

An Overview of Neurophenomenological Approaches to Meditation and their Relevance to Clinical and Consciousness Research

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Abstract: There is a renewed interest in taking first-person perspective and lived experience seriously in consciousness research, contemporary psychiatry, and neurocomputation. The neurophenomenology research program, pioneered by Varela (1996), rigorously examines subjective experience using first-person methodologies, inspired by phenomenology and contemplative practices. This chapter explores recent advancements in neurophenomenological approaches, particularly their application to meditation practices, consciousness research and potential clinical research translations. We first examine innovative multi-dimensional phenomenological assessment tools designed to capture subtle, dynamic shifts in experiential contents and structures of consciousness during meditation. Secondly, 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, which updates the theoretical ambitions of neurophenomenology to

“naturalize phenomenology” (Varela, 1997). 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. This computational formalism could contribute to understanding consciousness by serving as a formal bridge between phenomenological descriptions and physiological instantiations.

1. A landscape review of neurophenomenological approaches

There is a renewed interest in taking the first-person perspective and lived experience seriously in consciousness research, computational neuroscience and contemporary psychiatry. In consciousness research, this trend is driven in part by the growing exploration of altered states of consciousness in meditation, psychedelics and hypnosis (Preller and Vollenweider, 2018; Timmermann et al., 2023). Within computational neuroscience, the emerging field of “computational phenomenology” (Ramstead et al., 2022) is reinvigorating the agenda to “naturalize phenomenology” originally proposed two decades ago (Roy et al., 1999), as discussed further below. In contemporary psychiatry, some authors have highlighted the limited ability of neurobiology and neurocomputational psychiatry to be used in daily clinical application in diagnosis and therapy (Northoff et al., 2023). For some authors, this “crisis in contemporary psychiatry” is just a limitation of knowledge about the computational mechanisms underlying the psychopathological symptoms (‘crisis of mechanism’) (Kyzar and Denfield, 2023; Nour et al., 2022) while others diagnose a neglect of subjective first-person experience (‘crisis of subjectivity’) (Northoff et al., 2023). The advocates for considering lived experience seriously suggest prioritizing the examination of structural aspects of experience in psychopathologies through qualitative or phenomenological interviews, aiming to integrate clinical phenomenological research with neuroscience (Berkovich-Ohana et al., 2025; Kyzar and Denfield, 2023; Northoff et al., 2023).

Aligned with these trends, the aim of this chapter is to review recent developments in the research program of neurophenomenology (NPh), particularly in the context of mindfulness meditation research.¹ NPh was initially introduced by Francisco Varela as a methodological approach to the scientific investigation of consciousness (Varela, 1996; Varela and Shear, 1999) (for a metaphysical discussion on this approach see (Bitbol, 2021)). NPh emphasizes the careful examination of experience using rigorous first- and second-person methodologies inspired by the phenomenological tradition in philosophy and by 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 prereflective dimensions of subjective experience, which may otherwise go unnoticed and be unavailable for verbal report (Berkovich-Ohana et al., 2020; Lutz and Thompson, 2003; Timmermann et al., 2023). This allows for the disciplined descriptions of experiential contents (‘What’ appears to the experiencer) and also 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

¹This chapter is based on the article by Lutz et al. (2024), with significant extensions and elaborations, particularly in Sections 4 and 5; Section 4 and part of section 5 are largely adapted from the article by Sandved-Smith et al. (2024).

interpretation of neurophysiological processes relevant to consciousness in such a way that first-person data and empirical data mutually constrain each other (Varela, 1996). The epistemological value of employing this methodology has been discussed in a clinical context (Kyzar and Denfield, 2023) and demonstrated in empirical studies, revealing novel neurodynamic correlates of attention (Lutz, 2002), and of alter state of consciousness (Lewis-Healey et al., 2024), providing insights into the plasticity of false memory (Černe and Kordeš, 2023; Petitmengin et al., 2013) and the volitional plasticity of self-awareness and its boundaries (Dor-Ziderman et al., 2016, 2013), as well as integrating neurofeedback with mindfulness meditation (Garrison et al., 2013; van Lutterveld et al., 2017).

As an organizing framework, we propose in this first section five approaches (A1-A5) to integrate a systematic examination of lived experience into empirical research, fulfilling complementary roles and yielding different epistemic outcomes (see Table 1). More specifically, the five approaches are as follows: A1) Phenomenological inquiries, which can involve trained disciplined meditators, and which employ in-depth interviews, with the epistemic gain of enabling the identification of novel phenomenological structural invariants (both the 'what' and 'how' of experience), which can be intersubjectively validated and replicated. A2) Experimental/clinical phenomenology, which, for pragmatic reasons, focuses on selected structural invariants or contents of experience. These features of lived experience, while building on A1, are simple enough to be empirically investigated in experimental, quantitative, and/or (neuro-)physiological research contexts. The epistemic gain here lies in describing statistical regularities in phenomenological reports. A3) Experimental neurophenomenology builds on A2 to create mutual constraints between the first-person perspective (1PP) and the third-person perspective (3PP). The epistemic gain is identifying novel neurophysiological correlates or behavioral markers of conscious experience, and vice versa. Next, there are two complementary computational approaches, offering computational models of the embodied and enactive mind. These models derive from Bayesian theories of the brain (Friston, 2010; Friston et al., 2018), even if alternative formalisms exist (see Moye and Van Vugt, 2019 for a review). A4) Computational phenomenology uses generative modelling techniques to formally model existing structural invariants, with the epistemic gain of connecting them to biologically plausible inferential processes (Ramstead et al., 2022) A5) (Deep) Computational neurophenomenology, which creates a formal circulation or generative passage across 1PP, formal level (A4) and 3PP with the epistemic gain of explanatory/predictive power of specific model parameters and neurophenomenological invariants (Figures 3-4). The adjective 'deep' is used when modeling the 'how', and not just the 'what' of experience. 'Parametric depth' refers to a property of hierarchical generative models that can form beliefs about the parameters of their own modelling process.

In the second section, we present recent methodological tools to assess lived experience during the practice of meditation (discussing A1 and A2). Next, in the third section we show 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" (Varela, 1997; Lutz, 2002; Thompson and Zahavi, 2007; Bitbol, 2021) and how this framework has been recently updated. This updated computational framework, grounded in Bayesian mechanics (Ramstead et al., 2022; Sandved-Smith et al., 2024), facilitates the establishment of a formal bridge between lived experience 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 and consciousness research.

Approaches	Domains	Methods	Epistemic outcomes	Examples
A1. Phenomenological inquiries	1PP ("thick")	<ul style="list-style-type: none"> - Training in a <i>first-person method</i> (e.g., mindfulness meditation, <i>phenomenological epoche</i>) - <i>Second-person method</i> (e.g., micro-phenomenological interview, clinical interview) 	<ul style="list-style-type: none"> - Increase in meta-cognitive skills (e.g., meta-awareness, <i>dereification</i>) - Produce and maintain a target state or phenomenological feature (e.g., compassion) - Insights about and identification of novel phenomenological <i>structural invariants</i> about the 'what' and 'how' of experience for the trained participant and researcher 	Alcaraz-Sánchez et al., 2022; Petitmengin et al., 2019; Poletti et al., 2021; Przyrembel and Singer, 2018
A2. Experimental or clinical phenomenology	1PP ("thin" or "thick" reduced to "thin")	A1 + quantitative methods using phenomenological scales	Statistical regularities in phenomenological reports across time and individuals, as well as between phenomenological dimensions	Abdoun et al., 2024; Jachs et al., 2022; Kok and Singer, 2017; Nave et al., 2021; Segal et al., 2019
A3. Experimental neurophenomenology	1PP+3PP (behavior + physiology)	Participants trained in A1 or A2 to help the scientist to create mutual constraints between 1PP and 3PP	Identification of novel (neuro)physiological correlates from A1 or A2	Dor-Ziderman et al., 2016, 2013; Garrison et al., 2013; Lutz, 2002; Petitmengin et al., 2007; Trautwein et al., 2024; van Lutterveld et al., 2017
A4. Computational Phenomenology	Formal modeling, with or without 3PP	Modeling of existing data from formal phenomenology (A1)	<ul style="list-style-type: none"> - Explanatory and predictive models of specific phenomenological invariants from A1 - <i>Isomorphic relationships</i> between 1PP and 3PP 	Bogotá and Djebbara, 2023; Costa et al., 2024; Farb et al., 2015; Moye and Van Vugt, 2019; Pagnoni, 2019; Ramstead et al., 2022; Sandved-Smith et al., 2021
A5. Deep computational neurophenomenology	1PP + formal modeling + 3PP	Disciplined circulation between 1PP and 3PP (A3) enabled by the formalism (A4). A paradigmatic formalism is deep parametric active inference.	<i>Generative passage</i> between 1PP and 3PP: explanatory and predictive model of specific neurophenomenological invariants	Beckmann et al., 2023; Sandved-Smith et al., 2024

