



## FUNCTIONAL CHANGES IN BRAIN ACTIVITY IN ALTERED STATES OF CONSCIOUSNESS : AN SDM-PSI COMPARATIVE SYSTEMATIC REVIEW AND META-ANALYSIS

Ayla V. Gay<sup>1</sup>, Cherine Fahim<sup>1,2\*</sup>, Chantal Martin-Soelch<sup>1,2</sup>

<sup>1</sup> Department of Psychology, University of Fribourg, 1700 Fribourg, Switzerland

<sup>2</sup> IReach Lab, Unit of Clinical and Health Psychology, Department of Psychology, University of Fribourg, 1700 Fribourg, Switzerland

**\*Auteur·e correspondant·e** : Cherine Fahim, University of Fribourg, Department of Psychology, Rue P.-A. Faucigny 2, CH-1700 Fribourg, Switzerland. E-mail: [cherine.fahimfahmy@unifr.ch](mailto:cherine.fahimfahmy@unifr.ch)

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### Résumé

Les états modifiés de conscience (EMC) induits par des pratiques psychologiques (méditation de pleine conscience, hypnose, transe auto-induite) et des agents pharmacologiques (psychédéliques classiques et atypiques) sont de plus en plus associés au changement thérapeutique, pourtant leurs signatures neurales communes et spécifiques restent incertaines. Nous avons mené trois méta-analyses préenregistrées basées sur les coordonnées à l'aide de SDM-PSI, portant sur la méditation de pleine conscience ( $k = 9$ ), l'hypnose ( $k = 7$ ) et les psychédéliques ( $k = 25$  ; kétamine, MDMA, LSD, psilocybine, ayahuasca, DMT), avec un nombre total de sujets  $N = 961$ , ainsi qu'une revue narrative de la transe ( $k = 1$ ). Deux objectifs ont guidé l'étude : (1) cartographier les altérations fonctionnelles à l'échelle du cerveau entier pour chaque EMC ; (2) examiner de manière exploratoire la convergence entre les états par le biais du chevauchement descriptif des cartes seuillées. Les trois analyses ont montré une faible hétérogénéité et aucune preuve de biais lié aux études de petite taille ; cependant,  $k < 10$  pour la méditation et l'hypnose rend les tests de biais insuffisamment puissants. Des effets corrigés par TFCE ont été observés uniquement pour la méditation ; les résultats concernant l'hypnose et les psychédéliques sont restés non corrigés et exploratoires. Au seuil de significativité exploratoire, toutes les catégories d'EMC ont montré une diminution de l'activité dans les régions centrales du réseau du mode par défaut (cingulaire postérieur, préfrontal médian), avec un engagement plus important des régions de saillance et exécutives (cingulaire antérieur, insula, préfrontal dorsolatéral) ; les psychédéliques impliquaient en outre les circuits visuels et thalamiques, tandis que l'hypnose modulait préférentiellement les zones d'intégration sensorimotrice. Ces résultats suggèrent des points communs potentiels au niveau régional,

parallèlement à des caractéristiques spécifiques à chaque modalité. Ils fournissent une base transparente pour des travaux confirmatoires : conjonctions inter-états préenregistrées et contrôlées pour les corrections ; analyses homogènes par modalité et spécifiques aux substances (classiques vs atypiques) ; et analyses de sensibilité pondérées en fonction de la qualité, permettant potentiellement de faire le lien entre la neurophénoménologie et les applications cliniques en santé mentale.

**Mots clés** : méditation ; hypnose ; psychédéliques ; transe ; activité cérébrale fonctionnelle

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## Abstract

Altered states of consciousness (ASCs) induced by psychological practices (mindfulness meditation, hypnosis, self-induced trance) and pharmacological agents (classical and atypical psychedelics) are increasingly linked to therapeutic change, yet their shared and unique neural signatures remain uncertain. We conducted three preregistered, coordinate-based meta-analyses using SDM-PSI, mindfulness meditation ( $k = 9$ ), hypnosis ( $k = 7$ ), and psychedelics ( $k = 25$ ; ketamine, MDMA, LSD, psilocybin, ayahuasca, DMT), with a total subject number  $N = 961$ , and a narrative review of trance ( $k = 1$ ). Two aims guided the study: (1) map whole-brain functional alterations for each ASC; (2) examine exploratory cross-state convergence via descriptive overlap of threshold maps. All three analyses showed low heterogeneity and no evidence of small-study bias; however,  $k < 10$  for meditation and hypnosis renders bias tests under-powered. TFCE-corrected effects were observed only for meditation; findings for hypnosis and psychedelics remained uncorrected and exploratory. At exploratory significance, all ASC categories showed decreased activity in default-mode hubs (posterior cingulate, medial prefrontal) with greater engagement of salience and executive regions (anterior cingulate, insula, dorsolateral prefrontal); psychedelics additionally involved visual and thalamic circuits, whereas hypnosis preferentially modulated sensorimotor-integration zones. These results suggest candidate region-level commonalities alongside modality-specific features. They provide a transparent scaffold for confirmatory work: preregistered, correction-controlled cross-state conjunctions; modality-homogeneous and substance-specific analyses (classical vs atypical); and quality-weighted sensitivity checks, potentially bridging neurophenomenology with clinical applications in mental health.

**Keywords**: meditation ; hypnosis ; psychedelics ; trance ; functional brain activity

## Introduction

Altered states, or “non-ordinary”, states of consciousness (ASCs/NOSCs) induced through either psychological techniques or psychoactive agents are depicted as transitory alterations of self-experience with crucial changes in self-narrative and multisensory embodied aspects (Cofré et al., 2020; Vaitl et al., 2005). Mostly originating from ancient contemplative and shamanic traditions, mind-body techniques such as meditation, yoga and hypnosis, or the administration of pharmacological substances with psychoactive features, depicts the volitional modulation of one’s consciousness regardless of culture or religion (Lewis-Healey et al., 2024; Newberg, 2014; Winkelman, 2013; Wittmann, 2015; Zaccaro et al., 2022). The self-induced alterations cover a wide range of effects on cognition, behaviours, sensations but also on emotions and metaphysical beliefs, thus reflecting the extended variety of experiential phenomena (Fingelkurts et al., 2022; Lifshitz et al., 2019; Sandilands & Ingram, 2024; Wahbeh et al., 2018; Winkelman, 2011). ASC is considered as a temporary, reversible alteration of one’s individual’s own relation to inner and external subjective experiences, an alteration of one’s representation of self-experience (Cofré et al., 2020; Revonsuo et al., 2009; Tassi & Muzet, 2001). Indeed, the very specific convergent aspect between diverse ASC modalities is thought to be on self-experience itself, including personal representation of experiential phenomena and reflective processes (Canby et al., 2024; Nour & Carhart-Harris, 2017; Wittmann, 2015).

While meditation and hypnosis have long been interrogated in phenomenological, clinical, and neuroscientific domains (Farahzadi & Kekecs, 2021), the empirical exploration of trance states has accelerated only recently with neuroimaging studies of self-induced cognitive trance (SICT) (Gosseries et al., 2024; Grégoire et al., 2024; Marie et al., 2024). In parallel to this trajectory, the marked renaissance of psychedelic science undergone during the past decade (Preller & Vollenweider, 2016), has reinforced the theoretical overlaps of ASCs in cognitive-affective processes such as ego dissolution and enhanced sensory salience (Penazzi & De Pisapia, 2022; Yu et al., 2024). Within this scope, these otherwise heterogeneous induction increasingly appear to occupy a common mechanistic landscape (Garcia-Romeu et al., 2016; Palsson et al., 2023; Reiff et al., 2020; Shonin et al., 2015) with overlapping phenomenological profiles, most notably deep absorption, perceptual distortion, and transient attenuation of self-referential cognition, as well as suggested partially shared neural signatures such as down-regulation of the default-mode network (DMN), fronto-limbic decoupling, and altered thalamo-cortical gating (Brandmeyer & Delorme, 2021; Carhart-Harris & Friston, 2019; Fox et al., 2016).

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**Box 1. ASCs modality summary description****Meditation**

Meditative states are considered to facilitate and elicit ASCs such as alteration in the sense of time, space and body representation (Brandmeyer et al., 2019; Yordanova et al., 2020). Differential effects are suggested regarding the meditation practice type and classification currently integrates the affect and cognition paradigm from which intention and directionality of enhanced or altered states are defined (Nash & Newberg, 2023), as well as the embodied features, including dimensions of activation level and amount of body orientation (Matko & Sedlmeier, 2019). Despite substantial differences between techniques, convergent effects and phenomenology are suggested upon emotional and attentional regulation, corresponding to the cognitive theoretical framework that combines focused attention (FA) and open monitoring (OM) components (Brandmeyer et al., 2019; Lutz et al., 2008). Overall, meditative states seem to evolve pre-reflective dimensions of the sense of self, as revealed by the emergent phenomena of self-boundarilessness, relative to an experiential feature integrating components of first-person perspective, sense of location, agency, attention, body sensations and affective valence, sometimes referred to as selflessness or self-transcendence (Dambrun, 2016; Nave et al., 2021).

**Hypnosis**

Hypnosis has been described as an interaction effect fitting a relational matrix of dynamics and experiential components (Baker & Spiegel, 2019), holding two prominent features of awareness division and reduced sense of agency, the experience of involuntariness (Kihlstrom, 2013). However, no robust consensus is yet depicted by current findings on the definition of hypnotic state, rather hypnosis is suggested as not restricted to a state of focused attention and reduced peripheral awareness but more alike to a general consciousness functioning mode, where cognitive and perceptual abilities for flexible goal-directed response to suggestions are possible, while reduced peripheral awareness is not strictly necessary (De Benedittis, 2021; Fernandez et al., 2021; Lynn et al., 2015). Thus, hypnosis is held as a product of suggestions and its associated expectancies, variations of effect depend on individual traits and biopsychosocial mechanisms of hypnotized individual and hypnotherapist (Geagea et al., 2024; Landry & Raz, 2015; Oakley et al., 2021), while strongest predictors of hypnotic response seems to rely on the non-hypnotic suggestibility, the baseline suggestibility of the individual (Acunzo, 2021; Halsband & Wolf, 2021; Lynn et al., 2020). Suggestions can be categorized upon three differential effects: the positive, and the negative hallucinations, or the reduced sensory acuity in visual, auditory and tactile modalities (De Benedittis, 2021; Halligan & Oakley, 2013; Kihlstrom, 2013). Despite substantially different hypnotic procedures, convergent features can be summed under the experiential dimensions of hypnosis such as relaxation and mental ease, absorption, altered sense of self characterized by shifts in orientation, monitoring and self-agency (Alter, 2019; De Benedittis, 2021; Rainville & Price, 2003).

**Trance**

Defined as ASCs, different modalities of trance are comparable and all are mostly inherited from shamanistic traditions, their psychological characteristics are described in terms of modification of internal and external consciousness, including alteration in sense of self and time, inner imagery and absorption, modulation of somatosensory perceptions, alteration in the sense of agency with increased feeling of automaticity and in terms of emotional and/or mystical experiences (Flor-Henry et al., 2017; Gosseries et al., 2024). The cultural evolution perspective emphasizes a dependence upon multiple personal and environmental factors, that shapes the acute state experience as well as outcome effects (Marie et al., 2024; Singh, 2018). A novel standardized induction of trance states,

namely the self-induced cognitive trance (SICT), has recently added to the findings on phenomena and neural signatures of trance state, such as features of lucid but narrowed peripheral attention, hyper-focused immersive experience of flow with altered sense of self, enhanced inner imagery, somatosensory processing and spiritual experiences (Gosseries et al., 2020; Grégoire et al., 2024; Vanhaudenhuyse et al., 2024).

