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# An Overview of Neurophenomenological Approaches to Meditation and Their Relevance to Clinical Research

Antoine Lutz, Oussama Abdoun, Yair Dor-Ziderman, Fynn-Mathis Trautwein, and Aviva Berkovich-Ohana

## ABSTRACT

There is a renewed interest in taking phenomenology seriously in consciousness research, contemporary psychiatry, and neurocomputation. The neurophenomenology research program, pioneered by Varela, rigorously examines subjective experience using first-person methodologies, inspired by phenomenology and contemplative practices. This review explores recent advancements in neurophenomenological approaches, particularly their application to meditation practices and potential clinical research translations. First, we examine innovative multidimensional phenomenological assessment tools designed to capture subtle, dynamic shifts in experiential content and structures of consciousness during meditation. These experience sampling approaches enable shedding new light on the mechanisms and dynamic trajectories of meditation practice and retreat. Second, we highlight how empirical studies in neurophenomenology leverage the expertise of experienced meditators to deconstruct aversive and self-related processes, providing detailed first-person reports that guide researchers in identifying novel behavioral and neurodynamic markers associated with pain regulation, self-dissolution, and acceptance of mortality. Finally, we discuss a recent framework, deep computational neurophenomenology, that updates the theoretical ambitions of neurophenomenology to naturalize phenomenology. This framework uses the formalism of deep parametric active inference, where parametric depth refers to a property of generative models that can form beliefs about the parameters of their own modeling process. Collectively, these methodological innovations, centered around rigorous first-person investigation, highlight the potential of epistemologically beneficial mutual constraints among phenomenological, computational, and neurophysiological domains. This could contribute to an integrated understanding of the biological basis of mental illness, its treatment, and its tight connections to the lived experience of the patient.

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Despite advances in neurobiology and neurocomputational understanding of psychopathology, some authors have recently identified a “crisis of contemporary psychiatry” (1). This crisis stems from the limited ability of these disciplines to be used in daily clinical application in diagnosis and therapy (2,3). Some authors argue that we do not yet know the computational mechanisms underlying the psychopathological symptoms (“crisis of mechanism”), whereas others diagnose a neglect of subjectivity, namely, first-person experience (“crisis of subjectivity”) (1). The advocates for considering lived experience suggest prioritizing the examination of structural aspects of experience in psychopathologies through qualitative or phenomenological interviews, aiming to integrate clinical phenomenological research with neuroscience (1,3). Similarly, there is a growing interest in phenomenologically oriented studies across various domains, including cognitive sciences (4), consciousness (5), psychedelics (6), and hypnosis (4).

Aligned with this trend, we reviewed recent developments in the research program of neurophenomenology, particularly

in the context of mindfulness meditation research. Neurophenomenology was initially introduced by Varela as a methodological approach to the scientific investigation of consciousness (7,8). Neurophenomenology emphasizes the careful examination of experience using rigorous first- and second-person methods inspired by phenomenology and contemplative practices. These practices involve systematically training attention and regulating emotions to achieve refined and rigorous analyses and descriptions of experience, such as transient affective states; the quality of attention; or the tacit, preverbal, and pre-reflective dimensions of subjective experience, which may otherwise go unnoticed and be unavailable for verbal report (9–11). This allows for disciplined descriptions of experiential content (what appears to the experienter) as well as its structure (how it appears; e.g., sense of time, self, subject-object duality). These first-person accounts of experience can then guide and inform the interpretation of neurophysiological processes relevant to consciousness in such a way that first-person data and empirical data mutually constrain each other (7). The epistemic

value of employing this methodology has been discussed in a clinical context (3) and demonstrated in empirical studies, revealing novel neurodynamic correlates of attention (12), providing insights into the plasticity of false memory (13,14) and the volitional plasticity of self-awareness and its boundaries (15,16), and integrating neurofeedback with mindfulness meditation (17,18).

As an organizing framework, we propose in the first section below 5 approaches (A1–A5) to integrate a systematic examination of lived experience into empirical research, fulfilling complementary roles and yielding different epistemic outcomes (Table 1). In the second section, we present recent methodological tools to assess lived experience during the practice of meditation (discussing A1 and A2). Next, we show in the third section the pragmatic value of incorporating trained participants in research by exemplifying the

neurophenomenological methodology through fresh empirical insights drawn from the domain of mindfulness meditation research (demonstrating A3). In the fourth section, we explore how the previously mentioned crises concerning mechanism and subjectivity were initially tackled within the theoretical framework of neurophenomenology with the aim to naturalize phenomenology (12,19–21) and how this framework has been recently updated. This updated computational framework, grounded in Bayesian mechanics (22,23), facilitates the establishment of a bridge between phenomenology and neurobiological mechanisms, enabling the interplay between first-person and third-person perspectives on understanding consciousness (discussing A4 and A5). In the last section, we discuss the implications of this framework for mental health research.

Box 1 contains a glossary of terms relevant to this article.

**Table 1. Approaches (A1–A5) to Investigate the Lived Experience of Contemplative Practices**

| Approaches                                 | Domains                               | Methods  | Epistemic Outcomes  | Examples   |
|--|---------------------------------------|--|---|--|
| A1: Phenomenological Inquiries             | 1PP (thick)                           | Training in a first-person method (e.g., mindfulness meditation, phenomenological epoche)  | Increase in meta-cognitive skills (e.g., meta-awareness, dereification)   | Przyrembel and Singer, 2018 (52); Petitmengin <i>et al.</i> , 2019 (50); Segal <i>et al.</i> , 2019 (84); Poletti <i>et al.</i> , 2021 (32)  |
|  |                                       | Second-person method (e.g., microphenomenological interview, clinical interview)   | Produce and maintain a target state or phenomenological feature (e.g., compassion)  |  |
| A2: Experimental or Clinical Phenomenology | 1PP (thin or thick reduced to thin)   | A1 and quantitative methods using phenomenological scales  | Statistical regularities in phenomenological reports across time and individuals as well as between phenomenological dimensions   | Kok and Singer, 2017 (55); Segal <i>et al.</i> , 2019 (84); Nave <i>et al.</i> , 2021 (47); Poletti <i>et al.</i> , 2021 (32); Jachs <i>et al.</i> , 2022 (38); Abdoun <i>et al.</i> , 2024 (39)   |
| A3: Experimental Neurophenomenology        | 1PP and 3PP (behavior and physiology) | Participants trained in A1 or A2 to help the scientist create mutual constraints between 1PP and 3PP   | Identification of novel (neuro) physiological correlates from A1 or A2  | Lutz <i>et al.</i> , 2002 (37); Petitmengin <i>et al.</i> , 2007 (85); Garrison <i>et al.</i> , 2013 (17); Dor-Ziderman <i>et al.</i> , 2013 (15); Ziderman <i>et al.</i> , 2016 (16); van Lutterveld <i>et al.</i> , 2017 (18); Kyzar and Denfield, 2023 (3); Trautwein <i>et al.</i> , 2024 (33) |
| A4: Computational Phenomenology            | Formal modeling, with or without 3PP  | Modeling of existing data from formal phenomenology (A1)   | Explanatory and predictive models of specific phenomenological invariants from A1<br>Isomorphic relationships between 1PP and 3PP | Farb <i>et al.</i> , 2015 (72); Moye and Van Vugt, 2019 (26); Pagnoni, 2019 (71); Sandved-Smith <i>et al.</i> , 2021 (68); Hesp <i>et al.</i> , 2021 (74); Smith <i>et al.</i> , 2021 (70); Ramstead <i>et al.</i> , 2022 (23)   |
| A5: Deep Computational Neurophenomenology  | 1PP and formal modeling and 3PP       | Disciplined circulation between 1PP and 3PP (A3) enabled by the formalism (A4); a paradigmatic formalism is deep parametric active inference | Generative passages between 1PP and 3PP: explanatory and predictive model of specific neurophenomenological invariants            | Beckmann <i>et al.</i> , 2023 (86)<br>Sandved-Smith <i>et al.</i> , 2024 (22)  |

1PP, first-person perspective; 3PP, third-person perspective.