Table 1. Varieties of approaches to investigate the lived experience while engaging in contemplative practices. These diverse approaches fulfill complementary roles, each pursuing somewhat distinct research agendas. A1, allows for an investigation of “thick” complex phenomenology (Berkovich-Ohana et al., 2020), while A2-A5 focus, for pragmatic reasons, on selected, “thin”, structural invariants simple enough to be investigated in experimental, quantitative and/or (neuro-)physiologic 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-A2 are preliminary and necessary steps for the naturalization of target structural invariants. They lie on a thick-to-thin continuum (Berkovich-Ohana et al., 2020), 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 for illustration purposes, see (Berkovich-Ohana et al., 2020; Timmermann et al., 2023) for a review. Here 1PP (resp. 3PP) refers to *first-person* (resp. *third-person*) perspective.

Box 1. Glossary: This glossary defines the words in italics

Deep computational neurophenomenology (DCNPh) uses deep parametric generative modelling techniques to construct formal models of the trained participant’s descriptions of their first-person experiences, which serves as a formal bridge to link first-person data and third-person neurophysiological data. The generative models have a hierarchical structure with a dual geometry that encodes both the subject’s first person reports, and the intrinsic dynamics of their neurophysiological processes. Parametric depth is a property of models that encode higher-order beliefs - beliefs about beliefs - and make inferences about the results of other inferential processes.

'Dereification' - 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 (Lutz et al., 2015).

'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 is enacted through the body and its engagements with the world, emphasizing the active, relational, and emergent nature of the mind (Varela et al., 1991).

'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 (Friston, 2009; Friston et al., 2018)). Similarly, in this context, insights from meditation practices or the phenomenological reduction 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 (NPh) paradigm, who leverages the epistemic insights of meditators to generate new knowledge by modeling meditation and conducting experimental research (see ‘meta-Bayesian approach’).

'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 (Desbordes et al., 2015).

'First-person methods' are disciplined practices aiming at increasing participants' sensitivity to their own experiences at various time-scales (Varela and Shear, 1999). These practices involve the systematic training of attention and self-regulation of emotion and can be found for instance in the philosophical tradition of phenomenology, psychotherapy and contemplative meditative traditions. A canonical example is the practice of mindfulness meditation.

'Focused attention' (FA) 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 three skills: monitoring for distractions, disengaging from them, and redirecting focus. Progress is measured by reduced effort needed to maintain focus (Lutz et al., 2008).

'Generative passages' is a term coined by Francisco Varela to describe the epistemologically fruitful exchange of knowledge between phenomenology, formalism, and neurobiology (Varela, 1997). A passage is considered generative when there is 'mutual circulation and illumination' between the neurobiological domain and 'the entire phenomenal domain' (Varela, 1997). In his work on time-consciousness, Varela initially suggested using dynamical systems theory to facilitate this exchange (Varela, 1997). More recently, Sandved-Smith et al. proposed generating these passages through the deep computational neurophenomenology framework (see Figure 4, (Sandved-Smith et al., 2024)).

'Gesture' - 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 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" (Merleau-Ponty, 1973).

'Isomorphic relationship' refers to a structural similarity or correspondence between two systems, models, or sets of elements, where the relationships between elements in one system are mirrored in the other. In NPh, 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 processes or (see level A3).

'Loving-kindness and compassion' (LKC) 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 (Gallagher et al., 2024). Any reduction in attachment, aversion or delusion as cultivated by OM and FA 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.

'Meta-Bayesian approach' refers to a modeling approach where the experimenters "observe the observer", to gather evidence about the participant's generative model and their preferences (Daunizeau et al., 2010). By doing so, they make (Bayesian) statistical inferences about participant's (Bayesian) perceptual inferences (i.e., an inference about an inference). DCNPh extends this approach by integrating evidence not only about the participant's actions or neurophysiology, but also about the insights of the trained participant into the what and how of experience (Figure 4).

'Mutual, or reciprocal, constraints' (Varela, 1996) refers to the methodology 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., neuro-feedback). There are different ways of bridging between these two domains (see (Berkovich-Ohana et al., 2020; Lutz et al., 2002; Timmermann et al., 2023).

'Open monitoring' (OM) meditation involves maintaining open, moment-by-moment awareness of experiences without selecting any particular focus. The monitoring skill developed in FA becomes central, with an emphasis on "reflexive" awareness, allowing one to notice aspects of experience like emotional tone without making them explicit focuses. As practice progresses, the need to "grasp" objects fades, replaced by an "effortless" awareness. OM aims to enhance awareness of implicit mental features, helping transform cognitive and emotional habits, reducing emotional reactivity, and fostering sensitivity to body and environment (Lutz et al., 2008).

'Phenomenological reduction' - a philosophical 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 subject-independent existence of the external world to examine an experience purely as it is presented to consciousness. This process involves suspending habitual judgment, redirecting attention inwards and receptivity towards the experience (Depraz et al., 2000). The epoche is closely related to the construct of 'cognitive defusion' in psychology, or of dereification (see below).

'**Second-person methods**' are interview techniques designed to elicit both verbal and non-verbal information from participants aiming to capture aspects of experience that remain pre-reflective (i.e., everyday ways of understanding and engaging with the world that are prior to reflective linguistically articulated thought) and that typically go unnoticed by the participants themselves (Olivares et al., 2015; Petitmengin, 2006). 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 micro-phenomenological interview (Petitmengin, 2006).

'**Subjective realism**' refers to the way one perceives the content of experience, such as memory, as subjectively real (Lebois et al., 2015). This concept aligns with the notions of **cognitive fusion**, **experiential fusion**, or **reification**.

'**Structural invariant**' - refers, in phenomenology and 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.

2. Recent advances in first- and second-person approaches to assess (meditative) experience

Phenomenological assessment tools for NPh paradigms of meditation (see Table 1, A1-A2) share a common interest to move beyond conventional trait-based measures of mindfulness, in order 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 (Grossman, 2008; Van Dam et al., 2012), and are responded to differently by meditators and non-meditators (Van Dam et al., 2009). At least one study has shown that non-meditators did not have an adequate understanding of items from a mindfulness questionnaire (Belzer et al., 2013), which may explain implausible findings such as binge-drinkers and opioid users reporting similar levels of mindfulness than healthy participants or even experienced meditators (Dakwar et al., 2011; Grossman, 2008). In contrast, phenomenological assessments intend to probe *embodied*, situated and immediate or recent experience beyond self-representations (Petitmengin et al., 2013). Such assessments have shown somewhat better predictive power of behavior and neural activity than gold standard trait scales (Poletti et al., 2021; Trautwein et al., 2024b).

The methodological approaches that have been developed can be organized along two orthogonal axes: (i) A thick-to-thin continuum (Berkovich-Ohana et al., 2020), where "thick" refers to rich descriptions of singular experiences over different time-scales, and "thin" refers to a brief assessments of pre-defined variables (i.e., experience sampling or a brief semi-structured self-report). Here, "thin" data can be formalized as 3PP data or correlated to neural activity (Abdoun et al., 2019; Hasenkamp et al., 2012; Zanesco et al., 2013). (ii) The time span of the phenomenon of interest, which can range from the retention of just-past

moments (Lutz et al., 2002), the ongoing monitoring of a few moments (Jachs et al., 2022), a meditation session (Abdoun et al., 2024), or salient experiences in life (Lindahl et al., 2017).

