universität wien

MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

„The self-transcendent brain:
A meta-analysis of functional neuroimaging on meditation and psychedelics"

verfasst von / submitted by

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angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien, 2018 / Vienna 2018

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	A 066 840
Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet:	Masterstudium Psychologie
Betreut von / Supervisor:	Dr. Henryk Bukowski, BSc MSc

Acknowledges

First, I would like to thank my family, friends, mentors and colleagues for every support, for every thought-provoking talk and for enduring my philosophical streak. I thank my supervisor Dr. Henryk Bukowski who enabled this research project and always provided me useful advises. Thanks to everybody who made it possible for me to delve deeply into this freely chosen topic and to answer an integral question for my personal understanding. I would also like to acknowledge the University of Vienna and the European Union for the possibility to study over five formative years in a transcultural metropolis. Finally, my thanks also to the many who inspired me in creative conversable time propelling me to study one psychological summit of humanity.

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1. Introduction

The possibility of self-consciousness and its relation to the brain are big riddles for 21st century science. Ever since Darwin, Marx and Freud hypothesized mental states are reducible to brain events (de Beer, 1960; Marx & Engels, 1845-46/1978; Freud, 1920/1955), modern sciences are strongly influenced by materialist world views. Thus, idealist theories appeal less scientific and metaphysics is often argued to be based on figments. Particularly in capitalistic societies, materialism accompanies reductionism whereas holism tends to be neglected (Haraway, 1988; Wrigley, 2004). According to the existential security hypothesis, improvements in economic status and health status make spiritual belief rather redundant (Barber, 2011, 2013). Thus, the dominance of materialism lead to a metaphysical gap.

However, throughout history, many humans sought after a self-transcendent connection even when the satisfaction of their physiological and social needs are secured. Humans meditated or consumed psychoactive plants in multifarious spiritual rituals across prehistoric and ancient cultures and interconnected them in shamanist and alchemistic practices (Eliade, 1964; Harner, 1973; Jung, 1968; La Barre, 1972; Nencini & Grant, 2010; Rudgley, 1993; Sayin, 2014; Schultes, Hofmann, & Rätsch, 2001; Winkelman, 1990). In Western sphere, spiritual practices became popular again in the mid-20th century when counterculture arose (MacFarlane, 2010; Stevens, 1987). It was predominantly the hippies who rediscovered meditation and psychedelics who wanted to exceed personal boundaries, to develop themselves mentally and to edify worldwide peace. By that time, it was attempted to fill the metaphysical gap by intensifying relationships with nature and within humanity. Indeed, the ability to experience something beyond the self-centered conception is part of the human condition, so researchers started to investigate the spiritual aspect of psychedelics and meditation (e.g. Deikman, 1963; Pahnke, 1966). The evoked meaningful experiences were connected to Eastern contemplative traditions by academic influencers (Leary, Metzner & Alpert, 1964; Watts, 1964) and inspired to practice and teach meditation (Osto, 2016). The subdiscipline transpersonal psychology emerged with the aim to systematically explore experiences beyond the individual and mundane perspective (Chinen, 1996). Though, political defamation campaigns caused prohibition of psychedelics (Baum, 2016; Lee & Shlain, 1992; MacFarlane, 2010; McAllister, 2002) which still restricts research (Nutt, 2014) and criminalizes their consumers. Studying meditation remained a niche.

Nonetheless, thanks to their therapeutical potential, their research started to revive in the 1990s and accelerated lately (Goyal et al., 2014; Gasser, Kirchner, & Passie, 2015; Krebs

& Johansen, 2012; MacLean, Johnson, & Griffiths, 2011). They are likely to be counteragents for addiction and affective disorder. For recreational purposes however, besides religious traditions, only some nowadays subcultures like trance, goa and psychonautics preserved few spiritual rituals, most noticeable with involvement of psychedelic consumption (D'Andrea, 2007; Móró, Simon, Bárd & Rácz, 2011). In comparison, meditation has been widely accepted by the mainstream culture and is professionally commercialized, for instance by workshops, advice literature and even by military. Acceleration, alienation and constant availability make techniques for reaching equanimity more attractive to maintain or recover productivity and mental health. With this in mind, the current trend of microdosing psychedelics in Silicon Valley marks a possible turn for psychoactive substances. Subhallucinogenic administration of psychedelics to boost one's performance is practiced in more and more workplaces (Sahakian, d'Angelo, & Savulich, 2018).

General research interest in religious, spiritual and mystical experiences (RSME) advances. RSME capture a wide range of ineffable and transient phenomena with noetic quality (Braud, 2002; Coyle, 2008; James, 1902/2012; Pahnke, 1996; Stace, 1960). The advent of spiritual neuroscience (i.e. neurotheology) signals the attempt to map RSME onto the brain (e.g. Beauregard & Paquette, 2006, Davidson & Lutz, 2008; Newberg & d'Aquili, 2000) challenging the inductive metaphysical concept of the self which emerged intersubjectively through evolution (Thompson, 2001). Furthermore, experiments replicated that psychedelics induce special and surprising consciousness-expanding experiences (Griffiths, Richards, Johnson, McCann, & Jesse, 2006, 2008; Shanon, 2002; Strassman, Qualls, Uhlenhuth, & Kellner, 1994). Literature body on meditation and psychedelics is still growing (Fox et al., 2016; Fox, Girn, Parro, Christoff, 2018), studies about their neural correlates receive great media attention and neural similarities of them were proposed several times (Cahn & Polich, 2006; d'Aquila & Newberg, 1993; Garcia-Romeu, Himelstein, & Kaminker, 2015; Goodman, 2002; Palhano-Fontes et al., 2015; Winkelmann, 2017; Yaden, Haidt, Hood Jr, Vago, & Newberg, 2016). Both alter the ordinary sense of self, especially the self–other relation seems to be affected. In social, cognitive and affective neuroscience, the self–other relation describes whether individual, relational or collective contents of awareness are represented in social contexts (Decety & Sommerville, 2003; Sedikides & Brewer, 2015). Moreover, it relates to whether one distinguishes oneself from others (i.e. self–other distinction) or one identifies oneself with others (i.e. self–other integration). Meditation and psychedelics can foster a special form of self–other integration (e.g. Colzato et al., 2012; Pokorny, Preller, Kometer, Dziobek, &

Vollenweider, 2017). On that basis, more and more researchers speculate on the everlasting dispute between materialism and idealism, even under the consideration of quantum mechanics (e.g. Ceylan, Dönmez, Ünsalver, Evrensel, & Yertutanol, 2017; Liou et al., 2016; Pereira, 2015). Some even assumed that the question about the primary substance of the world can be traced by investigating the neural substrates of the self (Reiner, 2013). Apparently, there is need to explore whether there are common functional brain patterns during meditative and psychedelic experiences. Therefore, here, a meta-analysis of their functional neuroimaging studies was examined. But before conducting this quantitative comparison, meditative practices and psychedelics need to be categorized in terms of the self–other relation.

1.1 Self-transcendent experiences

Meditation practice and psychedelic consumption are both linked to greater openness, higher empathy, prosocial and ecological sustainable behavior, less materialistic values, egalitarian attitude, hope creativity, greater mindfulness capacities, higher trait absorption, equanimity, reduced psychological distress, increased energy, heightened sensory sensitivity, and enhanced neuropsychological functioning (Alexander, Newman, Chandler, & Davies, 1987; Bouso et al., 2015; Arenander, 1996; Berkovich-Ohana & Glicksohn, 2017; Davidson, Goleman, & Schwartz, 1976; Grant et al., 2013; Dolder, Schmid, Müller, & Liechti, 2016; Forstmann & Sagioglou, 2017; Hendricks, Thorne, Clark, Coombs, & Johnson, 2015; Horan, 2009; Jedrczak & Clements, 1985; Jacob, Jovic, & Brinkerhoff, 2009; Kang, Gray, & Dovidio, 2014; Lebedev et al., 2016; Lerner & Lyvers, 2006; Mascaro, Rilling, Negi, & Raison, 2013; McEvoy, Frunkin, & Harkins, 1980; MacLean et al., 2011; Nour, Evans, Carhart-Harris, 2017; Sears & Kraus, 2009; Soler et al., 2016; Wallace, 1999). These common features indicate that meditation and psychedelics relate to *self-transcendence* (ST) that Sartre (1960) defined as being in the world for itself in relation with others. Transcending the self means to go beyond the intrapersonal and interpersonal perspective (Cloninger, Przybeck, Svrakic, & Wetzel, 1994; Frankl, 1966). Measuring trait ST with psychometric measurements also resulted in positive correlation with many of the above-mentioned facets of meditation and psychedelic consumption (e.g., Cardeña & Terhune, 2008; Caprara, Alessandri, & Eisenberg, 2012; Coward, 1991, 1996; Ellerman & Reed, 2001; Le & Levenson, 2005) and evidently, both are strongly related to higher trait ST (Bouso et al., 2012, 2015; Haimerl & Valentine, 2001; Fiori, David, & Aglioti, 2014).

However, the terminology of ST and operationalization have been inconsistent in psychological literature (Cloninger et al., 1994; Frankl, 1966, 2000; Gutiérrez-Zotes et al., 2004; Maslow, 1969; Levenson, Jennings, Aldwin, & Shiraishi, 2005; Reed, 1991; Tornstam, 1994). Most recently, this lack of conceptual clarity was deconstructed (Garcia-Romeu, 2010; Garcia-Romeu et al., 2015; Yaden et al., 2017). Garcia-Romeu et al. (2015) arranged STE in their grounded theory study positing three major themes: context, phenomenology and aftermath. Yaden et al. (2017) defined *self-transcendent experiences* (STE) as "transient mental states marked by decreased self-salience and increased feelings of connectedness to other people and one's surroundings" (Yaden et al., 2017, p.143) Apparently, STE consist of an *annhilational component* and a *relational component* which are both necessary conditions.

The annhilational component comprises a various decreased self-referential mode of awareness. Temporal and spatial perception vanishes, sometimes down to vastness and the salience of one's body dissolves (Berkovich-Ohana, Dor-Ziderman, Glicksohn, & Goldstein, 2013; Ott, 2013; Masters & Houston, 2000; Travis & Pearson, 2000; Shanon, 2001). The narrative self (Dennet, 1991; i.e. autobiographical self; Damasio, 2010) is disintegrated, tendentially unbound (Letheby & Gerrans, 2017) so one passes social, cultural and historical influences (Scharf, 2015). Ego-dissolution can commence in which the sense of 'I' temporarily disappears and the ability to reflection and attribution is reduced (Pahnke, 1969; Shanon, 2002; Stace, 1960). The most intense annhilational experience are voidness and nothingness. Overall, self-awareness lowers and a decentered, hypoegoic sense of self emerges (Leary & Guadano, 2011).

The relational component covers a variety of increased other-referential processing. Individuals experience positive and prosocial emotions such as joy, elevation, compassion, love, trust, gratitude, sublime and peacefulness (Algoe & Haidt, 2009; Kesbir & Diener, 2013; Keltner & Haidt, 2003; Le et al., 2005; Vago & Silbersweig, 2012). During STE, individuals feel more socially interconnected, typically shown by universalistic belief, collective identification and prosocial concerns (van Cappellen & Rimé, 2013; Pfiff, Dietze, Feinberg, Stancato, & Keltner, 2015). Further intense relational examples are the feeling to merge with the universe, to dealienate from nature, to be close to god or to unify with oneness (Fredrickson, 2009; Grof, Grob, Bravo, & Walsh, 2008; Johnestone et al., 2012; Maslow, 1964). Briefly summarized, awareness for interrelationships rises and an expanded, allocentric sense of self develops (Walsh & Vaughan, 1993). Afterwards, individuals frequently feel awakened or enlightened (de Castro, 2017).

ST coincides with the self-expansion model claiming the self is intrinsically motivated to broaden itself, for example by the inclusion of others into one's self-concept (Aron, Aron, &

Smollan, 1992; Aron, Aron, & Norman, 2001). To define the self–other relation as dichotomous appeals rather reductionist because there are many interpersonal and transpersonal phenomena in which individuals feel as rather as a collective (Sedikides & Brewer, 2015). Accordingly, STE align on a dependent two-dimensional spectrum of the relational and annhilational component (d'Aquila et al., 1993; Newberg & d'Aquili, 1998, 2000; Yaden et al., 2017). By that conceptualization, STE are explicable in terms of social, cognitive and affective neuroscience and reflect contemplative traditions (Davis & Vago, 2013; Lutz et al., 2007) and expresses different labels in a phenomenological precise way (Yaden et al., 2014).

STE are dereifying modes of existential awareness which Dorjee (2016) defines as changes in perception of reality and self towards an experiential recognition that both are construed. Dorjee (2016) postulates a hierarchical model with nondual and self-transcended awareness as the most advanced mode. Here, a pure, original, thoughtless state is described as transcendental consciousness (Husserl, 1913/1990; Kant, 1787/1998; Travis & Shear, 2010a which is here interpreted as a nonrepresentational mental state. STE are understandable as nondual mental states in which processing goes beyond the subject-object distinctions and awareness without names and forms appears (Josipovic, 2010; Vago & Zeidan, 2016). The nonduality of ST can be explained either by a dialectal synthesis of contradictions (i.e. self and others are integrated into a common collective construct), or by monist idealism of a transcendent entity (i.e. self and others are part of one higher-order being), which are both paraphrased in many spiritual teachings. The attempt to describe nonduality with dualistic language frequently results in paradoxicality or alleged ineffability (de Castro, 2017). Meditating and psychedelic administration are eminent for achieving transcendental consciousness (Austin, 1999; Griffith et al., 2006, 2008; Josipovic, 2010; Travis & Shear, 2010a).

Walsh and Vaughan (1993) assumed six characteristics for the transformative effects of STE: moral behavior, heightened attentional capacities, positive emotions, redirected motivation, present-moment awareness, and cultivation of wisdom. Apparently, STE are proposed to cultivate societal progress (Wilber, 1983) but are not inherently positive because the evaluation depends on the individual's expectations and intentions (Simpson, 2014).

Besides there are other events capable of eliciting STE (James, 1902/2017; Maslow, 1964). According to the above-mentioned grounded theory, psychotherapy and dance are catalysts, whereas spiritual ceremonies, being outdoors in nature and group festivities are facilitating settings and prior life situation such as stress, spiritual seeking and self-examination gives a set (Garcia-Romeu et al., 2015). Gorelik (2016) illustrates a broader variety of catalysts for STE: movement-based STE like in taijiquan or qigong (Yang et al., 2011), group-directed STE like in festivals (O'Grady, 2015), theory of mind-evoked STE like in animistic belief (Bering, 2002), epistemic STE like in scientific discoveries (Charlton, 2007), aesthetic STE like in art perception (Aldridge & Fachner, 2006), and nature-based STE like in mountaineering (Arzy, Idel, Landis, & Blanke, 2005), in forests (Williams & Harvey, 2001) or in space flight (Yaden et al., 2016). According to Yaden et al. (2017), mindfulness, flow, absorption, other-praising emotions, awe, peak experiences and RSME are potential STE (Yaden et al., 2017). The scope here focuses on meditative and psychedelic experiences because they are comparably easy to induce in experimental settings, form a synergistic relationship in terms of that they tend to reciprocally intensify their effects (Griffiths et al., 2017; Tart, 1991; Travis, Arenander, & DuBois, 2004; Yaden et al., 2016) and their body of literature is comparatively profound.