## Neurophenomenology of Meditation: Clinical Relevance

**Box 1. Glossary of Relevant Terms**

**Dereification** refers to the cognitive process of recognizing thoughts, feelings, or mental images as mere mental constructs rather than as concrete realities. It involves seeing one's internal experiences—thoughts, feelings, and perceptions—as transient, subjective events in the mind rather than as objective truths or facts about the world, and phenomenally interpreted as mental processes rather than as accurate depictions of reality (56).

**Embodied and enactive mind** refers to the idea that cognition is not just a product of brain processes, but also deeply rooted in the body's interactions with the environment. In this view, cognition and consciousness are understood as deeply rooted in the dynamic interactions between brain, body, and environment. Cognition is not just something that happens in the brain, but rather is enacted through the body and its engagements with the world, emphasizing the active, relational, and emergent nature of the mind (78).

**Epistemic gains** in active inference refer to the process by which an agent (biological or artificial) seeks information through action to reduce uncertainty about its environment (24,25). Similarly, in this context, insights from meditation practices or the phenomenal reductions achieved during meditation represent a form of epistemic gain arising from the mental actions employed. Additionally, epistemic gains apply to the scientist within a neurophenomenology paradigm, who leverages the epistemic insights of meditators to generate new knowledge by modeling meditation and conducting experimental research.

**Equanimity** refers to a state of mental and emotional stability, calmness, and balance, especially in difficult or challenging situations. It is the ability to maintain a level-headed demeanor and remain composed, regardless of external circumstances. Equanimity often involves being able to accept both positive and negative experiences with a sense of serenity, without becoming overly attached or reactive to them. It is a mental experience that is neither pleasant nor unpleasant and that involves neither intensifying nor dampening current mental states (82).

**First-person methods** are disciplined practices aimed at increasing participants' sensitivity to their own experiences at various timescales (8). These practices involve the systematic training of attention and self-regulation of emotion and can be found, for instance, in phenomenology, psychotherapy, and contemplative meditative traditions. A canonical example is mindfulness meditation.

**Focused attention** meditation involves sustaining selective attention on a chosen object, such as localized sensations from breathing. The meditator monitors attention quality, and when focus shifts to distractions (e.g., pain), they recognize it, release the distraction, and return to the object. This practice develops 3 skills: monitoring for distractions, disengaging from them, and redirecting focus. Progress is measured by reduced effort needed to maintain focus (80).

**Generative passages** is a term coined by Varela (19) to describe the epistemologically fruitful exchange of knowledge between phenomenology, formalism, and neurobiology. A passage is considered generative when there is mutual circulation and illumination between the neurobiological domain and the entire phenomenal domain (19). In his work on time consciousness, Varela (19) initially suggested using dynamical systems theory to facilitate this exchange. More recently, Sandved-Smith *et al.* (22) proposed generating these passages through the deep computational neurophenomenology framework (see Figure 4).

**Gesture** is a dynamic, embodied, and meaningful movement that plays a crucial role in how we experience, express, and communicate with the world. It is not just seen as a physical movement, but rather as an integral part of cognition and consciousness, intertwining body, mind, and environment in the co-construction of meaning: "It is characteristic of the human gesture to signify beyond its simple factual existence and to inaugurate a meaning" (79).

**Isomorphic relationship** refers to a structural similarity or correspondence between 2 systems, models, or sets of elements, where the relationships between elements in one system are mirrored in the other. In neurophenomenology, this will refer, for instance, to a functional relationship between a phenomenal structural invariant (levels A1 and A2) (e.g., level of perceived attentional stability) and some patterns of brain or physiological processes (level A3).

**Lovingkindness and compassion** meditation is a practice that involves focusing on cultivating feelings of compassion, love, and goodwill toward oneself and others. The practice aims at increasing emotional resilience, empathy, and a sense of interconnectedness, while reducing feelings of anger and isolation (81). Any reduction in attachment, aversion, or delusion as cultivated by open monitoring and focused attention meditations helps refine and expand the force of loving-kindness.

**Meta-awareness** refers to the ability to monitor one's own mental processes, such as being aware of one's thoughts or awareness itself, enabling individuals to recognize and potentially modulate their current mental state.

**Mutual, or reciprocal, constraints** (7) refer to the epistemology of neurophenomenology by which specific first-person data collected via first- or second-person methods can provide novel knowledge to help the researcher to validate, interpret, or analyze third-person data such as physiological data. Reciprocally, empirical findings could lead to adjustments and refinements in the subjective reports (e.g., neurofeedback). There are different ways of bridging between these 2 domains [see (10,11,37)].

**Open monitoring** meditation involves maintaining open, moment-by-moment awareness of experiences without selecting any particular focus. The monitoring skill developed in focused attention meditation becomes central, with an emphasis on reflexive awareness, allowing one to notice aspects of experience such as emotional tone without making them explicit focuses. As practice progresses, the need to grasp objects fades, replaced by an effortless awareness. Open monitoring meditation aims to enhance awareness of implicit mental features, helping transform cognitive and emotional habits, reducing emotional reactivity, and fostering sensitivity to body and environment (80).

**Phenomenological epoche** is a concept from phenomenology, introduced by Edmund Husserl, which refers to the practice of suspending or bracketing one's judgments, biases, and preconceived beliefs about the existence of the external world to examine an experience purely as it is presented to consciousness. This process involves suspending habitual judgment, redirecting attention inward and receptivity toward the experience (77). The epoche is closely related to the construct of cognitive defusion in psychology, or of dereification.

**Second-person methods** are interview techniques designed to elicit both verbal and nonverbal information from participants aimed at capturing aspects of experience that remain pre-reflective and unnoticed by the participants themselves (60,76). These research approaches focus on the interactive, relational aspects of experience, involving a direct exchange or dialogue between the researcher and participants. A canonical example is the micro-phenomenological interview (60).

**Structural invariant** refers, in phenomenology or cognitive science, to a consistent, underlying feature or pattern of experience that remains stable across different contexts or variations in the content of consciousness. It represents the fundamental structures that shape how we perceive, think, or feel, regardless of specific experiences.

**Subjective realism** refers to the way one perceives the content of experience, such as memory, as subjectively real (83). This concept aligns with the notions of **cognitive fusion, experiential fusion, or reification**.

## LANDSCAPE REVIEW OF NEUROPHENOMENOLOGICAL APPROACHES

We propose 5 approaches (A1–A5) to integrate a systematic examination of lived experience into empirical research, fulfilling complementary roles and yielding different epistemic outcomes (Table 1). These diverse approaches fulfill complementary roles, each pursuing somewhat distinct research agendas. A1 allows for an investigation of thick complex phenomenology (10), whereas A2–A5 focus, for pragmatic reasons, on selected thin phenomenological invariants, simple enough to be investigated in experimental, quantitative, and (neuro)physiological research contexts. Note that phenomenologically thin data may be obtained directly from self-reports or distilled from interviews conducted with an experienced meditator. Approaches A1 and A2 are preliminary and necessary steps for the naturalization of target phenomenological invariants. They lie on a thick-to-thin continuum (10), representing the tension between capturing the depth and density of lived experience (thick descriptions, A1) and the practical need for rapid, standardized, and intensive sampling (thin approaches, A2). Selected recent examples are provided in Table 1 for illustration purposes [see (10,11) for a review]. More specifically, the 5 approaches are as follows:

- A1: Phenomenological inquiries, which can involve trained disciplined meditators and which employ in-depth interviews, with the epistemic gain (EG) of enabling the identification of novel phenomenological structural invariants (both the what and the how of experience), which can be intersubjectively validated and replicated.
- A2: Experimental/clinical phenomenology, which, for pragmatic reasons, focuses on selected phenomenological invariants. These invariants, while building on A1, are simple enough to be empirically investigated in experimental, quantitative, and (neuro)physiological research contexts. The EG here lies in describing statistical regularities in phenomenological reports.
- A3: Experimental neurophenomenology, which builds on A2 to create mutual constraints between first-person and third-person perspectives. The EG is identifying novel neurophysiological correlates of conscious experience and vice versa.