**Psychedelics**

Psychedelics represent a sub-group of different psychoactive pharmacological substances, including atypical and classical psychedelics also labelled as entheogen, empathogen or entactogen with characteristic features of altered sensory perception (including somatosensory, visual, auditory and proprioceptive content), self-referential, recollective and psycho-dynamic processes (changes on perception of time, effects on cognition, mood, memory and self-awareness), and spiritual, self-transcendent and existential symbolic experiences (Barrett & Griffiths, 2017; Nichols, 2016; Preller et al., 2019; Zhang et al., 2024). Classical psychedelics refer to three different chemical categories, tryptamines, ergolines and phenethylamines, including lysergic acid diethylamide (LSD), psilocin, N,N-dimethyltryptamine or 5-MeO-DMT (DMT), peyote, and mescaline, whereas atypical psychedelics include substances of comparable effects but distinct chemical compositions, such as ketamine, a dissociative drug and 3,4-methylenedioxymethamphetamine (MDMA), holding some stimulant properties. Most of them are plant derivatives but can be semi- or fully synthetic as for MDMA or ketamine (Kelmendi et al., 2022; Mastinu et al., 2023) and the main biochemical effects are suggested to rely on the different neurotransmitters, mainly serotonergic and dopaminergic systems (Lawn et al., 2022; Olsen et al., 2022).

Clinically, each technique has been advanced as a candidate therapy across a spectrum of affective, anxiety, pain-related, and substance-use disorders (Bender & Hellerstein, 2022; Kim et al., 2022; Železik & Sadowski, 2020). However, most investigations remain siloed within specific therapeutic niches, limiting direct cross-modal comparisons despite mounting neurobiological evidence for shared modulation of self-referential processing, executive control, and sensory integration (Mograbi et al., 2024; Panda et al., 2023; Peres et al., 2012). Comparative neuro-phenomenology research on ASCs remains nascent, existing syntheses typically rely on small numbers of studies and emphasise broad points of convergence rather than fine-grained mechanistic details (Lemerancier & Terhune, 2018; Millière et al., 2018; Moujaes et al., 2024; Sim et al., 2024; Timmermann et al., 2023).

**Box 2. Comparative neural correlates of Altered States of Consciousness : A literature-based summary**

| Compared condition             | Literature-based summary of neural correlates                                                                                                                                                                                                                                                                                                                                                                          |
|--------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Psychedelics versus meditation | Both psychedelic and meditation are characterised by a loosening of narrative, agentic and interoceptive facets of self-consciousness. Convergent deactivation within the medial prefrontal cortex (mPFC) and posterior cingulate cortex (PCC), nodal hubs of the default-mode network (DMN), is consistently reported, whereas the precise somatosensory substrates remain less well defined (Millière et al., 2018). |

|                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Psychedelics versus hypnosis | Direct comparisons suggest opposing patterns in global functional connectivity: hypnosis is typically associated with more focal, task-relevant modulation, whereas psychedelics induce a broader, more heterogeneous redistribution encompassing frontal association cortices, medial temporal structures, occipital cortex, hippocampus and amygdala (Lemerrier & Terhune, 2018).                                                                                                                                                                                                               |
| Hypnosis versus meditation   | Meta-analytic and qualitative summaries indicate overlapping activity reductions in the PCC, mPFC, hippocampus, dorsolateral prefrontal cortex (dlPFC), intraparietal sulcus (IPS), superior parietal lobule (SPL), cerebellum and visual cortices. Nonetheless, the temporal dynamics of large-scale interactions differ: hypnosis appears to modulate salience-network gating of DMN and central-executive-network (CEN) exchanges, whereas mindfulness-based meditation more strongly engages sustained fronto-parietal control over DMN sub-regions (Moujaes et al., 2024; Sim et al., 2024). |
| Cross-state convergence      | Taken together, the literature converges on a triad of structures, PCC, mPFC and parahippocampal cortex, all integral to the DMN and repeatedly implicated across ASC modalities (Moujaes et al., 2024; Timmermann et al., 2023). The reproducibility of this triad across pharmacological and psychological inductions underscores its candidacy as a common neural denominator of self-processing alterations in ASCs and provides a rational scaffold for future hypothesis-driven network-level investigations.                                                                               |

Taken together, this convergent evidence underscores the utility of combining psychological and neural perspectives to capture the acute-to-protracted arc of ASC-related changes. However, due to the early stages of research, the effects of ASCs and their comparison currently remain complex and intrinsically multidimensional, with influential factors of set and setting directly modulating the experiential features. Thus, the main goal of this study was to investigate the state-specific whole-brain functional changes of ASCs in healthy adults, aiming at a preliminary quantitative comparison of convergent neural activation patterns. Keeping in line with this consortium-based approach, the present study does not seek to localise the phenomenological nuances of altered states, rather it aims to delineate the neurophysiological signatures and potential neurocognitive networks that typify each state. Nonetheless, coordinate-based techniques precluding the assessment of dynamic connectivity and causal interactions of brain regions, thus neurocognitive description with attribution and comparison of neurocognitive networks or regions and associated psychological constructs were literature based and used for the interpretation of results and final discussion. Functional characterization of specific brain regions was not of first concern, rather a dynamic brain functional network organization was preferred as a more reliable predictor of cognitive states, whereas network nodes appear to shift location with flexible cohesive or disjoint dynamics (Safron et al., 2021; Salehi, Greene, et al., 2020; Van Eijsden et al., 2009).

Two specific aims drove this study (Aim 1) to update and summarize current neuroimaging studies of functional brain activation of each ASCs, (Aim 1a) meditative, (Aim 1b) hypnotic, (Aim 1c) trance

and (Aim 1d) psychedelic states, and (Aim 2) to investigate whether distinct ASC modalities (meditation, hypnosis, trance and psychedelics) recruit overlapping brain regions.

To address this question, four strict ASC modalities were selected for comparison based on evidence-based literature. Aligned with the criteria of task-free condition, and aiming to reduce between study heterogeneity for subsequent state comparisons, intervention procedures including task-positive concentration such as mantra repetition typical in transcendental meditation, or autobiographical memory task during hypnosis were excluded from the current review. The psychologically induced ASC modalities were the following: (1) hypnosis (confounded comparable procedures), (2) meditation (restricted to mindfulness-based interventions and comparable techniques such as open-awareness meditation) and (3) trance (SICT or comparable shamanic trance procedure). The pharmacological induction methods included (5) psychedelics, both atypical (ketamine and 3,4-methylenedioxymethamphetamine (MDMA)) and classical (lysergic acid diethylamide (LSD), psilocin, N,N-dimethyltryptamine or 5-MeO-DMT (DMT), and Ayahuasca). Despite substantial differences, the main biochemical effects of psychedelics are suggested to rely on serotonergic and dopaminergic systems (Lawn et al., 2022; Olsen et al., 2022), and overlap of the induced subjective experience allows to reunite these defined psychoactive substances (Mograbi et al., 2024).

To maintain scientific transparency, this study was registered on the international prospective register of systematic reviews (PROSPERO: CRD 420251008466), based on a pre-test literature review for relative estimation of the study of ASCs, in terms of quantity of studies and domain of research (available on <https://www.crd.york.ac.uk/PROSPERO/view/CRD420251008466>).

## Method Phase 1 : Systematic review

### Literature search, article selection

Following PRISMA statement (Page et al., 2021) and methodological guidance from the Cochrane Handbook for Systematic Reviews of Interventions (Devaney et al., 2021), four systematic reviews were performed separately for each ASC modality. Candidate studies published from January 1st, 2000, up to February 11th, 2025 were retrieved from the databases PubMed (including Elsevier, Science direct, Scopus, Embase), Web Of Science, EBSCOhost (including Eric, APA PsycINFO, Medline), Cochrane Central Register of Controlled Trials (CENTRAL). The study collections were restricted to original studies and randomized controlled trials with human subjects, and mentioned as fully complying with the Helsinki Declaration for research studies on human participants. All citations in language other than English or French were excluded. To reduce the risk of bias at a

study level, this current review only included peer-reviewed studies from registered scientific literature databases and “grey literature” was not addressed. Theses, dissertations and unpublished studies were not searched for or included. Literature search, articles screening and data extraction were conducted by the first author (AVG) with review and confirmation from the second author (CF).

Search parameters common to all four categories included the following keywords: (1) fMRI OR BOLD OR PET OR neuroimaging, and (2) healthy. The distinct term combination for each ASC modality, representing independent clusters, were the following: (1) meditation OR mindfulness OR MBSR OR MBCT, (2) hypnosis OR hypnotherapy OR “cognitive hypnotherapy” OR “hypnotic induction”, (3) psychedelic OR hallucinogen OR psilocybin OR psilocin OR DMT OR mescaline OR peyote OR “lysergic acid diethylamide” OR LSD OR Ayahuasca OR ketamine OR MDMA, and (4) trance OR “altered state of consciousness” OR “shamanic state”.

Inclusion and exclusion criteria were settled in order to minimize risk of bias and heterogeneity in experimental designs across studies and reinforce the study appraisal and comparative strength, typically the inclusion of specific paradigms. Measurements criteria were the following: (1) whole-brain neuro-imaging studies of functional activity (fMRI and PET studies), (2) of task-free state condition, (3) as compared to a control group, control state condition or baseline resting state, with (4) reported activation and deactivation peak coordinates in a standard stereotactic space Talairach or Montreal Neurological Institute (MNI) and effect values (t-values, z-values or p-values). Missing data were requested to corresponding authors. If only functional changes in regions of interest (ROI) were reported, then the study was excluded. All procedures including sensory stimulation or assessments of perceptual or cognitive correlates during the state condition were excluded. The population inclusion criteria were the following: (1) healthy adult population (from 18 to 85 years old), with (2) no current medication, and (3) absence of mental disorder, endocrinal disease, brain injury, history or presence of neurological disorder. No criteria were set upon level of practice or substance naivete, both group and individual intervention setting were included. If a study’s participant group was only partly eligible for the review, the study was included if at least 50% of its participants were eligible for this review. The sample size criteria for each study was  $> 5$ .

The literature search across all electronic databases yielded a total of 938 articles for mindfulness-based meditation (324 duplicate citations), 1576 articles for psychedelics (676 duplicate citations), 681 articles for hypnosis (308 duplicate citations) and 254 articles for trance (91 duplicate citations). After removing all duplicates, two screenings were performed based on the exclusion criteria list, first based on titles and abstracts and second based on articles full-text content. Screening process and detailed exclusion reasons are summarized under the standardized PRISMA flowchart (see

Supplementary Material 1). The most represented exclusion reasons were the following : the ASC modality, the neuro-imaging condition of task-free state, the non-clinical population criteria and the reported measures of peak coordinates and effect values. Baseline states and control conditions were differential at some point but methodologically confoundable and mostly recurrent throughout all included studies, generally using a non-ASC resting state control comparator. Among all categories, a total of 41 eligible studies were retained (N=961), mindfulness meditation (k = 9, N = 185), hypnosis (k = 7, N = 168), psychedelics (k = 25, N = 608). The single eligible study from the trance cluster (k = 1, N = 8) was excluded for subsequent quantitative analysis (<7 studies).

**Table 1**

*Summary table for phase one : Systematic review through PRISMA and study corpus*

| Modality                     | Records screened | Full texts evaluated | Studies included (K) | Participants (N) | Mean age (years) | Design profile                                   |
|------------------------------|------------------|----------------------|----------------------|------------------|------------------|--------------------------------------------------|
| Psychedelics                 | 899              | 47                   | 25                   | 608              | 29.4<br>(25–37)  | 20 cross-over, 5 parallel (placebo)              |
| Mindfulness-based meditation | 614              | 16                   | 9                    | 185              | 34.0<br>(22–46)  | 7 within-subject, 2 mixed (meditators vs. naïve) |
| Hypnosis                     | 373              | 21                   | 7                    | 168              | 31.1<br>(24–47)  | All within-subject                               |
| Trance                       | 163              | 6                    | 1*                   | 8                | 49 ± 5           | Between-subjects (mediums vs. controls)          |

*Note.* PRISMA flow and exclusion reasons are visualised in Supplementary Material 1, \* = excluded for phase two.

## Data extraction

The study characteristics data (article's ASC category, year of publication and name of the first author, participants characteristics (mean age and sex), sample size, state conditions and induction protocol, total number of extracted foci and details about the study design) are summarized in Table 1 (see Supplementary Material 2). The total sample was predominantly characterized by young adults (mean weighted age across all categories equal to 30.05) and the sex distribution revealed a male preponderance. Among the reported group or state condition contrast, measures were preferentially extracted from within-subject design for psychological interventions and placebo cross-over placebo design for pharmacological studies, except for two studies from meditation cluster (N = 46), and two studies from psychedelics cluster (also N = 46), using a control sample for neural activation contrast.