1.2 Self-transcending meditation

Contemplative research underwent a dichotomy between focused-attention meditation (FAM) and open-monitoring meditation neglecting meditation forms that open into STE (OMM; Lutz, Brefczynski-Lewis, Johnstone, & Davidson, 2008). In FAM the meditator focuses on her/his mind, body or environment and tries to stay aware of the directed object (e.g. breath control or body scan in mindfulness-based practices). OMM aims at direct and unbiased representation of any perception, emotion or cognition without any focus (e.g. excursive awareness of environmental stimuli). Several FAM forms achieve enhanced self-regulation, whereas various OMM forms enhance self-awareness, many do both, but some intend none of the two. When the meditative experience grounds on self-purpose like in many styles of FAM or OMM, other meditation forms contemplate feeling compassion with others, approaching a deity or reaching transcendental consciousness. After all, meditation practices are different from meditative experiences (Newberg, 2010).

Lately, Travis and Shear (2010a) extended the dichotomy with *automatic self-transcending meditation* where the individual transcends self-centered mental states. Travis (2014) argues in line with Maharishi Mahesh Yogi (1963) that self-transcending is automatic because the mind cannot transcend while intending or directing. In Transcendental Meditation (TM), on which they focus on, the individual silently repeats a mantra. TM practitioners usually begin with the intention to meditate or to reach transcendental consciousness, even though they may intend to not intend. Note the paradoxical use of dualistic language. Moreover, despite that the ancient greek origin αὐτόματος means self-moving, *automatic* is connotated within a mechanistic framework which appeals rather counterintuitive to spontaneous occurrence as described by Travis. At first glance, it seems reasonable to limit this style on intuitively processed meditation, however as stated above self-transcending is a gradual process with diverse states and hence not necessarily automatic. Josipovic (2010) elucidated that FAM may precede to initiate self-transcending which Travis and Shear (2010b) consented to. For other examples, in Taoist nei-yeh meditation and in Zen Buddhist zazen meditation, individuals often start to concentrate on a single content like in FAM or to observe the stream of consciousness without reactions like in OMM but ultimately, they also target STE (Guenther, 1993; Nicholson, 2000). A functional neuroimaging meta-analysis revealed neural differences between Buddhism- and Hinduism-inspired meditation styles which were explained by Buddhism's focus on self-awareness and Hinduism's focus on ST (Tomasino, Chiesa, & Fabbro, 2014). To categorize meditation styles by their intention seems a fruitful approach (Dorjee, 2016). Therefore, all meditation practices that intend to evoke STE can be assigned into a meditation category defined here as *self-transcending meditation* (STM).

Many meditation traditions such as Dzogchen, Yoga, Advaita Vedanta, Taoism, Tibetan and Hindu Tantra target STE and explicate them as constitutive elements (Josipovic, 2011; Vestergaard-Poulsen et al., 2009). Even vipassana and rigpa mediation, two foundations of mindfulness meditation, show a similar phenomenological variety as psychedelics, including synaesthesia (Kornfield, 1979; Louchakova-Schwartz, 2015; Walsh, 2005). Visualization of an egg or a mandala display the source of the universe and are classic STM by formal instructions (Lou et al., 1999; Louchakova-Schwartz, 2015). Other mantra-based meditation (MBM) than TM like soham yoga also fall into the STM category (Guleria, Kumar, Kishan, & Khetrapal, 2013) just as so-called mental silence meditation (MSM) like sahaja yoga not at least because mental silence is used synonymous to transcendental consciousness (Manocha, 2011).

Kindness-based meditation (KBM; e.g. loving-kindness meditation, compassion meditation) obviously fulfills the relational requirements for STE but whether it is also annhilational can be scrutinized. In social, cognitive and affective neuroscience, it is hotly debated whether self–other distinction or self–other integration is crucial for empathy and compassion. Many spiritual and contemplative individuals highlight the importance of self–other identification (Mascaro, Darcher, Negi, & Raison, 2015). Loving-kindness mediation increases awe (Fredrickson, Cohn, Coffey, Pek, & Finkel, 2008), has aspects of both FAM and OMM (Vago & Silbersweig, 2012) and brings others and social interconnection into focus

(Hutcherson, Seppala, & Gross, 2008), which all favor the latter position. In some KBM forms, the individual not only provokes nondesignated compassion but also transcends itself by feeling unity with others, eventually towards a humanistic, global, cosmic or transcendental consciousness (Desbordes et al., 2012; Josipovic, 2016; Lutz et al., 2008b; Salzberg, 1995).

On the contrary, some meditation forms preserve self–other distinction. Secularized meditation forms like mindfulness-based approach often lack the idea of ST. However, a suggested intersection of ST with mindfulness was already addressed. Definitions of mindfulness, that can be condensed as the state/trait to be nonjudgmentally aware of present-moment sensory, affective, and cognitive experiences (e.g. Bishop et al., 2004; Desbordes et al., 2015; Dreyfus, 2011; Kabat-Zinn, 2003), don't adequately integrate ST. Mindfulness faces semantic differences, unclear operationalization and insufficient correlations between self-report scales (Grossman & Van Dam, 2011). To encounter some of these flaws, Vago and Silbersweig (2012) provided a neuropsychological framework called S-ART which allocates mindfulness into following three components: (1) self-awareness which is the reflective meta-awareness of one's own cognitions, emotions and perceptions, (2) self-regulation which is the ability to effectively modulate one's own actions and reactions, and (3) ST which is the ability to build positive relationships between the concept of oneself and others that go beyond selfish interests. Within S-ART, ST neglects the annhilational component, yet it can be expressed to lowered self-awareness. This triadic taxonomy matches that of Thagard and Wood (2015) who summarized self-phenomena to (1) the representing self comprising self-awareness, (2) the effecting self-comprising self-regulation and (3) the changing self comprising ST. It also fits in line with another research project that divided meditation practices into three secularized modules, namely (1) Presence (promoting attention to present moment and interoception), (2) Affect (promoting socio-affective and motivational skills) and (3) Perspective (promoting metacognitive and socio-cognitive skills; Hildebrandt, McCall, & Singer, 2017). Still, mindfulness meditation and mindfulness-based stress reduction are adapted and abridged as they are not capable to single-handedly evoke STE (Dorjee, 2016), except in the form of a detached self-perception as a non-static self (Hölzel, Lazar, Gard, Schuman-Olivier, Vago, & Ott, 2011). For some cultivating attention and mindfulness alone is ignorant towards meditation traditions' gist regarding strengthened dualistic awareness through these practices which is why Dunne (2011) complemented mindfulness by nondual mindfulness. Furthermore, ego-dissolution induced by mindfulness lacks the relational component (Dor-Ziderman, Berkobuch-Ohana, Glicksohn, & Goldstein, 2013). Another secular form is acem meditation which is akin to TM, though it does not aim transcendental consciousness, probably due to a historical rift from each other (Løøv, 2015). When allowed open-monitoring occurs, the meditator is encouraged to direct her/his attention back to the mantra (Xu et al., 2014), so allocation to nondirective meditation seems misleading and thus acem meditation is rather a hybrid of FAM and OMM but not a STM form.

As mentioned above, meditation has been deeply embedded in many religious traditions. However, many RSME ascribe to paranormal or supernatural experiences, for instance being possessed, having visions or apparitions (McClenon, 1995). Supernatural experiences differ strikingly, highly depend on cultural constructions (Kirmayer, Corin, & Jarvis, 1998; Kleinman, 1980; Lukoff, Lu, & Turner, 1992), are similar to psychotic-like experiences (Cella, Vellante, & Preti, 2012; Kirmayer, Corin, & Jarvis, 1998), have an own tradition of operationalization (Tobacyk & Milford, 1983; Tobacyk, 2004) and don't necessarily have any relational or annhilational features. Nevertheless, mystical traditions like Brahmanism, Chassidism, Hermeticism, Hesychasm, Kabbalism, Meister Eckhart's teaching, Neoplatonism, Sufism, Taoism and many Native American religions report an all-encompassing unity (i.e., samādhi, unio mystica, henosis, devekut, tauhīd, etc.) in religious practitioners (Thalbourne, 1991) which is equivalent to transcendental consciousness. In fact, some religious practices share procedures with certain meditation techniques, for instance rosary prayer resembles MBM not only by its repetitive recitation but also in its beneficial cardiovascular effects (Bernardi et al., 2001). Some religious practitioners also report similar phenomenology to STE (Lazar & Kravetz, 2005; Garcia-Romeu et al., 2015; Newberg, Wintering, Yaden, Waldman, Reddin, & Alavi, 2015). It has been argued that religious interpretations might be transfigured epiphenomena of STE (Nencini & Granz, 2010) passed on over time. For these reasons, STM comprises some religious experiences, too.

1.3 Psychedelics

Classic psychedelics are major hallucinogenic serotonin (5-HT) receptor agonists whereby many ergolines such as lysergic acid diethylamide (LSD) or d-lysergic acid amide (LSA), many trypamines such as *N*,*N*-dimethyltryptamine (DMT; major agent of ayahuasca) and many phenethylamines such as psilocybin, mescaline or 4-bromo-2,5-dimethoxyphenethylamine (2C-B) fall within this definition (Nichols, 2004). Their effects are mainly mediated by the 5-HT_{2A} receptors (Canal & Murnane, 2017; Halberstadt, 2015; Preller et al., 2015) which are augmented in cortical layer V pyramidal neurons (Aghajanian & Marek, 1999) that have highly integrative properties (Bachmann, 2015). The psychological effects highly depend on dosage, expectations, personality, affect, environment and many other psychosocial factors and can result in terrible and even terror-fraught experiences what is referred to as a bad trip (Nichols, 2004; Studerus, Kometer, Hasler, & Vollenweider, 2011). Fox et al. (2018) divided the psychedelic into different stages: (1) onset, (2) core, (3) peak, (4) resolution, (5) assimilation, and (6) sequelae, whereby the first phase continues from the onset to the resolution, the sub-acute phase reflects assimilation (commonly known as afterglow) and the long-term phase corresponds to sequelae. However, multiple peaks can occur, especially when consumed orally. Acute psychedelic administration (APA), meaning that dosage is comparatively high, can elicit intense emotional reactivity (Soler et al., 2016) and unlike in meditation practices STE set in even in psychedelic-naïve individuals (Griffiths et al., 2006, 2008, 2011). Recent preliminary evidence confirm that APA can be safe and inhere therapeutic qualities (Griffith et al., 2016; Ross et al., 2016; dos Santos et al., 2016; Studerus et al., 2011). For example, when consumed for self-development and ST, APA positively correlated with elevated life purpose and personal coping strategies (Móró et al., 2011). Due to their potential to elicit RSME some refer to them as entheogens (Nichols, 2004; Wasson, Ruck, Bigwood, Ott, & Staples, 1979) meaning to generate devine inside, whereas psychedelic means revealing the soul. Yet STE by LSD receive a more emotional than metaphysical notion while reducing anxiety (Gasser et al., 2015). However, besides classic psychedelics, there are other psychoactive substances considered to produce psychedelic experiences.

Psychoactive major *N*-methyl-D-aspartate receptor (NDMAR) antagonists such as ketamine, phencyclidine (PCP) or dextromethorphan (DXM) are considered to form a distinct class called dissociatives because these glutamatergic drugs produce mainly dissociative effects. On the one hand, because of their assumed psychotomimetic and schizophrenomimetic effects as they occasionally evoke apathy, indifference and cognitive impairments, hallucinations, delusions and depersonalization, some use them as model for mental disorders (for a review see Frohlich & Van Horn, 2013). On the other hand, classic psychedelics were also consulted to model psychosis (Gonzalez-Maeso & Sealfon, 2009). As lately documented, after acute administration of ketamine or DXM, individuals report STE similar to classic psychedelics but often with less intensity (Reissig et al., 2012; Carbonaro, Johnson, Hurwitz, Griffiths, 2018; Studerus, Gamma, & Vollenweider, 2010; Vlisides et al., in press; Vollenweider & Kometer, 2010). Classic psychedelics too function on the glutamatergic system (Halberstadt, 2015; Martín-Ruiz, Ugedo, Honrubia, Mengod, & Artigas, 2001; Nichols, 2004; Winter et al.,

2004) which may enhance neuroplasticity (Vollenweider et al., 2010) and on the other hand, ketamine and PCP also affine to 5-HT2 receptors (Kapur & Seeman, 2002). Evidence for transformative impact of dissociative substances are growing (Wilson, 2014). Based on these similarities, the present work accounts ketamine, its analogues and DXM as psychedelics albeit their psychedelic status is not unanimous.

Apart from that, PCP differs from the others. Instead of transcending, individuals often experience perseveration and concreteness (Davies & Beech, 1960; Luby, Cohen, Rosenbaum, Gottlieb, & Kelly, 1959; Rosenbaum, Cohen, Luby, Gottlieb, & Yelen, 1959) and instead of benefiting, PCP is more neurotoxic (Nakki. Koistinaho, Sharp, & Sagar, 1995). Hence, PCP here is not considered a psychedelic. By the same token, deliriants like the major psychoactive substances in some Solanaceae are not regarded as psychedelics (Móró et al., 2011). By contrast the κ-opioid receptor agonist salvinorin A, which is incorparated into the dissociative class, shows a distinct pharmacokinetic (Butelmann & Kreek, 2015; Cruz, Domingos, Gallardo, & Martinho, 2017). It can induce intense experiences akin to STE (Maqueda et al., 2015) but the phenomenology is rather unique (Turner, 1996) which is why here it is not comprehended as a psychedelic. Further, cannabinoids like cannabis' major agent (−)-trans-Δ-9-tetrahydrocannabinol (THC) are not included mainly because of their amotivational potential which highly contradicts with psychedelics' transformative effects (Hendricks et al., 2015; Lac & Luk, 2018) and they show diverse psychopharmacological effects (Bhattacharyy et al., 2010; Deiana et al., 2011; Fusar-Poli et al., 2009) and are mostly poly drug used (at least many cannabinoids at once). However, THC has been linked to increased trait ST (Kleinloog, Stevens, Heuberger, Spinhoven, & van Gerven, 2014).

Other candidates are entactogens that are represented by substituted methylenedioxyphenethylamine with 3,4-methylenedioxymethamphetamine (MDMA; commonly known as ecstasy) as the most prominent prototypical agent. Entactogens also operate on the serotonergic system (Liechti & Vollenweider, 2001; Van Wel et al., 2011) but additionally release dopamine and norepinephrine and inhibit their uptake (Bradbury et al., 2013). Evidence link entactogens with enhanced socio-emotional and socio-cognitive processes (Baggot et al., 2016; Hysek et al., 2013) and greater openness (Wagner et al., 2017) but transpersonal phenomena are very rare for conventional acute dosages (Lyvers & Meester, 2012). Normally, self–other distinction is preserved, and authenticity is increased, distinguishing entactogens from psychedelics (Baggot et al., 2016; Crownfield, 1979). Also, entactogens provoke dissociative symptoms lower than ketamine (van Heugten-van der Kloet et al., 2015). In this preliminary approach, entactogens are not regarded as psychedelics.

