann R, Tuin I, et al. (2009) Lucid dreaming: A state of consciousness with features of both waking and non-lucid dreaming. *Sleep* 32(9): 1191–1200.

Wahbeh H, Radin D, Mossbridge J, et al. (2018) Exceptional experiences reported by scientists and engineers. *Explore (NY)* 14(5): 329–341.

Walker MP, Liston C, Hobson JA, et al. (2002) Cognitive flexibility across the sleep-wake cycle: REM-sleep enhancement of anagram problem solving. *Brain Research. Cognitive Brain Research* 14(3): 317–324.

Walkup LE (1965) Creativity in science through visualization. *Perceptual and Motor Skills* 21(1): 35–41.

Wallas G (1926) *The Art of Thought*. New York: Harcourt, Brace and Company.

Waters F, Blom JD, Dang-Vu TT, et al. (2016) What is the link between hallucinations, dreams, and hypnagogic-hypnopompic experiences? *Schizophrenia Bulletin* 42(5): 1098–1109.

White GL and Taytroe L (2003) Personal problem-solving using dream incubation: dreaming, relaxation, or waking cognition? *Dreaming* 13(4): 193–209.

Wießner I, Falchi M, Palhano-Fontes F, et al. (2021a) Low-dose LSD and the stream of thought: increased discontinuity of mind, deep thoughts and abstract flow. *Psychopharmacology* DOI:10.1007/s00213-021-06006-3

Wießner I, Falchi M, Maia LO, et al. (2021b) The effects of LSD on creativity: increased novelty and symbolic thinking, decreased utility and convergent thinking. *Journal of Psychopharmacology* 36(3): 348–359.

Wier D. (2008) Use of LSD-25 for computer programming. *MAPS* 18(1): 22.

Winkelman M (2019) Introduction: evidence for entheogen use in prehistory and world religions. *Journal of Psychedelic Studies* 3(2).

Winkler P and Csémy L (2014) Self-experimentations with psychedelics among mental health professionals: LSD in the former czechoslovakia. *Journal of Psychoactive Drugs* 46(1): 11–19.

Withers R (2008) Descartes’ dreams. *Journal of Analytical Psychology* 53(5): 691–709.

Wired (2006) LSD: the geek’s wonder drug?. *Wired*. Available from: https://www.wired.com/2006/01/lsd-the-geeks-wonder-drug/

Zegans LS, Pollard JC and Brown D (1967) The effects of LSD-25 on creativity and tolerance to regression. *Archives Of General Psychiatry* 16(6): 740–749.

Zedelius CM and Schooler JW (2015) Mind wandering "ahas"; versus mindful reasoning: Alternative routes to creative solutions. *Frontiers in Psychology* 6: 34.

Zedelius CM and Schooler JW (2016) The richness of inner experience: relating styles of daydreaming to creative processes. *Frontiers in Psychology* 6: 2063.

Zeidner M and Matthews G (2000) Intelligence and personality. In Sternberg R (Ed.) *Handbook of Intelligence*. New York: Cambridge University Press, 581–610.