

# Cessations of consciousness in meditation: Advancing a scientific understanding of *nirodha samāpatti*

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## Abstract

Absence of consciousness can occur due to a concussion, anesthetization, intoxication, epileptic seizure, or other fainting/syncope episode caused by lack of blood flow to the brain. However, some meditation practitioners also report that it is possible to undergo a total absence of consciousness during meditation, lasting up to 7 days, and that these “cessations” can be consistently induced. One form of extended cessation (i.e., *nirodha samāpatti*) is thought to be different from sleep because practitioners are said to be completely impervious to external stimulation. That is, they cannot be ‘woken up’ from the cessation state as one might be from a dream. Cessations are also associated with the absence of any time experience or tiredness, and are said to involve a stiff rather than a relaxed body. Emergence from meditation-induced cessations is said to have profound effects on subsequent cognition and experience (e.g., resulting in a sudden sense of clarity, openness, and possibly insights). In this paper, we briefly outline the historical context for cessation events, present preliminary data from two labs, set a research agenda for their study, and provide an initial framework for understanding what meditation induced cessation may reveal about the mind and brain. We conclude by integrating these so-called *nirodha* and *nirodha samāpatti* experiences—as they are known in classical Buddhism—into current cognitive-neurocomputational and active inference frameworks of meditation.

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## Keywords

Consciousness, Meditation, Cessation, Awareness, Active inference, Predictive processing, Nirodha samāpatti, Jhāna, Fruition

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## 1 Introduction

Many unique states of mind have been described by meditators and contemplatives. These can range from ecstatic and mystical absorptions to out-of-body experiences, and even states of so-called pure consciousness (Metzinger, 2020). However, as yet, no scientific papers that we are aware of have explored a meditation-induced event known in *Pāli* (the liturgical language of *Theravada* Buddhism) as *nirodha samāpatti* (*NS*), which literally means “cessation attainment,” but often is rendered as “cessation of feeling and perception” (Nanamoli and Bodhi, 1995). Compared to other non-ordinary experiences that scientists might be tempted to dismiss due to their inherently subjective and variable nature, the *NS* experience is concrete: an internally induced *absence* of consciousness. The event is outwardly comparable to general anesthesia and differentiated from deep sleep in that after a *NS* event there is no sensation of time having passed, there are no dreams, and one cannot be ‘woken up’ by physical stimulation or pain (Nanamoli and Bodhi, 1995).<sup>a</sup> Clearly, in terms of understanding the mind and brain, the capacity to voluntarily turn off consciousness, analogously to general anesthesia, is immensely interesting, also given how rare the capacity is and its implications for our understanding of top-down processing in the brain.<sup>b</sup> There are also notable after-effects of *NS* (and other cessation) experiences involving a profound sense of clarity, which some meditators describe as a kind of inner “reset,” which further differentiates this experience from (coming out of) sleep or general anesthesia.

The aim of the present paper is to describe the cessation event to a scientific audience, to contextualize it within contemporary cognitive neuroscience, and to generate a research agenda. All authors on the present paper—including PIs of three independent research programs and a *Theravada* Buddhist meditation teacher—have been directly involved in collecting neuroimaging and physiological data on cessation events. Hence, this paper developed out of a desire to generate a clearer characterization of what is so far known about the state(s) of cessation, how it might be integrated in the mind sciences, and what might be learned by studying it further.

Below we begin with a relatively colloquial description of *nirodha samāpatti* and a more general phenomenon *nirodha*—and how these are said to occur in the course meditation according to canonical Buddhist texts, known collectively as

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<sup>a</sup>With some exceptions, for example when a meditator “intends” to be woken up by a certain stimulation.

<sup>b</sup>Consider also the question “what the evolutionary imperative of such a capacity might be?.” As we discuss in later sections, one speculative possibility is that the capacity for *NS* is evolutionary spandrel related to a latent capacity for hibernation. Curiously, and similar to other mammals, meditators have inclined for thousands of years to practice intensively in caves.

the *Pāli Canon*.<sup>c</sup> In later sections we focus our attention on what *nirodha* might reveal about the plasticity of mind and brain, describe some of the initial studies we have conducted, explore how these phenomena might be disruptive to certain metaphysical viewpoints about the nature of self, and finally what they mean for the practice and theory of meditation. Note that we are not approaching the topic as historians, but as scientists: We draw on a combination of relevant textual evidence, on phenomenological reports from contemporary practitioners, conversations with meditation teachers, and on our own understanding from studying cessation (both *nirodha* and *NS*) under laboratory conditions based on preliminary data that we have collected. Moreover, we present an attempt to place *NS* within the influential framework of active inference or predictive processing (Friston, 2009), that has rapidly gained influence in the cognitive and neurosciences in recent years as an all-encompassing theory of brain and mental functioning.

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## 2 Nirodha and nirodha samāpatti

There is a distinction to be made between *nirodha* (cessation) and *nirodha samāpatti* (translates to “cessation attainment” but also called “cessation of feeling and perception”). *Nirodha* events can happen spontaneously in the course of deep meditation and are experienced as a short “gap” or “cut” in the stream of consciousness in the realm of milliseconds or seconds, often followed by a sense of clarity and openness. The *subsequent* changes to cognition can be short- (e.g., minutes to hours) or long-lasting (e.g., days, weeks, months, years or permanent). *Nirodha* cessations can represent an important stage of progress in meditation and is sometimes equated with other phases of meditation known as path (*magga*) or realization and fruition (*phala*) (e.g., Berkovich-Ohana, 2017; Sayadaw, 2016).<sup>d</sup> On the other hand, *nirodha samāpatti* (*NS*) involves a much more intentional process where one needs to be able to pass through various stages of *samadhi* (i.e., concentration, serenity, or tranquility) and then willfully create the conditions for *NS* to occur for a pre-specified amount of time (ranging from very short to up to as long as 7 days, Buddhaghosa, 2020).<sup>e</sup> Moreover, it is said that *NS* is only available to the most advanced meditators who have already experienced multiple brief cessations. Note that we refer to both *nirodha* and *NS* as different forms of cessation. To illustrate the nature of *NS*, the *Maha Vedalla sutta* (Nanamoli and Bodhi, 1995) distinguishes the state from death as follows:

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<sup>c</sup>The *Pāli Canon* consists of three collections of books, 1. The Vinaya (rules that the monks have to obey), 2. The Suttas, discourses ascribed to the Buddha and his close students (Bodhi, 2000; Nanamoli and Bodhi, 1995; Walshe, 1995; and two more series), and 3. The Abhidhamma (summarized in Bodhi, 2012), also called Buddhist psychology. In the later Visuddhimagga (Buddhaghosa, 2020), the teachings of the Suttas have been systematized.