In the field of mindfulness research, three investigative themes have emerged in the last two 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 and colleagues (Lindahl et al., 2017) pioneered the study of underreported, challenging, difficult, distressing, or functionally impairing, meditation-related experiences, identifying a taxonomy of 59 experiences across seven domains. Following this broadened scope of meditation-related experiences, subsequent studies started to document their prevalence in both clinical and non-clinical populations ((Schlosser et al., 2019; Farias et al., 2020; Goldberg et al., 2022); but see (Sparby, 2019a) for a re-contextualization of these so-called “adverse” effects within larger transformative trajectories). Importantly, Lindahl and colleagues 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 (Dunne, 2011; Metzinger, 2024; Poletti et al., 2021), which are traditionally thought to require extensive training and mastery 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 and colleagues (Nave et al., 2021) conducted a comprehensive phenomenological inquiry into what is considered an important stage in many contemplative traditions, namely self-boundary dissolution (see section 3 for more details). Alcaraz-Sanchez (Alcaraz-Sanchez, 2023; Alcaraz-Sánchez et al., 2022) 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, Petitmengin and colleagues (Petitmengin et al., 2019) 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 to a significant portion of mind-wandering episodes (Killingsworth and Gilbert, 2010). Przyrembel and (Przyrembel and Singer, 2018) explored

how novice participants applied different meditation instructions and found distinctive linguistic, affective and bodily fingerprints for breathing, loving-kindness and thought-observing practices. Poletti and colleagues (Poletti et al., 2021) interviewed and compared novice and expert practitioners on their habitual relationship to and management of pain. They identified five 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 (Sparby, 2019b) or pursuing a collaborative first-person science of consciousness (Kordes et al., 2019).

Theme 3: dynamics of phenomenological shifts

The 1P information garnered with MPI can be used to refine the interpretation of 3P data or inform the design of new studies (see section 3). However, one 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.

In their 2017 study, Kok and Singer (2017) 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 this questionnaire within the ReSource project, a 9-month modular mental training program designed to elucidate the specific effects of four distinct meditation practices. They found that all investigated practices shared some common effects, notably in reducing distraction and improving emotional states. However, loving-kindness meditation uniquely fostered positive thoughts towards 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 (Kok and Singer, 2017).

Zooming in on the dynamics of individual meditation sessions, Jachs and colleagues (Jachs et al., 2022) 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 four metastable states, each characterized by a specific phenomenological profile and dominating distinct practices (Jachs et al., 2022).

Extending these efforts, the *Lyon Assessment of Meditation Phenomenology* (LAMP) questionnaire was recently introduced as a multidimensional experience-sampling approach to characterize the dynamics of meditative experience over many sessions (Abdoun et al.,

2024). In contrast to most self-report questionnaires, the LAMP questionnaire requires specific methodological considerations due to the phenomenological nature of many of its items. Here, mindfulness meditation itself is assumed to function as a first-person method, cultivating an explicit attitude of attentive self-awareness. Additionally, the authors conducted a 1.5-hour training session to introduce the questionnaire, providing experiential examples to ensure participants engaged with it both cognitively and experientially, accessing the subtle features of their experience. This novel assessment tool allows the measurement of shifts in subjective experiences across six domains: conative, affective, somatic, attentional, meta-cognitive/reflexive and cognitive. In their validation study, the authors administered the LAMP 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, FA) to a broader scope of non-selective attention (open monitoring, OM). 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 FA 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 OM 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 (Lutz et al., 2015). 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 inter-individual 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 (section 4).

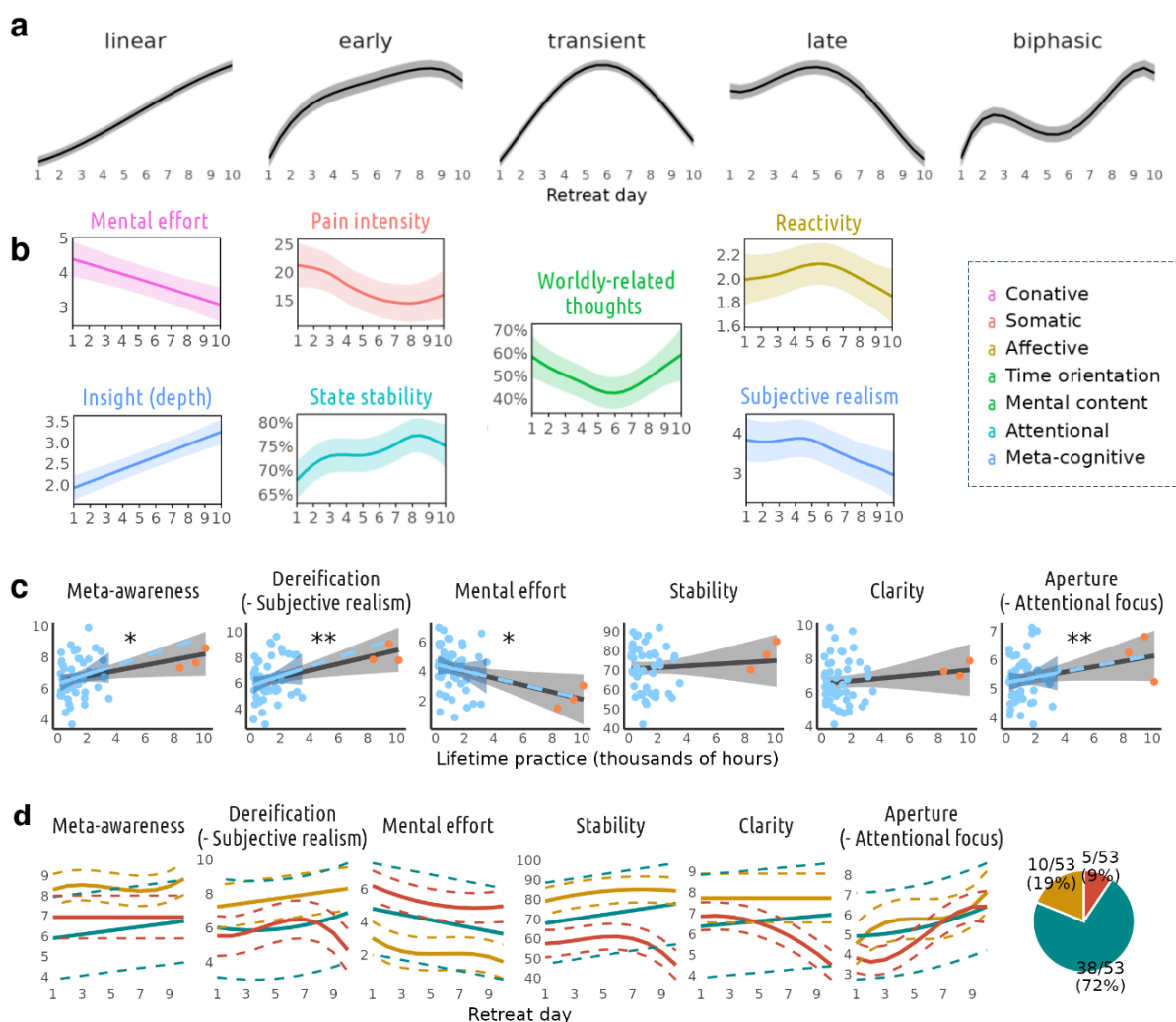


Figure 1: Thin phenomenology: intensive, multidimensional assessment of meditation experience over the course of a 10-day retreat. (a) Participants reported significant shifts in meditation experience following dimension-dependent temporal trajectories. Here, only a sample of the 30 phenomenological dimensions assessed by or derived from the Lyon Assessment of Meditation Phenomenology (LAMP) are shown. (b) The temporal trajectories of the 30 dimensions could be clustered in merely 5 templates. Most dimensions ($n=10$) displayed linear changes, possibly reflecting specific, cumulative effects of intensive practice. Given that FA practices were predominant in the first half of the retreat and OM in the second part, early and late trajectories could be ascribed to FA and OM 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) The relationships between the phenomenological scores averaged across all retreat sessions and the participants' total lifetime practice are congruent with the PMM 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 three outliers participants (with more than 8,000 hours of practice), slopes remain in fact 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 PMM. The green cluster included 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 gathers 5 participants who exerted high effort in their meditation practice yet reported low stability. Unlike others, these participants decreased in dereification, stability and clarity in the second part of the retreat. Significance: *, $p<0.05$; **, $p<.01$; ***, $p<.001$

3. Recent advances in NPh approaches in mindfulness meditation research

Recent NPh projects include studies of meditative cessation states (Nirodha Samapatti), a volitionally-induced suspension of consciousness (Chowdhury et al., 2023; Laukkonen et al., 2023), and intentional respiration modulation to induce ASCs (Lewis-Healey et al., 2024). While promising, here, following Varela (Varela, 1997, 1996), we showcase the unfolding of a mature NPh research program designed to facilitate the scientific study of consciousness utilizing 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 a self-world boundary (SB) dissolution magnetoencephalography (MEG) paradigm. High-grade first-person reports were obtained (using micro-phenomenological interviews (Petitmengin, 2006)) from 46 long-term mindful-awareness practitioners, trained to produce and stably maintain front-loaded conscious states-of-interest (Trautwein et al., 2024b). Phenomenological results highlighted six core experiential 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 (Nave et al., 2021). Neurophysiologically, full-blown suspension of self-experience was associated with robust beta-band power reductions in the posterior-medial cortex (PMC), establishing it as a key contributor to an integrated embodied perspective in conscious experience (Trautwein et al., 2024b).