A4 and A5 are 2 complementary computational approaches, offering computational models of the embodied and enactive mind. These models derive from Bayesian theories of the brain (24,25), even if alternative formalisms exist (26).

- A4: Computational phenomenology models of existing phenomenological invariants, with the EG of constraining the necessary conditions of a (biological) agent by specific phenomenological invariants.
- A5: (Deep) Computational neurophenomenology, which creates a formal circulation or generative passages across first-person perspective, formal level (A4), and third-person perspective with the EG of explanatory/predictive power of specific model parameters and neurophenomenological invariants. The adjective “deep” is used when modeling the how and not just the what of experience.

## RECENT ADVANCES IN FIRST- AND SECOND-PERSON APPROACHES TO ASSESS (MEDITATIVE) EXPERIENCE

Phenomenological assessment tools for neurophenomenology paradigms of meditation (A1 and A2 in Table 1) share a common interest to move beyond conventional trait-based measures of mindfulness to enrich both the synchronic (co-occurring, parallel) and diachronic (temporal, dynamic) descriptions of subjective experience. Mindfulness questionnaires measure the self-representations of a variety of processes that do not necessarily reflect an overarching trait (27,28) and are responded to differently by meditators and nonmeditators (29). At least one study has shown that nonmeditators did not have an adequate understanding of items from a mindfulness questionnaire (30), which may explain implausible findings such as binge drinkers and opioid users reporting similar levels of mindfulness as healthy participants or even experienced meditators (27,31). In contrast, phenomenological assessments intend to probe embodied, situated, and immediate or recent experience beyond self-representations (13). Such assessments have shown somewhat better predictive power of behavior and neural activity than gold-standard trait scales (32,33).

The methodological approaches that have been developed can be organized along 2 orthogonal axes. One axis is a thick-to-thin continuum (10), where thick refers to rich descriptions of singular experiences over different timescales, and thin refers to brief assessments of predefined variables (i.e., experience sampling or a brief semistructured self-report). Here, thin data can be formalized as third-person-perspective data or correlated to neural activity (34–36). The second axis is a time span of the phenomenon of interest, which can range from the retention of just-past moments (37), the ongoing monitoring of a few moments (38), a meditation session (39), or salient experiences in life (40).

In the field of mindfulness research, 3 investigative themes have emerged in the last 2 decades: advanced or non-ordinary meditative experiences, core processes and gestures of meditation practice, and the dynamics of phenomenological shifts induced by meditation.

### Theme 1: Advanced or Non-ordinary Experiences

Lindahl *et al.* (40) pioneered the study of underreported, challenging, difficult, distressing, or functionally impairing meditation-related experiences, identifying a taxonomy of 59 experiences across 7 domains. Following this broadened scope of meditation-related experiences, subsequent studies started to document their prevalence in both clinical and nonclinical populations (41–43) [but see (44) for a recontextualization of these so-called adverse effects within larger transformative trajectories]. Importantly, Lindahl *et al.* (40) have also investigated the factors that positively or negatively influence meditation-related challenges, finding that they range from psychiatric and trauma history to worldviews, sociocultural mismatch, and quality of relationships.

Other studies have focused on non-ordinary meditative states, such as non-dual meditations (32,45,46), which are traditionally thought to require extensive training and mastery

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in meditation. An important methodology in this context is the micro-phenomenological interview (MPI), which enables researchers to identify a set of distinctive co-occurring experiential features associated with a specific state, gesture, or event that generalize well across practitioners and instances of the targeted phenomenon. Using this technique, Nave *et al.* (47) conducted a comprehensive phenomenological inquiry into what is considered an important stage in many contemplative traditions, namely, self-world boundary (SB) dissolution (see [Recent Advances in Neurophenomenology Approaches in Mindfulness Meditation Research](#) for more details). Alcaraz-Sanchez *et al.* (48,49) explored the synchronic and diachronic expressions of objectless awareness during sleep, a minimal state of consciousness that is theorized and cultivated in Indian Yogic systems (*sushupti* in Sanskrit) and Buddhist Tantric schools (*ösel* in Tibetan, commonly translated as clear light sleep). Although this area of research remains speculative and primarily limited to case studies, posing a great challenge for external validation, it illustrates the promise of mobilizing first-person and contemplative expertise to understand non-ordinary states of consciousness.

### Theme 2: Core Processes and Gestures

Somewhat paradoxically, more ordinary processes and gestures commonly involved in meditation practice have received less empirical scrutiny. The MPI remains the preferred tool for most studies investigating that theme. For instance, Pettimengin *et al.* (50) used MPIs to explore the initiation of mind-wandering episodes and the emergence of a thought and found that they were accompanied by bodily tension and uncomfortable sensations of head-body disconnection, which might partly explain the unpleasantness associated with a significant portion of mind-wandering episodes (51). Przyrembel and Singer (52) explored how novice participants applied different meditation instructions and found distinctive linguistic, affective, and bodily fingerprints for breathing, lovingkindness, and thought-observing practices. Poletti *et al.* (32) interviewed and compared novice and expert practitioners regarding their habitual relationship to and management of pain. They identified 5 phenomenological clusters organized along a gradient of cognitive defusion: While most novices conceived of pain as a primarily physical phenomenon to be avoided and suppressed or controlled and distanced, a majority of experts leveraged the nociceptive experience to develop metacognitive insight into their own suffering and support compassion for all beings. These clusters predict phenomenological self-reports during a pain paradigm. As many contemplative scientists are practitioners themselves, some have started to turn the lens inward, conducting self-interviews on meditation experiences (53) or pursuing a collaborative first-person science of consciousness (54).

### Theme 3: Dynamics of Phenomenological Shifts

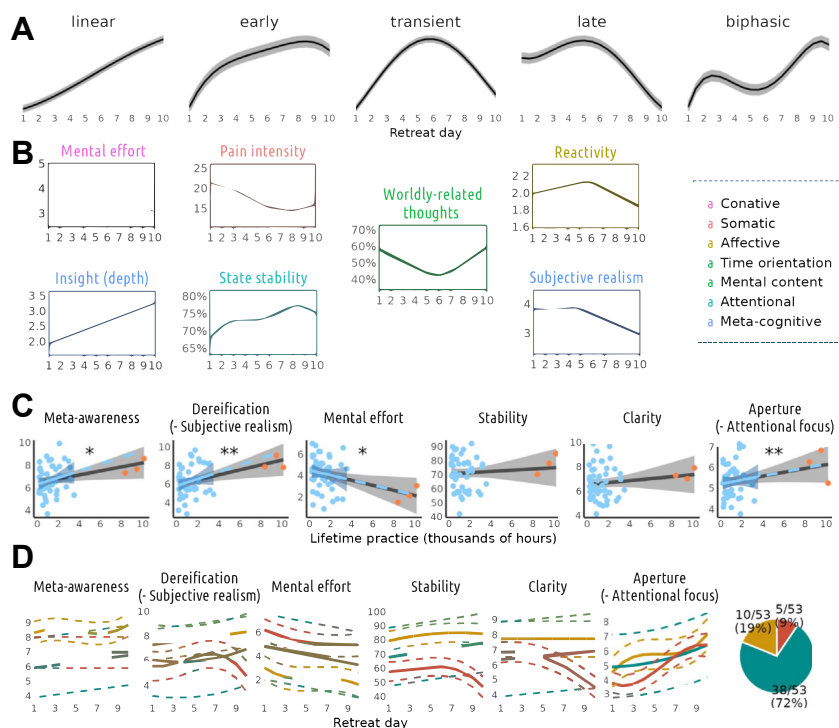
The first-person information garnered with MPI can be used to refine the interpretation of third-person data or inform the design of new studies (see [Recent Advances in Neurophenomenology Approaches in Mindfulness Meditation Research](#)). However, a limitation of this approach is its requirement for high-level methodological skills and the time-

consuming nature of the process, making it less suitable for larger-scale or longitudinal investigations (e.g., capturing developmental trajectories of meditative expertise). Several teams have addressed this challenge by developing instruments that could be used by practitioners autonomously, without the intervention of the experimenter, and that were amenable to quantification.