Further anecdotal reports obtained from Erowid.org (https://erowid.org/experiences/), Land-der-Traeume.de (https://www.land-der-traeume.de/tripberichte.php) and personal conversations with psychonauts supported the present conceptualization of psychedelics and inconsistency for entactogens in terms of their self-transcendent quality.

1.4 Brain activities during STM and after APA

A proposed commonality between STM and APA is their relation to the serotonergic system since STM also activates it (Goodman, 2002; Yu et al., 2011). Moreover, trait ST is also evidently correlated with the serotonergic system (Borg, Andrée, Soderstrom, & Farde, 2003; Comings, Gonzales, Suacier, Jonhson, & MacMurray, 2001; Ham et al., 2004; Lorenzi et al., 2005; Nilsson et al., 2007). The infamous STE of Siddhartha Gautama is hypothesized to be produced by release of tryptamine and serotonin after fast-breaking (Joseph, 2012). However, many other neurotransmitter systems are affected by both meditation and psychedelics (Rickli, Moning, Höner & Liechti, 2016; Guglietti, Daskalakis, Radhu, Fitzgerald, & Ritvo, 2013; Halberstadt, 2015; Kjaer et al., 2002; Nichols, 2004; Tylš et al., Páleníček, & Horáček, 2014).

Neuroanatomical studies provide contradictional findings. It is generally acknowledged that meditation works against the depleting effects of aging attested by increased prefrontal cortical thickness and larger gyrification and overall heightened neural plasticity (for a meta-analysis see Fox et al., 2014). Some effects occur even after a single session (Klimecki, Leiberg, Lamm, & Singer, 2012). Both STM and psychedelics have been linked to neurogenesis in hippocampus (Catlow, Song, Paredes, Kirstein, & Sanchez-Ramos, 2013; Luders, Kurth et al., 2013; Luders, Thompson, et al., 2013). Also, gray matter volume (GMV) is increased for practicing STM frequently (Hernández et al., 2016; Vestergaard-Poulsen et al., 2009). On the contrary, praying regularly is associated with reductions in the left medial orbitofrontal cortex (Kober et al., 2017) whereas intense relationship with god correlates with an increased GMV in the right middle temporal cortex (Kapogiannis et al., 2009). Chronic ketamine use reduces GMV in the dorsal prefrontal cortex (Liao et al., 2011), again GMV in left frontotemporal and right parietotemporal regions was increased for elders with higher trait ST (Kaasinen et al., 2005). Nevertheless, to comprehend the nature of STE means to reveal functional neural levels.

Comparisons of event-related potentials reveal some inconsistencies. Transcendental meditators show higher alpha coherence (Travis et al., 2002, Travis, 2011, Yamamoto et al.,

2006) and zen meditators higher theta activity (Yu et al., 2011). Throughout, gamma activity seems to be prominent during STM (Cahn & Polich, 2006). In total, electroencephalography (EEG) during meditation demonstrates reduced amplitudes in all bands indicating the annhilational component of STE (Hinterberger, Schmidt, Kamei, & Walach, 2014). EEG studies investigating psychedelics also show increased coherence in high frequency bands and decreased low frequency bands (Riba et al., 2002, 2004; Muthukumaraswamy et al., 2013; Carhart-Harris et al., 2013; Kometer et al., 2015; Stuckey et al., 2005; Valle et al., 2016). There is still ongoing controversy about the interpretation of neural synchrony in gamma frequency. One hypothesis is that these gamma waves represent the relational component (Sokhadze & Daniels, 2016). However, EEG signals during STE could rather represent the brain's arousal and corresponding processes of different stages than the STE itself (Josipovic, 2010; Travis & Shear, 2010b). The same might pertain for functional neuroimaging methods.

Three large-scale brain hubs play a crucial role for self- and other-referential processes and integration of cognitive and affective information: default mode network (DMN), central executive network (CEN) and salience network (SLN; for a review see Bressler & Menon, 2010). The DMN is prominent for self-referential processing, mind-wandering and theory-of-mind and comprises big nodes among the medial prefrontal cortex, the posterior cingulate cortex (PCC), and by lesser extent the inferior parietal cortex and the medial temporal lobes (for a review see Davey et al., 2016). The CEN is anchored in the dorsolateral prefrontal cortex (dlPFC) and the posterior parietal cortex and is responsible for high-level cognitive processes, especially working memory, attention control and inhibitory control. The major hubs for the SLN are the anterior cingulate cortex (ACC), the anterior insula and subcortical regions comprising the amygdala, the ventral striatum, the ventral tegmental area and the thalamus to receive multisensory and limbic inputs (for review see Bressler et al., 2010). The SLN is involved in redirecting attention to salient internal and external events and dynamically switches between DMN and CEN activity (Goulden et al., 2014; Menon & Uddin, 2010; Sridharan et al., 2008).

STM is frequently associated with deactivations in the DMN and SLN (Tomasino et al., 2014; Fox et al., 2016) and the more automatically an individual meditates, the more deactivated the DMN gets (Jerath et al., 2012). Notably, in LTP of zen meditation, myo-inositol is increased in the PCC (Fayed et al., 2013) hinting at antidepressant effects (Chiapelli et al., 2015). On the other side, parts of the CEN happen to be activated in STM (Tomasino et al., 2014; Fox et al., 2016). Psychedelics also affect these networks. Psilocybin affects functional connectivity of all three networks and notably lower baseline functional connectivity of the CEN predicted ego-dissolution (Tagliazucchi et al., 2014). Strengthened overall functional connectivity during LSD-induced ego-dissolution emerged through the desintegration of both SLN and DMN (Tagliazucchi et al., 2016) whereas mental time travel was only lowered for the latter (Speth et al., 2016). Additionally, long-term ayahuasca consumers show thinned PCC and a shrinked ACC without neuropsychological impairements, while the volume in PCC was anticorrelated with trait ST and prior ayahuasca use (Bouso et al., 2015). For psilocybin-induced ego-dissolution, it has been suggested that not DMN but the SLN displays the bodily self, whereas the DMN represents the narrative self because the decoupling of the medial temporal lobes is more widespread than to solely concern the DMN (Lebedev et al., 2015). Furthermore, a meta-analysis for self-referential processes provided evidence for the involvement of the ventromedial prefrontal cortex (vmPFC), ACC, bilateral AI, left striatum, right thalamus, and amygdala (Northoff et al., 2006) further supporting the critical role of the DMN and SLN in STE.

According to S-ART framework, a frontoparietal control network integrates external stimuli with internal representation and switches self-processing (Vago & Silbersweig, 2012; Vago, 2014). Activity of lateral left frontotemporoparietal cortices seems to be decreased during STM (Hargety et al., 2013; Garrison et al., 2013; Garrison et al., 2014). Medial regions of frontal cortices including the ACC and parietal cortices including the PCC and the dorsolateral parietal cortex seem crucial for psychedelic effects (Carhart-Harris et al., 2012; Hermle et al., 1992; Muthukumaraswamy et al., 2013; Palhano-Fontes et al., 2015; Riba et al., 2004, 2006; Vollenweider et al., 1997).

During STE, sensory, perceptual, and cognitive layers are hypothesized to lessen processing environmental information (de Castro, 2017). The thalamus is argued to gate signals into the cortex (Behrens et al., 2003) in which 5-HT_{2A} receptors are broadly expressed (Cyr, Landy, & Di Paolo, 2000). Presumably, thalamus' filtering function is partly suspended after APA (Geyer & Vallenweider, 2008; Vollenweider & Geyer, 2001). P50 suppression after ayahuasca intake confirms with less thalamic gating (Riba et al., 2002). Ayahuasca transiently modifies information transfer indicated by decreasing anterior-to-posterior and increasing posterior-to-anterior functional connectivity (Alonso et al., 2015) and reduced brain oscillations in posterior-parietal regions (Muthukumaraswamy et al., 2013; Riba et al., 2004). Psilocybin administration lead to decreased functional connectivity between prefrontal and parietal regions, including ACC and PCC (Carhart-Harris et al., 2012) and connects normally segregated networks (Roseman et al., 2014). This induced entropy in the brain (i.e. disruption of neural hierarchies) is further supported by reduced current density in medial posterior and anterior regions in ayahuasca-induced STE (Alonso et al., 2015; Riba et al., 2004). Deafferentation in the posterior superior parietal lobe and nondominant parts of the inferior parietal lobe in Tibetan Buddhist meditators hint at similar consequences of STM (Newberg, Alavi, Baime, d'Aquli, & Mozley, 1998; Newberg et al., 2001). Zen meditators' low levels of glutamate and *N*-acetylaspartate in the left thalamus could be interpreted as altered integration of sensory information through the posterior superior parietal lobe and less inhibition of neural networks (Fayed et al., 2016). Anti-correlation between cognitive and perceptual networks is stronger during STM (Josipovic, Dinstein, Weber, & Heeger, 2012) strengthening the view of perceptual processing's dominance over cognitive processing (de Castro, 2017). Brain entropy in both STM and APA are candidates to lower the threshold of consciousness and may explain emergence of STE (Carhart-Harris et al., 2013, 2014; Lebedev et al., 2016; Sparby, 2015; Strick et al., 2012).

Beyond all of that, there is a connection between brain dysfunctionality and STE. Temporal lobe epilepsy and lesions in frontotemporal regions have been associated with RSME and hyperreligious behavior (Cristofori et al., 2016; Johnstone, Holliday, & Cohen, 2016; Saver & Rabin, 1997) consorting with necropsy findings in brains of prophets and saints (Devinsky & Lai, 2008). Increases of trait ST are associated with lesions in the left and right inferior posterior parietal regions (Urgesi, Aglioti, Skrap, & Fabbro, 2010) and in right posterior parietal lobe, whereas increased frontal lobe functioning is linked with more intense religious behavior (Johnstone, Bodling, Cohen, Christ, & Wegrzyn, 2012). Simulating these impairments via transcranial magnetic stimulation (TMS) replicated the same effects (Crescentini, Aglioti, Fabbro, & Urgesi, 2014; Crescentini et al., 2015). Overall, decreased right parietal lobe functioning is highly involved in RSME (Johnstone & Glass, 2008; Johnstone et al., 2012, 2017) which is suggested to play a critical role in self-related processing (Decety & Sommerville, 2003; Platek, Keenan, Gallup, & Mohamed, 2004). On the contrary, STM seem to be beneficial for epilepsy (Orme-Johnson, 2006; Panebianco, Sridharan, & Ramaratnma, 2015) and temporal lobe activations in psilocybin consumers are inconsistent with deactivations in patients experiencing postictal spirituality (Geyer & Vollenweider, 2008; Nencini & Grant, 2010). Nevertheless, STE are not reducible to pathological conditions, neither to depersonalization or derealization, instead STE can initiate to overcome affective and cognitive disorders (Lee & Newberg, 2005; Newberg, 2014; Vago & Silbersweig, 2012; Yaden et al., 2017).

1.5 Aims of this study

Until now five functional neuroimaging meta-analyses on meditation studies were published. (Boccia, Piccardi, & Guariglia, 2015; Falcone & Jerram, 2018; Fox et al., 2016; Sperduti, Martinelli, & Piolino, 2012, 2011; Tomasino et al., 2014). Although a meta-analysis on STM was already considered, it was claimed that there are not enough studies for STM due to traditional categorization. On that account, the present meta-analysis assigned studies by the intention of the meditation practice and focused on STM in LTP. LTP were shown to have different peak foci than novices and it takes presumably extensive training and expertise to reliably elicit STE (Sharf, 1995; Travis et al., 2002; Wallace, 1999), especially in neuroimaging settings (Boccia et al., 2015; Falcone et al., 2018).

In addition, to the best of the author's knowledge no meta-analysis on psychedelics has been conducted yet. Instead, three reviews have been published, two focused on classic psychedelics (dos Santos, Osório, Crippa, & Hallak, 2016; Halberstadt, 2015) and another included dissociatives (Fox et al., 2018). Even though STE may persist in the sub-acute and long-term phases, the acute phase is a reliable interval for occurrence of STE.

STM and APA are subject to several different cognitive, affective and perceptual processes. Despite of early stages and accordingly, preceding heterogenous neural patterns, the acute phase after APA and late meditative stages were promising to arouse STE. To further investigate the proposed similarity between psychologically and pharmacologically induced STE, this anisotropic effect-size seed-based d mapping (AES-SDM) meta-analysis summarized and compared neural correlates of STM and APA.

2. Methods

2.1. Literature review

The databases PubMed (https://www.ncbi.nlm.nih.gov/pubmed/), PsycINFO (https://www.apa.org/pub/databases/psycinfo/index.aspx) and Web of Science (https://webofknowledge.com/) were searched for terms related to STE and coordinate-based functional coordinate-based neuroimaging methods and further avoided clinical and animal samples and non-psychedelic substances (for the search string see Table 1). The literature search considered results from January 1st, 1990 (first functional neuroimaging study for meditation:

Table 1

Search string for the literature review

Search operators and search fields	Terms
IN Title/Abstract	self-transcendence, self-transcending, self-transcendent, meditation, meditative, yoga, prayer, praying, contemplation, contemplative, ego-dissolution, transcendental consciousness, nondual awareness, religious experience, spiritual experience, mystical experience, peak experience, transpersonal, enlightenment, awakening, psychedelic, hallucinogenic, hallucinogen, tryptamine, ergoline, phenethylamine, entheogen, LSD, lysergic acid diethylamide, psilocybin, magic mushrooms, DMT, dimethyltryptamine, ayahuasca, mescaline, peyote, San Pedro, Peruvian torch, Peganum harmala, wild rue, 2-CB, dissociative, ketamine, dextromethorphan, DXM, methoxetamine, MXE
AND IN Title/Abstract	fMRI, functional MRI, functional magnetic resonance imaging, PET, positron emission tomography, SPECT, single-photon emission computed tomography, neuroimaging, brain, neural
NOT IN Title	patients, disorder, depression, schizophrenia, schizophrenic, PTSD, post-traumatic stress disorder, Parkinson, Parkinson’s, Alzheimer, Alzheimer’s, epilepsy, sclerosis, impairment, impairments, injury, injuries, lesion, lesions, rodent, rodents, mice, mouse, rats, rat, monkeys, monkey, primate, primates, zebrafish, MDMA, methylenedioxymethamphetamine, phencyclidine, PCP, THC, cannabis, marijuana, deliriant, deliriants, salvinorin A, Salvia divinorum

Note. Terms to be written as multiple words were written with quotation marks. Operators are written in capitals.

Herzog et al., 1990; first for APA: Hermle et al., 1992) up to April 30th, 2018 without any language constraints. Resulting papers' abstracts were checked for presence of adult healthy human participants, utilization of functional magnetic resonance imaging (fMRI), positron emission tomography (PET) or single-photon emission computed tomography (SPECT), assessing STM or APA and for STM at least a subsample of LTP. In addition, references of relevant meta-analyses and reviews were checked, too.

Mandatory aspects were (1) peak foci or stereotactic maps of functional correlates for activations and deactivations in Montral Neurological Institute space (MNI; Collins et al., 1994) or Talairach space (TAL; Talairach & Tournoux, 1988) with significance according to individually specified threshold, (2) human, adult healthy and non-clinical participants, (3) scanning participants during or immediately after STM or APA, (4) original articles published in peer-reviewed scientific journals, and for STM studies (5), a specific contrast for LTP. Studies with following criteria were excluded: (1) book chapters, dissertations, case reports, qualitative studies, meta-analyses and reviews, (2) neurological or psychic impairments in participants, (3)

assessment with confounding tasks, (4) foci of changes in neural structure or foci of functional connectivity, (5) studies without any relevant contrast, (6) articles with missing data which could not be acquired from the authors, (7) studies with samples equal to already included ones, and for STM studies (8) meditation practices without the intention to evoke STE.