<sup>d</sup>There may be disagreements about the value of cessations for fruition depending on the Buddhist tradition.

<sup>e</sup>While this is considered the common way to enter into *nirodha samāpatti*, some meditators report alternative methods that may also work.

*“In the case of the one who is dead, who has completed his time, his bodily, verbal and mental fabrications have ceased and subsided, his vitality is exhausted, his heat subsided, and his faculties are scattered. But in the case of a monk who has attained the cessation of perception and feeling, his bodily, verbal and mental fabrications have ceased and subsided, his vitality is not exhausted, his heat has not subsided, and his faculties are exceptionally clear.”*

The above quote indicates that *NS* is different from death because only the person who has died has lost their physiological capacity to maintain a normal body temperature, their life energy (or vitality), and their capacity to regulate their body (faculties). On the other hand, *NS* is similar to death because one is also no longer experiencing any perceptions and feelings and they have no bodily, verbal, or mental *fabrications* (i.e., experiences, which are characterized as fabrications in Buddhism, [Burbea, 2014](#)). Thus, according to Buddhist literature, *NS* is a kind of suspended animation where key physiological processes remain intact (although possibly slowed down), but all conscious experience has ceased ([Buswell and Lopez, 2014](#)).

Cessation (both *nirodha* and *NS*) is therefore also distinct from experiences of pure consciousness and non-dual awareness ([Josipovic, 2019](#); [Laukkonen and Slagter, 2021](#); [Metzinger, 2020](#); [Millière et al., 2018](#); [Milliere and Metzinger, 2020](#)), selfless experiences ([Deane, 2020](#); [Dor-Ziderman et al., 2013](#); [Milliere and Metzinger, 2020](#)), or other spiritual or altered states of consciousness that might be elicited through meditation or other means (e.g., psychoactive substances, psychological disorders, or brain traumas). Experiences of selflessness or events that might resemble pure consciousness or non-dual awareness may happen either before or after cessation, but not during cessation. This distinction between pure consciousness and cessation is clarified further in the theoretical frameworks sections.

Although our goal in this paper is to focus on the peculiar prospect that meditation can induce an absence of consciousness, why might it be of value to a meditator to undergo cessation? Anecdotal evidence from participants in our research, which is consistent with the ancient texts ([Buddhaghosa, 2020](#); [Thera, 1961](#)), proposes that cessation causes an important transformation for how the mind works and triggers a profound clarity and openness, although this is yet to be tested. Moreover, in some cases, what is discovered upon emergence is believed to be important because one is exposed experientially to the progressive reconstitution of the mind. In Buddhism, the processes through which the *samsāric*<sup>f</sup> mind assembles itself are known as *paṭiccasamuppāda*. (dependent origination or arising), sometimes dissected into 12 stages or *nidānas* (i.e., links). The experience and understanding of dependent origination, which some meditators associate with the stages of how the mind reassembles, is an important hallmark of contemplative realization or understanding in all Buddhist traditions ([Boisvert, 1995](#)).

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<sup>f</sup>Samsara represents a mind or life that is characterized by dukkha or unsatisfactoriness.

We also acknowledge that there are many uses of the term *nirodha* even within Buddhism and across Buddhist traditions. For instance, and as noted above, in some cases *nirodha* is associated with other terms, such as path(*magga*)/fruition(*phala*) (Berkovich-Ohana, 2017; Sayadaw, 2016). However, for the purposes of our current presentation, we equate *nirodha* specifically with the experienced absence of consciousness that can occur, which may or may not be associated with the other stages of meditation progress. On the other hand, *NS* refers to the willful entry into such an absence for a determined period. Thus, for scientific purposes and based on reported phenomenology of subjects we have worked with in the laboratory, here we define cessation as:

*“The absence of all experience and consciousness—with no retrospective awareness of anything having taken place during the absence—accompanied by a subsequent profound sense of clarity, openness, and vitality.”*

Other important experiences may occur after cessation, but these may not be consistent for all meditators (e.g., insights or pure awareness events), hence we have adopted the characteristics that seem to be the most consistent or “necessary and sufficient” conditions.

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### 3 Buddhist meditation context

In order to contextualize cessation, below we begin with the soteriological description of *Theravada* Buddhist *jhāna* meditation, the prerequisites for being able to spontaneously enter *nirodha*, and the procedure to actually enter into and emerge from this state on demand<sup>§</sup> (i.e., *NS*). Practicing meditation in order to attain certain levels of *jhāna* has received relatively little attention within science (with a few exceptions, Dennison, 2019; Hagerty et al., 2013). *Jhāna* practice encourages maintaining one “object” of attention largely at the exclusion of others (although in some traditions this can involve an accompanying openness; Vimalaramsi, 2015). This kind of *samatha* (tranquility) practice—sometimes dubbed focused attention (Lutz et al., 2008)—when ongoing, is thought to lead to various reliable changes in one’s experience as the meditation deepens. It can be used as a support for mindfulness or *vipassanā* (insight) practices (Catherine, 2010; Nanamoli and Bodhi, 1995), or mindfulness can be brought into the *samatha* meditation and be present throughout the *jhānas*. The *jhānas* can also be one-pointed (highly focused) or more open and aware (Catherine, 2010; Vimalaramsi, 2015). There are eight *jhānas* and after the eighth

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<sup>§</sup>Note that although some meditators can voluntarily enter cessation, they cannot choose to do so in the same way that one might turn off a light switch. Instead, the meditator creates certain conditions and intentions before meditation, then engages in the practice that leads to a voluntary but *spontaneous* cessation (Buddhaghosa, 2020).

*jhāna* (or subsequent signless state, tbd), if the conditions are right (Buddhaghosa, 2020; Thera, 1961), *NS* occurs. Notably, *NS* requires a combination of mastery in both insight (*vipassanā*) and *samatha* (i.e., *jhāna*) practice (Buddhaghosa, 2020; Thera, 1961). One way to think of *jhānas* are as levels of deepening *samatha* (concentration) meditation. Another way is to think of them as levels of serenity or 'letting go' (Armstrong, 2021; Johnson, 2017), which uncover aspects of the mind that usually go unnoticed.

### 3.1 The four *rupa* (form/material) *jhānas*

The first four *jhānas* have different characteristics described in terms of thinking/attention, feeling, and the quality of awareness. Each *jhāna*, somewhat counterintuitively, is a reduction in some mental quality or habit. Hence why they have sometimes been referred to as levels of cessation (Armstrong, 2021). The first four *jhānas* are known as *rupa* or "form" *jhānas* because they involve some experience of the senses and the object of focus is "material" in nature. The four form/material *jhānas* are presented in Table 1 (Bodhi, 2012; Nanamoli and Bodhi, 1995).