We demonstrate the added value of this methodology by detailing the *epistemic gains* (EG) incurred from acquiring high-grade experiential reports from phenomenologically-trained participants and bridging first- and third-person data. These EGs substantiate the A1-A3 approaches to NPh.

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 ineffable. Thus, their study demands rigorous and systematic first- and second-person interviewing methods (Petitmengin, 2006), as well as sustained meditation practice (Figure 2A). These involve suspending naive beliefs about the experience-of-interest and guiding attention towards its pre-reflective facets (e.g., subtle inner acts or "micro-gestures" associated with an experience). Here, this rich experiential exploration of the SB phenomenon set the stage for integration with third-person measures.

EG2: 'Bringing' non-ordinary states of consciousness to the lab (A1)

A second barrier to studying non-ordinary states of consciousness is 'bringing' them to the lab. 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, noise, maintaining certain bodily postures, being observed, and time limitation.

By collaborating with a highly-adept contemplative, initially as participant (Dor-Ziderman et al., 2013;) and later as co-researcher (Dor-Ziderman et al., 2016; Schweitzer et al., 2024; Trautwein et al., 2024a) a custom-tailored training regime 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 lab conditions, allowing 'front-loading' the phenomenology-based SB-dissolution construct onto a neuroscientific experiment (Figure 2C).

EG3: Quantifying experiential dimensions for assessing statistical relations (A2)

Reducing complex qualitative information into categorical/quantitative data (EG3a) is an important part of the NPh methodology as it enables quantifying relations between experiential dimensions, study conditions, and external factors (EG3b). Here, this process allowed mapping participants' experiences onto a multidimensional space (Figure 2B) and clustering five 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 NPh method aims to account for otherwise disregarded variations in cognitive states when analyzing neurophysiological data. Identifying a subgroup of 'full-dissolvers' (highest ratings on the intercorrelated dimensions of SB dissolution, (Trautwein et al., 2024b) 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 (Dor-Ziderman et al., 2016, 2013)), full-blown dissolution was additionally characterized by pronounced PMC 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)

NPh 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 (Lindahl et al., 2017). We hypothesized that wholesome experiences of self-dissolution hinged on embodied pre-reflective mortality 'acceptance'. The meditators came back to the lab and underwent a previously-validated visual MisMatch Response (vMMR) task (Dor-Ziderman et al., 2019) 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, pre-conceptual processing level, death-related stimuli were categorized as pertaining to 'other', shielding 'self' from existential threat. In neurophysiological terms, this manifested as an attenuated vMMR self-advantage effect (self vs. other facial images) when death-related words were in the background. This defense mechanism was absent for the meditators (Dor-Ziderman et al., in press) (Figure 2D). Their

vMMRs reflected neural processes readily coupling ‘self’ and ‘death’—indicating acceptance rather than denial. Coming back to our hypothesis, death-acceptance degree predicted the valence (but not depth) of meditators’ self-dissolution (neurophysiology constraining phenomenology): brains ‘accepting’ of their finitude co-varied with more positive self-dissolution experiences (Figure 2E). Thus, newly collected neurophysiological data constrained and explained phenomenological results.

In sum, we presented a pragmatic NPh 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’ of their respective pathological conscious states (Figure 5).

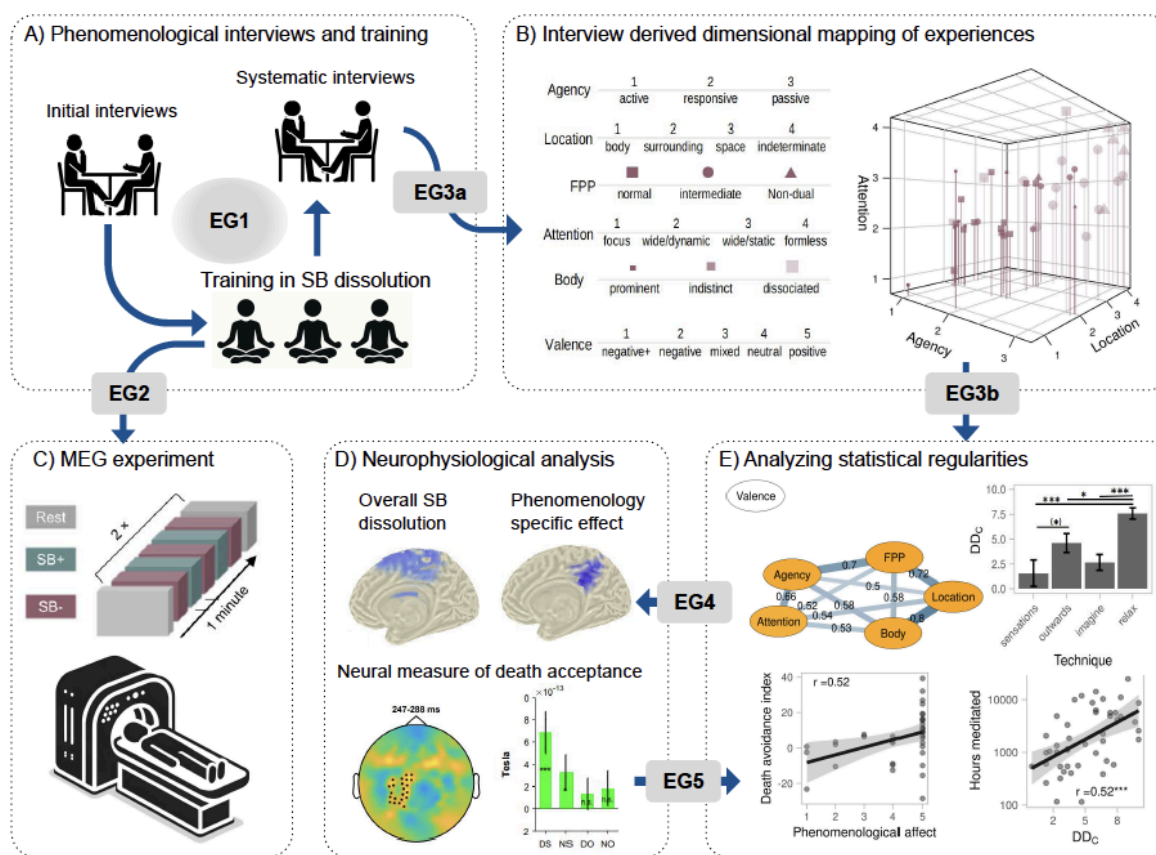


Figure 2: Neurophenomenological studies of self-dissolution

The epistemological gains (EG) obtained throughout the unfolding of the methodological approach are highlighted (see main text for details): Panel **A** shows the first stages of this line of research including initial interviews with an expert meditator (detailed in (Ataria et al., 2015)), providing a first grasp on the phenomenon of SB dissolution and allowing training of a larger sample of meditators in volitionally inducing the targeted phenomenology in the lab. In turn, the induced experiences were described in systematic interviews. Panel **B** shows the mapping of these reports into a multidimensional space characterizing individual SB dissolution experiences (Agency = sense of agency, Location = self-location, FPP = first-person perspective, Attention = mode of attention, Body = body sensations) (graph adapted from (Nave et al., 2021)). Panel **C** shows the experimental design that was applied in the MEG scanner (Rest = resting state; SB+ = control meditation state with boundaries; SB- = SB dissolution state). Panel **D** shows neurophysiological results from this task: Inflated cortical surfaces on the top 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., 2024a)). The scalp topography at the bottom-left shows the significant sensors cluster (in bold) of the MEG visual MisMatch Response (vMMR) task (deviant>standard stimuli within the 247-288 ms post-stimulus time-window across all the experimental conditions), whereas the bottom-right barplot shows its distribution as a function of the experimental conditions (DS = death self; NS = negative self; DO = death other; NO = negative other). Notably, death acceptance is indicated by the stronger (instead of inhibited, as in (Dor-Ziderman et al., 2019)) responses to the 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., under review). Panel E shows results from quantitative analyses of the phenomenological data (graph adapted from ((Nave et al., 2021))): The top-left network graph shows associations between the phenomenological dimensions. Yellow coloring indexes centrality strength for 5 out of 6 phenomenological dimensions. Note that 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 (DD_c) (used to constrain the analysis in panel D). The top-right bar graph shows the effects of different meditative techniques derived from the interviews on dissolution depth (DD_c). Employed techniques included scanning sensations (“sensations”), directing attention outwards (“outwards”), imagining one’s spatial expansion (“imagine”) and gestures of mental relaxation and letting go (“relax”). The bottom-right scatter plot shows the correlation between dissolution depth and lifetime hours of meditation. The bottom-left scatter plot shows the correlation between the valence dimension and a neural index of death acceptance derived from the vMMR task in panel D (subtracting the DO from the DS condition, graph adapted from(Dor-Ziderman et al., 2023)).