Kok and Singer (55) proposed metrics to quantify changes in meditation-induced experiential aspects, including the characteristics of spontaneous thoughts (temporality, self-relevance, valence), emotion and attentional states, and meta-cognition. They implemented a questionnaire within the ReSource project, a 9-month modular mental training program designed to elucidate the specific effects of 4 distinct meditation practices. They found that all investigated practices shared some common effects, notably in reducing distraction and improving emotional states. However, lovingkindness meditation uniquely fostered positive thoughts toward others, whereas body scan and observing-thought meditations were the most effective to enhance interoceptive and metacognitive awareness, respectively. Notably, observing-thought meditation was the sole practice that did not decrease the frequency of spontaneous thoughts (55).

Zooming in on the dynamics of individual meditation sessions, Jachs *et al.* (38) introduced temporal experience tracing as a continuous graphical method allowing practitioners to report the multidimensional fluctuations of experience occurring during a single meditation session. The researchers identified 4 metastable states, each characterized by a specific phenomenological profile and dominating distinct practices (38).

Extending these efforts, the Lyon Assessment of Meditation Phenomenology questionnaire was recently introduced as a multidimensional experience-sampling approach to characterize the dynamics of meditative experience over many sessions (39). It allows the measurement of shifts in subjective experiences across 6 domains: conative, affective, somatic, attentional, meta-cognitive/reflexive, and cognitive. In their validation study, the authors administered the Lyon Assessment of Meditation Phenomenology to experienced practitioners during a 10-day intensive meditation retreat and extracted statistical regularities in the temporal evolution of various dimensions of contemplative experience (Figure 1B). These dimensions could be grouped into a small number of temporal evolution classes (Figure 1A), paralleling the natural progression of the retreat from concentrative practices (focused attention) to a broader scope of nonselective attention (open monitoring). Thus, while many dimensions showed a linear progression during the course of the retreat, suggesting that they are general outcomes of practice (e.g., physical relaxation, mental ease, meta-cognitive insight), others increased more markedly early in the retreat, including some widely considered specific targets of focused attention practices (attentional stability, alertness). Two core dimensions of contemplative experience, equanimity and dereification (operationalized as reactivity and subjective realism, respectively), changed only later, possibly reflecting the specificity of open monitoring practices or the requirement for greater proficiency (Figure 1B). The study findings also aligned closely with predictions derived from a theoretical model of contemplative states, known as the phenomenological matrix of mindfulness



**Figure 1.** Thin phenomenology: intensive, multi-dimensional assessment of meditation experience over the course of a 10-day retreat. **(A)** Participants reported significant shifts in meditation experience following dimension-dependent temporal trajectories. Only a sample of the 30 phenomenological dimensions assessed by or derived from the Lyon Assessment of Meditation Phenomenology are shown. **(B)** Temporal trajectories of the 30 dimensions could be clustered in 5 templates. Most dimensions (10 dimensions) displayed linear changes, possibly reflecting specific, cumulative effects of intensive practice. Given that focused attention practices were predominant in the first half of the retreat and open monitoring practices were predominant in the second part, early and late trajectories could be ascribed to focused attention and open monitoring practices, respectively. However, the design of the retreat could not fully disentangle practice style effects from effects of proficiency increasing with time into retreat. **(C)** Relationships between the phenomenological scores averaged across all retreat sessions and the participants' total lifetime practice are congruent with the phenomenological matrix of mindfulness model for meta-awareness, dereification, mental effort, and aperture. While the estimation of the regression lines (black lines) may seem to be driven by the 3 outlier participants (with more than 8000 hours of practice), slopes remain similar when these points are removed (blue lines). **(D)** Data-driven clusters of

participants based on the joint temporal trajectories across the 6 dimensions of the phenomenological matrix of mindfulness model. The green cluster includes the majority of participants ( $n = 38/53$ ). They progressed rather linearly over the time course of the retreat over all dimensions. The yellow cluster is composed of 10 participants with significantly higher lifetime practice. They started high on all dimensions and remained rather stable across the retreat. The red cluster is composed of 5 participants who exerted high effort in their meditation practice yet reported low stability. In contrast to others, these participants decreased in dereification, stability, and clarity in the second part of the retreat.  $*p < .05$ ,  $**p < .01$ .

(56). Participants with extensive accumulated lifetime meditation experience demonstrated higher scores in meta-awareness and dereification, indicating the accrual of practice-related effects over time (Figure 1C). Finally, analysis of interindividual variability via multivariate trajectory modeling revealed the existence of a small subgroup of practitioners ( $n = 5/53$ ) experiencing struggles, especially in the last few days of the retreat (Figure 1D).

To summarize, self-reported and computerized methods complement intersubjectively mediated phenomenological interviews by enabling intensive longitudinal sampling and high-throughput experiments. Critically for our purpose here, it facilitates the fitting, testing, and forecasting of computational models (see [Formal Bridge: Emerging Role of Neurocomputational Approaches in Neurophenomenology](#)).

## RECENT ADVANCES IN NEUROPHENOMENOLOGY APPROACHES IN MINDFULNESS MEDITATION RESEARCH

Recent neurophenomenology projects include studies of meditative cessation states (*nirodha samapatti*), a volitionally induced suspension of consciousness (57,58) and intentional respiration modulation to induce altered states of consciousness (59). While promising, here, following Varela (7,19), we showcase the unfolding of a mature neurophenomenology research program designed to facilitate the scientific study of

consciousness using trained participants. This decade-long research program recently ripened as the first rigorous confirmatory neurophenomenological characterization of conscious states lacking a sense of being a bounded and embodied knower and agent.

Building on an evolving circulation of expertise between phenomenologists, neuroscientists, and contemplatives, selflessness was operationalized using an SB dissolution magnetoencephalography paradigm. High-grade first-person reports were obtained [using MPIs (60)] from 46 long-term mindful-awareness practitioners (33) trained to produce and stably maintain front-loaded conscious states of interest (33). Results highlighted 6 core phenomenological dimensions of embodied self-experience—agency, self-location, first-person perspective, attentional disposition, bodily sensations, and affective valence—associated with dissolution techniques and meditative expertise. Neurophysiologically, full-blown suspension of self-experience was associated with robust beta band power reductions in the posterior medial cortex, establishing it as a key contributor to an integrated embodied perspective in conscious experience (33).

We demonstrate the added value of this methodology by detailing the EGs incurred from acquiring high-grade experiential reports from phenomenologically trained participants and bridging first- and third-person data. These EGs substantiate the A1 through A3 approaches to neurophenomenology.

### EG1: Gaining an Experiential Hold on Dynamic and Elusive Mental States (A1)

A barrier to studying non-ordinary states is mapping their experiential features, which can be subtle, fleeting, and inefable. Thus, their study demands rigorous and systematic first- and second-person interviewing methods (60), as well as sustained meditation practice (Figure 2A). These involve suspending naive beliefs about the experience of interest and guiding attention toward its pre-reflective facets (e.g., subtle inner acts or microgestures associated with an experience). Here, this rich experiential exploration of the SB phenomenon sets the stage for integration with third-person measures.