### 3.2 The four *arupa* (formless/immaterial) *jhānas*

The four subsequent *jhānas* are known as formless or *arupa jhānas* because they no longer include a sensory experience. Instead, the key characteristics of these *jhānas* are mental and their qualities predominate when sensory experience has largely (or totally) abated. Moreover, the basis of the *arupa jhānas* is equanimity, i.e., *jhāna* four. These *jhānas* and their translations are presented in Table 2 (Bodhi, 2012; Nanamoli and Bodhi, 1995). As an illustrative example of the transition from the last form *jhāna* to the first formless *jhāna*, the fifth *jhāna* known as *ākāsānañcāyatana* or "infinite space" is described as follows:

**Table 1** Description and translation of the four "form/material" *jhānas*.

<i>jhāna</i>	Qualities or objects of mind in Pali and in English					
ONE:	<i>Vitakka</i>	Applied att.	<i>Pīti</i>	Joy	<i>Karuna</i>	Compassion
	<i>Vicāra</i>	Sustained att.	<i>Sukkhā</i>	bliss	<i>Mudita</i>	Empathy
TWO:			<i>Pīti</i>	Joy	<i>Karuna</i>	Compassion
			<i>Sukkhā</i>	bliss	<i>Mudita</i>	Empathy
THREE:					<i>Karuna</i>	Compassion
					<i>Mudita</i>	Empathy
FOUR:					<i>Upekkā</i>	Equanimity

Note: Att. = Attention/thought. There are variations in translations, however for our purposes it is sufficient to note that the progression of the *jhānas* involves a reduction in different qualities of mind (or mind activities) that are usually considered positive. Hence, the initial *jhānas* already feel "positive" but the later *jhānas* are more stable and calm. Note that some traditions use *karuna* and *mudita* as objects of meditation in the form of *metta*.

**Table 2** Description and translation of the four “formless/immaterial” *jhānas*.

<i>jhāna</i>	Qualities of mind in Pali and in English	
FIVE:	<i>Ākāsānañcāyatana</i>	Infinite/boundless Space
SIX:	<i>Viññānañcāyatana</i>	Infinite/boundless Consciousness
SEVEN:	<i>Ākiñcaññāyatana</i>	Nothingness
EIGHT:	<i>Nevasaññānāsaññāyatana</i>	Neither Perception nor Non-Perception

Note: *The use of the word consciousness in classical Buddhism tends to be different than the way consciousness is construed in contemporary science (i.e., as the presence of phenomenality as such). Clearly, jhānas seven and eight still have some, albeit subtle, phenomenal experience present. There is also a transitional state after the eighth jhāna known as the signless state.*

*“By passing entirely beyond bodily sensation, by the disappearance of all sense of resistance, and by non-attraction to the perception of diversity, seeing that space is infinite, he reaches and remains in the sphere of infinite space (Walshe, 1995, 9:14).”*

It is beyond the scope of this paper to detail the experience of each of the *arupa jhānas*. It is sufficient to say that in the current context, like the first four *jhānas*, each progression of the formless *jhānas* is thought to represent the discovery of more subtle and deeper qualities of the mind, that is, with less and less contents of consciousness. Put differently, as one’s relaxed concentration (*samatha*) deepens and greater letting go occurs (Armstrong, 2021; Johnson, 2017) then the qualities of the present *jhāna* disappear and give rise to the qualities of the next *jhāna*, and so on. Contemporary practitioners of *jhāna* meditation may also use particular instructions at each stage in order to progress the mind from one *jhāna* to the next (e.g., Burbea, 2014; Catherine, 2010). Note that in *jhānas* 1–4 there is a gradual refinement of the mental factors present. In *jhānas* 5–7 the mind-state remains as in *jhāna* four (equanimity), but the qualities of the mind are increasingly refined. After *jhāna* eight is the ‘signless state’, where the difference between subject and object seems to melt away, and hence is comparable to a non-dual state.

### 3.3 *Nirodha samāpatti*: Preparation, procedure, and prerequisites

As mentioned in the introduction, although rare, a *nirodha* event can occur in the course of meditation and does not necessarily require one to pass through all of the *jhānas* (Berkovich-Ohana, 2017). However, in order to master *NS* and be able to turn off consciousness at will and for a predetermined amount of time, it is suggested that one needs to be capable of passing easily through all eight *jhānas* (Buddhaghosa, 2020; Thera, 1961). According to these texts, it is necessary that the meditator is able to:

1. Direct attention to a chosen *jhāna*
2. Enter the chosen *jhāna*
3. Predetermine how long one will be in the chosen *jhāna*
4. Emerge from the *jhāna*
5. Reflect on the *jhāna*

But even more is said to be needed in order to be able to willfully induce *nirodha* (Buddhaghosa, 2020). The meditator must also be at an advanced stage of “liberation,”<sup>h</sup> known as an *Anāgāmi* or “non-returner” (i.e., partially enlightened, having eradicated aversion and sensual desire, but still with “conceit” and other hindrances remaining) or an *Arahant* (i.e., being fully enlightened, Nanamoli and Bodhi, 1995). And finally, the meditator must be able to repeat easily the insights leading to this stage.

There are also certain directions for preparation and intentions that the meditator should engage in before entering NS. For example, the meditator is directed to set an intention for the number of hours or days to remain in NS and to know that they will not die during the state. It is also advised that the meditator *does not* enter NS for longer than 6 days (or 7 days at the most) because this could be dangerous for the body (Buddhaghosa, 2020). Some practitioners also engage in training *determinations* (cf. capacity 3 above) in order to refine their ability to automatically or physiologically track the passage of time. For example, the practitioner may set an intention to sit for a specific number of minutes and regularly test themselves in order to improve their ability to predict when the intended amount of time has passed (Buddhaghosa, 2020). Once the practitioner has mastered meditating for the chosen amount of time, then they are said to be able to set an intention to enter NS for a prespecified time, and the body is said to naturally “wake up” the meditator after that time has passed (Buddhaghosa, 2020).

It is also highly likely that many contemplatives from traditions outside of Buddhism have undergone similar experiences, either intentionally or spontaneously in the course of meditation. There are certainly recognizable anecdotes to be found from renowned teachers in other traditions, including Ramakrishna (Saradananda, 2015) and Ramana Maharshi (Godman, 2017). In both of these cases, the contemplatives report experiencing states during which the body’s normal functioning changed dramatically, and the body remained stiff and unresponsive to external stimulation.

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## 4 Contemplative science context

Next, we briefly consider how cessations fit into the broader literature on meditation and styles of practice. Currently, contemplative science literature is following several branches of inquiry. These include smaller branches conducting basic mechanistic investigations into the neural systems involved in meditation as well as psychobiological assessments of meditation correlates in long term practitioners.