4. Formal bridge: the emerging role of neurocomputational approaches in neurophenomenology

In this last section, we discuss a neurocomputational version of NPh that aims at “naturalizing phenomenology” (Roy et al., 1999; Varela, 1997), and which has seen recent developments (Ramstead et al., 2022; Sandved-Smith et al., 2024) (table 1, levels A4-A5). This approach focuses on aspects of subjective experience, differing from other models that primarily target psychological processes of meditation (e.g., (Moye and Van Vugt, 2019) for a review (Van Vugt et al., 2019)).

As discussed briefly in the introduction to our chapter, the working hypothesis of neurophenomenology (NPh) is that: “Phenomenological accounts of the structure of experience and their counterparts in cognitive science relate to each other through reciprocal constraints” (Varela, 1996: p. 343). NPh is rooted in both the philosophical tradition of phenomenology (Gallagher, 2022; Zahavi, 2018) and in the enactive approach to cognition that takes consciousness and cognition to be the result of self-organising autonomous processes in their dynamical sensorimotor coupling with the surrounding world Varela et al., 1991; see also Gallagher, 2023; Thompson, 2010). This program explicitly requires the use of first-person methods inspired by phenomenology and contemplative practices to explore the field of conscious phenomena in order to obtain refined and rigorous phenomenological analyses and descriptions of experience. This corresponds to the level A1 described above in section 2, where we focused on mindfulness meditation as one important style of first-person method. Sharing similar aims to this contemplative technique (Depraz et al., 2003), phenomenology offers a philosophical method for directing our attention away from its immersion in the world, allowing us to describe how a meaningful world comes to be present or disclosed to consciousness through time. The phenomenologist studies their own experiences from the first person point of view of the subject who is living through those experiences. They seek to describe *how* the things we experience come to appear experientially to us. Varela’s idea was that subjects could be trained in phenomenological

methods to identify and describe invariant categorical and structural features of their own lived experiences (see levels A1-A2). The first-person descriptions subjects provide can then be used to guide the analysis and interpretation of neurophysiological data. Neuroscientific findings can in turn be used to provoke refinements and revisions in phenomenological analyses providing resources with which to test phenomenological claims about the necessity of experiential invariants and structures (see level A3).

Varela further argued for a “generative passage” between the mathematical, phenomenological and neurobiological domains by which he meant a “mutual circulation and illumination” between these three domains (Varela, 1997, p. 372). Formal models can provide a metaphysically neutral vocabulary that can connect the distinct domains of first-person lived experience (as accessed through phenomenological methods and contemplative practices) and the neurobiological processes correlated with conscious experience (as measured using the techniques of cognitive neuroscience). Establishing these generative passages is challenging due to the distinct methodologies of phenomenology and neuroscience. NPh suggests that neither has epistemic primacy, implying that models must be both biologically and phenomenologically plausible.

4.1. Computational Phenomenology

Recently, a novel approach to generative passages has been proposed under the label *computational phenomenology* (CPh) (Ramstead et al., 2022; see also Bogotá and Djebbara, 2023; Costa et al., 2024; Sandved-Smith et al., 2021). CPh operates within the free energy principle (FEP) and active inference framework, which unifies concepts from statistical physics, information theory, and Bayesian inference (Friston, 2010; Friston et al., 2023). The FEP is premised on a description of self-organising systems as maintaining a dynamic state of equilibrium with their environment by minimising an information-theoretic quantity referred to as ‘free energy’. One of the main claims of the FEP framework is that, to maintain order, and thus its structure, the organism must revisit a set of unsurprising states specified by its phenotype. How surprising a given state is can be quantified by an information-theoretic quantity known as *surprisal*. From this perspective, for it to remain viable, the organism must minimise surprisal. However, surprisal is often intractable (Parr et al., 2022, p. 27). Thus the FEP introduces a further information-theoretic quantity known as *variational free energy* that is an upper bound on surprisal. Minimising the free energy can implicitly minimise surprisal. Therefore, according to the FEP, a self-organising system that keeps its integrity must minimise its free energy.

Active inference models specify how an adaptive self-organising system can minimise its free energy. In a nutshell, its free energy can be mathematically defined as the divergence between a generative model and sensory observations. To minimize its free energy, the system must infer the model that best explains its sensory observations. Within the active inference framework, this inferential process can be done by fitting the model to the incoming sensory observations (this is known as perception, and it involves learning), and by changing the environment so that it fits the generative model (this is known as action). These inferential processes can also be interpreted as the ongoing accumulation of evidence for the encoded generative model, or more succinctly, as self-evidencing (Hohwy, 2016). Active inference thus conceptualises perception, learning and action as working for the same end of gathering evidence for a model that underwrites the existence of the agent in its niche.

Living processes are “self-evidencing” (Hohwy, 2016), gathering evidence for the model that the agent embodies and enacts. Active inference models the processes by which 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 (Friston, 2010). Several studies have used active inference to model aspects of subjective experience like attention regulation (Parr and Friston, 2019; Sandved-Smith et al., 2021a), interoception (Smith et al., 2021), including meditative practices (e.g. Farb et al., 2015; Pagnoni, 2019). 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 (Sandved-Smith et al., 2021b).

CPh uses generative modelling techniques as a formal bridge between phenomenology and neurophysiology. A generative model provides a probabilistic mapping from some data of interest to infer latent causes that best explain this data. In a nutshell, CPh uses generative models to formally describe “aspects of lived experience” described in phenomenology. (See also: Albarracin et al., 2022; Clark and Journal of Philosophy Inc., 2019; Sandved-Smith et al., 2021 for examples of mapping from phenomenological categories to generative model parameters).

The aim of CPh is to construct a generative model that can model “the structure and dynamics of lived experience” (Ramstead et al., 2022: p.843). Generative models map out the dynamics - the flows of sensory states - as graphs of probabilistic relations between sensory states. In CPh, the variables of the generative model refer to structures of consciousness as described in phenomenological analyses. Thus, Ramstead and colleagues propose that the “...things that are experienced (what Husserl called *noema*) are the result of particular inferences or interpretations (*noesis*) about raw sensory data (*hyle*).” (p.841).

Ramstead and colleagues made use of analyses from Husserl’s static phenomenology when they first introduced CPh. Static phenomenology offers an analysis of intentionality (understood as the directedness of conscious mental states at objects in the world) in terms of the correlation between the experienced object (*noema*) and the subjective act of apprehension (*noesis*) of sensory data (*hyle*). The static analysis of constitution (i.e., the processes that allow for the appearance of objects to us as such in lived experience) is provided to describe how it is possible for consciousness to be directed at unified objects. The hyletic component of the intentional relation corresponds to what Husserl sometimes describes as the sensory matter or sensation-contents of an intentional state (Husserl, 1983 pp. 203-207). The noetic component is the intentional form, which refers to the experiential acts and their relationships that are necessary for the constitution of a given object. Finally, the noema refers to the meaning that each act of consciousness carries. The static method consists in analysing the noetic structures that disclose the noematic pole as such. Ramstead and colleagues characterised the noema as the object as it is experienced, and interpret Husserl as claiming that the noema is constituted through the hyletic data being interpreted by the noesis, which they suggest “threads together” the hyletic matter into a temporally extended experience of a thing (Ramstead et al., 2022: p.841). Ramstead and colleagues suggest that we think of the causes that must be inferred by the model as noemata. Thus, they propose to interpret the phenomenological concept of static constitution as the process of bestowing meaning on raw hyletic data.