### EG2: Bringing Non-ordinary States of Consciousness to the Laboratory (A1)

A second barrier to studying non-ordinary states of consciousness is bringing them to the laboratory. While SB dissolution may arise spontaneously, and with higher frequency when consuming psychoactive substances, during meditation, or as a result of certain psychopathologies, measuring their associated neural activity requires on-demand production in a repeated and stable manner. Laboratory conditions involve being connected to devices, the presence of noise, maintaining certain bodily postures, being observed, and time limitation. By collaborating with a highly adept contemplative—initially as participant (15) and later as co-researcher (16,33,61)—a custom-tailored training regimen capitalizing on participants' meditative attentional skills was developed to systematically generate these states. This yielded phenomenologically trained participants capable of producing the target mental state under laboratory conditions, allowing front-loading the phenomenology-based SB dissolution construct onto a neuroscientific experiment (Figure 2C).

### EG3: Quantifying Experiential Dimensions for Assessing Statistical Relationships (A2)

Reducing complex qualitative information into categorical/quantitative data (EG3a) is an important part of the neurophenomenology methodology as it enables quantifying relationships between experiential dimensions, study conditions, and external factors (EG3b). Here, this process allowed mapping participants' experiences onto a multidimensional space (Figure 2B) and clustering 5 highly correlated dissolution facets into a global dissolution score, demonstrating its orthogonality to affective valence, and identifying the meditative mental gestures conducive to dissolution (Figure 2E).

### EG4: Using Phenomenological Dimensions for Constraining Neurophysiological Data (A3)

The neurophenomenology method aims to account for otherwise disregarded variations in cognitive states when analyzing neurophysiological data. Identifying a full-dissolution subgroup (high ratings on the intercorrelated dimensions) allowed separating core phenomenology and neurophysiology from background processes and variations: While the experimental condition of SB dissolution, contrasted to control states, was associated with frontoparietal high-beta-power reductions [as hypothesized by previous studies (15,16)], full-blown dissolution was additionally characterized by pronounced posterior

medial cortex beta deactivation (Figure 2D). Crucially, while interview-derived categorical and continuous indicators of dissolution depth correlated with neurophysiological changes, no correlations were found for a gold-standard self-report measure tapping into the same concept.

### EG5: Using Neurophysiological Results for Constraining Phenomenological Data (A3)

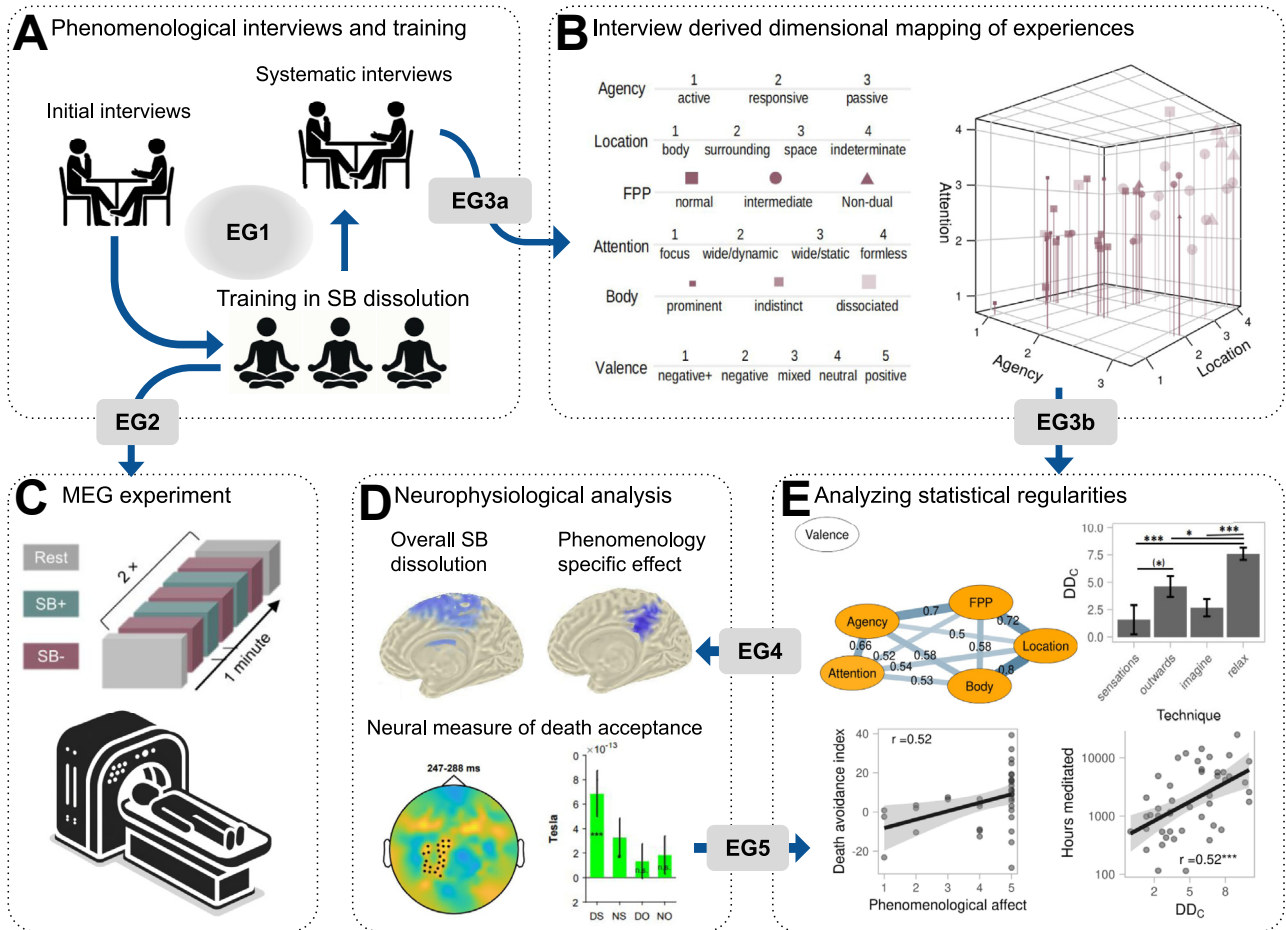
Neurophenomenology circulation can also flow from neurophysiology to phenomenology. Here, we illustrate how novel neurophysiological measurements constrained the interpretation of SB dissolution phenomenology. The dissociation between SB dissolution valence and depth (Figure 2E) allowed testing the first empirically grounded hypothesis explaining why selfless states could manifest as the epitome of spiritual attainment, but also as severely disruptive and pathological (40). We hypothesized that wholesome experiences of self-dissolution hinged on embodied pre-reflective mortality acceptance. The meditators came back to the laboratory and underwent a previously validated visual mismatch response task (62) indexing prediction-based neural mechanisms of death denial at millisecond resolution. The task capitalized on the notion that the biological imperative for maintaining one's existence was self-specific, i.e., not extending to others. Thus, on an embodied, preconceptual processing level, death-related stimuli were categorized as pertaining to other, shielding the self from existential threat. In neurophysiological terms, this manifested as an attenuated visual mismatch response self-advantage effect (self vs. other facial images) when death-related words were in the background. This defense mechanism was absent for the meditators (63) (Figure 2D). Their visual mismatch responses reflected neural processes readily coupling self and death—indicating acceptance rather than denial. Coming back to our hypothesis, degree of death acceptance predicted the valence (but not depth) of meditators' self-dissolution (neurophysiology constraining phenomenology): Brains “accepting” of their finitude covaried with more positive self-dissolution experiences (Figure 2E). Thus, newly collected neurophysiological data constrained and explained phenomenological results.

In sum, we presented a pragmatic neurophenomenology research program facilitating the scientific study of consciousness using trained participants. We contend that this methodological progression can be adapted to the clinical domain by collaborating with phenomenologically trained psychiatric patients as experts in their respective pathological conscious states, as discussed in the perspective below.