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<sup>h</sup>Enlightenment in classical Buddhism is defined by the absence of specific mental qualities known as fetters (or obstacles). Examples of fetters (*samyojana*), of which there are 10, include: Ignorance, ill will, desire, conceit, and restlessness (Bodhi, 2000). From a cognitive perspective, this could map onto a decrease in harmful habits (see also footnote i).



The smaller branch is complementing a main branch investigating mindfulness training interventions for alleviation of clinical symptoms or increased wellbeing. Cessation has received little attention in the contemplative science literature, no doubt partially due to the technical challenges of studying the phenomenon (*nirodha* cessations are very brief, e.g., milliseconds), and longer periods of NS require significant practice expertise to attain, thereby rendering practitioners exceedingly rare and difficult to recruit. However, [Davis and Vago \(2013\)](#) report preliminary data that in meditators trained by Shinzen Young, the BOLD signal dramatically increased in front-polar cortex during “Gone” events (which share some, but not all, features with *nirodha*). They also emphasize the importance of quantitative measures to attenuate bias in self-reports of meditative states, measures which will be particularly important in verifying practitioner reports of cessation in future studies ([Davis and Vago, 2013](#)).

While NS requires specific cultivation to achieve, *nirodha* can occur in several different practice contexts. Previously, meditation techniques have been categorized according to four types of practices: focused attention (FA), open monitoring (OM), loving kindness (LK) and nondual (ND) meditation ([Josipovic, 2010](#); [Laukkonen and Slagter, 2021](#); [Lutz et al., 2007, 2008](#)). Briefly, FA meditation involves exclusive focus on one “object” of meditation (e.g., the breath) at the exclusion of others. OM involves a more open and relaxed attentional scope, and emphasizes a non-judgmental or mindful observation of experience (vipassanā meditation falls in this category). Relative to OM practice, ND may involve no “attention” as it is usually understood. ND releases the separation between subject (self) and object (other) in favor of resting in and as awareness ([Laukkonen and Slagter, 2021](#); i.e., the deepest form of inner “silence” [Paoletti et al., 2022](#); [Paoletti and Ben-Soussan, 2020](#)). However, it has also been noted ([Malinowski, 2013](#)) that several meditation practices draw on all of these techniques, and that they exist on a continuum more than as separate categories. Moreover, for advanced meditators, ND awareness may be reflexively present at all levels of practice ([Josipovic, 2019](#); [Laukkonen and Slagter, 2021](#); [Paoletti et al., 2022](#)).

More recently, this system has been refined from a set of bins (FA, OM, LK) to a series of dimensions, along which any practice can vary ([Dahl et al., 2015](#); [Lutz et al., 2015](#)). It has been proposed that the relevant dimensions for a typology of meditation are: dereification, object orientation, and meta-awareness, with meditation techniques sorted into “families” of practice: attentional (e.g., *jhāna*, *samatha* with support, mantra), constructive (e.g., *bhramavihara*/loving kindness practices), and deconstructive (e.g., Vipassanā, Koan practice) ([Dahl et al., 2015](#); [Lutz et al., 2015](#)). Attentional practices draw upon cognitive processes of attention regulation and meta-awareness, constructive practices recruit perspective taking and reappraisal, and deconstructive practices rely upon the cognitive process of self-inquiry. The attentional family of practices, including mindfulness meditation, has received the most scientific attention, with a relative paucity of studies on constructive and deconstructive practices, including insight and “do nothing” practices ([Dahl et al., 2015](#); [Lutz et al., 2015](#)).

While the key contributing practice factors for cessation have not yet been described directly, [Desbordes et al. \(2015\)](#) advanced equanimity as a viable outcome measure of meditative experience, and all of the practice categories in the deconstructive family (e.g., vipassana) advanced by [Dahl et al. \(2015\)](#) simultaneously depend on equanimity for efficacy and cultivate equanimity as an outcome of practice. Taken together, these works suggest that practices of cultivating and sustaining equanimity, some degree of focused attention, and deconstruction may be necessary for *nirodha* ([King, 1977](#)). However, the deep absorptive concentration associated with the *jhānas* is said to only be necessary for *NS* ([Buddhaghosa, 2020](#)).

Although often touted as a risk-free way to move the practitioner toward a greater sense of well-being and flourishing, meditation practice is not without risks ([Lindahl et al., 2017](#); [Schlosser et al., 2019](#)). Lasting adverse effects of even a short (8-day) mindfulness intervention include hyperarousal and dissociation ([Britton et al., 2021](#); [Lindahl et al., 2020](#)). Given the level of expertise required for both *nirodha* and *NS*, it is relevant to note that in long term practitioners, documented adverse effects are predicted based on having been on an overnight meditation retreat ([Schlosser et al., 2019](#)). Thus, understanding how to resource and support practitioners pursuing these states in long—multiple day, week, or month—retreats is vital (e.g., adequate preparation and beneficial integrative practices).

The full extent of preparation and integration that is sufficient to mitigate adverse effects is not known, but prior work suggests that factors that can ameliorate difficult experiences include mentors and friends working directly with the practitioner in their own social context ([Lindahl et al., 2017](#)), and having practitioners balance deconstructive practices with other types of practices, such as *samatha* or loving kindness ([Schlosser et al., 2019](#)). It may also be supportive to have a conceptual framework that manages expectations such that difficult experiences are not as surprising to the practitioner, and to have trained psychologists available when particularly troubling experiences occur.

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## 5 Preliminary findings

Below we outline preliminary findings from two experiments (in preparation for publication). As research into cessation is in its infancy, we describe these findings as they may support others who might be starting out on a similar research project and they may be useful in the development of (initial) neurocognitive models for generating hypotheses. These findings cannot yet be used to draw strong conclusions.

In a recent pilot study conducted by authors MDS and AC, we used EEG to examine the neural correlate of *nirodha* in an adept meditator with over 6000 hours spent in meditation retreats. In this case, what the participant considers *nirodha* was observed during *vipassanā*/open-monitoring/insight meditation practice. In some traditions, *nirodha* is believed to be a culmination of the Stages of Insight meditation ([Sayadaw, 2016](#)), whereas *NS* is the culmination of both insight and *samatha* practice. As described earlier, this meditator reported *nirodha* as a momentary extinction of

experience that was followed by profound alterations of consciousness,<sup>1</sup> a sort of “reset” that is characterized by mental clarity. In the study, we employed a neurophenomenological approach where our phenomenologically trained subject systematically evaluated the mental and physiological processes relevant to *nirodha* as he experienced them, and these evaluations were used to classify and select 37 high-grade *nirodha* events for subsequent EEG-based analysis.