Supplementary materials were checked. For studies without reported coordinates for peak foci or stereotactic maps, corresponding authors were asked via email for supplementary data. If studies reported multiple independent samples, appropriate data were included as separate studies. This literature review yielded to an inclusion of 33 studies with 20 results for STM and 13 for APA (for flow chart see Figure 1). Despite some authors stated a partly overlap to other samples, each study was assumed as an independent dataset.

2.2 Study encoding

The encoded variables for every study incorporated in the meta-analysis were: authors, year of publication, STE relevant characteristics, number of subjects, age, neuroimaging method, contrast, voxel analysis level, and peak foci. The additional variables for STM studies specifically were: meditation tradition, meditation category and expertise. Extracted data for APA studies only were: psychoactive substance, psychopharmacological category, administration form, dosage and expertise. Units were transformed if necessary. Missing data were computed and included when original information was given.

2.3 Anisotropic effect-size seed-based d mapping meta-analysis

The AES-SDM meta-analysis was conducted using SDM software, version 5.15 (https://www.sdmproject.com/) for AES-SDM and MRIcron software (https://people.cas.sc.edu/rorden/mricron/) for image viewing. Functional principles AES-SDM were already described elsewhere (Radua & Mataix-Cols, 2009, 2012, Radua, Romeo, Mataix-Cols, & Fusar-Poli 2013, Radua, Radua, Rubia, Canales, Pomarol-Clotet, Fusar-Poli, & Mataix-Cols,2014). TAL coordinates were automatically converted in MNI space via SDM software and effect-sizes were semi-automatically converted into *t*-statistics via the web application Statistics converter (https://www.sdmproject.com/utilities/?show=Statistics). Separate contrasts from the same experiment were pooled into one study without any further computation (Turkeltaub et al., 2012). Preprocessing parameters were set to 50 randomizations, gray matter template, gray matter mask, anisotropic kernel to 1.00 and isotropic full width at half maximum (FWHM) to 40 mm (Radua et al., 2014), peak height threshold at SDM $z > 1$ to proximate a corrected threshold of $p < .05$ (Radua et al., 2012) and cluster-size threshold at $\geq$ 20 mm³ with SDM z scores > 1 to comprise between reducing both false positives and false negatives. Means were analyzed without any filter.

The functional overlap between STM and APA was assessed in the main analysis which localized general brain regions for STE with a single AES-SDM meta-analysis (Radua et al., 2013). In accordance with the resulting four tails of two distributions, the extent voxel threshold was lowered to $p < .0025$. The differences between STM and APA were investigated via meta-regression. An extra meta-regression highlighted potential characteristics for classic self-transcending meditation and classic psychedelics in comparison to the rest.

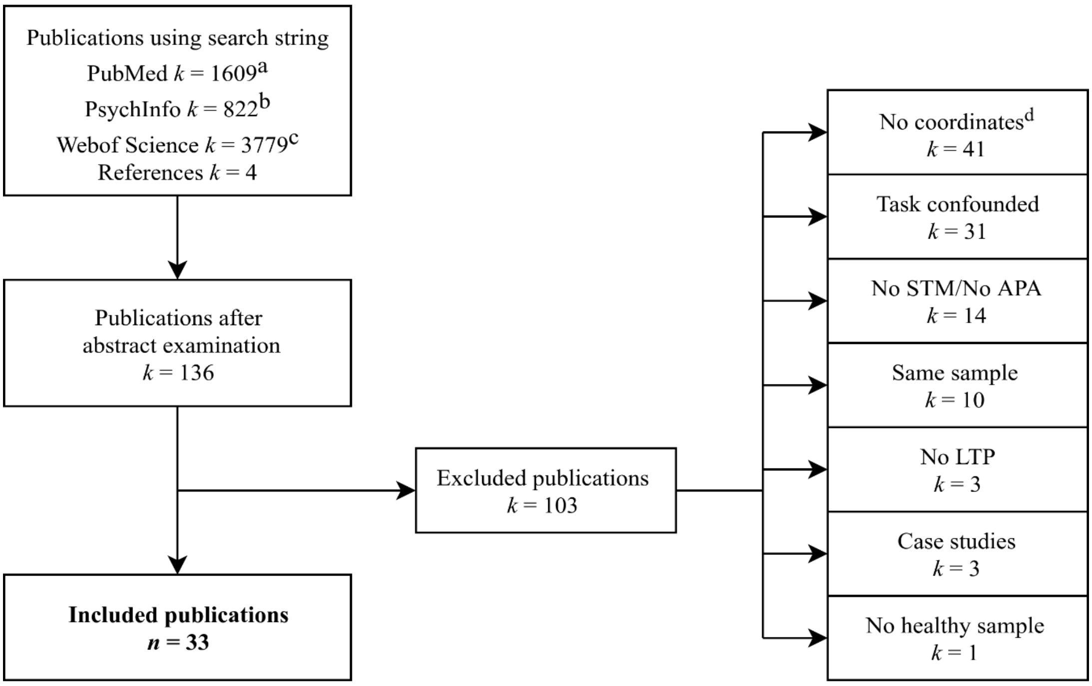
The subgroup AES-SDM meta-analyses for STM and APA were separately conducted with a significance threshold below $p < .005$. Since meditation styles are meta-analytically attested to alter brain function and classic psychedelics and dissociatives show different pharmacodynamics, separate subdomain analyses were performed for both STM (classic STM; MBM; KBM; religious experience) and APA (classic psychedelics). The subdomain influences were investigated with meta-regressions with a lowered probability threshold of $p < .0005$ to minimize dubious detections (Radua et al., 2009).

Furthermore, supplementary analyses were conducted. Interstudy heterogeneity was qualitatively assessed guided by visual maps of Q_H statistics converted into SDM z-scores. Voxel-based jackknife analysis iteratively excluded one study from meta-analysis' computation to investigate the sensitivity of the data set to each particular study. Moreover, funnel plots for the significant blobs and peaks were constructed with the effect-size plotted against the *SE* of each studies' contrast to check for publication bias which was supported by Egger's tests regressing of standard normal deviation on the precision (Egger, Smith, Schneider, & Minder, 1997).

3. Results

3.1 Study characteristics

The encoded studies are summarized in Table 2 for STM studies and in Table 3 for APA studies. In total, the literature review yielded in 430 peak foci consisting of 267 activations (n_{STM} = 128; n_{APA} = 139) and 163 deactivations (n_{STM} = 77; n_{APA} = 86) from 33 studies (n_{STM} = 20; n_{APA} = 13). Only one study (Carhart-Harris et al., 2016b) provided a stereotactic map. The overall sample was N = 471 participants who had STE, existing of 272 LTP and 199 psychedelic experiencers.



[a] Species: Human
[b] Limits: Peer Reviewed Journal, Human
[c] Index: ScienceCitation Index Expanded; Document Type: Article
[d] including methodologically capable and incapable studies

Figure 1. Flow diagram of literature search and applied exclusion criteria.

Table 2

Included self-transcending meditation studies for the meta-analysis

References	*n*, n_{CG}	*M* Age (y)	Tradition; expertise	Relevant characteristics	Scanner	Contrast	Analysis	Foci
Lou et al., 1999	9	23–41[a]	Kriya Yoga; > 5 y	cSTM: abstract joy & golden egg visualization	^{15}O-$H_2$0 PET	(STM > rest)	whole	12+
Lazar et al., 2000	5	33.5	Kundalini Yoga; > 4 y	MBM: mantra synchronized with breath	3T fMRI	(Late STM > early STM)	whole	15+
Azari et al., 2001	6, 6	31	Evangelical Fundamentalist Christianity; Converts	RE: reciting 1st verse of Psalm 23	^{15}O PET	(STM > CT) in (LTP > CT)	whole	4+
Beauregard et al., 2006	15	49.9	Carmelite Catholic Christianity; nuns for *M* 19 y	RE: relive most intense connection to god	3T fMRI	(STM > rest)	whole	14+
Lutz et al., 2008	15	45	Nyingmapa & Kagyupa Tibetan Buddhism; 10000–50000 h	KBM: loving-kindness & compassion; randomized auditory stimuli	3T fMRI	(STM > rest)	ROI	16+
Shimomura et al., 2008	8	40.8	Japanese Buddhism; Monks	MBM: mantra-supported Buddha envisioning & sutra recitation	1.5T fMRI	(STM > rest)	whole	12+
Lutz et al., 2009	10, 12	40	Nyingmapa & Kagyupa Tibetan Buddhism; 10000–50000 h	KBM: loving-kindness & compassion; randomized auditory stimuli	3T fMRI	(STM > rest) in (LTP > CG)	whole	2+
Schjoedt et al., 2009	20	25.4	Danish Lutheran Christianity; orthodox praying individuals	RE: Lord’s prayer & personal praying	1.5T fMRI	(STM > CT)	whole	7−

Table 2 (continued)

References	n, n_{CG}	M Age (y)	Tradition; expertise	Relevant characteristics	Scanner	Contrast	Analysis	Foci
Engström et al., 2010	8	35	ACEM, Kundalini Yoga; 6–24 m	MBM: silent mantra	1.5T fMRI	(STM > CT)	whole	6+ 3−
Bærentsen et al., 2010	21	44.5	Danish M, Danish T, inspired by yoga & Tibetan Tantric Buddhism; 1.5–25 y	MBM: imaginative mantra synchronized with breath	1.5T fMRI	(STM > rest)	whole	1+ 33−
Brewer et al., 2011	12, 13	50.5	Theravada Buddhism; >10 y, *M* 10565 h	KBM: generalizing loving-kindness	3T fMRI	(STM > rest) in (LTP > CG)	ROI	1+ 3−
Wang et al., 2011	10	53.7	Kundalini yoga; > 30 y	MBM: mantra synchronized with breath (Shabad Kriya)	3T fMRI	(STM > CT)	whole	5+ 4−
Guleria et al., 2013	14	29.4	SOHAM; 5–7 y	MBM: silent mantra synchronized with breath	fMRI	(STM > CT)	whole	4+ 4−
Lutz et al., 2013	14, 14	45.6	Nyingma & Kagyu Tibetan Buddhism, *M* 12500 h	cSTM: 45 s open presence meditation, then cueing thermal pain	3T fMRI	(STM > CG)	ROI	7−
Engen et al., 2015	15	56.1	Nyingma Tibetan Buddhism; *M* 40000 h	KBM: compassionate feeling of a warm, positive affect & caring for others	3T fMRI	(STM > watch-negative task)	whole	13+ 5−
Hernandez et al., 2015	19	46.6	Sahaja yoga; 3–24 y	cSTM: e.g. focus on fontanelle; Indian classical music	3T fMRI	(STM > breath focus)	whole	2+ 2−

Table 2 (continued)

References	*n*, n_{CG}	*M* Age (y)	Tradition; expertise	Relevant characteristics	Scanner	Contrast	Analysis	Foci
Liou et al., 2016	16	48.5	Chinese Taoism; *M* 12.4 y	cSTM: Chinese Original Quiet Sitting: automatic energy flow preceded by silent mantra synchronized with energy-visualization	3T fMRI	(STM > rest)	whole	5+ 7−
Panda et al., 2016	20, 20	35	Raja yoga; *M* 15.2 y	cSTM: e.g. visualizing glowing star between eyes	3T fMRI	(STM > rest)	ROI	3+
Engen et al., 2017	16, 15	56	Nyingma Tibetan Buddhism; *M* 30 y, *M* 40000 h	KBM: feel loving-kindness for close individuals	3T fMRI	(STM > rest) in (LTP > CG)	whole	1+ 2−
Ferguson et al., 2018	19	27.4	Mormonist Restorationist Christianity; devouts with weekly church attendance & missionary service	RE: scripture reading with spiritual reflection proceeded by quotations & prayer	3T fMRI	(intense STM > weak STM)	whole	12+

Note. + = increased response; − = decreased response; CG = control group; cSTM = classic self-transcending meditation; CT = control task; h = hours; KBM = kindness-based meditation; LTP = long-term practitioners; m = months; MBM = mantra-based meditation; RE = religious experience; ROI = regions of interests; STM = self-transcending meditation; y = years.

[a]Range instead of *M* was reported.

[b]The subsample of ACEM meditation was included although mere ACEM meditation studies were excluded (Davanger et al., 2010; Xu et al., 2014).

Table 3

Included acute psychedelic administration studies for the meta-analysis

References	n, n_{CG}	M Age (y)	Administration; expertise	Relevant characteristics	Scanner	Contrast	Analysis	Foci
Holcomb et al., 2001	13, 10	31.3	Ketamine, i.v. 0.3 mg/kg; no prior experience	DIS; scan after 7 min; + in psychotomimesis	$H_2{}^{15}O$ PET	(PSY > CG)	whole	6+ 3−
Långsjö et al., 2003	9	24.7	Ketamine, i.v. 30, 100 & 300 ng/ml	DIS; scan after 15 min; contrast for highest concentration; + in altered body image, hallucinations, pleasantness, − in vigilance, anxiety	$H_2{}^{15}O$-${}^{15}O_2$-$C^{15}O$ PET	(PSY > BL)	ROI	11+ 6−
Långsjö et al., 2004	9	22−29 [a]	Ketamine, i.v. 300 ng/ml	DIS; scan after 15 min; + in altered body image, hallucinations, feeling of floating, times disturbances	[${}^{18}F$] FDG PET	(PSY > BL)	ROI	[b] 23−
Aalto et al., 2005	8, 8	24	Ketamine, i.v. 200 ng/m, constant concentration over an hour	DIS, scan after 15 min; + in arousal, euphoria, perceptual distortion, thought disorganization, delusions, disorientation	[${}^{11}C$] FLB PET	(PSY > CG)	ROI	1+
Riba et al., 2006	15	22.2	Ayahuasca, oral (DMT 1, harmine 1.7, harmaline 0.12, TTH 1.36 mg/kg); ≥ 10 experiences	cPSY; scan after 3 h; + in altered somaesthesia, positive mood, euphoria, arousal, thought disorganization, altered visual perception	${}^{99m}TC$-ECD SPECT	(PSY > PC)	whole	5+

Table 3 (continued)

References	n, n_{CG}	*M* Age (y)	Administration; expertise	Relevant characteristics	Scanner	Contrast	Analysis	Foci
Deakin et al., 2008	19	28	Ketamine, i.v. 0.25mg/kg/h	DIS; scan in middle of 16 min; + in thought disorganization, arousal, hallucinations, derealization, depersonalization	1.5T fMRI	(PSY > PC)	whole	43+ 15−
De Simoni et al., 2013	10	25.5	Ketamine, i.v. 0.23 mg/kg/h + 0.31 mg/kg/h	DIS; scan after 15 min; + in psychotomimesis, derealization, − in altertness	3T fMRI	(PSY > PC)	n/a	7+ 2−
Tagliazucchi et al., 2014	15	32	Psilocybin, i.v. 2 mg; >1 psilocybin experience	cPSY; scan after 8 min; + in ego-dissolution, affective valence	3T fMRI	(PSY > BL)	whole	16+ 11−
Khalili-Mahani et al., 2015	12	19−36 [a]	S(+)-Ketamine, i.v. 20 mg/70kg + after 1h 40 mg/70kg	cPSY; scan after 45 & 105 min; − in alertness, calmness	ASL 3T fMRI	(PSY > PC)	whole	5+ 5−
Pollak et al., 2015	23	26.3	Ketamine, i.v. 150 ng/ml for high-dose	DIS; scan after 10 min; + in psychotomimesis	ASL 3T fMRI	(PSY > BL)	whole	1+ 1−
Carhart-Harris et al., 2016b	15	30.5	LSD, i.v. 75 µg	cPSY; contrast after 70-130 min; + in altered states of consciousness	ASL 3T fMRI	(PSY > PC)	whole	11+

Table 3 (continued)

References	n, n_{CG}	*M* Age (y)	Administration; expertise	Relevant characteristics	Scanner	Contrast	Analysis	Foci
Preller et al., 2017	22	25.7	LSD, oral 100 µg; $n = 6$ with experience	cPSY; meaningful music vs. meaningless & neutral music; + in altered states of consciousness	3T fMRI	(Meaning > other) in (PSY > PC)	whole	26+ 3−
Lewis et al., 2017	29, 29	25	Psilocybin, oral 0.16 or 0.215 mg/kg; no prior heavy use	cPSY; scan after 60 min; 2 sessions ≥ 10 days apart; + in altered states of consciousness	3T fMRI	(PSY > PC)	whole	7+ 17−

Note. + = increased response; − = decreased response; ASL = Arterial Spin Labeling; BL = baseline; CG = control group; cPSY = classic psychedelic; DIS = dissociative; i.v. = intravenous; OL = open-labeled; PC = placebo-control; PSY = psychedelic; ROI = regions of interest; THH = tetrahydroharmine.