## FORMAL BRIDGE: EMERGING ROLE OF NEUROCOMPUTATIONAL APPROACHES IN NEUROPHENOMENOLOGY

In this last section, we discuss a neurocomputational version of neurophenomenology that aims at naturalizing phenomenology (19,64) and that has seen recent developments (22,23) (A4–A5 in Table 1). This approach focuses on aspects of subjective experience, differing from other models that primarily target psychological processes of meditation [e.g. (26); for a review, see (65)]. It operates within the free energy principle and active inference framework,





**Figure 2.** Neurophenomenological studies of self-dissolution. The epistemic gains (EGs) obtained throughout the unfolding of the methodological approach are highlighted (see main text for details). **(A)** First stages of this line of research including initial interviews with an expert meditator [detailed in (61)], providing a first grasp on the phenomenon of self-world boundary (SB) dissolution, and allowing training of a larger sample of meditators in voluntarily inducing the targeted phenomenology in the laboratory. In turn, the induced experiences were described in systematic interviews. **(B)** Mapping of these reports into a multidimensional space characterizing individual SB dissolution experiences [graph adapted from Nave *et al.* (47)]. **(C)** Experimental design that was applied in the magnetoencephalography (MEG) scanner. **(D)** Neurophysiological results from this task. Inflated cortical surfaces (top panel) show the effect of SB dissolution vs. the control state (meditation state with boundaries) (left) and the correlation of this contrast with the depth of dissolution metric derived from the interviews (right) [graph adapted from Trautwein *et al.* (33)]. (Bottom panel) Scalp topography (left) shows the significant sensors cluster (in bold) of the MEG visual mismatch response task (deviant > standard stimuli within the 247- to 288-ms poststimulus time window across all experimental conditions), whereas bar graph (right) shows its distribution as a function of the experimental conditions. Notably, death acceptance is indicated by the stronger [instead of inhibited, as in (62)] responses to the death self (DS) condition, that is, self face appearing under death-related words priming maintained the self-advantage effect under existential threat [graph adapted from Dor-Ziderman *et al.* (63)]. **(E)** Results from quantitative analyses of the phenomenological data [graph adapted from Nave *et al.* (47)]. (Top panel) Network graph (left) shows associations between the phenomenological dimensions. Yellow color indexes centrality strength for 5 out of 6 phenomenological dimensions. Valence was not associated with any of the other dimensions, whereas the latter were highly intercorrelated, supporting their combination into a global score of dissolution depth (DDC) [used to constrain the analysis in panel (D)]. Bar graph (right) shows the effects of different meditative techniques derived from the interviews on dissolution depth (DDC). Employed techniques included scanning sensations (sensations), directing attention outward (outwards), imagining one's spatial expansion (imagine), and gestures of mental relaxation and letting go (relax). (Bottom panel) Scatter plot on the right shows the correlation between dissolution depth and lifetime hours of meditation. Scatter plot on the left shows the correlation between the valence dimension and a neural index of death acceptance derived from the visual mismatch response task in panel (D) (subtracting the death other [DO] condition from the DS condition) [graph adapted from Dor-Ziderman *et al.* (63)]. \* $p < .05$ , \*\* $p < .05$ , \*\*\* $p < .001$ . Agency, sense of agency; Attention, mode of attention; Body, body sensations; FPP, first-person perspective; Location, self-location; NO, negative other; NS, negative self; n.s., not significant; Rest, resting state; SB-, SB dissolution state; SB+, control meditation state with boundaries.

which unifies concepts from statistical physics, information theory, and Bayesian inference (66,67). Active inference, a biologically embedded modeling framework, explains how agents interact with their environment to gather information that updates their internal models, shaping perception,

learning, and behavior through a dynamic integration of top-down predictions and bottom-up prediction errors (66).

Several studies have related these predictive processes to aspects of subjective experience such as attention regulation (68,69) and interoception (70), including in meditative practices

## Neurophenomenology of Meditation: Clinical Relevance

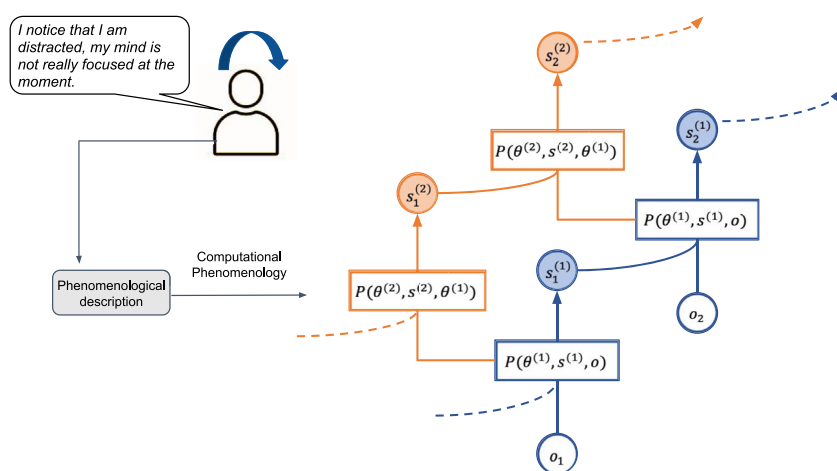
(71,72). For instance, one model relevant to mindfulness research simulated mind-wandering and its regulation during a task involving sustained selective attention on a perceptual object (68). Neurocomputational neurophenomenology aims to leverage this formalism by integrating it with first-person approaches (levels A1–A3). The main claim is that building a formal circulation between phenomenology and neurobiology (levels A4 and A5) (Figure 3) offers additional explanatory power. Varela (19) described this as generative passage, a bridge between the neurobiological and phenomenal domains. This model acts as a metaphysically neutral framework, connecting subjective first-person experience with objective neurobiological processes. Establishing these generative passages is challenging due to the distinct methodologies of phenomenology and neuroscience (73). Neurophenomenology suggests that neither phenomenology nor neuroscience has epistemic primacy, implying that models must be both biologically and phenomenologically plausible (5), a double constraint solved by active inference. Active inference offers a biologically plausible framework (66,67), and computational phenomenology (22,23,68,70,74) recently proposed using generative modeling techniques to explain characteristics of lived experience described by phenomenologists and contemplatives. Generative models in Bayesian statistics map observed data to infer hidden causes, and computational phenomenology (level A4) interprets perceptual intention as an inferential process on some raw sensorial qualitative data (23), where the intended perceptual object is interpreted as the most probable inferred latent cause based on the subject's generative model (23). This approach has modeled not only the what but also the how of experience (11,22), requiring deep parametric active inference (25) (Figure 3). Parametric depth in Bayesian mechanics refers to a property of generative models that can form beliefs about the parameters of their own modeling process (22,68). These self-referential models, used to model affective feelings (70) or mental actions (68), make it possible to bridge computational

phenomenology and neurobiological models through Bayesian mechanics, linking internal neural dynamics to beliefs about lived experience (22) (Figure 4).

On the basis of this formalism, Sandved-Smith *et al.* (22) introduced the deep computational neurophenomenology approach, which proposes to experimentally establish generative passages between lived experience and its physiological counterpart by mapping deep parametric models from computational phenomenology (level A4) to the ones from computational neurobiology (52). This requires actively engaging and training participants, as untrained agents cannot report on low-level inferential processes (Figure 3). This is done through incremental epistemic cycles, in which the trained participants and the scientists gradually accumulate evidence about their phenomenological invariants and models, respectively, so that novel hypotheses about the architecture of neurophenomenological models are generated and selected in interaction with the participant, and the accuracy and generality of the formal model (i.e., our explanation) increases. In this framework, the parameters from the phenomenological model (A4) could guide the identification of more refined neurophysiological processes than the A3 level alone. Reciprocally, some parameters from the neurophysiological model could constrain the first-person level and as such could refine existing neurofeedback approaches to meditation training (17,18) [for detailed predictions see (22)]. Though still in its infancy, the deep computational neurophenomenology approach offers a framework for experimentally testing explanatory and predictive models of mindfulness meditations.