Overall, the meditative states were compared to free mind-wandering states, control groups were generally used to compare baseline resting states and so not considered for the following analytical investigation. The identified meditation techniques were mainly breath focused mindful meditation and comparable practice from vipassana meditation and Raja yoga meditators, as well as one study with experienced practitioners in mindfulness-based meditation. Regarding hypnosis induction and procedure, most studies applied a condition of relaxed pleasant state and passive pleasant visual imagery, and inductions were guided by a trained hypnotist. Two studies included distinction upon low and high suggestible participants but this was not retained for the subsequent analyses. Psychedelic states were measured as represented by task-free resting states with eyes closed or open without focus point. From eligible studies, classical psychedelics ( $k = 7$ ) were represented by LSD ( $k = 3$ ), psilocybin ( $k = 2$ ), Ayahuasca ( $k = 1$ ) and DMT ( $k = 1$ ), and atypical psychedelics ( $k = 20$ ) covered ketamine ( $k = 17$ ) and MDMA ( $k = 3$ ).

The peak coordinates and effect values, from most representative contrast in regard to subsequent states comparison, were extracted from each study. A total number of 701 peak foci were extracted, respectively 92 foci for hypnosis, 99 foci for meditation and 510 foci for psychedelics.

## Method Phase 2 : Coordinate-based meta-analysis

Analyses were first separately conducted for each category of interest, such as primary meta-analysis of ASCs states from mindfulness-based meditation, hypnosis and psychedelics, from which three sets of pairwise conjunction analyses were then separately conducted. Overall, this method permits a quantitative summary and comparison of functional brain increased and decreased activation.

The meta-analyses adopted a voxel-wise coordinate-based approach to quantify activation and overlaps of brain functional activity (obtained via fMRI or PET imaging), and was conducted at a whole-brain level using the method of Seed-based  $d$  Mapping with Permutation of Subject Images (SDM-PSI), using SDM-PSI software's version 6.22 (Albajes-Eizaguirre et al., 2019; Radua et al., 2014). The calculation processing allows the generation of study-specific maps based on anisotropic Gaussian kernel, which accounts for direction-specific variability of activation foci, and the subsequent corresponding meta-analytical maps of most likely effect sizes using Rubin's rules and random-effects model. Methodological steps consisted into several blocks of analysis namely the (1) pre-processing, (2) Maximum Likelihood Estimation (MLE) mean analysis, and (3) statistical significance corrections. Optional assessment of moderating effects, via (4) linear model meta-regression, such as for sample characteristics or group condition, are included in the method but were not assessed in this current study at one exception, psychedelic interventions were classified

upon classical or atypical psychedelic substance family for sub-group analysis. The software's processing allows the automated conversion of all peak values ( $p$ -values and  $z$ -score) into necessary  $t$ -values. Additionally, an automated certainty assessment of study effect is provided by SDM-PSI calculation, including heterogeneity tests for between study variability ( $I^2$  value) and publication bias analysis via Egger's test of funnel plot asymmetry ( $p$ -value  $< .05$ ). Effect sizes were computed based on Hedges's  $g$  and Jackknife sensitivity analyses is used for testing the robustness of the main meta-analytic output through repetitive iterations calculation.

### Method Phase 3 : Statistical thresholding and multiple-comparison control

Primary inference for confirmatory results are based on Threshold-Free Cluster Enhancement (TFCE) with family-wise error (FEW) correction at  $p < .05$  (two-tailed), implemented in SDM-PSI v6.22. The following SDM-PSI parameters were used: permutations = 1000, anisotropic Gaussian kernel FWHM = 20 mm, gray-matter mask = gray\_matter\_2, voxel size = 2 mm isotropic, and SDM-PSI default TFCE settings. The uncorrected maps were used for exploratory visualization and hypotheses-generating inspection, using two conventional thresholds: (i)  $SDM-Z \geq 2.30$  (approximate  $p < .01$ , two-tailed) for statistical significance, and (ii)  $SDM-Z \geq 1.645$  (approximate  $p < .05$ , two-tailed) for subthreshold context, thus labelled "exploratory" and never used for confirmatory claims. In the present corpus, TFCE-corrected effects were obtained only for meditation; hypnosis and psychedelics are therefore presented exclusively as uncorrected/exploratory maps. All maps were cluster-extent gated at  $\geq 10$  voxels, and full maps were summarized respectively for increased and decreased activity.

Multimodal conjunction analysis permits pairwise comparison from meta-analytical results. Thus, cross-state overlap by pairwise conjunction was computed on binarized TFCE-corrected maps where available; when a domain lacked corrected findings, overlap was computed on binarized uncorrected maps ( $SDM-Z \geq 1.65$ ) and was interpreted descriptively (hypothesis-generating), not as a formal conjunction with family-wise control. The visual conjunction maps represent the intensity of overlaps, all values from meta-analytical results are rescaled from 0 to 125.00 or 130.00 with a standardized internal threshold of 51.00 or 52.00, corresponding to the upper approximative 61% of significant overlap (Albajes-Eizagirre & Radua, 2018; Radua et al., 2012).

All brain maps schematic representation were neurologically oriented in MNI stereotactic space, and coloured bars represent the absolute value of the  $Z$ -score ( $p < 0.05$ ) for the meta-analytical maps, and intensity scores of activation for the pre-processed meta-analytical maps and overlapping activation of pairwise conjunction maps. For all visual representation of brain maps results, 3D

coordinate data were mapped to a high-resolution template using MRICron software (version 1.0.20190902) (Rorden, 2020).

## Results

In each analysis, all statistically significant results are reported for the corrected meta-analytical maps, with a minimal statistical significance threshold automatically produced by SDM-PSI calculation and combined chosen correction type ( $p < 0.05$ ). When no significant results were available for the corrected values, the uncorrected meta-analytical results were reported with an established threshold minimum  $\text{SDM-Z} \geq \pm 1.645$  for exploratory significance, and for statistical significance only  $\text{SDM-Z} \geq \pm 2.3$  were retained. The uncorrected threshold results corresponding to the clusters with corrected threshold were not reported twice, however the uncorrected cluster voxel size was informed. Exploratory whole brain maps from meta-analytical results, with liberal threshold of uncorrected values, are summarised into a graphical abstract for global visualization of each state condition (see Figure 3).

The mindfulness-based meditative state meta-analysis was computed from an omnibus sample size of 185 healthy adults. Three statistically significant clusters of decreased activation were retained from analyses (size 367 to 2749 voxels), and one exploratory cluster for increased activation (24 voxels size), (see Table 3 to 5 for details). The principal cluster of decreased activation was located in the right medial superior frontal gyrus (BA 10; peak MNI: 4, 50, 6;  $\text{SDM-Z} = -4.15$ ), which survived TFCE family-wise correction ( $p < .05$ ). The cluster extended bilaterally across the medial superior frontal gyrus, left anterior cingulate, and right medial orbitofrontal cortex (extent = 1220 voxels), with all voxels  $\text{SDM-Z} \leq -2.45$  and four significant local maxima ( $\text{SDM-Z}$  range  $-3.97$  to  $-2.91$ ). Two additional clusters of decreased activation were detected at uncorrected thresholds ( $p < .01$ , statistically significant): right precuneus (BA 5; peak MNI: 2, -48, 54;  $\text{SDM-Z} = -3.17$ ), spanning bilateral precuneus, left medial cingulate, and precentral gyrus (extent = 717 voxels; voxel  $\text{SDM-Z}$  range  $-3.17$  to  $-3.07$ ); and left supplementary motor area (BA 6; peak MNI: -2, 0, 66;  $\text{SDM-Z} = -2.90$ ), extending bilaterally within SMA (extent = 367 voxels), with three local maxima ( $-2.91$  to  $-2.37$ ). An additional exploratory increase (uncorrected  $p < .05$ , exploratory) was observed in the left insula (BA 48\*; peak MNI: -34, -24, 18;  $\text{SDM-Z} = +1.84$ ; extent = 24 voxels), spanning the left insula, rolandic operculum, and superior longitudinal fasciculus III, with subthreshold local peaks ( $\text{SDM-Z}$  range 1.72 to 1.80).

**Table 3**

*Primary analyses : Meta-analysis results of Meditation hypoactivation (corrected p-value)*

| Cluster, local peaks | MNI Coordinate (x,y,z) | SDM-Z      | Voxel p-value | Voxels | Description                                         |
|----------------------|------------------------|------------|---------------|--------|-----------------------------------------------------|
| 1                    | 4,50,6                 | - 4.147*** | 0.000999987   | 1220   | Right superior frontal gyrus, medial, BA 10         |
| 1.1                  | 4,50,6                 | - 4.147*** | 0.000999987   | 101    | Right superior frontal gyrus, medial, BA 10         |
| 1.2                  | -4,44,4                | -3.972***  | 0.000999987   | 138    | Left anterior cingulate / paracingulate gyri, BA 10 |
| 1.3                  | -4,52,14               | -3.812***  | 0.000999987   | 62     | Left superior frontal gyrus, medial, BA 32          |
| 1.4                  | 6,42,-4                | -3.508***  | 0.000999987   | 103    | Right superior frontal gyrus, medial orbital, BA 10 |
| 1.5                  | 6,42,-6                | -2.905***  | 0.000999987   | 103    | Right superior frontal gyrus, medial orbital, BA 10 |

Note. Blobs of  $\geq 1220$  voxels with all voxels  $\text{SDM-Z} \leq -2.447$  and all peaks  $\text{SDM-Z} \leq -4.147$ . Voxel threshold:  $\text{TFCECORRECTED} > p$ . Peak height threshold: peak  $\text{TFCECORRECTED} > 0.05000$ . Extent threshold: cluster size  $\geq 10$  voxels, \*\*\* =  $p \leq 0.001$ .

**Table 4**

*Primary analyses : Meta-analysis results of Meditation hypoactivation (uncorrected p-value)*

| Cluster, local peaks | MNI Coordinate (x,y,z) | SDM-Z     | Voxel p-value | Voxels | Description                                |
|----------------------|------------------------|-----------|---------------|--------|--------------------------------------------|
| 2                    | 2,-48,54               | -3.174*** | 0.000751376   | 717    | Right precuneus, BA 5                      |
| 3                    | -2,0,66                | -2.905**  | 0.001833618   | 367    | Left supplementary motor area, BA 6        |
| 2.1                  | 2,-48,54               | -3.174*** | 0.000751376   | 117    | Right precuneus, BA 5                      |
| 2.2                  | -2,-44,54              | -3.070**  | 0.001070142   | 102    | Left median cingulate / paracingulate gyri |
| 2.3                  | -2,-30,5               | -1.804*   | 0.035588026   | 18     | Left paracentral lobule                    |
| 3.1                  | -2,0,66                | -2.905**  | 0.001833618   | 256    | Left supplementary motor area, BA 6        |
| 3.2                  | -2,2,60                | -2.622**  | 0.004367828   | 45     | Left supplementary motor area              |
| 3.3                  | 0,10,60                | -2.428**  | 0.007593811   | 45     | Left supplementary motor area              |
| 3.4                  | 2,6,68                 | -2.367**  | 0.008956313   | 60     | Right supplementary motor area, BA 6       |

Note. Blobs of  $\geq 367$  voxels with all voxels  $\text{SDM-Z} \leq -1.645$  and all peaks  $\text{SDM-Z} \leq -2.905$ . Voxel threshold:  $\text{UNCORRECTED} > p$ . Peak height threshold: peak  $\text{UNCORRECTED} > 0.05000$ . Extent threshold: cluster size  $\geq 10$  voxels, \* =  $p \leq 0.05$ , \*\* =  $p \leq 0.01$ , \*\*\* =  $p \leq 0.001$ .