[a]Range instead of *M* was reported.

[b]Peak foci for increased responses were not available anymore in online supplementary material.

[c]Calculated via http://neurosynth.org/decode/?neurovault=14479 with arbitrary threshold of $z = 2.3$.

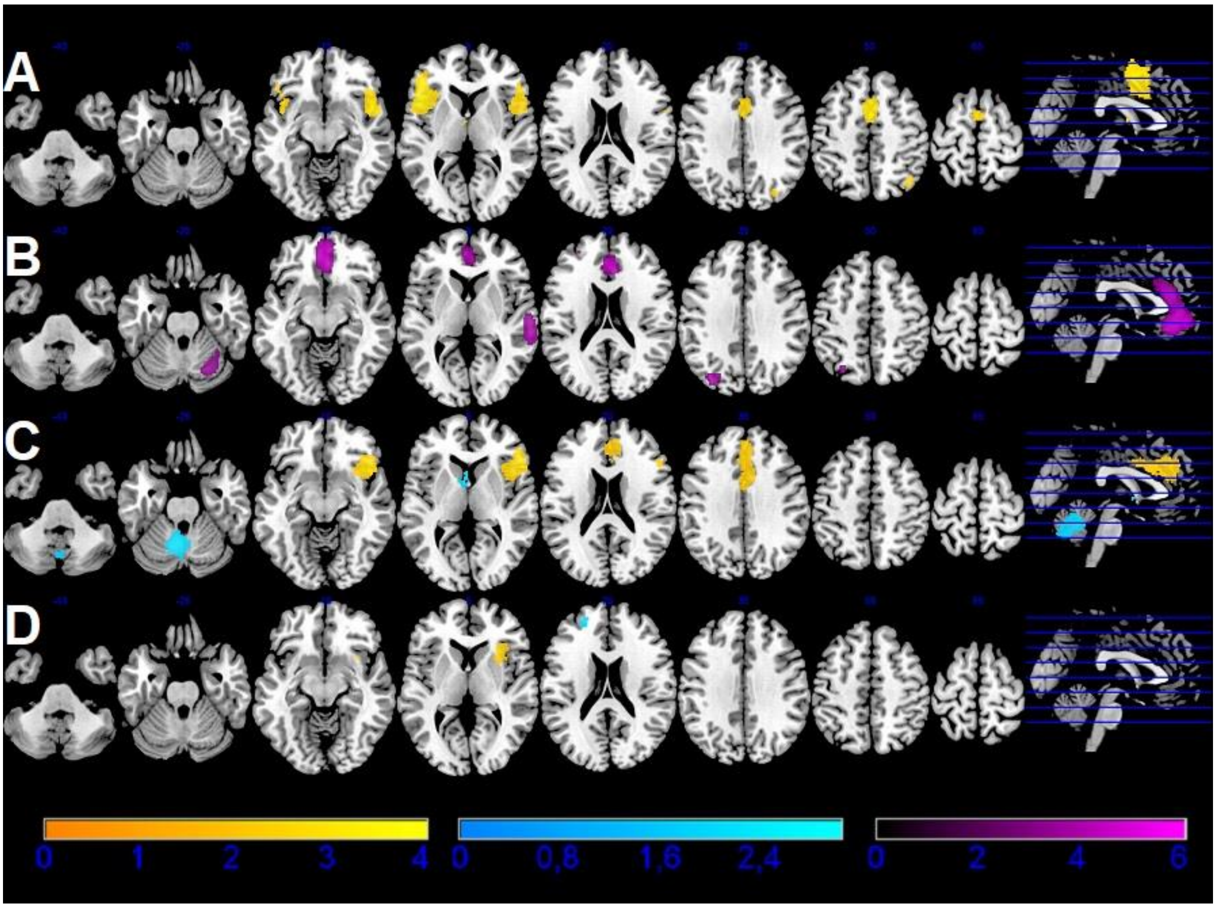


Figure 2. A. Brain regions engaged during self-transcendent experiences. B. Heterogenous brain regions across all studies. C. Brain regions predicted by acute psychedelic administration in comparison to self-transcendent meditation. D. Brain regions predicted by classic self-transcending meditation and classic psychedelics in comparison to non-classic forms. Increased activations in yellow, decreased activations in cyan, and heterogeneity in purple (all in SDM *z*).

3.2 Main meta-analysis for STE

The major results for the main meta-analysis are illustrated in Figure 2 and Table 4. Condensing all studies together, significant activations for STE were shown in the triangular portion of the left inferior frontal gyrus (lIFG), the right supplementary motor area (rSMA), the right insula, the right angular gyrus (rAG), and the left anterior thalamus to control conditions. No decreased activations reached significance.

The first meta-regressions showed that APA predicted increased activations in the right inferior frontal gyrus (rIFG) and the right median cingulate gyri whereas the cerebellum and the left anterior thalamus was negatively predicted in comparison to STM. The second meta-regression revealed increased right insula activity during classic STM and after acute classic psychedelic administration and decreased left dorsolateral superior frontal gyrus activity compared to other STE forms.

However, interstudy heterogeneity was found in the right gyrus rectus, the right superior temporal gyrus, the right cerebellum, the left inferior parietal gyri and the opercular part of the right inferior frontal gyrus. The jack-knife analyses consistently replicated all blobs except for the right anterior thalamic projections which was the smallest one.

3.3 Subgroup meta-analysis for STM

Figure 3 and Table 5 reflect the findings of the subgroup meta-analysis for STM. The left anterior thalamus, the rSMA, the opercular part of the lIFG, the left cerebellum and the right parietal gyri were positively associated with neural activity whereas the right middle temporal gyrus and the right inferior occipital gyrus were negatively associated compared to control conditions. Results of the meta-regressions are depicted in Supplementary Figure 1 and Supplementary Table 1.

Nevertheless, interstudy heterogeneity was present in the right middle temporal gyrus, the right fusiform gyrus, the left middle occipital gyrus and the rostral ACC. The jackknife analyses resulted in relatively consistency. For excluding some studies, few new blobs appeared. However, the right inferior parietal gyri were less replicated being the smallest blob.

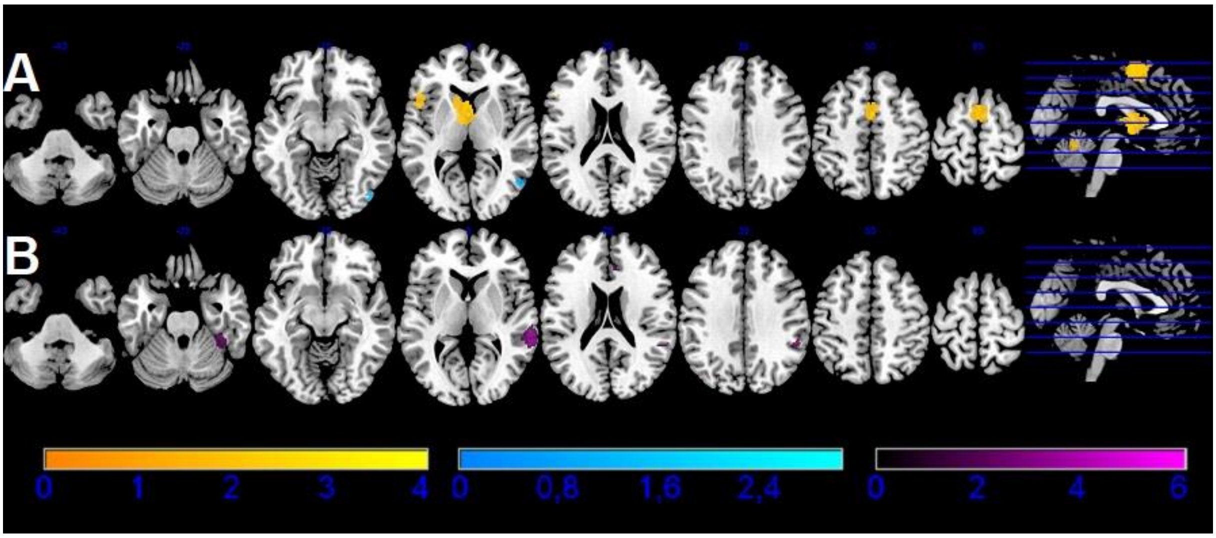


Figure 3. A. Brain regions engaged during self-transcendent meditation. B. Heterogenous brain regions across self-transcendent meditation studies. Increased activations in yellow, decreased activations in cyan, and heterogeneity in purple (all in SDM *z*).

3.4 Subgroup meta-analysis for APA

Results of the subgroup meta-analysis for APA were similar to the meta-regression of the main meta-analysis on APA and are illustrated in Figure 4 and Table 6. Increased activations were found int the right median cingulate gyri, the triangular parts of the rIFG and the lIFG, and the right superior occipital gyrus. The cerebellum showed relatively lower activations to compared to control conditions. Results of the meta-regression are depicted in Supplementary Figure 2 and Supplementary Table 2.

Though, between all psychedelic studies, activations differed in the right medial-orbital superior frontal gyrus, the cerebellum, the opercular part of the rIFG, the left inferior parietal gyri and the right superior temporal gyrus. The jack-knife analyses revealed many blobs failed reaching significance but shifted, especially the cerebellum blob. The right superior occipital gyrus was less replicated without reporting shifts. Overall, the findings appear less replicable because even big blobs were sensitive for individual studies.

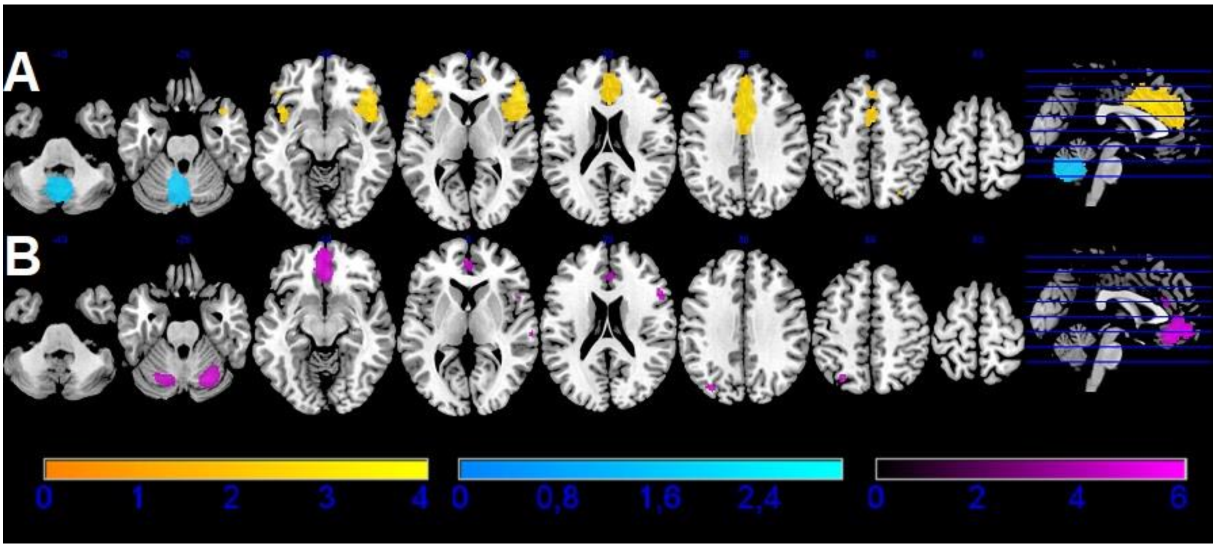


Figure 4. A. Brain regions engaged during acute psychedelic administration. B. Heterogenous brain regions across acute psychedelic administration studies. C. Brain regions predicted by classic psychedelics in comparison to dissociatives. Increased activations in yellow, decreased activations in cyan, and heterogeneity in purple (all in SDM *z*).

Table 4

Results for the main meta-analysis (thresholded at p > .005, peak SDM z > 1, cluster extent ≥ 20 voxels)

Analysis	n		Regions	x	y	z	SDM z	p	Voxels	JK[a]
STE > control	33									
		+	L inferior frontal gyrus, triangular part	−48	18	4	3.8	~0	1601	100
			R supplementary motor area	4	10	48	3.45	2.68E−6	1076	97
			R insula	48	8	−6	3.26	9.9E−6	1105	94
			R angular gyrus	40	−64	50	2.68	5.13E−4	299	94
			R anterior thalamic projections	−4	−4	6	2.6	8.07E−4	26	79
Interstudy heterogeneity										
			R gyrus rectus	2	40	−16	5.3	~0	2081	
			R superior temporal gyrus	64	−34	8	4.93	2.68E−6	676	
			R cerebellum, hemispheric lobule VI	24	−66	−28	4.51	9.89E−6	513	
			L inferior parietal gyri	−28	−70	44	5.04	5.13E−4	329	
			R inferior frontal gyrus, opercular part	52	16	8	3.57	8.07E−4	25	
APA > STM	13/20									
		+	R inferior frontal gyrus, triangular part	52	26.	4	3.58	9.54E−7	1727	
			R median cingulate/paracingulate gyri	4	36	34	2.68	1.84E−4	1388	
		−	Cerebellum, vermic lobule VI	−4	−58	−22	−2.68	7.07E−5	1341	
			L anterior thalamic projections (42 voxels)[b]	−4	4	4	−2.23	5.23E−4	108	

Table 4 (continued)

Analysis	*n*		Regions	x	y	z	SDM *z*	*p*	Voxels	JK[a]
(cSTM + PSY) > control	11/22									
		+	R insula (141 voxels)[b]	30	20	4	2.8	7.19E−5	372	
		−	L superior frontal gyrus, dorsolateral	−22	50	20	−2.45	3.56E−4	171	

Note. + = increased response; − = decreased response; APA = acute psychedelic administration; cSTM = classic self-transcending meditation; JK = jackknife analysis; L = left; PSY = classic psychedelic; R = right. Coordinates in MNI space.