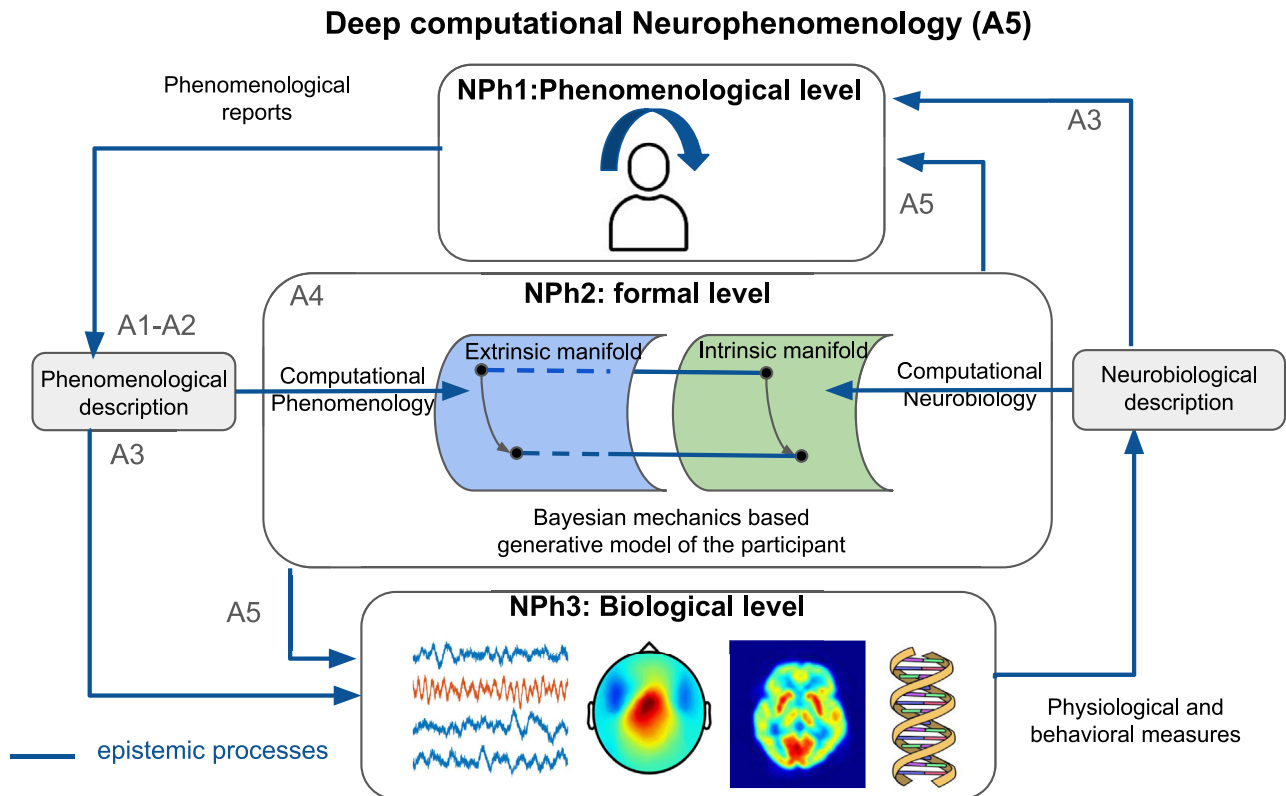
## PERSPECTIVES: IMPLICATIONS FOR MENTAL HEALTH RESEARCH

This review focused on highlighting the EGs that can be derived from rigorously training participants in first-person methods such as mindfulness meditation. As a perspective,



**Figure 3.** Modeling beliefs about beliefs using deep parametric depth. This figure depicts the inferential process as it unfolds for a metacognitive agent, which can be modeled as involving higher-level inferences about the parameters of lower-level inferences. This process allows the agent to opacity (i.e., make inference about) otherwise transparent elements of its cognitive process (68,87). In this example, the agent is engaged in monitoring of an episode of mind wandering. This process is displayed above the head of the agent by a curved blue arrow. The diagram displays the temporal unfolding of the state inference using a Bayes graph. The blue part of the figure describes the lower level perceptual inferences,  $s_t^{(1)}$ , at time  $t = 1$  and then at time  $t = 2$ , as output by the generative model  $P(\theta^{(1)}, s^{(1)}, o)$  given observations  $o$ , in this case the content of a thought. The orange part of the figure describes the agent's higher-level inferences about the parameters of their lower level generative

model, i.e., the output  $s_t^{(2)}$  of the generative model  $P(\theta^{(2)}, s^{(2)}, \theta^{(1)})$  given lower level parameters  $\theta^{(1)}$  at time  $t = 1$  and time  $t = 2$ . Importantly, this higher-level generative model now casts predictions about the dynamics of the lower-level parameters (68). This formal description has been labeled as computational phenomenology by Ramstead *et al.* (23) and corresponds to level A4 in Table 1. This type of parametric depth architecture is used in the deep neurophenomenological framework from level A5 to model explicitly the mental actions that the trained participants deploy to monitor and regulate the mind [for a model of meta-awareness see (68)]. The first-person account of these low-level processes from trained participants can be directly used to fit or select specific parameters of the model itself (see Figure 4). [Adapted with permission from Sandved-Smith *et al.* (22).]