**Table 5**

*Primary analyses : Meta-analysis results of Meditation hyperactivation (uncorrected p-value)*

| Cluster, local peaks | MNI Coordinate (x,y,z) | SDM-Z  | Voxel p-value | Voxels | Description        |
|----------------------|------------------------|--------|---------------|--------|--------------------|
| 4                    | -34,-24,18             | 1.840* | 0.032869458   | 24     | Left insula, BA 48 |
| 4.1                  | -34,-24,18             | 1.840* | 0.032869458   | 8      | Left insula, BA 48 |

|     |            |        |             |    |                                           |
|-----|------------|--------|-------------|----|-------------------------------------------|
| 4.2 | -38,-22,2  | 1.806* | 0.035435438 | 3  | Left rolandic operculum, BA 48            |
| 4.3 | -34,-20,18 | 1.751* | 0.040001392 | 8  | Left insula, BA 48                        |
| 4.4 | -36,-16,22 | 1.724* | 0.042320132 | 12 | Left superior longitudinal fasciculus III |

Note. Blobs of  $\geq 24$  voxels with all voxels  $\text{SDM-Z} \geq 1.645$  and all peaks  $\text{SDM-Z} \geq 1.840$ . Voxel threshold:  $\text{UNCORRECTED} > p$ . Peak height threshold: peak  $\text{UNCORRECTED} > 0.05000$ . Extent threshold: cluster size  $\geq 10$  voxels, \* =  $p \leq 0.05$ .

Egger's test  $p$ -value was non-statistically significant ( $p > 0.05$ ) for meditation meta-analysis ( $p = 0.260$ ), suggesting an absence of publication bias and a funnel plot symmetry. The statistic  $I^2$  value of 10.26% indicated a low heterogeneity, meaning a consistent effect across studies, in other words a low between-study variance. Moderate negative effect size (Hedges'  $g = -0.42$ ), consistent with decreased functional activation, and a highly significant negative convergence ( $\text{SDM-Z} = -4.15$ ) was retained.

### Meta-analytical map of hypnosis

The hypnotic state meta-analysis was computed from an omnibus sample size of 168 healthy adults. Two clusters of hypoactivation were retained at uncorrected threshold ( $p < .05$ , exploratory), with all voxel  $\text{SDM-Z} \leq -1.65$  (see Table 6 for details): left anterior cingulate and paracingulate gyri (BA 24; peak MNI: -2, 34, 24;  $\text{SDM-Z} = -2.30$ ), extended bilaterally across anterior and median cingulate and paracingulate gyri, and bilateral superior medial frontal gyrus (extent = 454 voxels; voxel  $\text{SDM-Z}$  range -1.94 to -2.25) ; and left anterior cingulate and paracingulate gyri, (BA 10; peak MNI: 0, 50, 4;  $\text{SDM-Z} = -2.11$ ), extending bilaterally within anterior cingulate and paracingulate gyri, and superior medial frontal gyrus (extent = 78 voxels; voxel  $\text{SDM-Z}$  range -1.67 to -2.11).

**Table 6**

Primary analyses : Meta-analysis results of Hypnosis hypoactivation (uncorrected  $p$ -value)

| Cluster, local peaks | MNI Coordinate (x,y,z) | SDM-Z    | Voxel $p$ -value | Voxels | Description                                          |
|----------------------|------------------------|----------|------------------|--------|------------------------------------------------------|
| 1                    | -2,34,24               | -2.300** | 0.010735989      | 454    | Left anterior cingulate / paracingulate gyri, BA 24  |
| 2                    | 0,50,4                 | -2.106*  | 0.017609596      | 78     | Left anterior cingulate / paracingulate gyri, BA 10  |
| 1.1                  | -2,34,24               | 2.300**  | 0.010735989      | 106    | Left anterior cingulate / paracingulate gyri, BA 24  |
| 1.2                  | 0,28,24                | -2.248*  | 0.012282014      | 37     | Left anterior cingulate / paracingulate gyri         |
| 1.3                  | 2,48,28                | -1.956*  | 0.025229037      | 24     | Left superior frontal gyrus, medial                  |
| 1.4                  | 2,44,28                | -1.939*  | 0.026229501      | 56     | Left superior frontal gyrus, medial, BA 32           |
| 2.1                  | 0,50,4                 | -2.106*  | 0.017609596      | 26     | Left anterior cingulate / paracingulate gyri, BA 10  |
| 2.2                  | 6,50,8                 | -1.668*  | 0.047705352      | 10     | Right anterior cingulate / paracingulate gyri, BA 32 |

Note. Blobs of  $\geq 78$  voxels with all voxels  $\text{SDM-Z} \leq -1.645$  and all peaks  $\text{SDM-Z} \leq -2.106$ . Voxel threshold:  $\text{UNCORRECTED} > p$ . Peak height threshold: peak  $\text{UNCORRECTED} > 0.05000$ . Extent threshold: cluster size  $\geq 10$  voxels, \* =  $p \leq 0.05$ , \*\* =  $p \leq 0.01$ .

Egger's test  $p$ -value was non-statistically significant ( $p > 0.05$ ) for hypnosis meta-analysis ( $p = 0.943$ ), suggesting an absence of publication bias and a funnel plot symmetry. The  $I^2$  value of 2.47% indicated a very low heterogeneity, meaning a consistent effect across studies, in other words a low between-study variance. Small negative effect size (Hedges'  $g = -0.22$ ), suggesting modest functional deactivation, and exploratory significance (SDM- $Z = -2.30$ ), under conventional corrected thresholds but above uncorrected, were retained.

### Meta-analytical map of psychedelics

The psychedelic state meta-analysis was computed from an omnibus sample size of 608 healthy adults. Two clusters of increased activation were retained at uncorrected threshold ( $p < .05$ , exploratory), with all voxel SDM- $Z \geq 1.65$  (see Table 7 for details): left anterior cingulate and paracingulate gyri (BA 10; peak MNI: -6, 46, 2; SDM- $Z = 2.01$ ), extending bilaterally within anterior cingulate and paracingulate gyri, and superior medial frontal gyrus (extent = 141 voxels; voxel SDM- $Z$  range 1.73 to 2.01) ; left insula (BA 47; peak MNI: -32, 22, 2; SDM- $Z = 2.21$ ), just subthreshold to statistical significance (SDM- $Z \geq 2.30$ ), and extending to left inferior frontal gyrus, triangular part (extent = 65 voxels; voxel SDM- $Z$  range 1.96 to 2.21).

Meta-regression results through linear model, were extracted from SDM- $Z$  maps at a fixed threshold of SDM- $Z \geq 1.645$  (uncorrected  $p < 0.05$ , exploratory), showing the contrast activation of atypical over classical psychedelics. From visual extraction, common regions with activation differences were located in cingulate gyrus, left hippocampal and extending from temporal pole to inferior frontal gyrus, including insular and operculum cortex. Activations were also found in putamen, caudate, occipital pole, posterior cingulate cortex and precuneus.

**Table 7**

*Primary analyses : Meta-analysis results of Psychedelics hyperactivation (uncorrected  $p$ -value)*

| Cluster, local peaks | MNI Coordinate (x,y,z) | SDM-Z  | Voxel $p$ -value | Voxels | Description                                          |
|----------------------|------------------------|--------|------------------|--------|------------------------------------------------------|
| 1                    | -6,46,2                | 2.097* | 0.018006623      | 141    | Left anterior cingulate / paracingulate gyri, BA 10  |
| 2                    | -32,22,2               | 2.208* | 0.013623536      | 65     | Left insula, BA 47                                   |
| 1.1                  | -6,46,2                | 2.097* | 0.018006623      | 36     | Left anterior cingulate / paracingulate gyri, BA 10  |
| 1.2                  | -2,46,6                | 2.009* | 0.022246480      | 36     | Left anterior cingulate / paracingulate gyri, BA 10  |
| 1.3                  | -2,44,10               | 1.979* | 0.023887217      | 54     | Left anterior cingulate / paracingulate gyri, BA 32  |
| 1.4                  | -2,48,12               | 1.965* | 0.024697602      | 54     | Left anterior cingulate / paracingulate gyri, BA 32  |
| 1.5                  | 4,40,20                | 1.786* | 0.037024319      | 23     | Right anterior cingulate / paracingulate gyri, BA 32 |

|     |           |        |             |    |                                                      |
|-----|-----------|--------|-------------|----|------------------------------------------------------|
| 1.6 | 4,48,8    | 1.732* | 0.041677713 | 23 | Right anterior cingulate / paracingulate gyri, BA 32 |
| 2.1 | -32,22,2  | 2.208* | 0.013623536 | 54 | Left insula, BA 47                                   |
| 2.2 | -32,20,-4 | 1.951* | 0.025535166 | 54 | Left insula, BA 47                                   |

*Note.* Blobs of  $\geq 65$  voxels with all voxels  $\text{SDM-Z} \geq 1.645$  and all peaks  $\text{SDM-Z} \geq 2.097$ . Voxel threshold: UNCORRECTED  $> p$ . Peak height threshold: peak UNCORRECTED  $> 0.05000$ . Extent threshold: cluster size  $\geq 10$  voxels, \* =  $p \leq 0.05$ .

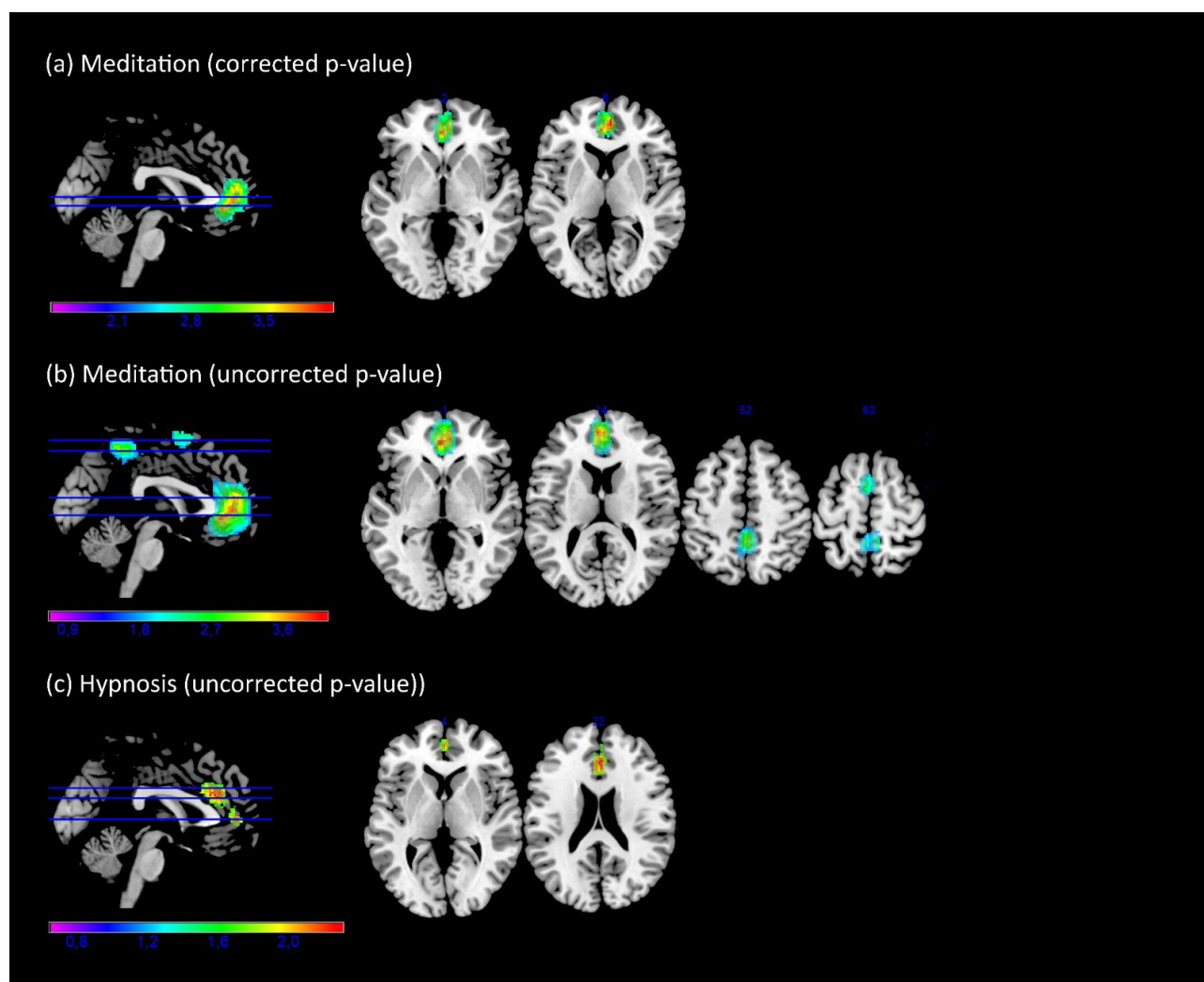
Egger's test  $p$ -value was non-statistically significant ( $p > 0.05$ ) for psychedelic meta-analysis ( $p = 1.00$ ), suggesting an absence of publication bias and a funnel plot symmetry. The  $I^2$  value of 0.02% indicated a negligible heterogeneity, meaning a strong consistent effect across studies, in other words a low between-study variance. Small positive effect size (Hedges'  $g = 0.11$ ), suggesting mild increased activation, and exploratory significance ( $\text{SDM-Z} = 2.10$ ) were retained.