[a]Sensitivity is represented in percentage of studies replicating the results.

[b]Cluster was declared undefined.

Table 5

Results for subgroup meta-analysis of self-transcending meditation (thresholded at $p > .005$, peak SDM $z > 1$, cluster extent ≥ 20 voxels)

Analysis	n		Regions	x	y	z	SDM z	p	Voxels	JK[a]
STM > control	20									
		+	L anterior thalamic projections	−8	−4	0	2.53	9.66E−5	685	85
			R supplementary motor area	2	2	56	2.49	1.21E−4	670	95
			L inferior frontal gyrus, opercular part	−52	18	10	2.33	3.33E−4	261	100
			L cerebellum, hemispheric lobule IV / V	−8	−60	−18	2.21	7.08E−4	251	90
			R inferior parietal gyri	42	−54	48	1.94	2.93E−3	23	70
		−	R middle temporal gyrus	50	−66	6	−1.42	8.57E−4	82	90
			R inferior occipital gyrus	46	−80	−10	.1.3	1.75E−3	34	90
Interstudy heterogeneity										
			R middle temporal gyrus,	64	−38	6	4.04	6.84E−5	776	
			R fusiform gyrus	38	−36	−28	2.72	1.9E−3	148	
			L middle occipital gyrus	−28	−72	40	2.73	1.87E−3	36	
			R anterior cingulate / paracingulate gyri	8	34	22	2.52	2.91E−3	37	

Note. + = increased response; − = decreased response; cSTM = classic self-transcending meditation; JK = jackknife analysis; L = left; R = right. Coordinates in MNI space.

[a]Sensitivity is represented in percentage of studies replicating the results.

Table 6

Results for subgroup meta-analysis of acute psychedelic administration (thresholded at p > .005, peak SDM z > 1, cluster extent ≥ 20 voxels)

Analysis	n		Regions	x	y	z	SDM z	p	Voxels	JK[a]
APA > control	13									
		+	R median cingulate / paracingulate gyri	8	14	40	3.3	1.02E−5	3170	85
			R inferior frontal gyrus, triangular part	56	26	2	3.46	4.53E−6	2335	100
			L inferior frontal gyrus, triangular part	−48	34	0	3.13	9.72E−6	1285	92
			R superior occipital gyrus	26	−74	44	2.54	9.55E−4	82	69
		−	Cerebellum, vermic lobule VIII	4	−68	−38	−2.16	2.33E−4	2082	69
			R cerebellum, crus II	46	−50	−46	−1.75	2.19E−3	37	54
Interstudy heterogeneity										
			R superior frontal gyrus, medial orbital	2	40	−14	5.64	~0	1166	
			R cerebellum, hemispheric lobule VI	24	−64	−28	5.17	~0	695	
			L cerebellum, cyrus I	−16	−66	−30	5.17	~0	564	
			R inferior frontal gyrus, opercular part	52	16	10	5.3	~0	222	
			L inferior parietal gyri	−28	−70	46	5.3	~0	147	
			R superior temporal gyrus	60	−26	10	4.53	2.73E−3	97	

Note. + = increased response; − = decreased response; APA = acute psychedelic administration; JK = jackknife analysis; L = left; R = right. Coordinates in MNI space.

[a]Sensitivity is represented in percentage of studies replicating the results.

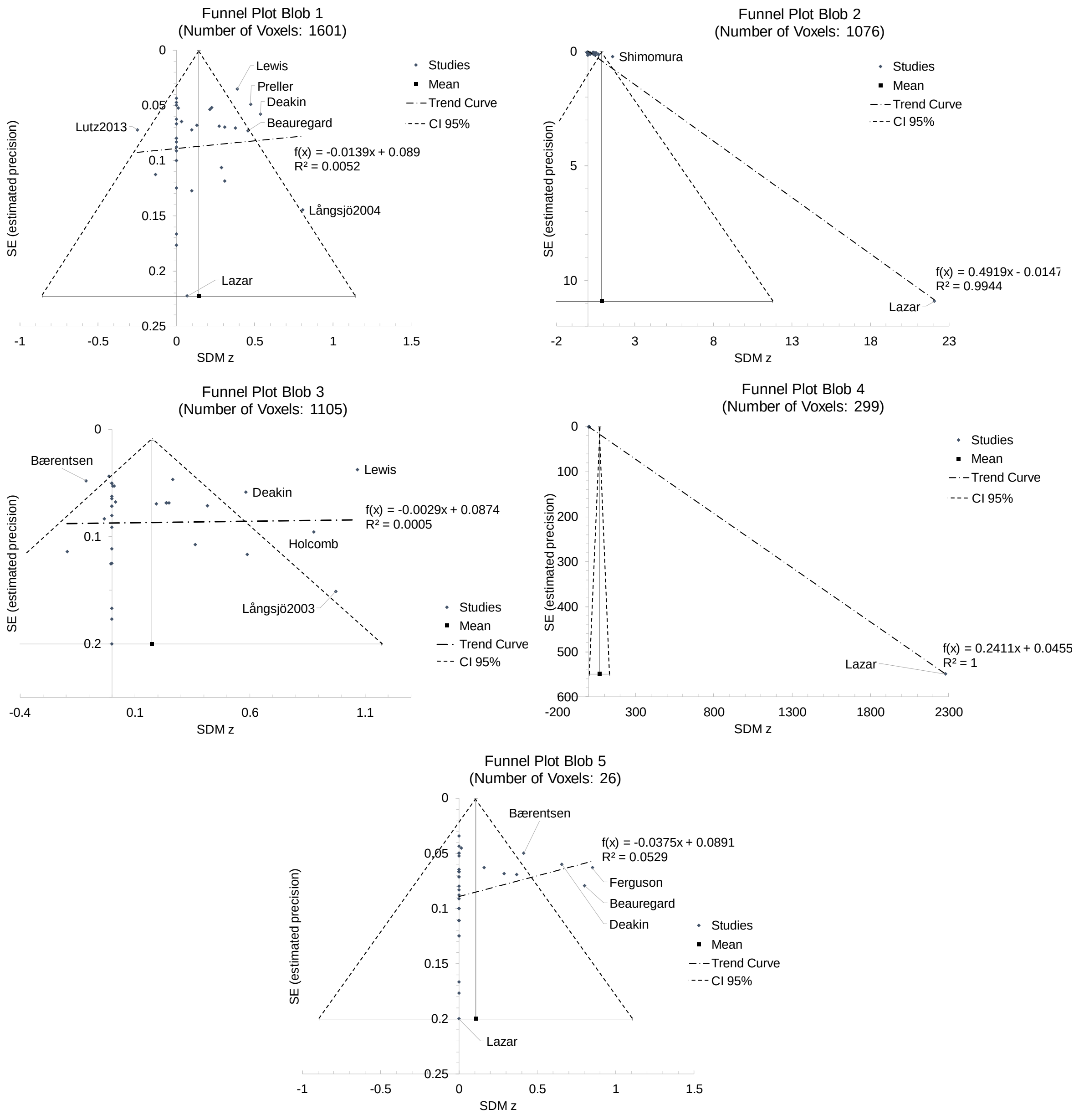


Figure 5. Funnel plots for the significant blobs with a 95 % confidence intervals and trend curves. Blob 1. Left inferior frontal gyrus, triangular part. Blob 2. Right supplementary motor area. Blob 3. Right insula. Blob 4. Right angular gyrus. Blob 5. Right anterior thalamic projections.

3.5 Publication bias

The funnel plots are displayed in Figure 5. After visual inspection, high precision studies did not differ greatly from low precision studies in three of the five blobs. At first sight, studies outside the 95% confidence interval seemed dubious but concerning many studies have SDM z = 0, funnel plots were rather distorted and hence, studies nearby were not considered. Neither did the Egger's test reach significance for them (p_{blob1} = .458; p_{blob3} = .377; p_{blob5} = .468) nor had the slopes of the trend curves considerable effect sizes which strengthened the former assumption.

4. Discussion

To the best of the authors knowledge, this is the first quantitative comparison of neural correlates between meditation and psychedelics. A series of coordinate-based meta-analyses utilizing AES-SDM investigated the neural correlates of STE in STM and after APA. Another aim was to identify differences in their neural substrates. For this reason, the influences of several subtypes were also highlighted. Note that significance and cluster thresholds were set arbitrary and many clusters are difficult to adequately interpret and thus, the discussion section is rather speculative (Fox et al., 2016).

4.1 Neural correlates of STE

The most prominent activation was found in the triangular portion of the lIFG. The lIFG is involved in linguistic processing, working memory and emotional perspective-taking (for a meta-analysis see Liakakis, Nickel, & Seitz, 2011). Similar activations were associated with self-referential processes (Morin & Hamper, 2012) and other types of meditation (e.g. Davanger et al., 2010; Lutz, Brühl, Scheerer, Jäncke, & Herwig, 2016). These opposing findings suggests that the lIFG does not inherently reflect STE. After APA, random thinking is common and in the first stages of STM, linguistic processing is not necessarily suppressed but an inherent component like in MBM, KBM or praying. KBM specifically aims directly at emotional perspective-taking. Even classic STM often starts with focused attention on one's energy that requires working memory capacity. Considering lIFG activity in response inhibition (Swick, Ashley, & Turk, 2008), self-perspective inhibition (Samson, Apperly, Kathirgamanathan, & Humphreys, 2005) and flow experiences (Ulrich, Keller, Hoenig, Waller, & Grön, 2014) this region might reflect the preceding initiatory phase of STE in which external stimuli and internal mental representations are either suppressed or promoted.

Secondly, across all studies activation occurred in the rSMA that is normally assumed to be responsible for body representations (Fink, Frackowiak, Pietrzyk, & Passingham, 1997), body movement control (e.g. Cunnington, Windischberger, Deecke, & Moser, 2002) and kinesthetic simulation (Naito et al., 2002; Solodkin, Hlustik, Chen, & Small, 2004). Together with the right temporal parietal junction, the rSMA is speculated to construe bodily self-awareness (Ionta, Martuzzi, Salomon, & Blanke, 2014) and a sense of external agency (Sperduti, Delaveau, Fossati, & Nadel, 2011). Moreover, the rSMA is hypothesized to be a main node of the timing network (for a review see Merchant, Harrington, & Meck, 2013). Activity in the rSMA replicated findings of previous meditation meta-analyses. Fox et al. (2016) argued in favor of responsibility for intentional attention regulation. Tomasino et al. (2013) already speculated rSMA hyperactivity to spatial and temporal disembodiment. Yet, the annhilational component was hypothesized to correlate with decreased activity, especially in in medial parietal regions (Berkovich-Ohana et al., 2013; Dor-Zierman et al., 2013; Hinterberger, Schmidt, Kamei, & Walach, 2014) which has been previously linked to the bodily self (Guterstam et al., 2015) and attention control (Leech & Sharp, 2014). Some LPT included in the meta-analysis focused on breath or specific body parts and after APA individuals commonly feel odd body changes. In collaboration with frontal hyperactivity rSMA activity may transcend body perception (Goodman, 2002) or may represent initiatory elements.

The third highest activation was found in the right insula. The right insula is engaged in many integrative processes such as interoception, emotions and metacognition (Fleming & Dolan, 2012; Kurth, Zilles, Fox, Laird, & Eickhoff, 2010). It is not only implicated in subjective feelings but also in selfaFox et al. (2016) recently demonstrated in a meta-analysis that this region is active across meditation styles. Probably, the right insula as part of the SLN helps to switch between the DMN and CEN and effectively regulates self-referential and emotional processes (Luders et al., 2012). Structurally alterations of the right insula in LTP (Lazar et al., 2005; Hölzel et al., 2008) and LTP's ability to control their emotions confirm this notion. On the contrary, psychedelics temporarily impair self-regulation and intensify emotional reactivity. That being said, insular activity is easily to be mistaken. In fact, the first cluster around the lIFG comprised the left insula, too, and respectively, the right insula cluster encompasses parts of the right inferior frontal gyrus indicating that actually the bilateral anterior insula is involved during STE. The left anterior side is dominantly active in positive emotions like unconditional love and the right anterior insula correlates to emotional intensity, but clear lateralization effects are still indeterminate (Duerden, Arsalidou, Lee, & Taylor, 2013; Ortigue, Bianchi-Demicheli, Patel, Frum, & Lewis, 2010; Pavuluri & May, 2015). Hyperactivity in the anterior insula is reported for ecstatic bliss (Landtblom, Lindehammar, Karlsson, & Craig, 2011; Picard & Craig, 2009) and co-constitutes the affective empathy network (Lamm, Decety, & Singer, 2011;

Bernhardt & Singer, 2012). Subsequently, increased activity near the anterior insula could correspond to the relational component. Overall, the most remarkable overlap between neural correlates of STM and APA was increased activations in inferior-frontal/insular regions. This network is also active in maintaining feelings with others (Smith et al., 2017) and may help to synthesize inhibition of self-referential and representation of other-referential processes (Samson et al., 2005; Shamay-Tsoory et al., 2009). It might resemble metacognitive empathy (Hildebrandt et al., 2017; Trent, Park, Bercovitz, & Chapman, 2016).

In addition, the rAG appeared to be increasingly activated during STE. The rAG is a main multimodal DMN hub for conceptual integration and in connection with the insula and prefrontal networks the rAG is for instance incorporated in the sense of agency (Seghier, 2013). It has been further demonstrated that this part of the inferior parietal lobe functions in body-space representations (Spitoni et al., 2013), other-referential processing (Kubit & Jack 2013) and semantic combinations (Price, Bonner, Peelle, & Grossman, 2015). In contrast to the present result, hypoactivity was hypothesized in this area (d'Aquili & Newberg, 2000) and seizures there have been linked to greater ST (Urgesi et al., 2010). The rAG is reported have reduced low-frequency power after ayahuasca (Riba et al., 2004) and psilocybin administration (Carhart-Harris et al., 2012a) but received the greatest effect size predicted by classic psychedelics within the APA subgroup meta-analysis. Moreover, activation in the left inferior temporal lobe was conflicted that further questions the role of the bilateral inferior lobe. Beside this contradiction, the rAG has been recently suggested to be also hyperactive during abstract relational reasoning, particularly in conjunction with the triangular parts of the bilateral inferior frontal gyrus (Wertheim & Ragni, 2017). Hence, the rAG could operate the cascade transition and be deactivated during STE.

At first glance, overall increased activation in areas in self-awareness and agency might surprise. However, these findings could also represent incongruency in agency and body representations (i.e. the contradiction between the experiential enactive self and the transcendent self; Vago & Silbersweig, 2012) and does not only refer to present moment awareness as it has been previously discussed for LTP (Boccia et al., 2015). Also, regions implicated in affective and social processing indicates that not only self-referential emotions such as well-being are represented (Boccia et al., 2015) but a conjunctive form such as metacognitive empathy.