Preliminary results have shown that 20s before *nirodha* (not *NS*), there begins a linear decrease in large-scale functional neural interactions in the alpha-band, as reflected by an EEG-based measure of functional connectivity. Markedly, this interaction was lowest immediately following a cessation, and there was a gradual increase from  $\sim 3$  to  $\sim 40$ s post cessation wherein these interactions returned to prior levels. The modulation of network integration was unique to the alpha frequency band—there were no significant differences in functional neural interactions before or after *nirodha* in the delta, theta, or beta frequency bands. This decrease in global functional connectivity may indicate a gradual reduction in information exchange between different brain areas and ultimately to the experience of a “cut” from consciousness during *nirodha*.

It is interesting to note that a study by [van Lutterveld et al. \(2017\)](#) previously reported increased alpha-band network integration during meditation in experienced meditators. In comparison, our results suggest that although progressive meditative stages may be characterized by increased alpha-synchronization, *nirodha* events appear to be experienced following a gradual decrease in overall brain connectivity. Another study by [Berkovich-Ohana \(2017\)](#), also using EEG, analyzed data from two adept meditators as they experienced three *nirodha* events (termed fruitions in the paper) each (i.e., a total of six *nirodhas*), and reported increased global long-range gamma (25–45 Hz) synchronization during states of *nirodha* as compared to non-*nirodha* states. The authors interpret the increased gamma signature as possibly offering an underlying mechanism for the un-learning of habitual conditioning and mental patterns.

In another EEG study of an adept meditator from authors RL, HB, MS, AC, and HS (in preparation for publication), we compared conditions of resting wakefulness

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<sup>1</sup>A typical description of alterations of consciousness following *nirodha* may include: a sense of increased clarity, less grasping of experience (i.e., de-reification), increased energy and vibrancy, “openness” of mind and emotions, greater mindfulness, increased cognitive flexibility, less self-centeredness, less concern for the past or future, just to name a few. Future research may benefit from interviewing experienced practitioners to confirm (e.g., via factor analysis) the consistency of these anecdotal characteristics, and their relative importance or strength. According to Buddhist literature ([Buddhaghosa, 2020](#)) the first *nirodha*/fruition associated with awakening leads to the absence of a subset of unwholesome mental factors (*cetasikas*), such as wrong view about self, greed, hatred, conceit (subsequent *nirodhas*/fruitions lead to the reduction or absence of yet other factors). One speculation is that as a consequence of putting an end to these unwholesome mental states (or bad habits) one may experience some of the side-effects described above, e.g., increased clarity and energy may follow because unwholesome habits cost energy. How *nirodha*/fruition could prevent particular mental states or habits from arising in the future is not known, and requires empirical investigation. We provide one potential computational mechanism in the discussion.

and a short duration of sleep (i.e., nap) to *nirodha samāpatti*. As described above, this particular type of cessation is the result of a hybrid *vipassanā* and *jhāna* or concentration meditation practice, and can be induced for a prespecified period of time. Interestingly, our result, albeit in  $n = 1$ , corroborated the previous finding concerning *nirodha* in that the *nirodha samāpatti* was also characterized by attenuated alpha-synchronization in comparison to the awake and nap conditions. Similar desynchronization of alpha has been found with ketamine (Blain-Moraes et al., 2014) and propofol (Kallionpää et al., 2020; Lee et al., 2013) induced unconsciousness, discussed further in the theoretical frameworks section.

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## 6 Theoretical frameworks: Predictive processing

Some of us (Laukkonen and Slagter, 2021) have previously proposed that the effects of meditation on (conscious) experience can be understood from the perspective of the predictive brain or active inference (Feldman and Friston, 2010; Friston, 2009). This perspective starts from the notion that our brains have no direct access to the outside world, only to their *own* sensory activation patterns, induced by electrical signals conveyed by the senses. Hence, in order to see and guide actions, brains must instantiate predictive models about the likely hidden causes of their sensory input, and continuously minimize prediction errors to ensure model reliability. In fact, in this perspective, the *main imperative* of the brain and mind is to minimize prediction errors.

Prediction error minimization can occur either by changing the predictions, through model updating (perceptual inference), or by generating the predicted sensory input through action (active inference). Importantly, not just perception and action, but all brain functions, including high-level cognitive processes, are understood as minimizing prediction errors, albeit at different time scales. That is, the deep temporal and hierarchical structure of generative models in the human brain allows for the entertainment of “what if” beliefs (or *counterfactual* hypotheses) about the world, and hypothesis testing that does not entail overt action (Friston et al., 2018). The ability to have beliefs about what it is like to act, to revisit how past events unfolded, and to internally simulate and weigh the potential consequences of one’s future actions underlies our ability to purposefully evaluate, imagine, remember, plan and make judgments (Buzsáki et al., 2014). Such covert or mental actions (Metzinger, 2017) allow the brain to reduce ambiguity over the outcomes expected under various policies in service of *future* action.

Crucially, brains not only predict upcoming sensory input, but also estimate the reliability of the sensory input (a second-order prediction). Obviously, it would be detrimental if the brain were simply at the whim of external influences, since sensory input can be noisy and/or not representative of the world at large. Therefore, brains also need to predict the reliability or *precision* of sensory input, which requires integrating information over time or experiences (Friston, 2009). It has been proposed that attention maps onto precision weighting, in line with empirical findings showing that attention can modulate the gain of sensory signals (Feldman and Friston, 2010; Hohwy, 2012).

In the predictive processing framework, the mind is hence constructed through past experience, which shows notable parallels to Buddhist ideas about the mind

as constructed in nature and conditioned by the past (Laukkonen and Slagter, 2021; see also Lutz et al., 2019 for an overview specific to FA meditation, as well as Pagnoni, 2019 for Zen practice). We previously put forward that predictive processing may hence provide a unifying framework for understanding the wide range of effects of meditation on mental experience (Laukkonen and Slagter, 2021). Specifically, we proposed that three main styles of meditation described earlier—FA meditation, OM meditation, and ND awareness meditation—can radically change ordinary mental experience by bringing the practitioner more and more into the present moment through physical and mental *inaction* and underlying changes in predictive processing. More specifically, we proposed that these styles of meditation can be placed on a continuum, and gradually reduce the temporal depth of predictive processing in the brain.

First, in FA meditation, high precision is assigned to one source of present-moment sensory input, typically breath sensations, which automatically reduces the precision assigned to other events that may normally habitually arise in experience (i.e., mind wandering thoughts at temporally deeper levels in the processing hierarchy). The way that reducing precision of thoughts reduces their arising is similar to the way that, while engaged with reading, we are not aware of the feeling of our shirt resting on our backs. Then, in OM meditation, any content of experience is assigned equal precision, and hence, consequently relatively low precision (bare attention), logically inducing a non-reactive mode of experiencing or a shift to pure sensing without evaluation. Finally, in ND meditation, a state of complete present-moment awareness is induced by releasing any (precision) expectations about even the very next possible moment. In this state, also the most temporally shallow mental processes should disappear.