### Meta-analytical results summary and visualization

In sum, activations of key cluster centroids (TFCE-corrected or nearest-significance peaks) are the following (see Figure 1 and 2 for visual schematic representation) : decreases for meditation at medial prefrontal cortex (MNI coordinates: 4, 50, 6;  $\text{SDM-Z} = -4.15$ ); bilateral precuneus (MNI coordinates: 2, -48, 54;  $\text{SDM-Z} = -3.17$ ); SMA (MNI coordinates: -2, 0, 66;  $\text{SDM-Z} = -2.91$ ), and increase at left insula (MNI coordinates: -34, -24, 18;  $\text{SDM-Z} = 1.84$ , exploratory); increases for psychedelic at dorsal ACC (MNI coordinates: -6, 46, 2;  $\text{SDM-Z} = 2.10$ , exploratory) and left insula (MNI coordinates: -32, 22, 2;  $\text{SDM-Z} = 2.21$ , subthreshold); decreases for hypnosis at anterior cingulate (MNI coordinates: -2, 34, 24;  $\text{SDM-Z} = -2.30$ ); medial frontal (MNI coordinates: 0, 50, 4;  $\text{SDM-Z} = -2.11$ , exploratory). All three analyses showed low heterogeneity and no evidence of small-study bias; however,  $k < 10$  for hypnosis and meditation renders publication-bias tests under-powered.

# Figure 1

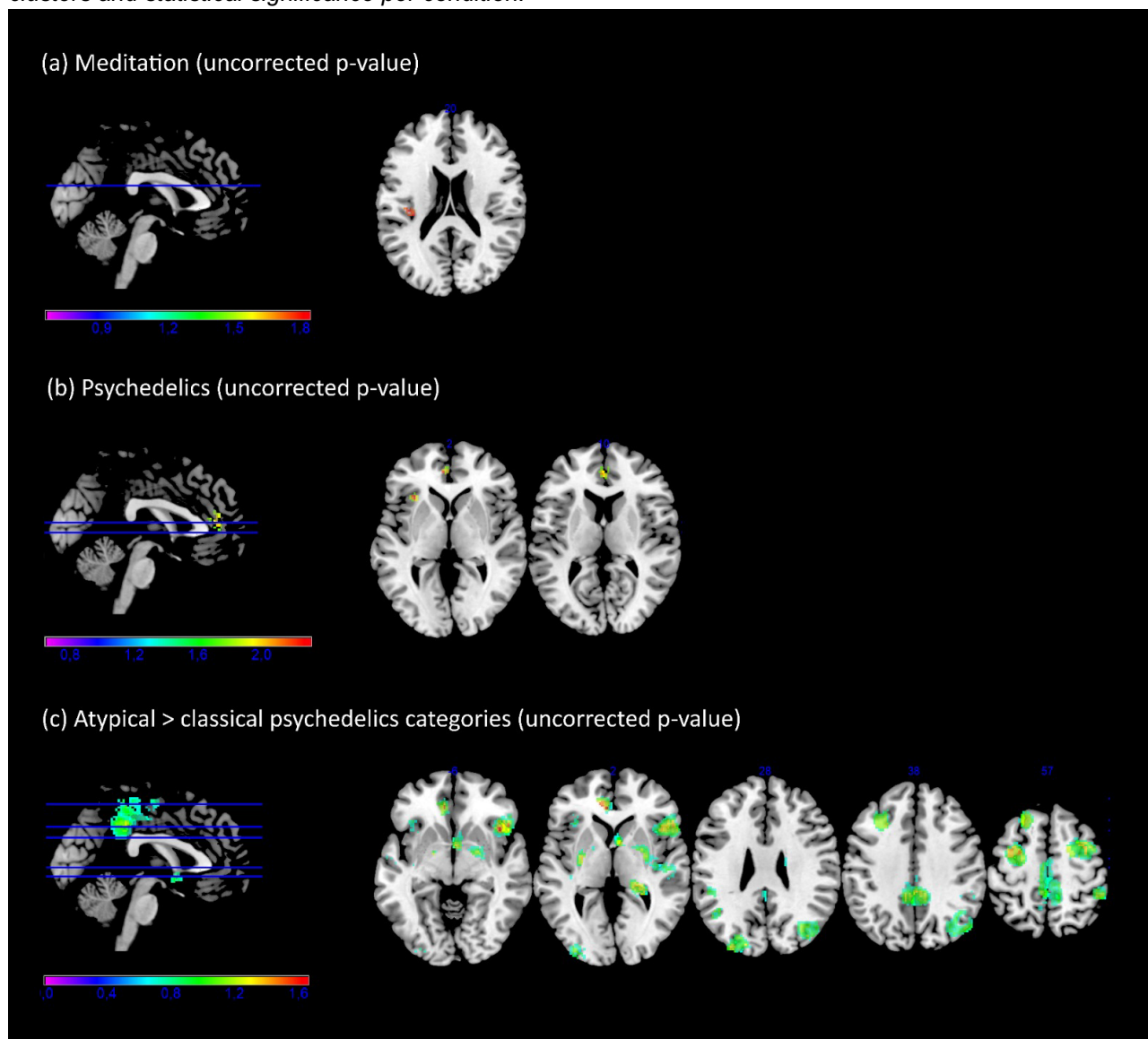
Visual brain slices of functional hypoactivation, with subfigures labelled from a to c, illustrating decreased clusters and significance per condition.



*Note.* Whole-brain maps of functional hypoactivation from SDM-PSI meta-analytical results, visualized using MRICron (version 1.0.20190902). Each panel represent clusters relative to the state condition and corresponding statistical correction type: panel (a) shows a cluster spanning superior frontal medial gyrus BA 10 and anterior cingulate and paracingulate gyri BA 11 for the meditation condition ( $p < .05$ , TFCE-corrected, statistically significant); panel (b) shows two additional clusters at bilateral precuneus and bilateral SMA ( $p < .05$ , uncorrected, statistically significant); panel (c) shows two clusters at bilateral anterior cingulate and paracingulate gyri BA 24 and BA 32 ( $p < .05$ , uncorrected, subthreshold statistically significant). The slices are shown in axial view and referred to MNI z coordinates, according to the state condition and statistical correction type. Coloured bars represent the threshold SDM-Z maps of voxel activation, the magnitude of effect sizes at  $p < .05$ .

## Figure 2

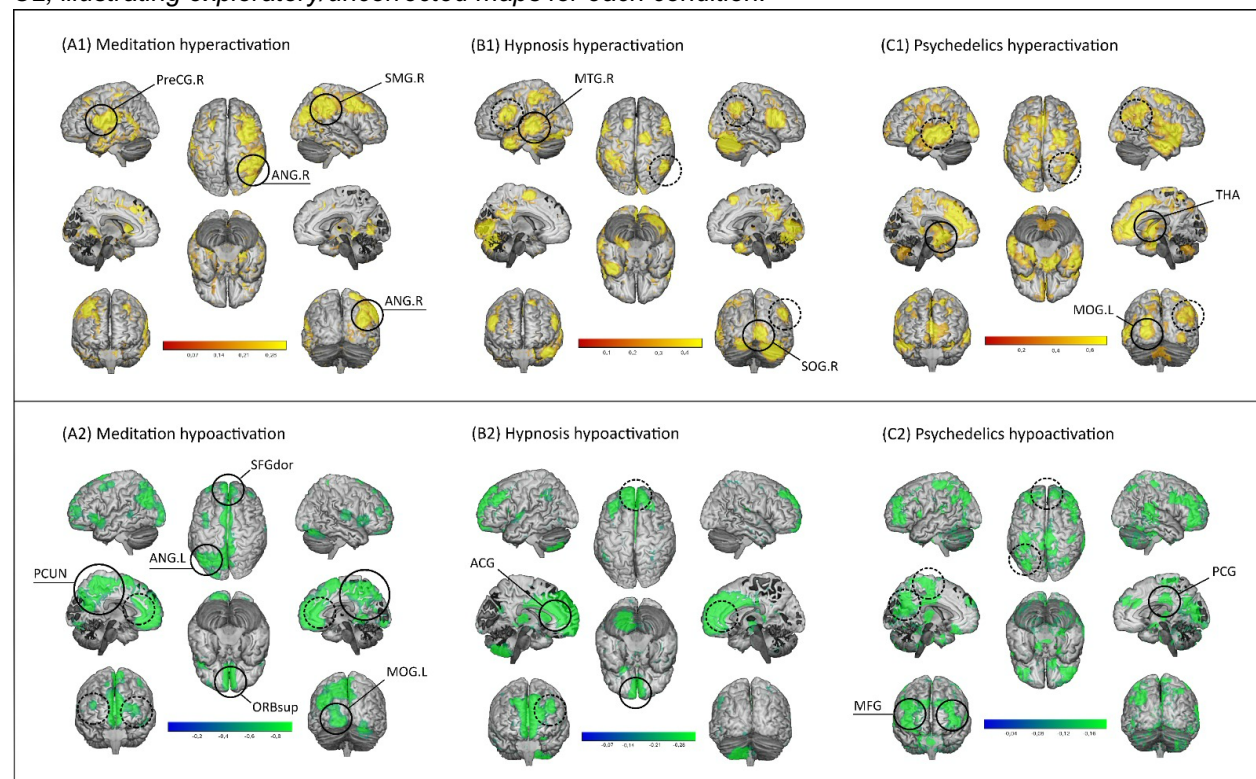
Visual brain slices of functional hyperactivation, with subfigures labelled from a to c, illustrating increased clusters and statistical significance per condition.



**Note.** Whole-brain maps of functional hyperactivation from SDM-PSI meta-analytical results, visualized using MRICron (version 1.0.20190902). Each panel represent clusters relative to the state condition and corresponding statistical correction type: panel (a) shows a cluster left insula for the meditation condition ( $p < .05$ , uncorrected, exploratory significant); panel (b) shows clusters at left insula, bilateral anterior cingulate and paracingulate gyri ( $p < .05$ , uncorrected, subthreshold statistically significant); panel (c) shows common cluster but of higher activation for atypical versus classical psychedelics, in cingulate gyrus, bilateral orbitofrontal cortex spanning to temporal pole, middle frontal gyrus, bilateral hippocampus ( $p < .05$ , uncorrected, exploratory significant). The slices are shown in axial view and referred to MNI z coordinates, according to the state condition and statistical correction type. Coloured bars represent the threshold SDM-Z maps of voxel activation, the magnitude of effect sizes at  $p < .05$ .

### Figure 3

Whole brain visualization of functional hypo- and hyperactivation, with subfigures labelled from A1-A2 to C1-C2, illustrating exploratory/uncorrected maps for each condition.



Note. Graphical abstract from pre-processed meta-analytical brain maps of functional hypoactivation (in blue-green display) and hyperactivation (in red-yellow display) for each state condition: meditation (A), hypnosis (B), psychedelics (C). Brain views are shown from lateral, medial, front, back, inferior and superior plan. Colour scales represent moderate to strong activation intensity of  $\pm 0.03$  to  $\pm 0.1$ , respectively for increase and decrease of functional activation, with exploratory significance due to liberal threshold.

Abbreviations : PreCG.R, right precentral gyrus; SMG.R, right supramarginal gyrus; ANG.R/L, right or left angular gyrus; ORBSup, superior frontal gyrus orbital part; SFGdor, dorsal superior frontal gyrus; PCUN, precuneus; ACG, anterior cingulum gyrus; SOG.R, right superior occipital gyrus; MOG.L, right middle occipital gyrus; MTG.R, tight middle temporal gyrus; MFG, middle frontal gyrus; THA, thalamus; PCG, posterior cingulum gyrus.