CP as it was originally proposed by Ramstead and colleagues (2022) is explicit in bracketing the question of how a generative model relates to neurophysiological processes. The project is best conceived of as aiming for the naturalisation of the structures of lived experience as they are described in phenomenology. This is one of the motivations behind the embodied enactive approach to cognition and neurophenomenology. In *The Embodied Mind*, Francisco Varela, Evan Thompson, and Eleanor Rosch (1991) already called for a circulation between human experience and empirical science, arguing for an enlargement of the horizon of science to include human lived experience, implying a non-objectivist science (see also Thompson, 2016). In the context of consciousness studies, Varela characterised the spirit of neurophenomenology by stating that “lived experience is where we start from and where all must link back to, like a guiding thread” (1996, p. 334). Generative models provide a neutral vocabulary that can support the naturalisation of first-person lived experience as they are described in phenomenology. However, insofar as CPh does not make use of first-person data gathered from trained participants, and explicitly brackets the question of how its models relate to neurophysiological processes, it is missing key ingredients of the NPh research program as it was originally proposed by Varela (1996, 1997). Deep Computational Neurophenomenology (DCNPh) to which we turn in the next section offers a synthesis of NPh with CPh.

4.2. Deep Computational Neurophenomenology (DCNPh)

DCNPh extends the Bayesian beliefs or posterior representations used to model first-person phenomenology in CPh to the *parameters* of beliefs about external causes. In other words, the targeted processes include the ones by which the posterior representation is inferred (i.e., the dynamics of the parameters implicated in the inferential process), in addition to the ones related to the ‘content’ of a posterior representation. Usually, the parameters in question pertain to the precision or inverse uncertainty encoded by the requisite high-order posterior representations. These parameters of the generative model can be interpreted as describing structures or invariant features of lived experience as they have been reported by subjects that have performed what phenomenologists call ‘the phenomenological reduction’, or that have gained access to those structures through the performance of mindfulness meditation practice. The function of the phenomenological reduction is to trigger a shift in the subject’s attention from the meaningful objects of experience to *how* it is possible for meaningful objects to be experienced. Through the phenomenological reduction, objects (the *what*) are brought back to their original subjective appearance (the *how*), revealing an inseparable correlation between subjectivity and the world as it is experienced.

DCNPh leverages two recent developments in active inference: 1) the dual aspect information geometry of Bayesian mechanics (Friston et al., 2023; Ramstead et al., 2023), which gives a first principles based account of the relationship between first-person experience as described by trained participants and neurobiological data; and 2) *parametric depth*, which provides a way to formalise the practice of the phenomenological reduction or dereification, and the resulting descriptions subjects provide of the how of first-person experience (e.g. (Hesp et al., 2021)). Together these recent developments allow for the generative passage at the heart of the neurophenomenological approach. The DCNPh framework implies that a trained participant’s description of their lived experience can be taken as evidence for a path on a statistical manifold representing the Bayesian beliefs of this individual—provided that the description is sufficiently trustworthy. In turn, the ensuing

statistical manifold provides a constraint on the predictions over the intrinsic dynamics of the physical system, yielding insights about the physiological states. The opposite is also true, fitting the model of the intrinsic dynamics to the observed evolution of the physical system provides a prediction about the evolution of the beliefs parameterised by the physical states, and by extension, of the phenomenology. Parametric depth in Bayesian mechanics refers to a property of generative models that can form beliefs about the parameters of their own modeling process (Sandved-Smith et al., 2024, 2021a). These self-referential models, used to model affective feelings (Hesp et al., 2021) or mental actions (Sandved-Smith et al., 2021a), make it possible to bridge computational phenomenology and neurobiological models through Bayesian mechanics, linking internal neural dynamics to beliefs about lived experience (Sandved-Smith et al., 2024) (see Figure 4 for details).

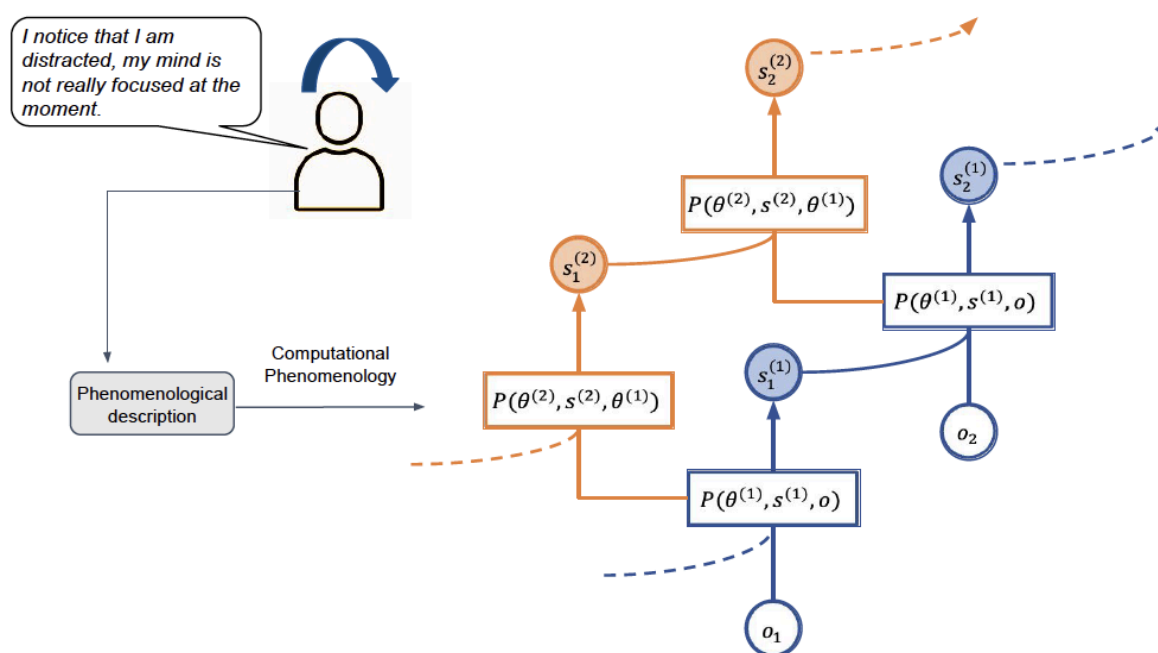


Figure 3: Modeling beliefs about beliefs using deep parametric depth.

This figure adapted from Sandved-Smith et al. (2024) depicts the reflective process allowed by the reduction or the dereification of experience as it unfolds for a metacognitive agent. Such a process can be modeled as involving higher-level inferences about the parameters of lower-level inferences. Within the model, this process is described as allowing the agent to “opacify” (i.e., make inference about) otherwise transparent elements of its cognitive process (Metzinger, 2003; Sandved-Smith et al., 2021a). In this particular example, the agent is engaged in the monitoring of an episode of mind-wandering. This process is displayed above the head of the agent by a circular 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, $s_1^{(1)}$, at time t , as output by the generative model $P(\theta^{(1)}, s^{(1)}, o)$ given observations o , in this case for instance 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 $s_1^{(2)}$ of the generative model $P(\theta^{(2)}, s^{(2)}, \theta^{(1)})$ given lower level parameters $\theta^{(1)}$. Importantly, this higher level generative model now casts predictions about the dynamics of the lower level parameters (Sandved-Smith et al., 2021a). This formal description has been labeled as *computational phenomenology* by Ramstead et al. (2022) and corresponds to the 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 one’s mind (for a model of meta-awareness see (Sandved-Smith et al., 2021a)). 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).

On the basis of this formalism, Sandved-Smith and colleagues introduced the ‘*Deep Computational Neurophenomenology*’ (DCNPh) approach, which proposes to experimentally establish generative passage between lived experience and its neurophysiological counterpart by mapping deep parametric models from computational phenomenology (level A4) to the ones from computational neurobiology (Sandved-Smith et al., 2024). This requires again to actively engage and train participants, as untrained agents cannot report on what low-level inferential processes may capture of the phenomenology of their lived experience (Figure 3). This is done through incremental epistemic cycles, where the trained participants and the scientists gradually accumulate evidence about the structural invariants of their experience and models, respectively. Such evidence allows for the generation and selection of novel hypotheses about the architecture of neurophenomenological models. The selection process is done in interaction with the participant. It is also expected that 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 could the level A3 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 (Garrison et al., 2013; van Lutterveld et al., 2017) for detailed predictions see Sandved-Smith et al., 2024). Though still in its infancy, the DCNF approach offers a framework for experimentally testing explanatory and predictive models of mindfulness meditations.