Note that even seemingly direct experiences, like that of a teacup, demand a complex process of construction from past experience and include anticipation of possible changes in sensory input (e.g., proprioceptive and sensory changes related to drinking from the cup), which intrinsically relies on active inference and inferring oneself as a hidden cause of sensory input in the future. Thus, if awareness rests only in the now, even very basic structures of ordinary cognition should logically fall away, including conceptualization, self-awareness and time perception. One proposal is that the state of non-dual awareness reflects a representation of tonic or intrinsic alertness (Metzinger, 2020), a proposal that aligns with the fact that this state is unaffected by transient events, devoid of conceptual content, and accompanied by the feeling of wakefulness (Gamma and Metzinger, 2021). This predictive model of tonic alertness is temporally shallow, given that it does not entertain complex state transitions or sequences over time.

The question arises, how can the unusual state of cessation—assuming it exists as described above—be explained within this predictive processing framework? While non-dual awareness is characterized by wakeful awareness in the present moment (Metzinger, 2020), cessation is characterized by an absence of awareness and wakefulness. Speculatively, cessation could thus reflect a final release of the expectation to be aware or alert. Clearly, if the state of cessation can be sustained across multiple days, the normal wake-sleep cycle must be disrupted, supporting the idea that the

very basic expectation to periodically be awake is not entertained in the brain. Yet, it is conceivable that cessation also shares characteristics with deep sleep or other states that are characterized by a lack of awareness at the (neuro)physiological level, as from an evolutionary point of view, it seems unlikely that one can induce an entirely novel state that the body did not evolve to occupy in the past. These may include physiological changes that would support an ability to sustain the state for longer time periods, without, for example, being disrupted by signals of hunger or thirst, in particular a reduction in arousal, body temperature and metabolic rate, as also seen during sleep (Tononi and Cirelli, 2006). Indeed, anecdotal evidence suggests that the body of practitioners in *NS* is cooled down, their heart rate is lowered, and their breathing barely perceptible.<sup>j</sup>

The brain does not only minimize exteroceptive prediction errors, but also interoceptive prediction errors, that signal deviations from expected bodily states. Notably, it cannot directly minimize interoceptive prediction errors that signal deviance from expected physiological states: it can only do so indirectly, via active inference (Pezzulo et al., 2015). Take the example of hunger. Hunger arises when certain predicted sensory signals from stretch receptors gastrointestinal (GI) tract and from certain hormones that track food intake do not arrive in the brain. The brain can only resolve these interoceptive prediction errors through action, i.e., by eating. Thus, the brain can only indirectly, in the future, minimize interoceptive prediction errors through minimization of proprioceptive and exteroceptive prediction errors. Indeed, many allostatic processes are anticipatory building on the fact that many homeostatic processes are periodic and hence predictable (Barrett and Simmons, 2015). For example, we typically eat well before we get hungry (Drazen et al., 2006). The fact that, for example, hunger signals are not anticipated, experienced or acted upon during cessation thus suggests a disconnect at higher levels in the hierarchy where generative models encode associations between sensorimotor and interoceptive events (Pezzulo et al., 2015), in line with our proposal that meditation progressively reduces hierarchical, temporally deep predictive processing in the brain (Laukkonen and Slagter, 2021).

It is also possible that a very low metabolic rate during *NS* prevents the need to eat or drink, similar to what is observed in daily torpor and longer periods of torpor (e.g., hibernation) in mammals (Ruf and Geiser, 2015). Strikingly, the state of *NS* is allegedly accompanied by immobility, as is also the case during torpor, and coming out of the state of *NS* is said to be accompanied by a feeling of renewed energy, and torpor serves energy conservation. Yet, although the human body can much better deal with body temperatures below its lower bound than once thought possible, as shown in medical studies in which hypothermia is induced in injured patients to prevent organ damage, there is no evidence to suggest that humans, as homeotherms, can willfully induce hypothermia (or torpor) (Ruf and Geiser, 2015).

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<sup>j</sup>Although, in our preliminary data involving a period of 90 min *NS*, these physiological changes were not observed. Hence, either dramatic changes to physiology take time (i.e., possibly days or weeks, as they usually do in hibernating animals, Blanco et al., 2016; Tøien et al., 2011), or these characteristics are not necessary conditions of *NS*.

On the other hand, there is evidence from studies in experts in *g-tummo* meditation (a form of advanced Tibetan Buddhist meditation training) that suggests that they are able to enhance their body temperature, albeit likely only to slightly above the normal range (Kozhevnikov et al., 2013). Moreover, some work has associated *g-tummo* meditation with a hypometabolic physiological state, as shown by reductions in oxygen consumption and metabolic rate (Benson et al., 1990). For example, one study in three meditation experts reported that they could up- and down regulate their metabolic rate by 61% and 64%, respectively, which is much lower than the reduction in metabolic rate that occurs in regular sleep (Benson et al., 1990), although this finding warrants replication given that it is one of the only studies showing such radical results. Nevertheless, these findings do provide some promise that meditation can have powerful effects on physiological processes usually considered automatic. Yet, these changes are induced through processes with temporal depth (that rely on active inference): imagery and forceful breathing.

Of further note, both sleep and torpor are associated with changes in the activity of the ascending reticular activation system (ARAS) which mediates tonic alertness and arousal and is responsible for human consciousness level (Laureys et al., 2009). Meditation, including the state of non-dual or pure awareness, has also been related to changes in arousal and the ARAS system (Britton et al., 2014; Metzinger, 2020). Thus, some forms of advanced meditation may modulate predictive processes related to controlling physiological systems that are critical to maintaining (the potential for) wakefulness, resulting in *NS*. Future studies should systematically investigate (neuro)physiological changes over time during both short and longer periods of *NS* to better understand the mechanisms underlying the state and their similarity or differences to other states characterized by a loss of awareness, such as deep sleep and torpor. Future studies are also necessary to clarify to what extent spontaneous and willfully induced *NS* rely on similar mechanisms.

To summarize, *NS* may reflect a final release of the expectation to be awake or aware. This could be brought about through (neuro)physiological changes that support a low-arousal, hypometabolic state. Coming out of *NS* may follow a reverse path in which the mind is progressively reconstructed going from simple wakefulness (e.g., pure awareness, Metzinger, 2020) to temporally shallow (e.g., sensory experience) to temporally deep predictive processes (e.g., thinking) (Laukkonen and Slagter, 2021).