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### **Overlap between meditation, hypnosis and psychedelics**

Due to the version of the SDM-PSI software, conjunction maps and the pre-processed input meta-analytical map do not provide automated statistical SDM-Z score or *p*-value for the displayed activations, rather it retains the overlap intensity score of convergent positive and negative activations at a whole brain level for spatial visualization. Regarding the liberal threshold settled for the primary meta-analyses, weak but consistent activations were displayed in the individual input pre-processed maps and despite no statistical map computed, the conjunction results stand in line with the exploratory significance of this whole-brain investigation. Descriptive statistics from the SDM-PSI conjunction maps indicated the number of voxels of the full brain mask, from which percentage of functional activity overlap was computed. Regarding the functional hyperactivation, overlap was wider between hypnotic and psychedelic state conditions (90% overlap), and comparable for the two pairs of meditative state condition (85% overlap between meditation and hypnosis, 86% between meditation and psychedelics). Functional hypoactivation was comparable for all three pairs with 81 to 84% of significant overlap. The retained region parcellation was visually extracted with superposition of the Automated Anatomical Labelling (AAL) Atlas (Tzourio-Mazoyer et al., 2002), and the Harvard-Oxford Cortical and Subcortical Atlases (Desikan et al., 2006). The corresponding reference citations for network attribution and functional properties are referenced in the interpretative section.

The conjunction analysis between meditative and hypnotic state conditions revealed 85% of significant overlap of functional hyperactivation, for clusters within: frontal lobe including frontal orbital cortex, precentral gyrus, frontal gyrus; parietal lobe including superior parietal lobule, right angular gyrus, postcentral gyrus, parietal operculum cortex, bilateral precuneus; temporal lobe including bilateral temporal gyrus, occipital fusiform, bilateral hippocampus and parahippocampal gyrus; occipital lobe including right lingual, bilateral intracalcarine cortex; subcortical structures including insular cortex, bilateral thalamus, right caudate nucleus; and parts of cerebellum vermis VI and cerebellum lobules III and IV. Regarding functional hypoactivation, 83% of significant overlap was covered with strong patterns identified within: frontal lobe including bilateral superior medial frontal gyrus, bilateral orbitofrontal cortex; parietal and occipital lobes including left calcarine cortex, bilateral cuneal cortex; temporal lobe including bilateral superior and inferior temporal gyri, bilateral parahippocampal gyri; cingulate cortex including bilateral anterior cingulate cortex; insular and subcortical structures including left insular cortex and right thalamus; and parts of cerebellum including vermis lobules VI and IX.

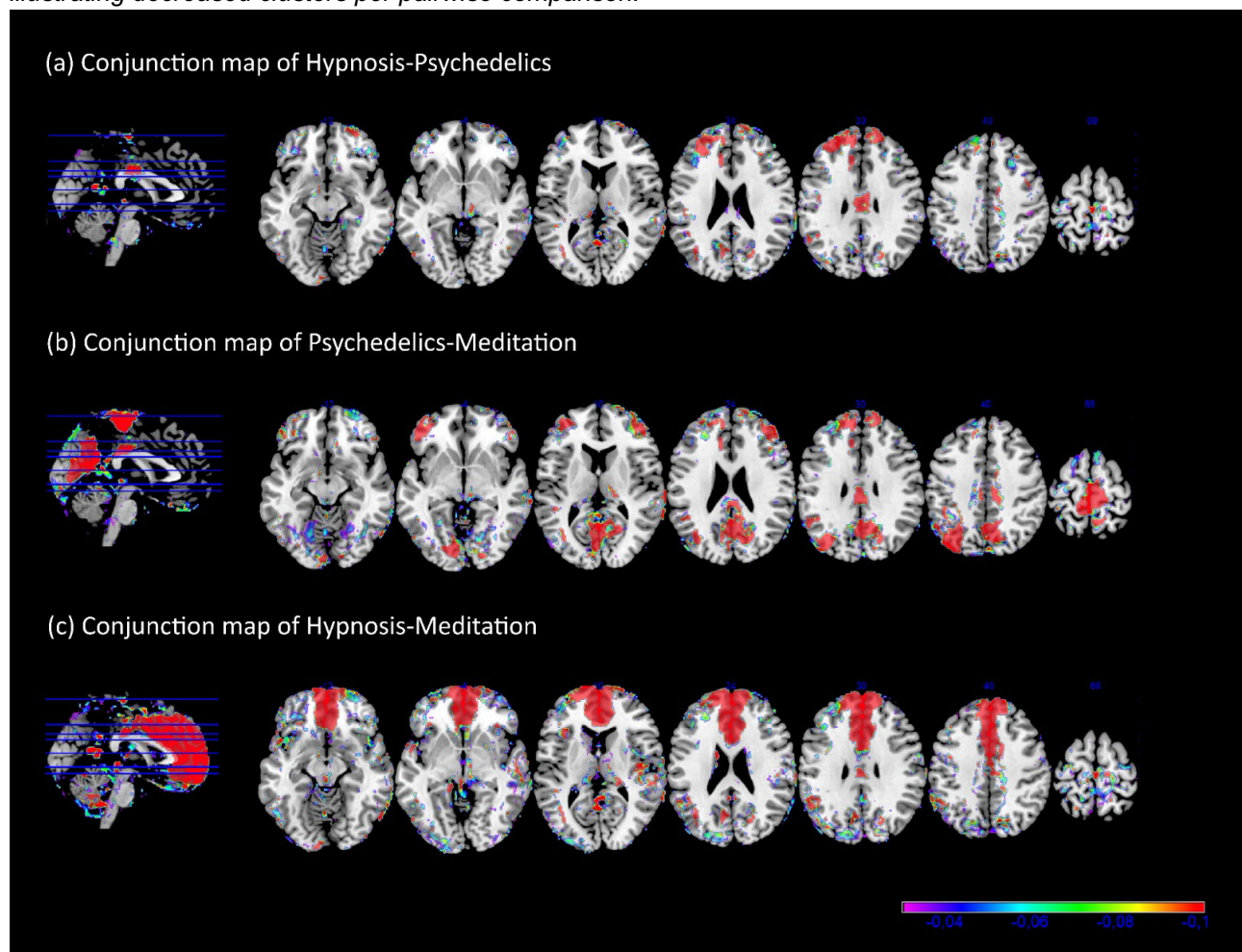
The conjunction analysis between hypnotic and psychedelic state conditions revealed 90% of significant overlap of functional hyperactivation with common peaks located in: frontal lobe including

bilateral inferior frontal gyrus and superior frontal gyrus; parietal lobe including bilateral inferior and superior parietal lobules, bilateral angular gyrus, bilateral precuneus, left cuneal cortex; temporal lobe including inferior and medial temporal gyri and fusiform, bilateral hippocampus and parahippocampal gyrus, bilateral amygdala; occipital lobe including, right calcarine, bilateral occipital cortex, bilateral lingual gyri; insular and cingulate cortex including left insula and bilateral cingulate gyrus; and parts of the cerebellum including vermis lobules IV and V. Decreased activation between both condition revealed 81% of significant overlap covering frontal lobe including bilateral superior frontal gyrus, bilateral orbitofrontal cortex, bilateral central gyrus; temporal lobe including inferior, medial and superior temporal gyri (bilateral), left parahippocampal gyrus; parietal and occipital lobe including bilateral calcarine cortex, bilateral occipital cortex, bilateral cuneus; and cingulate cortex including bilateral posterior and anterior cingulate cortex.

The conjunction analysis between psychedelic and meditative state conditions revealed 86% of significant overlap of functional hyperactivation over: frontal lobe including bilateral inferior frontal cortex, bilateral middle frontal gyrus, right superior frontal gyrus, bilateral frontal orbital cortex, left precentral gyrus, bilateral rolandic operculum; parietal lobe including left inferior parietal lobule, right angular gyrus (part of inferior parietal lobule), right supramarginal gyrus, left cuneal cortex (posterior parietal/occipital junction); temporal lobe including bilateral middle and inferior temporal gyrus, left superior temporal, bilateral hippocampus and parahippocampal gyrus; occipital lobe including bilateral calcarine cortex, right occipital cortex, occipitotemporal fusiform gyrus; the subcortical regions including bilateral insular cortex, bilateral putamen, right caudate nucleus, left thalamus; and parts of cerebellum including vermis lobule IV. Functional hypoactivation had 84% of significant overlap, covering frontal lobe including bilateral inferior orbitofrontal cortex, medial frontal cortex, bilateral superior frontal gyrus; parietal lobe including left angular gyrus, bilateral precuneus, bilateral central gyrus; temporal lobe including bilateral medial temporal cortex; occipital lobe including bilateral calcarine cortex, bilateral lingual gyri, left medial occipital cortex; cingulate cortex including bilateral posterior cingulate cortex and left anterior cingulate cortex; subcortical regions including bilateral thalamus; and cerebellum regions including vermis lobule IV and V.

#### Figure 4

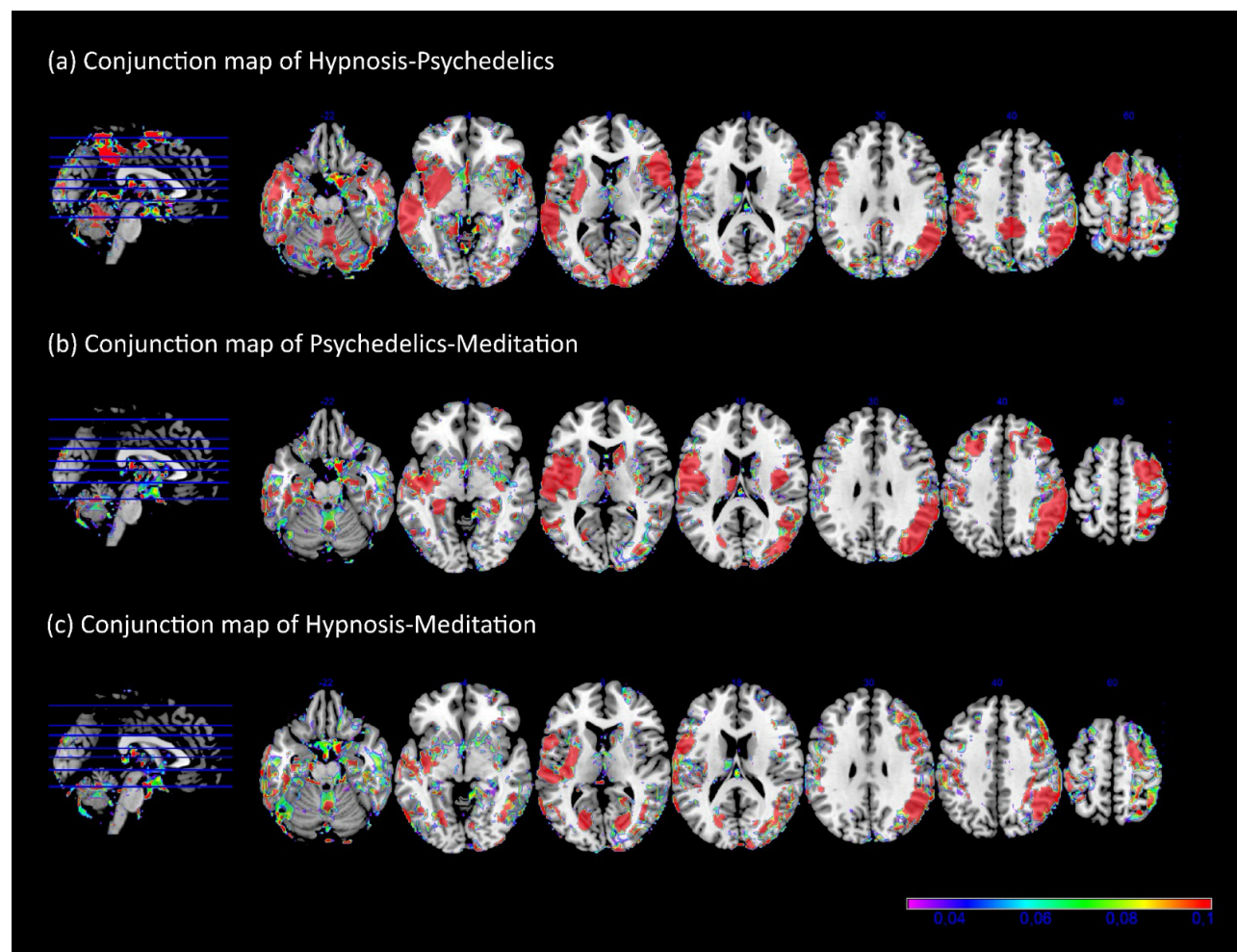
Visual brain slices of pairwise overlaps in functional hypoactivation, with subfigures labelled from a to c, illustrating decreased clusters per pairwise comparison.