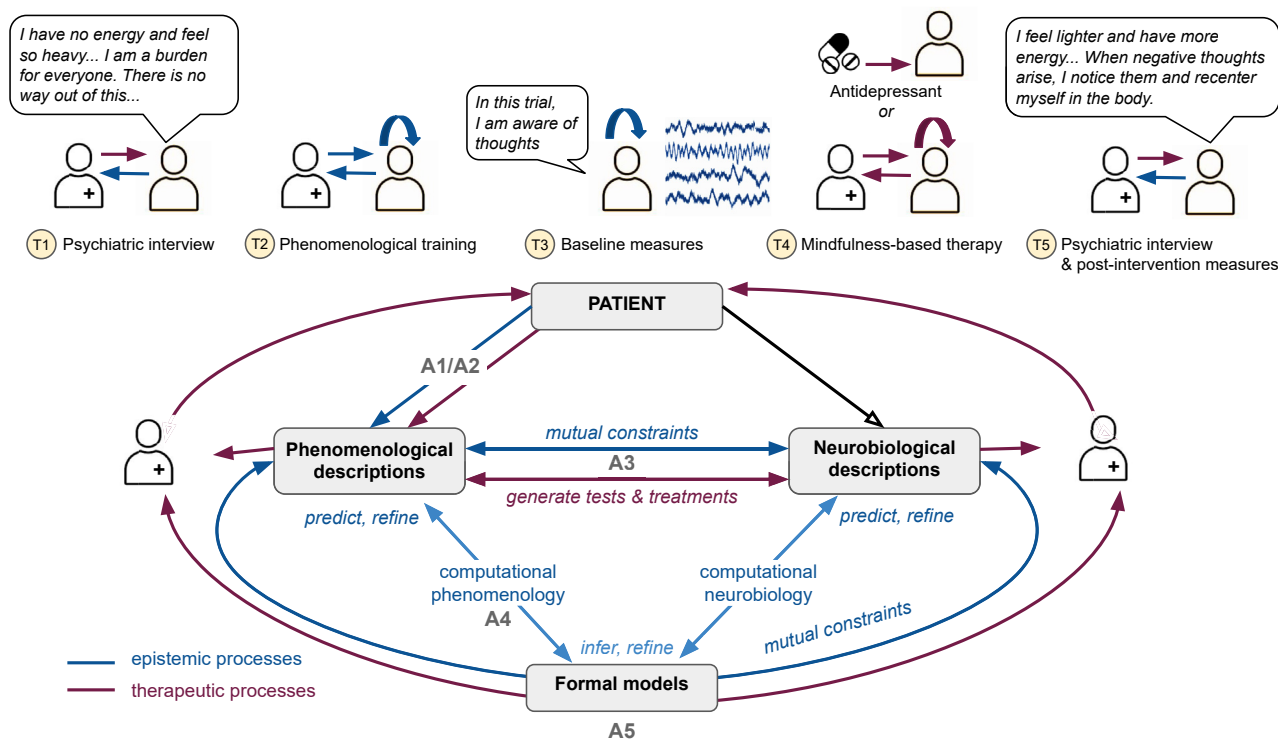


**Figure 4.** Deep computational neurophenomenology (DCN): a framework to study the how of consciousness. This figure illustrates the information flows and mutual constraints in a hypothetical mechanistic study leveraging the proposed framework from approach 5 (A5). This framework combines the epistemic gains from A1–A4 as well as the ones provided by the Bayesian formalism (see A5 in the figure). The blue arrows represent the epistemic gain in one domain and its constraint on another level. DCN aims at creating mutual constraints between the phenomenological (neurophenomenology 1 [NPh1]), computational (NPh2), and behavioral and physiological (NPh3) domains, where NPh2 provides a formal bridge between NPh1 and NPh3. The term deep highlights the requirement in this approach to use generative models that can form beliefs about the parameters of their own modeling processes (22,68). These self-referential computational models are illustrated in Figure 3 and can simulate some of the meta-cognitive processes mobilized in NPh (see A1–A2). Here, NPh3 includes behavioral and physiological data, which could span across multiple timescales (milliseconds for electroencephalography/magnetoencephalography, seconds and minutes for functional magnetic resonance imaging/positron emission tomography, or days for biomarkers). Sandved-Smith *et al.* (22) proposed that it is possible in principle to map deep parametric models from computational phenomenology (level A4) to the models from computational neurobiology by virtue of the dual information geometry of Bayesian mechanics, making it possible to establish, under certain conditions, generative passages (19) between lived experience and its physiological counterpart. Bayesian mechanics provides an explicit formal connection between 2 perspectives of the dynamics of the internal states of a biological system. It links, in a principled way, the intrinsic dynamics of the internal states (e.g., neural activity; see the green manifold in the figure) of the organism to the extrinsic dynamics of the beliefs parameterized by the internal states (88). Due to the dual geometry of Bayesian mechanics, DCN aims to experimentally establish generative passages between first-person and third-person data by mapping them into their respective intrinsic and extrinsic models (52). More specifically, phenomenological reports serve as the basis to construct a phenomenological description of given phenomenological invariants (NPh1). This description is expressed within the phenomenological framework of choice, e.g., terminology from contemplative practices or clinical psychology (see A1–A2). This first-person account can already be used to guide the analysis and interpretation of the (neuro)biological data (see A3). In a more demanding version, this description is subsequently translated into the computational model by the practice of computational phenomenology (22,23,70), which attempts to relate model parameters to phenomenological invariants or categories. In doing so, the agent's generative model can be fitted to the reported phenomenology. At this level, examples of epistemic gain can include a faster choice of model selections (arrow from NPh1 to NPh2) or the identification of novel neural correlates associated with specific parameters of the model (e.g., A5 in the figure). This is because changes in the extrinsic dynamics of the model are associated with changes in the intrinsic dynamics as modeled by computational neurobiology (e.g., the neural process theory of active inference) and estimated by the participant's behavioral and physiological measures (right part of the figure). Here, the epistemic constraints from the extrinsic to the intrinsic dynamics are bidirectional. For instance, the biological level can constrain the phenomenological model via the generative passages, providing possible guidance in the phenomenological investigation. Examples of constraints come from the neurofeedback literature on meditation (17,18), which could be refined via the formalism used in DCN. For details on the prediction of this approach, see (22). [Adapted with permission from Sandved-Smith *et al.* (22).]

we would like to highlight how these EGs also enable therapeutic gains, with both processes mutually constraining and enhancing each other. In a broad sense, both gains are part of a cyclical process where increased understanding leads to better treatments, which in turn can inform further research,

creating a feedback loop of continuous improvement in both knowledge and clinical practice. We expect that these recent advances in neurophenomenology can lead to specific and novel synergies between epistemic and therapeutic processes. One core reason is that mindfulness meditation is both a

## Neurophenomenology of Meditation: Clinical Relevance



**Figure 5.** Deep computational neurophenomenology in psychiatry: a framework to study the self-regulatory processes in patients trained with psychotherapies such as mindfulness-based interventions. This figure illustrates how epistemic and therapeutic processes could mutually constrain and enhance each other in the deep computational neurophenomenology framework described in Figure 4. Here, therapeutic processes refer to physiological treatments (e.g., drug, stimulation) or to psychotherapeutic interventions (e.g., meditation), while epistemic processes refer to physiological markers or mechanisms, or first-person meta-cognitive processes. Text in blue specifies the epistemic processes, and text in purple specifies the therapeutic processes. A canonical example of a trial with mindfulness-based cognitive therapy and its effect on depression relapse right after an acute episode of depression (89) is shown. The purple arrow from patient to phenomenological descriptions depicts, for instance, a refinement of the patient's coping mechanisms. The purple arrow with text "generate tests & treatments" represents how phenomenological descriptions have implications on the physical/objective domain by suggesting biological tests or treatments for the specific patient and vice versa how the physiological and behavioral descriptions may prompt new interview questions, phenomenological training, psychological treatment, or a combination of these. Finally, the purple arrow from the formal models to the clinician illustrates constraints on the diagnosis and treatment choices. This approach also enables individually tailored interventions. Even if this approach is particularly adapted to study self-regulatory processes induced by psychotherapies (actively engaging the first-person perspective), treatments and measurements on the physiological level (bottom left) can also be investigated and integrated, for example, (complementary) pharmacological or neuromodulation-based treatments, as well as biological measurements on various timescales (e.g., electroencephalography, functional imaging, genotyping).

technique to train the epistemic agent in neurophenomenology (Figures 3 and 4) and a psychotherapeutic intervention for alleviating a patient's suffering (75). Figure 5 illustrates this idea in a hypothetical case of a neurophenomenology clinical study using a mindfulness-based intervention for preventing depression relapse. In this conceptual example, the disciplined circulation between first- and third-person perspectives allowed by deep computational neurophenomenology provides a framework to constrain and test not only mechanistic hypotheses, but also therapeutic predictions related to both diagnoses and treatments (see Figure 5 for details). For instance, when integrated into mindfulness-based intervention, these new phenomenological assessments (A1 and A2) and their computational modeling could offer a way to determine whether depressed patients would benefit from a mindfulness-based intervention, a compassion-based approach, specific medications, or a combination of drug therapy and psychotherapy. Additionally, this integration could allow for more precise monitoring of trajectories, difficulties, and progress of

patients, paving the way for more personalized interventions. Because of the mutual constraints established experimentally (A3), the subjective side of the condition can play an explicit role in addition to its physiological manifestation in generating further tests and treatments. Furthermore, while the architecture of the formal model (A4 and A5) encodes general scientific knowledge about the medical condition, values of its precise parameters can be fitted to a patient's idiosyncratic conditions and help the clinician to diagnose a depression subtype or to decide between an antidepressant drug or psychotherapy. At each measurement point, this cyclical process is reiterated: After the intervention, individual differences in responses to treatments are modeled and used to guide treatment and model updates. Both the formal model and treatment are continuously informed and constrained by the patient's phenomenology and the clinical and scientific understanding of the patient's condition. The subjective experiences and symptoms of patients become not only a heuristic for designing research, but also a means to generate falsifiable

experimental predictions concerning some specific model parameters—a potential not yet currently harnessed in depression research. Future work will be needed to develop and test this possibility and to assess its relevance for the current crisis of mechanisms in psychiatry. We hope that these new updates on neurophenomenology provide useful conceptual and methodological tools to integrate, investigate, and mutually constrain the first- and third-person dimensions in meditation research and psychiatry.

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## ARTICLE INFORMATION

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