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## 7 Theoretical frameworks: Neural dis-integration

In addition to the above proposed mechanism of cessation related to a gradual deconstruction of hierarchical predictive processing, what might be the neural correlate of such a transition to unconsciousness? As described earlier, one replicated finding from our two unpublished studies is a reduction in alpha functional connectivity as measured by EEG (a preliminary finding). Yet, interestingly, a breakdown in alpha connectivity has been robustly connected to transitions from consciousness to

unconsciousness when induced by ketamine (Blain-Moraes et al., 2014) and propofol (Kallionpää et al., 2020; Lee et al., 2013) using the same measures as in our cessation research, i.e., the phase lag index.<sup>k</sup> This breakdown in normal synchronization may indicate an impairment in corticocortical communication (Supp et al., 2011) and thus a failure to bind together elements of a coherent conscious experience. Hence, it may be that some meditation styles, through their deconstructive elements (Dahl et al., 2015), actively dis-integrate or unbind aspects of phenomenology that results in a breakdown of functional connectivity, and thus unconsciousness. It is reasonable to expect that this final breakdown of consciousness can only occur once other, higher (in the hierarchy), levels of integration have been sufficiently relaxed, as described above (Laukkonen and Slagter, 2021).

Notably, the strength of network connectivity in subjects *before* anesthesia predicted their susceptibility to propofol (Chennu et al., 2016) suggesting that individuals may vary in their state or trait connectivity and that this can potentially determine the likelihood of unconsciousness. Meditation may progressively decrease the connectivity of aspects of conscious experience and thus make an episode of “unconsciousness” more likely to occur. This way of looking at cessation also shows consistencies with theories that propose consciousness rests on the capacity to integrate information (e.g., Tononi, 2004, 2008).

According to information integration theory (IIT, Tononi, 2005, 2008), one of the central features of consciousness is that it is a unitary phenomenon. That is, we always only experience a singular conscious experience instead of two or more separate consciousnesses. As noted by Tononi (2008, p. 219):

*“...underlying the unity of experience must be causal interactions among certain elements within the brain. This means that these elements work together as an integrated system, which is why their performance, unlike that of the camera, breaks down if they are disconnected.”*

That is why dis-integrating (i.e., dis-unifying) consciousness may unravel an essential and necessary feature of consciousness without which it does not occur. But how does consciousness remerge? This is a key question for future research. For now, we speculate that the processes are likely to be similar to re-emerging from deep sleep or other non-conscious state, e.g., via the release of particular hormones and neurotransmitters (Fuller et al., 2006).

Albeit speculative, there is an aspect of meditation that relates very closely to this kind of dis-integration of phenomenology and consciousness. A key concept in Buddhism is that of the five aggregates (*khandhas*) that are said to represent the totality of human existence from a phenomenological standpoint. These five aggregates are form, sensations, perceptions, mental activity, and consciousness. Without entering

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<sup>k</sup>The breakdown of alpha functional connectivity is one of the few common characteristics of propofol and ketamine induced unconsciousness, which otherwise seem to involve very different mechanisms at the neurochemical level (Kushikata et al., 2016) and at the systems level (Lu et al., 2008).



into a detailed discussion of the aggregates, it is taught that the meditator should discover that none of the aspects of experience (including consciousness) has any independent existence, and that each of the aggregates are characterized by suffering (*dukkha*), impermanence (*aniccā*), and non-self (*anatta*) (Buddhaghosa, 2020; Nanamoli and Bodhi, 1995; Sayadaw, 2016). As the meditation practice thus deconstructs the qualities of experience that make it into a whole, it is possible that the unbinding or dis-integrating of these aggregates play a role in the gradual breakdown of functional connectivity, information integration, and associated consciousness. Somewhat similarly, the practice of *advaita vedanta* also involves a deconstruction of one's experience through processes of self-enquiry (i.e., questioning the nature and continued existence of elements of experience such as the self, Nisargadatta, 2012), and this can anecdotally lead to similar events totally void of sensorial experience (Godman, 2017).<sup>1</sup>

In sum, inducing a state of unconscious from within may involve a combination of an initial reduction of hierarchically deep predictive processes (e.g., through *jhāna* and *vipassanā* meditation or FA, OM, and ND) followed by a final deconstruction/disintegration of phenomenology as such (i.e., awareness), that may be explained in a complimentary way through a reduction in mechanisms underlying expectations of wakefulness (cf. Metzinger) and a reduction in neural integration (i.e., an unbinding of the elements of experience that bind together a coherent consciousness, Tononi, 2004). Since all conscious experience is unified (Tononi, 2005), to dis-unify experience from within is to eventually give rise to unconsciousness—or cessation.

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## 8 Discussion

*“Our very existence is in the atmosphere of non-existence.”*

Bhagavad Gita, approximately 300 BCE (Bhaktivedanta and Prabhupada, 1972).

In the history of cognitive neuroscience and neuropsychology, many unique case studies have informed our understanding of how the mind and brain work and the malleability and vulnerability of our conscious experience. We add meditation-induced cessations to this list, which is the intriguing capacity of some advanced meditators to “turn off” consciousness from within. Even though such events are rare, what might they reveal about the way human psychology and biology work? And what are the implications for our understanding of the top-down malleability of consciousness and its contents? In this paper, we sought to provide an introductory overview of the state of cessation in its two documented forms, *nirodha* and *nirodha samāpatti*. We have reviewed historical descriptions and accounts from classical Buddhism, discussed preliminary data from several studies of different practitioners,

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<sup>1</sup>As in the famous case of Ramana Maharshi, wherein he was so absorbed in his meditation that insects were eating away at his body and food had to be placed in his mouth so that he would eat (Godman, 2017).

contextualized cessation within the field of contemplative neuroscience, and provided an initial theoretical explanation for its occurrence.

Here we briefly reiterate the process by which *nirodha* is thought to arise. First, short “nirodha” cessations is thought to occur as a result of insight/*vipassanā* practice which is characterized by non-judgmental and equanimous observation of experience through the lenses of *aniccā* (impermanence), *anatta* (non-self) and *dukkha* (dissatisfaction). In this context, cessations occur in deep stages of practice as a culmination of the Stages of Insight, and are experienced as a momentary cut, or absence, in consciousness (Sayadaw, 1994, 2016). A more extended, and more intentional form of cessation is *nirodha samāpatti*, wherein the advanced meditator can induce a period of absence for a predetermined amount of time, and up to 7 days (Buddhaghosa, 2020; Thera, 1961). *NS* is thought to be a consequence of mastering both insight and *jhāna* practices.