*Note.* Schematic representation of pairwise conjunction for functional hypoactivation: panel (a) convergent brain activation between hypnosis and meditation (83%), main cluster spanning orbitofrontal cortex, superior frontal gyrus and anterior cingulate cortex, smaller activated regions at superior temporal gyrus; panel (b) convergent brain activation between hypnosis and psychedelics (81%), main cluster situated in cingulate gyrus and superior frontal gyrus, smaller extent clusters in cuneal and occipital cortex; panel (c) convergent brain activation between psychedelics and meditation (84%), main clusters located in calcarine and occipital cortex, medial and superior frontal gyrus, left angular gyrus, precuneus and SMA. Colour scale of -0.03 to -0.1 represent moderate to strong overlap intensity.

## Figure 5

Visual brain slices of pairwise overlaps in functional hyperactivation, with subfigures labelled from a to c, illustrating increased clusters per pairwise comparison.



**Note.** Schematic representation of pairwise conjunction for functional hyperactivation: panel (a) convergent brain activation between hypnosis and meditation (85%), main clusters in bilateral intracalcarine cortex, left insular cortex, right angular gyrus; panel (b) convergent brain activation between hypnosis and psychedelics (90%), main clusters situated in left middle temporal gyrus, left putamen, inferior frontal gyrus, calcarine, precuneus, inferior parietal cortex, right angular gyrus, superior frontal gyrus; panel (c) convergent brain activation between psychedelics and meditation (86%), main clusters located in parahippocampal gyrus, orbitofrontal cortex, insular cortex, right caudate, right occipital cortex, middle frontal gyrus. Colour scale of 0.03 to 0.1 represent moderate to strong overlap intensity.

## General discussion

This meta-analytic study sought to delineate both commonalities and dissociations in whole-brain functional activity across three altered states of consciousness, mindfulness meditation, hypnosis, and psychedelics, using a unified SDM-PSI pipeline and whole-brain coordinates. Across domains, we observed at least exploratory convergence, while TFCE-corrected effects emerged for meditation only. Findings for hypnosis and psychedelics should therefore be regarded as uncorrected, hypothesis-generating signals, many of which fell below conventional statistical significance

thresholds ( $\text{SDM-Z} < 2.30$ ). Taken together, the results offer a cautious map of candidate regions that may differentiate or bridge these states, while underscoring the need for confirmatory analyses with larger, modality-homogeneous datasets and stricter multiple-comparison control. Across states, the spatial patterns were notably convergent: pairwise overlap of threshold maps reached 81 to 90% for both putative decreases and increases in activity. We emphasize that this overlap is descriptive (map co-localization) rather than a formal conjunction with family-wise error control, and thus should be interpreted as hypothesis-generating. Measures of functional activity do not by themselves confer process specificity, they index the magnitude and extent of voxel wise engagement. In line with current cautions about reverse inference and neurocognitive interpretation (Brouwer et al., 2015; Safron et al., 2021; Van Eijsden et al., 2009), the results were described at the level of network membership and plausible psycho-cognitive phenomenology, drawing on ASC-relevant literature (Bassett et al., 2018; Salehi, Karbasi, et al., 2020). Taken together, the findings suggest candidate circuits that may be shared across meditation, hypnosis, and psychedelics, while underscoring the need for confirmatory, corrected-controlled tests of cross-state convergence.

Having outlined the overall, descriptive, cross-state convergence and its interpretative limits, we next examine the network-level topology of each state. We begin with mindfulness meditation, where TFCE-corrected effects were obtained, and then summarize hypnosis and psychedelics as exploratory patterns. This ordering preserves evidential strength while situating regional findings within canonical networks, the DMN, salience network (SN), central executive network (CEN) and sensorimotor network (SMN).

### **Neurocognitive network of meditation, psychedelics and hypnosis**

Concerning mindfulness-based meditation (MM) state condition, decreased activations were identified in three clusters, the first spanning bilateral superior medial frontal gyrus, left ACC and right superior medial orbitofrontal at a cluster size of 1220 voxels, the second spanning bilateral precuneus, left medial cingulum and precentral gyrus at a cluster size of 717 voxels, and the last cluster of 367 voxels size including the bilateral supplementary motor areas (SMA). These regions typically involve DMN, SN and SMN, as well as frontal control system structures.

The breakdown of the decreased activations revealed the following regions and corresponding neurocognitive networks underscoring two main neural patterns at the level of the DMN and SN. The bilateral superior medial frontal gyrus and the bilateral precuneus are classically attributed to the DMN with functional roles of self-referential thought, internal mentation or visual-spatial imagery (Brewer et al., 2011; Cavanna & Trimble, 2006; Manna et al., 2010; Prakash et al., 2025; Raichle et al., 2001), while the right superior medial orbitofrontal classically refers to affective-control network

including both DMN and limbic circuits and functional role of reward processing and emotion regulation (Afonso, 2020; Rolls et al., 2020; Zeidan et al., 2011). Other regions were outlined and globally attributed to the SN, such as the left ACC and its functional role of cognitive control and emotion regulation (Hölzel et al., 2011; Nakata et al., 2014; Seeley et al., 2007; Sezer et al., 2022), the left medial cingulate cortex attributed to cognitive control and conflict monitoring, including emotional processing (Seeley et al., 2007; Tang et al., 2015), the precentral gyrus with a functional role of voluntary motor control (Cole et al., 2014; O'Connor et al., 2015), and lastly the bilateral SMA frequently attributed to both SMN and CEN and frequently associated to functional role of motor planning and coordination (Devaney et al., 2021; Manna et al., 2010; Nachev et al., 2008).

Regarding the neural hyperactivation of MM condition, the results revealed a single cluster spanning left insula, left rolandic operculum and left superior longitudinal fasciculus III (SLF III) at a cluster size of 24 voxels. These regions typically involve interoceptive SN, auditory-SMN interface and attentional control circuits. The left insula is generally attributed to salience and interoceptive network with a functional role of bodily awareness and emotion regulation (Craig, 2009; Farb et al., 2007; Lazar et al., 2005), the left rolandic operculum is frequently associated to auditory-SMN interface and somatosensory integration functional role (Fox et al., 2016; Hölzel et al., 2008), whereas SLF III often refers to frontoparietal attention network and supporting functional role of executive attention (De Schotten et al., 2011; Luders et al., 2011). Altogether, the functional neural activations linked to MM state underscored two main neural patterns at the level of the DMN and SN, aligning with characteristic effects of meditative states on top-down cognitive processes such as intentional regulation of attention by feedback mechanisms or attention control, and bottom-up sensory and spontaneous thought processes (Brandmeyer & Delorme, 2021; Vago & Silbersweig, 2012), including aspects of emotion regulation and self-awareness (Afonso, 2020; Prakash et al., 2025; Sezer et al., 2022).

Concerning psychedelic state condition, increased activations were identified in two clusters. The first cluster was active in bilateral anterior cingulate and paracingulate gyri and bilateral superior medial frontal gyrus at a cluster size of 141 voxels. The second and smaller cluster englobed left insula and left inferior frontal gyrus (triangular part), at a cluster size of 65 voxels and typically attributed to DMN, SN and ventral attention network (VAN). Regarding bilateral ACC and paracingulate gyri cluster with an overall ACC hyperactivation, cognitive attribution is emphasized to SN and aspects of emotion regulation, attention modulation and conflict monitoring, reflecting the heightened salience of internal experiences and emotional intensity frequently characteristic of the psychedelic state (Carhart-Harris et al., 2012; Müller, 2018; Viol et al., 2017). On the other hand, bilateral superior medial frontal gyrus is attributed to the DMN with functional roles of self-referential

processing, mental time travel and autobiographical memory, and often showing altered dynamics either hypo- or hyperactivated depending on psychedelic substance and state phase, typically linked to ego dissolution and introspection features (Carhart-Harris et al., 2016; Soares et al., 2023; Tagliazucchi et al., 2016; Vollenweider et al., 2023). Left insula can be functionally attributed to SN and seems responsible for switches between internal and external attentional states, and often related to interoception integration, with heightened awareness of bodily sensations and emotional states (Carhart-Harris et al., 2012; Craig, 2009; Stoliker et al., 2023; Viol et al., 2017). The left inferior frontal gyrus (triangular part) refers in general to the VAN with functional properties of attentional reorientation, language processing and affective regulation, for instance during the psychedelic state, altered linguistic processing can rely on inner dialogue and auditory-verbal phenomena, characterized by enhanced attentional shifts (Carhart-Harris et al., 2014; Palhano-Fontes et al., 2015).

Concerning hypnosis state condition, decreased activations were identified in two clusters. The first spanning bilateral anterior and median cingulate and paracingulate gyri, and bilateral superior medial frontal gyrus at a cluster size of 454 voxels. The second spanning bilateral anterior cingulate and paracingulate gyri, and bilateral superior medial frontal gyrus at a cluster size of 78 voxels. Bilateral anterior and median cingulate cortex and paracingulate gyri are generally attributed to the SN and salience cingulo-opercular network (CON), with functional roles in cognitive control and error detection, supporting aspects of diminished volitional attentional, enhanced absorption, and properties of emotion regulation featured by reduced emotional salience (Deeley et al., 2013; Del Casale et al., 2021; Jiang et al., 2016; McGeown et al., 2009). Bilateral superior medial frontal gyrus can be attributed to the DMN and frontal executive network such as the salience-CON, in relation to functional roles of self-referential thinking, mentalizing and executive introspection, thus supporting the characteristic features of reduced narrative self-awareness and spontaneous thought (Halligan & Oakley, 2013; Hoefft et al., 2012; Landry et al., 2017).

### **Neural activity convergence between ASCs**

Across all pairwise comparisons, overlap of threshold maps suggested relative convergence within the SN and SMN, with accompanying involvement of subcortical structures, the visual network, and temporal-limbic systems. We note that this convergence is descriptive (map co-localization) rather than a formal conjunction with family-wise error control. Functionally, the increases can be summarized into two provisional patterns. First, a visual-limbic and temporal-posterior DMN pattern encompassing visual cortex and medial temporal-limbic regions, consistent with mental imagery, affect-laden recall, and memory integration, aligning with ASC phenomenology of vivid internal

narrative, imagery, and ego transformation (Carhart-Harris et al., 2012; Deeley et al., 2013; Delli Pizzi, 2023; Gattuso et al., 2023; Soares et al., 2023). Second, a salience-sensorimotor-subcortical pattern involving anterior salience hubs with sensorimotor and subcortical circuitry, consistent with interoceptive monitoring, salience tagging, attentional switching, and action readiness, processes commonly reported during meditation, hypnosis, and psychedelic states (Avram et al., 2021; Craig, 2009; Fox et al., 2016; Preller et al., 2019; Van Elk & Yaden, 2022; Zeidan et al., 2011). However, each pair of ASC category still showed some specificity upon convergent increased activation. Specifically common to hypnosis and meditation were identified two functional patterns, the CEN and DMN with their potential interaction suggesting voluntary control over introspection (Brewer et al., 2011; Farb et al., 2007; McGeown et al., 2009; Sim et al., 2024), and the additional couple of thalamus and caudate referring to the cortical-subcortical loop of consciousness transitions regulation (Boly et al., 2011; Jiang et al., 2016). Unique to hypnosis and psychedelics were identified two functional patterns, the posterior parietal and dorsal attention network (DAN) hyperactivation referring to the characteristic heightened perceptual decoupling (Landry et al., 2017; Lemerancier & Terhune, 2018; Viol et al., 2017), and the increased limbic and amygdala recruitment as referred to features of affective intensity (Carhart-Harris et al., 2012; Craig, 2009). The last pair of psychedelics and meditation also depicted neural pattern of its own, such as increased frontal control circuits, supporting attentional effort and mental content regulation (Carhart-Harris et al., 2014; Hölzel et al., 2008; Millière et al., 2018; Tang et al., 2015).