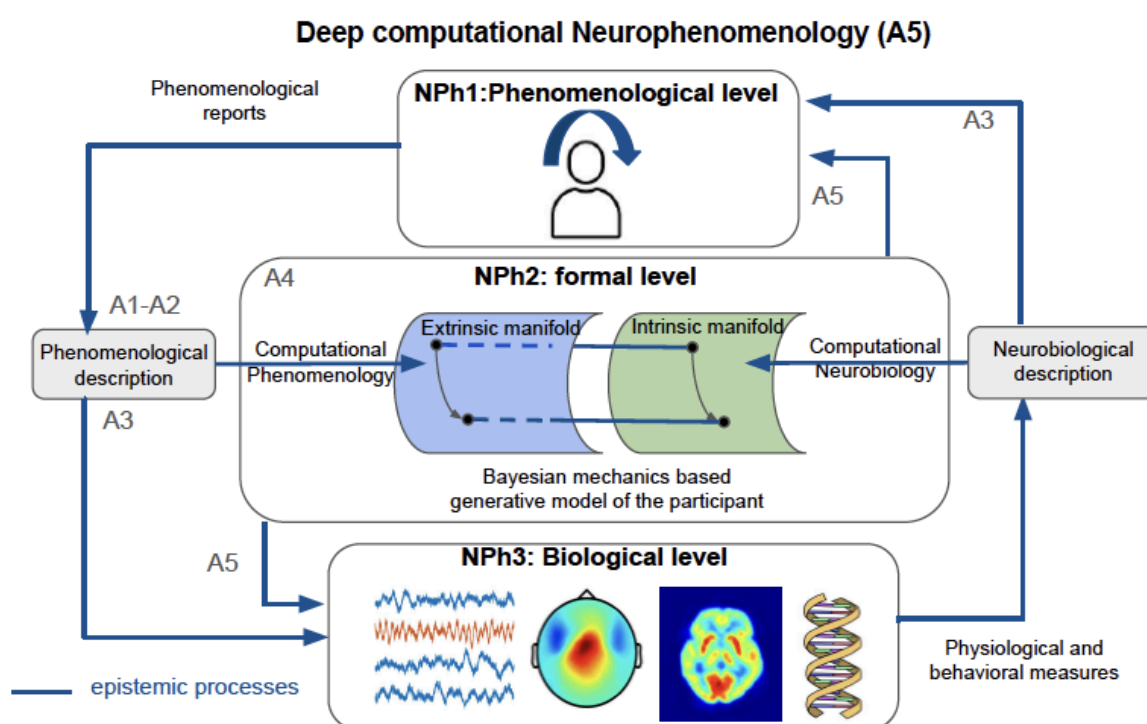


Figure 4: Deep computational neurophenomenology (DCNPh), a framework to study the ‘how’ of consciousness: This figure adapted from Sandved-smith et al. (2024) illustrates the information flows and mutual constraints in a hypothetical mechanistic study leveraging the proposed framework from level A5. This framework combines the epistemic gains from the levels A1 to A4 as well as additionally the ones provided by the Bayesian formalism (see A5 on 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 (NPh1), computational (NPh2), 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 (Sandved-Smith et al., 2024, 2021a). These self-referential computational models are illustrated in Figure 3 and can simulate some of the meta-cognitive processes mobilized in NPh (see level A1-A2). Here, NPh3 includes behavioral and physiological data, which could span across multiple time scales (milliseconds for EEG/MEG, seconds minutes for fMRI/PET, or days for biomarkers).

Sandved-Smith and colleagues (2024) proposed that it is possible in principle to map deep parametric models from computational phenomenology (level A4) to the ones from computational neurobiology by virtue of the dual information geometry of Bayesian mechanics, making it possible to establish, under certain conditions, ‘generative passage’ (Varela, 1997) between lived experience and its physiological counterpart. Bayesian mechanics provides an explicit formal connection between two 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 Figure 4) of the organism to the ‘extrinsic’ dynamics of the beliefs parameterised by the internal states (Friston et al., 2020). Thanks to the dual geometry of Bayesian mechanics, DCNPh aims to experimentally establish generative passage between first-person and third-person data by mapping them into their respective intrinsic and extrinsic models (Sandved-Smith et al., 2024). More specifically, phenomenological reports serve as the basis to construct a phenomenological description of given structural invariants (NPh1). This description is expressed within the phenomenological framework of choice, e.g., terminology from contemplative practices or clinical psychology (see level A1-A2). This first-person account can already be used to guide the analysis and interpretation of the (neuro-)biological data (label A3; see Figure 2). In a more demanding version, this description is subsequently translated into the computational model by the practice of computational phenomenology (Ramstead et al., 2022; Sandved-Smith et al., 2024; Smith et al., 2021) which attempts to relate model parameters to structural 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 (NPh1 on NPh2) or the identification of novel neural correlates associated to specific parameters of the model (e.g., level 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 side of Figure 4). Here, the epistemic constraints from the extrinsic to the intrinsic dynamics are bi-directional. For instance, the biological level can constrain the phenomenological model via the generative passage, providing possible guidance in the phenomenological investigation. Examples of constraints come from the neurofeedback literature on meditation (Garrison et al., 2013; van Lutterveld et al., 2017), which could be refined via the formalism used in DCNPh.

We will close this section by using the binocular rivalry paradigm to illustrate the epistemic gain that deep computational neurophenomenology provides as the participants are trained in increasingly refined phenomenological inquiry and report (see Sandved-Smith et al 2024 for details). Binocular rivalry is a perceptual phenomenon where two separate images are presented to the two eyes, which induces a perception alternating between the two images every few seconds. Normally, in studies that employ a binocular rivalry paradigm,

participants are not asked to report on *how* the stimulus appears, such as their affective or attentional state fluctuations, but only to report on *what* is being perceived. In a DCNPh study what is manipulated is how the percept is affecting the agent and to what extent the agent then interprets the percept as subjectively real. This opens up the possibility to integrate refined and reliable phenomenological data related to *how* experience is being constructed moment by moment, which can be used to fit a more inclusive generative model of human phenomenology that accounts for a broad range of causal factors implicated in conscious experience. A possible example would be to construct a deep computational model for the rivalry task presented in (Katyal et al., 2024). This model would bridge the phenomenological data and the EEG results and serve as a computational explanation of the regulation of response to affordances through the dereification stance. In this setting the degree of reification, or subjective realism, is experimentally manipulated by using one image that has higher associated affordances than the other (e.g. attractive vs neutral food image, see (Baquedano et al., 2017)), leading to an increase in the dominance of this image. Experienced meditators and novices are then asked to report on the rivalry during a meditation induced de-reified state, which was compared to a control state. The authors report that only the experienced participants attenuate the preferential processing of the high-affordance image in particular during the meditative state (Katyal et al. 2024). A deep computational model of this paradigm could in principle generate insights into the mechanisms underpinning the process of dereification in experienced meditators by combining evidence elicited from reports of the what (changing stimulus dominance) and the how (changing degree of dereification). Furthermore, the perceptual durations of objects across both states positively correlated with the degree of EEG μ -rhythm desynchronization, indicating that neural processing of affordance impacted perceptual awareness (Katyal et al. 2024). This suggests that the empirical EEG data the authors collected might constrain the intrinsic dynamics and provide further evidence for the resulting model of dereification.

5. Perspectives: implications for mental health and consciousness research

This chapter focused on highlighting the epistemic gains that can derive from rigorously training participants in first-person methods such as mindfulness meditation. As a perspective, we would like to highlight how these epistemic gains 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. Here, we expect that these recent advances in neurophenomenology (NPh) can lead to specific and novel synergies between epistemological and therapeutic processes (see Figure 5). One core reason is that mindfulness meditation is both a technique to train the epistemic agent in NPh (Figures 3-4), and also a psychotherapeutic intervention for alleviating the patient's suffering (Goldberg et al., 2018). Figure 5 illustrates this idea in an hypothetical case of a NPh clinical study using a mindfulness-based intervention (MBI) for preventing depression relapse. In this conceptual example, the disciplined circulation between first- and third-person perspectives allowed for by DCNPh 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 MBI, these new phenomenological assessments

(A1-A2) and their computational modeling could offer a way to determine whether depressed patients would benefit from a MBI, a compassion-based approach, specific medications, or a combination of drug therapy and psychotherapy. Additionally, this integration could allow for more precise monitoring of patients' trajectories, difficulties and progress, paving the way for more personalized interventions.