Surprisingly, no common hypoactivations were found although they were particularly expected for the DMN and 21 studies reported anti-correlated peak foci. Conjunction of several types of meditation and psychedelics and neglecting the impact of the initiatory phases could lead to nullifying DMN deactivations. Moreover, the multimodal approach may have affected the results. Concerning APA, resting-state fMRI studies frequently present reductions and in contrast PET and SPECT studies demonstrate activations in brain activities but still also within fMRI studies there are mixed results (dos Santos et al., 2016). Another explanation is that the inclusion and exclusion criteria were too liberal. The results covered some previous meta-analytic findings and comprised same studies. To differentiate meditation by intention instead of using the traditional typology confounded the analyses and presumably lead to overrepresentation of attentive networks. More importantly, overlaying the separate subgroup analyses only illustrated shared activations near between the lIFG and the left anterior insula and between the supplementary motor area and the dorsal anterior ACC, which further limits the results and particularly challenges the involvement of the rAG (see Figure 6).

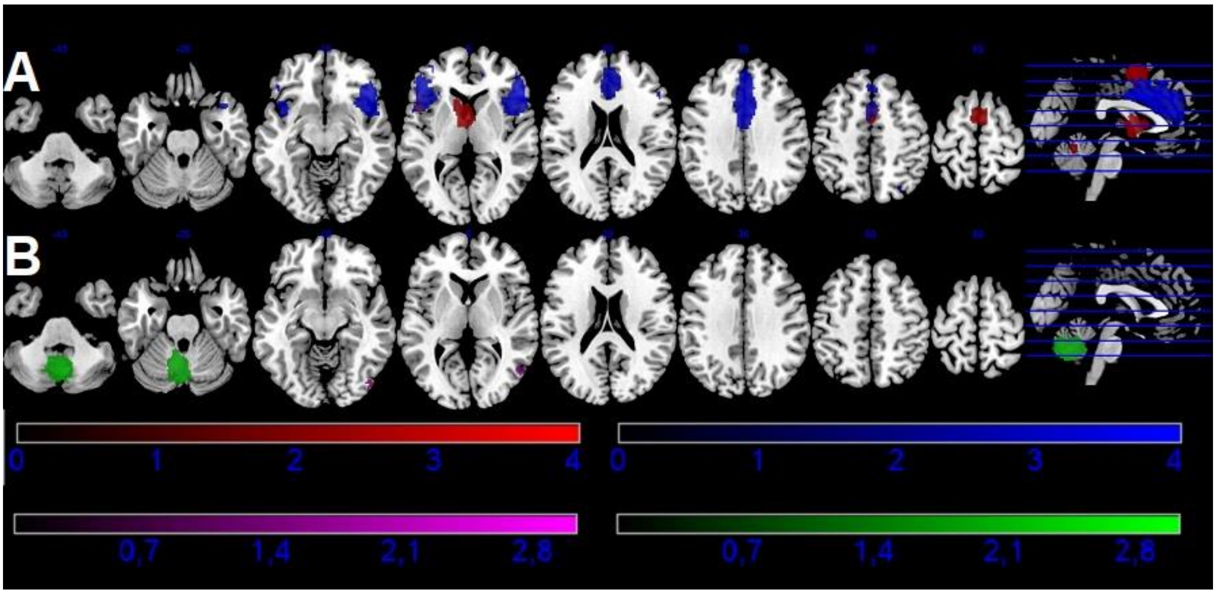


Figure 6. A. Overlay of activated brain regions during self-transcending meditation and acute psychedelic administration. B. Overlay of deactivated brain regions during self-transcending meditation and acute psychedelic administration. Increased activations for self-transcending meditation in red, for acute-psychedelic administration in blue, decreased activations for self-transcending meditation in purple, for acute-psychedelic administration in green (all in SDM *z*).

Since these restrictions were rather expectable, studies investigating classic STM and acute classic psychedelic administration were used as predictor against the rest. The ambition was to provide more valid neural patterns for STE. Increased activation in the right insula remained and deactivation in the left dlPFC was revealed. On the one hand, reduced left dlPFC activity could reflect the annhilational component of STE (Dorjee, 2016; Lutz et al., 2016). The dlPFC is supposed to be responsible for high order cognitive processes (for a review see Lau & Rosenthal, 2011). Temporarily disrupting that region with TMS impaired metacognitive visual awareness (Rounis, Maniscalco, Rothwell, Passingham, & Lau, 2010) and increased hypnotic suggestibility (Dienes & Hutton, 2013). On the other hand, this finding could have also resulted due to the relative computation via meta-regression. Being an integral part of the CEN suggests that the dlPFC is also active in self-aware breath control. During TM, this area was increasingly active that the authors explained by effortless manner the practice (Mahone, Travis, Gevirtz, & Hubbard, 2018). However, the CEN is goal-driven, meaning that it is self-directed, so reductions in CEN are rather expectable during STE. Regarding dissociatives, the dlPFC is heavily excited by ketamine (Wang et al., 2013) supposing classic psychedelics have relatively less impact on the dlPFC.

Some regions were adversatively activated. Predominant variety was investigated in the vmPFC. The vmPFC is proposed to synthesize conceptual content (Andrews-Hanna, Smallwood, & Spreng, 2015) like in true beliefs (Harris et al., 2009) or in cognitive self-referential representations (e.g. D'Argembeau, 2013; Moran et al., 2006). In cooperation with the dlPFC, the vmPFC is associated with goal-direction and context-dependent valuation (Rudorf & Hare, 2014). Interpretation like spiritual meaningfulness could be mediated by the vmPFC, thus leading to inconsistent activations. Also, the right superior temporal gyrus and inferior parietal gyrus were heterogeneously activated. Trait ST was anti-correlated with these areas (Turner et al., 2003) and during classic STM, the right superior temporal gyrus was the greatest deactivated cluster. Its relation to auditory processing (Bigler, et al., 2007) and verbal meaningfulness (Jung-Beeman et al., 2004) could produce ineffability and non-conceptuality.

The most sensitive region was the right anterior thalamic projections. The thalamus was not conspicuous in APA studies and the contralateral side happened to be the biggest active cluster for STM studies. The more thalamus filters the more active it is (e.g. Banich, 2004). Sensory gating is an integral part in many meditation practices to achieve mental silence and in psychedelic experiences to achieve hallucinations. The anterior thalamus is connected with the hippocampus, the ACC and the vmPFC, and thus, heterogenous activity might express differences in retrieval of episodic memory and alertness among the meditative practices (Behrens et al., 2003; Child & Benarroch, 2013; Jankowski et al., 2013). Still, interpretation is difficult because of the many afferent connections.

4.2 Differences in neural correlates between STM and APA

Giving these communalities, STM and psychedelics still differed in some neural patterns. One prominent pattern was higher activations in the right cerebellum after APA than during STM. The right cerebellum modulates motor control, working memory and language processing (Stoodley et al., 2009; Wolf et al., 2009) but lately has been also associated with control of empathic emotions (Schraa-Tam et al., 2012). The difference in emotion regulation between psychedelics and meditation could be explained be relatively reduced cerebellar activity in APA studies. What is more likely, however, is that this finding reflects difference in cognitive and attentional control. APA's effects are rather sudden and unexpected, on the contrary, STM is learned progressively. The cerebellum is active during implicit, effortless practices (Ito, 2012). Apparently, during TM, the cerebellum was indeed deactivated and prefrontal areas were activated (Mahone et al., 2018) resembling the psychedelic pattern.

Also, the right middle temporal gyrus which is involved in the recognition of known faces and accessing word meaning while reading (Acheson & Hagoort, 2013) showed decreased activity during STM. However, its great interstudy heterogeneity points that based on the present data, it is not assignable to a concrete function.

The subgroup meta-analysis for APA revealed no consistent activity in the visual cortex which was unexpected. Visual hallucinations in psychedelic experiences should presumably correspond to higher activation in the visual cortex. Despite these present meta-analytical results, Carhart-Harris et al. (2016b) observed higher activation in these areas. Interestingly, that study also found deactivations in the DMN which were almost significant to the present threshold and was the only study which provided a sterotactic map.

The predominant PFC activity after APA is well recognized. Considering that psychedelics produce cognitive unbinding through hyperstimulation of 5-HT_{2A} receptors in prefrontal pyramidal neurons, the resulting asynchrony in PFC networks and the glutamatergic recurrent network evokes hallucinations (for a review see Halberstadt, 2015). Furthermore, decoupling in frontal-posterior regions is related to cognitive unbinding (Mashour, 2013). Letheby and Gerrans (2017) understand ego-dissolution as a cognitive unbinding self within a hierarchical self-model, whereby cognitive unbinding is a dispersion of top-down predictive processing. If egoic self-awareness is the experience of neural integration and its emergent product, then STE are hypothesized to be experiences of neural hyperconnectivity and fading patterns (Letheby & Gerrenans, 2017). Accordingly, ego-dissolution occurs due to representation and disaccustomed attribution of self-irrelevant and unbound information (Letheby & Gerrenans, 2017). Brains of LTP are presumably habituated to that process reflected by frontal hypoactivations in classic STM. Thanks to tachyphylaxis (tolerance), consuming psychedelics daily in acute dosages does not evoke the typical effects (Halberstadt, 2015) but still long-term consumption affects the brain (Bouso et al., 2015). Nonetheless, after APA individuals experience novel, overwhelming compositions of mental states represented by hyperfrontal activity which may collapse the egoic perspective (Carhart-Harris et al., 2014).

The most striking neural correlate specific for STM is hypoactivation in the dorsal ACC. The dorsal ACC is linked to monitoring functioning such as social evaluation and conflict detection (Etkin, Egner, & Kalisch, 2011; Pereni et al., 2018). Because it is part of the SLN, this hypoactivation presumably leads to less salience of mental representations and consequently corresponds to annhilational effects. In other meditation practices which focused more on self-awareness, the dorsal ACC showed higher activation (e.g. Cahn & Polich, 2006; Hölzel et al., 2011; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010). Combined with enhanced right insula activations, ACC reductions characterize switching brain states (Tang, Rothbart, & Posner, 2012) supposing STM does not switch brain states by entropic brain states but by implicit, habituated processes.

4.3 Implications

How do the results relate to the subject-object relation? Presumably, consciousness cannot be unbound from subjectivity (Hinterberger, 2015) and the illusion of an observer is construed a posteriori (Metzinger, 2010). On a neuroquantological level, the ego appears as an epiphenomenal interpretation of reflective self-awareness just like defined subsystems appear through wave function collapses (Hinterberger, 2015). Following that, the remaining minimal self would turn out to be dialectical entity of both materialist and idealist origin. As quantum mechanics show that the material realm is not independent from observation, dualist models like the consciousness state space fail to predict STE (Berkovich-Ohana & Glicksohn, 2014, 2017) because mental states like transcendental consciousness may be not concretely locatable like quantic entities. The rational supervenience theory offers an emergentist approach to that problem which is in congruence with the S-ART framework. On that account, mental states are identical with neural states, but types of mental states are not necessarily identical with types of neural states and more importantly, rational types can supervene them (Davidson, 1980). Consequently, the shared neural patterns could be interpreted that some of the same types of mental states can be processed by different types of neural states. It can be speculated that self-transcendent types of mental states supervene neural states which allows altered stimulation of brain processes. However, the current state of neuroimaging methods lacks explanatory power for definite conclusions.

Regardless whether STE can be traced to definite biomarkers (Davis & Vago, 2013), the present data can be utilized in numerous ways. Neural markers of STE provide the possibility to intentionally evoke STE in a secularized way via neurofeedback or TMS and respectively STE-evoking practices might facilitate neurofeedback (Kober et al., 2017). Additionally, they help neuropsychiatrists to distinguish pathological conditions from healthy conditions.

Yet, there are not only benefits. STE have been exploited (Gorelik, 2016), especially in warfare contexts. Many key works for meditation and religious experiences justify murder and class society word for word. Neural functioning of STE can be abused to involuntarily evoke or inhibit STE which could be induced by future technology. Currently, military institutions are searching for bioelectrical interfaces to prevent disorders and avoid action inhibitions (Grifantini, 2016). Such a device triggering STE could also facilitate martyrdom.

4.4 Limitations and future directions

There was an indication of a publication bias for at least one study that was a meditation study (Lazar et al., 2000). Conflict of interest may have originated by authors who are also meditation teachers, had belief-driven hypothesis or were funded by related organization nurturing a potential experimenter bias.

General flaws of neuroimaging meta-analyses have been described elsewhere (Radua et al., 2012, 2014). Inclusion and exclusion criteria may have fostered homogenous data. Differences in thresholds for voxel- and cluster-level across the studies, studies restricted to ROI, studies only reporting activation without mentioning possible deactivations and dependent data due to overlapping subjects biased the results. These drawbacks were accepted in favor of a bigger sample size and thus a higher power.

More importantly, exclusion criteria for STM and APA were rather subjective and thus could be biased. Normally, at least two reviewers conduct the literature review. In functional neuroimaging settings, STE can be rather difficult to obtain. The unknownness of the laboratory, the noises of fMRI, PET and SPECT, and the narrowness in the tubes may have impeded the effects. Furthermore, short duration of STE makes them hard to capture (Newberg, 2014) and most of the studies did not check for presence of STE. Dependence on the general linear model further limit the results on sustained state and ignores presumed transitory states and different phases (Davis & Vago, 2013).

Furthermore, samples of STM and APA differed significantly in age. LTP were on average 14.5 y (95%-CI[9.7, 19.3]) older than psychedelic experiencers ($t(24) = 6.25$, $p < .0001$; ranges replaced with *Mdn*). Presumably, older participants for STM have the required expertise to qualify as LTP and are more likely organized in traditional institutions from which many studies recruited, while participants interested in APA are more explorative and frequently recruited in universities' environments.

Future experiments can replicate the common functional neural patterns by directly comparing STM and APA. By utilizing a STE measurement, annhilational peaks and relational peaks could be dismantled from each other. How LTP's brains react to psychedelics is another interesting question. Further, psychedelics still need neuroimaging contrasts investigating the psychedelic state without being confounded by tasks. Especially the distinction between classic psychedelics and dissociatives is to be challenged. Activity in 5-HT_{2A} receptors bridges glutamatergic recurrent networks which in turn are modulated by NDMAR antagonists (Nencini & Grant, 2010). In addition, how neuroendocrinological releases such as oxytocin modulate STE is a guiding question for upcoming studies (Machida, Sunagawa, & Takahashi, 2018; Nidhi, Padmalatha, Nagarathna, & Amritanshu, 2013; Schmid et al., 2015). Moreover, the STE-hindering effects of 5-HT_{2A} antagonists on psychedelics such as ketanserin (Vollenweider, Vollenweider-Scherpenhuyzen, Bäbler, Vogel, & Hell, 1998) could also apply for STM. This meta-analysis was based on functional segregation, though the entropy in the brain is better to be investigated with a meta-analysis for functional integrity (Carhart-Harris et al., 2014). Yet, neural correlates of other STE have to be conducted. Some STE are barely measurable within functional neuroimaging settings, however, aftermath can be target for future studies (Garcia-Romeu et al., 2015).

Besides that, presumably, the sociocultural background influences the effect of STE. Individualistic and collectivistic values lead to different self–other processing (Chio et al., 2009; Zhu, Zhang, Fan, & Han, 2007). Previously, differences in self-related processing between subjects with and without idealistic beliefs were shown (Han et al., 2008; Han et al., 2010), thus similar effects could emerge within STE. Additionally, a reproducible secularized operationalization of STE would be a fruitful step towards a compliant neurophenomenological approach (Cahn & Polich, 2006).