From the conjunction results of functional hypoactivation, all pairs showed relative convergence upon down-regulation of DMN, visual network, salience and CON, SMN, temporal association including memory systems, and orbitofrontal including affective valuation systems, suggested as a central pattern of ASCs and in line with the field of research (Kumar et al., 2024; Moujaes et al., 2024; Timmermann et al., 2023). The DMN, generally referring to self-referential thinking, narrative construction and autobiographical memory, seems typically decreased during all ASCs and stands in correlation to suppression of ego narrative and mind-wandering (Brewer et al., 2011; Carhart-Harris et al., 2012; Guldenmund et al., 2012; McGeown et al., 2009). Decrease in visual network, which is normally associated to visual processing, mental imagery and perceptual decoupling, seems indicating an inward shift of awareness during ASCs (Deeley et al., 2013; Luders et al., 2011; Viol et al., 2017). Downregulation of the SN and CON, usually responsible for attention switching between internal and external cues, conflict monitoring and salience mapping, seems reflecting the suspension of cognitive vigilance and loss of volition, typically characteristic of ASCs (Craig, 2009; Hölzel et al., 2011; Landry et al., 2017). SMN generally responsible for bodily representation, proprioception and motor readiness and decreased during the measured ASCs, supports a state of

body stillness, floating and/or detachment but this could be more representative of a passive ASC and potentially due to the setting of fMRI scans (Deeley et al., 2013; Fox et al., 2016). ASCs also impacted orbitofrontal and valuation systems and its modulation properties of emotional prediction and reward valuation, such as its decreased activation seems correlated to aspects of detachment from affective judgments and social relevance (Carhart-Harris et al., 2014; Dietrich, 2003; Zeidan et al., 2011). Semantic memory, episodic recall and inner speech typically relies on temporal association and memory networks, and while diminished during ASCs, potentially entails attenuated inner narrative and memory recall (Carhart-Harris et al., 2014; Hölzel et al., 2008; McGeown et al., 2009). This last suppression upon temporal regions were moreover uniform for hypnosis and psychedelics conjunction pair, suggesting a potential stronger perceptual-semantic disengagement (Carhart-Harris et al., 2014; Deeley et al., 2013; Landry et al., 2017).

Despite this overall convergence, one single distinction appeared for the pair hypnosis and psychedelics, such as thalamocortical and subcortical relay systems were not apparently activated, outlining the potential strength specific to meditation for introspective gating mode, a stronger detachment from sensory relays. Indeed, these networks are typically related to functional properties of sensory relay and consciousness modulation (Boly et al., 2011; Guu et al., 2023; Jiang et al., 2016; Tang et al., 2015).

**Table 7**  
*Summary table for the pairwise overlap results and neurocognitive networks distribution*

| State pair                | % voxel overlap for hyperactivation | % voxel overlap for hypoactivation | Dominant increased shared networks                                               | Dominant decreased shared networks                      |
|---------------------------|-------------------------------------|------------------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------|
| Meditation × Hypnosis     | 85%                                 | 83%                                | Saliency, sensorimotor, thalamo-striatal, visual                                 | DMN, orbitofrontal, temporal language, saliency         |
| Hypnosis × Psychedelics   | 90%                                 | 81%                                | DMN (hippocampus/parahippocampus), dorsal/ventral attention, limbic-amygdala     | DMN, saliency, visual, temporal association             |
| Psychedelics × Meditation | 86%                                 | 84%                                | Frontal control (IFG/MFG), parietal multimodal integration, subcortical saliency | DMN, thalamocortical relay, posterior cingulate, visual |

*Note.* Across all three pairs the triple-network motif (DMN, saliency, central executive) plus sensorimotor nodes accounted for the bulk of concurrence, supporting the hypothesis that these ASCs modulate common large-scale control systems rather than isolated loci.

Collectively, this two-tiered approach, systematic review followed by quantitative neuroimaging meta-analysis, provided a robust framework for elucidating convergent and divergent neural substrates underlying experimentally induced ASCs in healthy adults. In sum all three state

conditions related to hypnosis, meditations and psychedelics were overall strongly convergent for increased and decreased activation with over 80% overlap for all pairwise conjunctions. Regarding shared functional hyperactivation across ASC modalities, it is important to emphasise that convergent up-regulation emerged within salience-interoceptive nodes, sensorimotor areas and limbic-temporal regions, suggesting a recalibration from self-referential to embodied, affectively rich processing. On the other hand, regarding shared functional hypoactivation, results indicate robust decreases centred on canonical hubs of the default-mode network (posterior cingulate, medial prefrontal cortex), extended visual association cortex and anterior insula/cingulo-opercular system. This pattern aligns with diminished narrative self-processing, reduced external vigilance and attenuated interoceptive salience, phenomenological hallmarks of “ego-dissolution,” absorption and perceptual decoupling reported in ASC literature (Brandmeyer & Delorme, 2021; Hove et al., 2016; Lifshitz et al., 2019; Lindström et al., 2023; Mortaheb et al., 2024). State-specific differences were modest: meditation preferentially recruited thalamo-striatal loops consistent with volitional attention, psychedelics enhanced frontal-limbic coupling linked to emotional intensity, and hypnosis uniquely engaged dorsal parietal regions implicated in perceptual detachment.

Building on this, we propose that ASCs converge on key networks governing self-referential processing and salience detection, while retaining modality-specific signatures. Although these findings offer, from a preliminary perspective, a neural framework for trans-modal therapeutic effects and guide future mechanistic trials, several important limitations must be acknowledged. First, only the meditation analysis yielded TFCE-corrected clusters; findings for hypnosis and psychedelics rely on uncorrected, exploratory thresholds and should be interpreted cautiously. Second, the corpus is heterogeneous: imaging modalities (fMRI, PET, ASL, SPECT), baseline conditions (eyes open vs. closed; fixation vs. unconstrained rest), and induction protocols (e.g., hypnosis scripts; meditation styles) vary across studies and may contribute to residual between-study differences. The psychedelics set also combines classical 5-HT<sub>2A</sub> agonists with atypical agents (ketamine, MDMA), with limited granularity for dose, route, and timing, precluding definitive pharmacology-specific inferences. Third, two domains are small ( $k < 10$ ), rendering publication-bias tests underpowered and limiting subgroup/meta-regression options as for influential effects from individual variables (Buric et al., 2022; Vizeli, 2024). Fourth, our cross-state “convergence” is descriptive, based on overlap of threshold maps, rather than a formal conjunction with family-wise error control. Finally, although we excluded ROI-only studies and followed a common SDM-PSI pipeline, reporting practices and data/code availability varied, and we did not implement a quality-weighted sensitivity analysis; future updates should incorporate standardized risk-of-bias scoring, quality-based exclusions, and pre-specified subgroup/meta-regression frameworks to enhance robustness.

Functional characterization of overlapping brain regions could have relied on categorization of term-based meta-analyses within the Neurosynth databases (Yarkoni et al., 2011), specifically for interpretative purposes.

With this in mind, we understand that the data of the current review and meta-analyses should be taken with great caution. Nevertheless, we believe, this study offers several strengths. First, it is preregistered and follows PRISMA procedures, enhancing transparency and reducing analytic flexibility. Second, all three domains were processed with a unified, whole-brain SDM-PSI pipeline (ROI-only studies excluded), improving methodological consistency and comparability. Third, despite small  $k$  in two domains, the work includes robustness checks (random-effects modelling, jackknife and leave-one-out), and clearly separates TFCE-corrected findings from exploratory results, which helps readers calibrate evidential strength. Fourth, the psychedelics corpus ( $k = 25$ ) is comparatively large and diverse, offering a valuable synthesis that many single-substance reviews lack. Fifth, by analysing three ASCs separately and then inspecting descriptive cross-state overlap, the paper avoids inappropriate pooling while still providing hypothesis-generating convergence maps for future confirmatory tests. Sixth, the study demonstrates good reporting hygiene (coordinate space, thresholds, peak tables) and proposes a risk-of-bias and quality framework with pre-specified subgroup plan that can be adopted in subsequent updates. Finally, the integrative framing, linking candidate networks across meditation, hypnosis, and psychedelics, supplies a coherent neural model of altered states with direct clinical and translational relevance (such as targetable circuits for intervention and mechanistic predictions for trials).

### **Future perspectives**

Collectively, the findings support a “common ASC signature” characterised by interplay among the default-mode, salience and executive networks, an empirical extension of the triple-network model of cognitive and affective processing, and consciousness state transition (Menon, 2019). This central feature of ASCs, mindfulness meditative, hypnotic and psychedelic states, supports the suggested therapeutic effects and mechanisms, indeed the modulation of cognitive process and emotion regulation could foster adaptative or reinforcing psychological aspects of self-processing or self-specifying (Gattuso et al., 2023; Soares et al., 2023; Stoliker et al., 2024), and the activated or emergent content of conscious experience could allow transformative experiential phenomena, such as described for concepts of insight or spiritual awakening (Corneille & Luke, 2021; Tulver et al., 2023), both aspects suggested as a product of integrative mode of consciousness (Kumar et al., 2024; Mansell, 2024). Accordingly, alteration of sensory perception and disruption of self-referential thought processes linked to ASCs can be suggested as pivotal mechanisms in the complementary

application for mental health care, such as enduring effects on anxiety and depression symptoms, existential distress, capacity to manage stress, pain and emotions (Nguyen & LAVretsky, 2020; Nikolaidis et al., 2023; Schimmers et al., 2022; Williams et al., 2024; Yao et al., 2024; Zhang et al., 2024) (Nguyen & LAVretsky, 2020; Nikolaidis et al., 2023; Schimmers et al., 2022; Williams et al., 2024; Yao et al., 2024; Zhang et al., 2024), and synergistic effects with psychotherapy (Baker & Spiegel, 2019; Palsson et al., 2023; Shonin et al., 2015). Moreover, beyond mere brain functional activity, investigation of functional connectivity patterns will certainly be useful to depict brain dynamics, not only where but how activations occurs in time duration across space and between neural regions (Bremer et al., 2022; Girn et al., 2022; Luppi et al., 2021). Thus, regardless of the state or process nature of induced consciousness alterations, open prospects remain regarding target specification for clinical population and the long-term effects at neural or psychological levels (Aday et al., 2020; Fingelkurts et al., 2022).

## Conclusion

This work provides the first unified, whole-brain, coordinate-based synthesis of functional activity associated with three altered states of consciousness, mindfulness meditation, hypnosis, and psychedelics, together with a descriptive cross-state comparison. While TFCE-corrected effects were observed only for meditation, the remaining domains yielded uncorrected, hypothesis-generating patterns. Overlap of threshold maps suggested substantial spatial convergence (81-90%) across states, indicating a candidate motif of default-mode attenuation with salience, sensorimotor reconfiguration, alongside contributions from visual and temporal-limbic systems. We emphasize that this convergence is descriptive rather than inferential and should be interpreted cautiously given heterogeneity in modality, baselines, and substances.

Taken together, these results offer a transparent quantitative scaffold for future work: preregistered, correction-controlled tests of cross-state conjunction; modality-homogeneous and substance-specific analyses (classical versus atypical); and quality-weighted sensitivity checks. Beyond theory, the emerging pattern highlights network-level targets-DMN, salience, and sensorimotor circuits, that may help bridge neurophenomenology with clinical applications in mental health. As the field accumulates larger and more harmonised datasets, the framework presented here can guide confirmatory investigations into how distinct practices and compounds modulate common and dissociable neural circuits of conscious experience.

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## Supplementary materials

Supplementary materials to this article : (*available at Neuroscience of Consciousness Journal online*). Supplementary data sets can be found online at <https://doi.org/10.17605/OSF.IO/QBPSW> for the meta-analyses and at <https://doi.org/10.17605/OSF.IO/Z3MDN> for the pairwise conjunction analyses.

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