In virtue 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, its precise parameters' values can be fitted to a patient's idiosyncratic conditions and help the clinician to diagnose a depression sub-type, 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 patients' subjective experiences and symptoms 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 NPh provide useful conceptual and methodological tools to integrate, investigate, and mutually constrain the first- and third-person dimensions in meditation research and psychiatry.

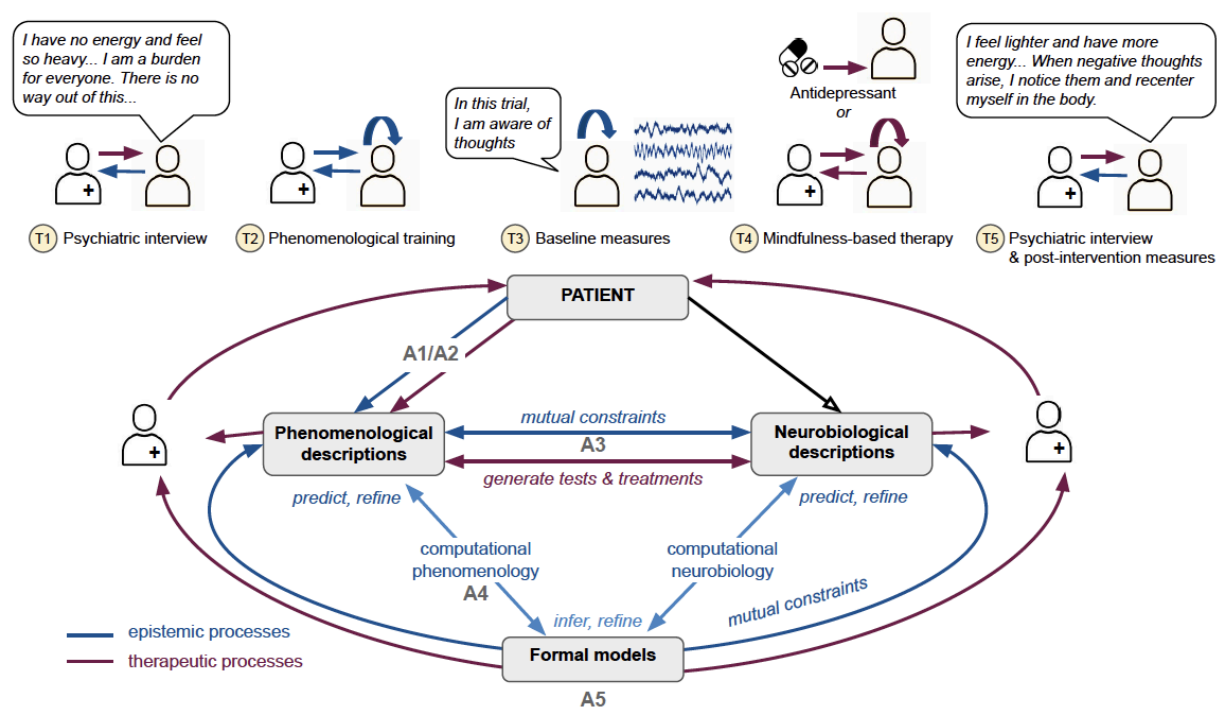


Figure 5: Deep computational neurophenomenology (DCNPh) in psychiatry: a framework to study the self-regulatory processes in patients trained with psychotherapies such as mindfulness-based

interventions. This figure illustrates how epistemic and therapeutic processes could mutually constrain and enhance each other in the DCNPh 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. The text in blue specifies the epistemic processes and the text in purple specifies the therapeutic processes. A canonical example of a trial with Mindfulness-Based Cognitive Therapy on depression relapse right after an acute episode of depression (Dimidjian et al., 2010) is shown. The purple arrow from patient to phenomenological descriptions depicts for instance a refinement of the patient's coping mechanisms. The arrow "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 and/or psychological treatment. Finally, the purple arrow from the formal models to the clinician illustrates its 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 neuro-modulation based treatments, as well as biological measurements on various time-scales (e.g., EEG, functional imaging, genotyping).

The recent DCNPh framework raises numerous questions for future research on consciousness. Much of the research in neuroscience concerned with the neural correlates of consciousness (NCCs) has attempted to correlate neural activity with the contents of conscious experience (Koch et al., 2016). We suggest that focusing exclusively on the contents of experience is too limited when it comes to the comprehensive study of subjective experience. DCNPh provides a method for investigating the "how" of conscious experience - the subjective givenness of experiences that the subject becomes explicitly aware of only after they have altered their attitude towards their experience by engaging in contemplative practices or by performing the phenomenological reduction.

As a conceptual framework for this chapter, we used the program of neurophenomenology. This program is historically rooted in the enactive approach to cognition (Gallagher, 2023; Thompson and Zahavi, 2007; Varela et al., 1991). It has recently been argued that the FEP and the active inference framework, which underwrite the generative modelling approach we draw upon in section 4, are fundamentally incompatible with the enactive approach to cognitive science (Aguilera et al., 2022; Di Paolo et al., 2022), which initially guided Varela's NPh program. We have not directly responded to the specific objections of Di Paolo, Aguilera and colleagues (but see Bogotá, 2024; Kiverstein et al., 2022). We have however attempted to demonstrate the fecundity of the FEP in providing formal tools that can allow for generative passage connecting phenomenology to neurobiology. This aspiration is consistent with the enactive research framework and the pragmatic goals of neurophenomenology.

Sandved-Smith and colleagues (2024) have suggested broadening the scope of consciousness research to include both the 'what' and 'how' of phenomenology by leveraging deep parametric generative models, which possess beliefs about the parameters of other beliefs. They argued that this makes it possible to model the process of 'dereification' or 'phenomenological reduction', advocated by Phenomenologists and contemplatives to explore consciousness.

Our chapter has brought together clinical applications of NPh with the use of this method for consciousness research (see Figure 5). A question for future research is how the NPh

method as an approach to consciousness studies that starts from and remains connected with lived experience can tackle ethical questions about how to reduce human suffering. Other key questions we have not tackled in this chapter concern the explanatory scope of this framework and its relationship to existing theories of consciousness. While this question is beyond the scope of this chapter, we can just emphasize that the DCNPh differs from axiomatic theories of consciousness (e.g. Integrated Information Theory (IIT), Tononi, 2008) by remaining neutral about the sufficient conditions from which the phenomenal qualities of conscious experience can be deduced. DCNPh is above all a methodological framework to create epistemically fruitful circulation of knowledge between phenomenology, formalism and neurobiology. In DCNPh the subject brings into the foreground (i.e; the what) through the use of phenomenological first-person methods what ordinarily lies in the background of their experience (i.e. the how of their lived experience). Without including the first-person data of trained participants, the how of experience would remain in the background of our awareness, so long as we remain involved with our experience and their objects by living through them. Crucially, the use of this method is open-ended because there is always more in the background than can be described. There is therefore a fundamental limit to what can be accessed through phenomenological first-person methods. The existence of such a limit and open-endedness to what can be phenomenologically described could be at odds with the axioms of IIT that seem to suggest that first-person experience can be exhaustively captured in formal mathematical terms. This possible tension will require further exploration and discussion in the future (for a mathematical presentation of these limitations see Fields et al., 2024; Sandved-Smith and Da Costa, 2024). A further key question pertains to the contribution of NPh to longstanding debates in introspection research, particularly regarding the reliability and reproducibility of first-person data. Additionally, the framework's potential role in teaching and understanding contemplative practices and well-being warrants exploration. For recent proposals of computational models of meditation see Laukkonen and Chandaria, 2024 and Sandved-Smith, 2024 and for a discussion on the relevance of computational neurophenomenology to subjective well-being see Smith et al., 2022. Future works will be required to address these and other questions as the framework of deep computational neurophenomenology is further developed to facilitate meaningful integration between first- and third-person methods for investigating the nature of consciousness.

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