4.5 Conclusion

This meta-analytical evidence gives a materialistic stand to the often-mystified STE. It emphasizes that meditation and psychedelic share increased activations in the inferior-frontal/insular regions which play a crucial role in integrative emotional processes and in the rSMA and rAG which relate to the relationship between subject and environment. However, the shared typical DMN deactivation was not found in the expected extent. While ego-dissolution induced by psychedelics may be mediated by hyperfrontality, in meditation ego-dissolution may rather emerge through habitual processes. Finally, the lack of direct comparisons and neurophenomenological approaches directs future research.

5. Literature

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6. Appendix

6.1 List of figures

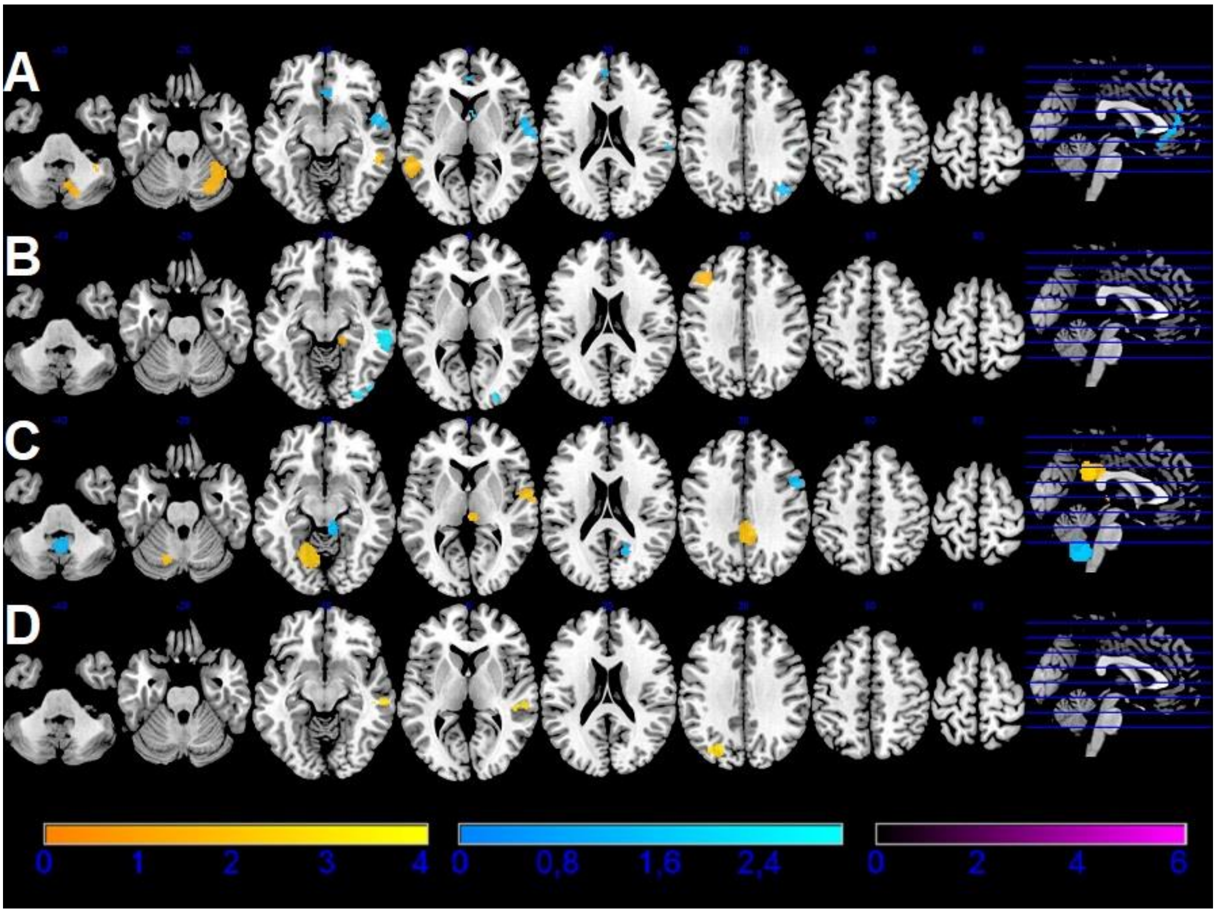
6.2 List of tables

6.4 List of abbreviations

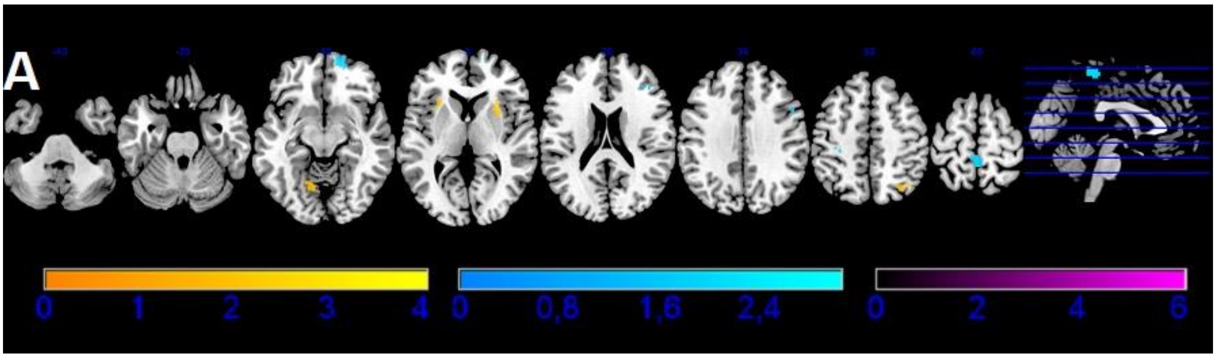
2C-B	4-bromo-2,5-dimethoxyphenethylamine
5-HT	Serotonin
ACC	Anterior cingulate cortex
AES-SDM	Anisotropic ffect-size seed-based d mapping
dlPFC	Dorsolateral prefrontal cortex
DMN	Default-mode network
DMT	*N*,*N*-dimethyltryptamine
DXM	Dextromethorphan

EEG	Electroencephalography
FAM	Focused-attention meditation
FWHM	Full width at half maximum
fMRI	Functional magnetic resonance imaging
GMV	Gray matter volume
KBM	Kindness-based meditation
lIFG	Left inferior frontal gyrus
LSA	d-lysergic acid amide
LSD	Lysergic acid diethylamide
LTP	Long-term practitioners
MDMA	3,4-methylenedioxy-*N*-methylamphetamine
MBM	Mantra-based meditation
MNI	Montral Neurological Institute space
NDMAR	*N*-methyl-D-aspartate receptoor
OMM	Open-monitoring meditation
PCC	Posterior cingulate cortex
PCP	Phencyclidine
PET	Positron emission tomography
rAG	Right angular gyrus
rIFG	Right inferior frontal gyrus
rSMA	Right supplementary motor area
RSME	Religious, spiritual and mystical experiences
SLN	Salience network
SPECT	Single-photon emission computed tomography
ST	Self-transcendence
STE	Self-transcending experiences
STM	Self-transcending meditation
TAL	Talairach space
THC	(−)-trans-Δ-9-tetrahydrocannabinol
TM	Transcendental meditation
TMS	Transcranial magnetic stimulation
vmPFC	Ventromedial prefrontal cortex

6.4 Supplementary material



Supplementary Figure 1. A. Brain regions predicted by classic self-transcendent meditation. B. Brain regions predicted by mantra-based meditation. C. Brain regions predicted by kindness-based meditation. D. Brain regions predicted by religious experience. Increased activations in yellow and decreased activations in cyan(all in SDM *z*).



Supplementary Figure 2. A. Brain regions predicted by classic psychedelics in comparison to dissociatives. Increased activations in yellow and decreased activations in cyan (all in SDM *z*)

Supplementary Table 1

Analysis			Regions	x	y	z	SDM *z*	*p*	Voxels
cSTM > (MBM + KBM + RE)	5/15								
		+	R cerebellum, crus I	36	−48	−34	2.07	2.92E−4	1122
			L middle temporal gyrus	−58	−50	6	2.16	1.75E−4	461
			R cerebellum, hemispheric lobule VIII (118 voxels)[a]	14	−72	−38	1.64	2.93E−3	197
			Corpus callosum	54	−36	−10	2.09	2.63E−4	116
		−	R superior temporal gyrus	62	−10	6	−1.86	2.35E−4	678
			R inferior parietal gyri	42	−54	48	−1.7	8.23E−4	433
			R anterior cingulate / paracingulate gyri	4	34	−4	−1.51	2.19E−3	299
			R supramarginal gyrus	52	−34	44	−1.48	2.59E−3	59
			L caudate nucleus (2 voxels)[a]	4	8	4	−1.46	2.78E−3	26
MBM > (cSTM + KBM + RE)	6/14								
		+	L middle frontal gyrus	−42	30	40	1.69	4.53E−4	301
			L inferior network, inferior longitudinal fasciculus	−36	−4	−32	1.25	2.51E−3	130
			R lingual gyrus	16	−34	−10	1.23	2.77E−3	45
		−	R middle temporal gyrus	62	−28	−12	−2.74	5.32E−4	257
			R inferior occipital gyrus	34	−88	−12	−2.46	1.75E−3	174
			R superior temporal gyrus	46	−40	12	−2.62	8.88E−4	48
			R inferior network, inferior longitudinal fasciculus	28	−82	10	−2.52	1.34E−3	21

Supplementary Table 1 (continued)

Analysis			Regions	x	y	z	SDM *z*	*p*	Voxels
KBM >	5/15								
(cSTM + MBM + RE)									
		+	L cerebellum, hemispheric lobule VI	−14	−66	−12	2.77	7.95E−5	835
			L posterior cingulate gyrus	2	−40	30	2.6	1.97E−4	689
			R rolandic operculum	60	−4	8	2.37	5.97E−4	283
			R thalamus	6	−24	6	2.16	1.44E−3	80
		−	R cerebellum, hemispheric lobule	2	−50	−48	−1.69	3.42E−4	1110
			R cerebellum, hemispheric lobule III	8	−36	−14	−1.47	1.35E−3	180
			R precentral gyrus	52	8	35	−1.63	4.85E−4	167
			Corpus callosum	20	−54	14	−1.41	1.9E−3	143
RE >	4/16								
(cSTM + MBM + KBM)									
		+	R middle temporal gyrus	58	−26	4	3.82	3.64E−4	363
			L middle occipital gyrus	−28	−72	30	3.48	7.18E−4	300

Note. + = increased response; − = decreased response; cSTM = classic self-transcending meditation; JK = jackknife analysis; KBM = kindness-based meditation; L = left; MBM = mantra-based meditation; R = right; RE = religious experience. Coordinates in MNI space.

[a]Cluster was declared undefined.

Supplementary Table 2

Results for subdomain analysis of acute psychedelic administration (thresholded at $p > .005$, peak SDM $z > 1$, cluster extent ≥ 20 voxels)

Analysis	*n*		Regions	x	y	z	SDM *z*	*p*	Voxels
cPSY > DIS	6/7								
		+	R angular gyrus	42	−66	44	2.62	7.1E−4	103
			R inferior network, inferior frontooccipital fasciculus	28	18	2	2.42	1.6E−3	74
			L lingual gyrus	−14	−62	−10	2.32	2.42E−3	47
			L insula	−28	20	2	2.51	1.12E−3	41
		−	R superior frontal gyrus, orbital part	16	62	−12	−2.12	5.91E−4	196
			L precuneus	−2	−38	60	−2.17	4.35E−4	139
			R inferior frontal gyrus, triangular part	48	36	26	−1.94	1.52E−3	60
			L precentral gyrus	−30	−28	54	−2.04	9.26E−4	55
			Right precentral gyrus	50	10	32	−1.87	2.15E−3	46
			L paracentral lobule	−12	−32	72	−1.86	2.36E−3	26

Note. + = increased response; − = decreased response; cPSY = classic psychedelics; DIS = dissociatives; L = left; R = right. Coordinates in MNI space.

[a]Sensitivity is represented in percentage of studies replicating the results.

6.5 English Abstract

Comparisons between the effects of meditation and psychedelics have been drawn many times. In certain contexts, both can elicit self-transcendent experiences (STE) which are simultaneously relational and annhilational phenomena that go beyond the self–other-distinction and lead to nondual awareness. This anisotropic effect-size seed-based d mapping meta-analysis investigated common functional neural correlates of STE induced by meditation and psychedelic states. Regarding meditation, here, the focus was on self-transcending meditation (STM) which was categorized by intention. Literature review of MEDLINE, PsycINFO and Web of Science yielded in 33 included studies (20 studies for STM, 13 for psychedelics) with 430 peak foci. Common activations were mainly localized in inferior-frontal/insular regions which were interpreted to represent the relational component and in the right hemisphere of the supplementary motor area and the angular gyrus which were suggested to initiate STE. However, no deactivations were found although they have been previously suggested. Dissociable areas for psychedelics were hyperfrontal activity and cerebellar deactivity whereas activity in the dorsal anterior cingulate cortex was only reduced during STM. Taken together, the results suggest that STM and psychedelics differ in processing ego-dissolution. In future neuroimaging studies, psychedelic states and self-transcending meditative states need to be directly investigated in contrasting juxtaposition to gain further information about the shares neural mechanisms.

Keywords: meditation, psychedelics, self-transcendence, neuroimaging, meta-analysis

6.6 German abstract

Vergleiche zwischen Meditation und Psychedelika wurden oft gezogen. Unter bestimmten Umständen können beide selbst-transzendente Erlebnisse (STE) auslösen. STE sind definiert als verbindende und auflösende Phänomene, die die herkömmliche Unterscheidung zwischen Selbst und Andere aufheben und zu einem nichtdualen Gewahrsein führen können. Diese Metaanalyse der Seed-basierten-d-Kartierungen mit anisotropischen Effektstärken untersuchte gemeinsame funktionale neurale Korrelate der STE, die von Meditation und Psychedelikakonsum induziert wurden. Dabei lag der Fokus in Bezug auf Meditation auf selbsttranszendente Meditation (STM), die nach der Intention der Meditationstechniken kategorisiert wurde. Die Literaturanalyse der Datenbanken MEDLINE, PsycINFO und Web of Science erbrachte 33 Studien (20 für STM, 13 für Psychedelika) mit 430 Peakfoki, die einbezogen wurden. Gemeine Aktivierungen wurden in inferior-frontalen/insularen Regionen gefunden, die die verbindende Komponente repräsentieren könnten, und in der rechten Hemisphäre des supplementär-motorischen Areals und des Gyrus angularis, die an dem Übergang zu STE beteiligt sein könnten. Nach dem Konsum von Psychedelika waren hyperfrontale Aktivierungen und cerebellare Deaktivierungen festzustellen, hingegen waren dorsale Teile des anterioren cingulären Cortex während STM weniger aktiv. Die Ergebnisse lassen vermuten, dass sich STM und Psychedelika im Prozess der Ich-Auflösung unterscheiden. Zukünftige Forschung kann die Hirnaktivitäten zwischen STM und Psychedelika direkt miteinander vergleichen.