Next, we turn our attention to outstanding questions and a research agenda. We have proposed that the absence of consciousness associated with cessation may be the logical result of progressively reducing abstract predictive processing in the brain (Laukkonen and Slagter, 2021; see also Paoletti et al., 2022). We have also proposed that this flattening of hierarchical processing can be even further “broken down” via a reduction in functional connectivity that might give rise to a disintegration in the binding elements of consciousness, as evidenced by a reduction in alpha synchronization during cessation. However, we have not yet proposed a mechanism for the possible *consequences* of *nirodha* to the mind and brain. Although speculative, one possibility that captures the strong phenomenological sense of clarity and openness associated with the post-cessation state is a reset of the precision-weighting landscape at levels of the brain’s functional hierarchy that maintain temporally deep (abstract) beliefs about the world and self.

One role of precision-weighting is to register one’s confidence in the reliability of priors vs prediction errors (Carhart-Harris and Friston, 2019; Feldman and Friston, 2010; Haarsma et al., 2021). From a Bayesian perspective, the more precise one’s priors, the less driven by bottom-up input the system is, as the new data is rigidly ignored if it does not match up with existing expectations. Alternatively, if one’s priors have low precision and the prediction errors (i.e., the input) have high expected precision, then one is willing to revise their generative model in light of new evidence. If priors undergo a precision-reset—the extent of which may be determined by the depth of the cessation—this would manifest as greater confidence in, and attention to, present moment sensory experience, or phenomenologically a sense of clarity and freshness, as if everything is new or as if “seen for the first time.” Or put simply, cessation would result in an experience of the present moment that is less conditioned by past beliefs.

Hence, one possibility is that cessation leads to a kind of inner reset of the precision-weighting landscape at higher-levels in the processing hierarchy, reducing one’s computational trust in priors that encode deep beliefs about (oneself in) the world—which have just been revealed to be highly vulnerable and volatile in light

of cessation—and hence increasing the vividness, attention, and confidence, associated with sensory data. In essence, this represents a shift in the system such that the generative model is driven by bottom-up input more than top-down expectations. This hypothesis could be tested using any paradigm that tracks the degree of top-down effects on perception or cognition. Notably, the presence of visual illusions or other cognitively driven distortions might be weakened or more flexible following *nirodha*. Logically, higher-level priors with relaxed precision, which are also implicated in psychedelic states (Carhart-Harris and Friston, 2019), should also result in greater cognitive/perceptual flexibility that could be evidenced by smaller decrements in performance as a consequence of task-switching, or improved problem-solving in tasks that require creative restructuring of representations, such as insight problems (Laukkonen and Tangen, 2017; Laukkonen et al., 2021; Ohlsson, 1984).

A complimentary possibility is that deep states of meditation such as cessation and ND awareness have an effect on hyperpriors on precision (Sandved-Smith et al., 2021). Hyperpriors on precision are “...prior beliefs about the precision of beliefs about the state of the world” (Friston et al., 2013, p. 1). Or put simply, beliefs about uncertainty in general. The profound surprise initiated by cessation or ND awareness may lead the organism to also relax hyperpriors on precision due to the experience of what was once taken as “permanent/certain” to be in fact “impermanent/uncertain” (e.g., the self, world, and one’s beliefs about them). This could foreseeably explain some trait effects often touted by meditators following such experiences. For instance, a relaxing of the hyperprior on precision would result in less “grasping”: the organism now expects that things are always changing so does not resist when things do in fact change.

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## 9 Challenges and future directions

One additional challenge to conducting research on cessation is the discrepancy between phenomenological absence and the absence of processing at a physiological level. As in comatose states or deep sleep, the brain may continue to respond to stimuli even though they are not registered consciously (Cossy et al., 2014; Morlet and Fischer, 2014; Strauss et al., 2015). Hence, the degree to which cessation actually disrupts automatic brain (sensory/perceptual) processes is unknown, although some level of breakdown in higher-order functioning is reasonable to expect (e.g., markers of language comprehension or emotional reactivity). Relatedly, it is difficult to know to what extent the feedforward sweep of processing is affected during cessation. Since the meditator is able to set an “intention” to re-emerge from *NS* given certain external conditions (e.g., a fire), some feedforward processing is certainly necessary as well as some minimal higher-order inferential processing that does not yet give rise to consciousness. Nevertheless, ordinary responses to pain or surprising/startling stimuli should considerably diminish during cessation (Antonova et al., 2015; Grant and Rainville, 2009; Levenson et al., 2012). Moreover, changes to physiological

processes are likely to take time, as in cases of torpor or hibernation (Ruf and Geiser, 2015). Hence, the most radical changes to processes like breathing, heart rate, or neural responses may only occur after the meditator has remained in NS for an extended period, e.g., 1 or 2 days, or longer.

As to a research agenda, as noted above, very few scientific studies have so far examined the mental and (neuro)physiological changes that accompany *nirodha* and NS, and what we know about the state is largely based on self-reports (long) after the NS experience occurred, and introspective reports can be inaccurate and biased (Nisbett and Wilson, 1977). Innovative methods are necessary to determine mental changes because an individual in a NS state is not able to respond or complete tasks using traditional cognitive-behavioral paradigms. We particularly propose two approaches: No-report paradigms and microphenomenology. No-report paradigms combined with measurements of brain activity allow researchers to make inferences about the nature of cognitive processing and consciousness (Tsuchiya et al., 2015), and have already proved useful in determining the extent to which mental operations are preserved in the comatose or asleep brain. Studies in comatose patients, for example, have used no-report paradigms and event-related potentials and shown normal auditory deviancy detection, but abnormalities in how unconscious brains track and integrate information over longer periods of time, or presented patients with their own vs close relatives' names to determine the presence of self-related processing as an index of preserved awareness (Morlet and Fischer, 2014; Tzovara et al., 2015). A similar approach can be taken to study the state of cessation, as these methods allow us to probe changes in sensory responding (e.g., to a startling sound) and conscious dynamics without disrupting the meditation.

Microphenomenology (Petitmengin et al., 2017, 2019), on the other hand, permits researchers to rigorously unravel the dynamics of experience through carefully structured interviews, and may be specifically useful in the study of meditation and consciousness, as expert meditators may be able to more reliably induce and maintain particular states and more accurately describe them (Lutz et al., 2007). Microphenomenology may be particularly valuable for uncovering changes to experience in the brief moments before and after cessation, which in turn can give rise to empirical hypotheses. For instance, it could be that the moments before cessation involve an unbinding of the unity of experience, consistent with the breakdown in functional connectivity and/or states of pure consciousness (Metzinger, 2020). Such combined neurophenomenological (Varela, 1996) modeling is a particularly promising approach. Microphenomenology may also help to better delineate to what extent *nirodha* and NS are subjectively different or similar, and whether it experientially matters whether one was in cessation for, e.g., 90 min vs 6 days.

In addition to no-report paradigms and neuro-phenomenology, as mentioned above, it is important that future studies include physiological measurements to track changes in bodily state, such as heart rate, breathing, skin conductance, blood oxygenation, temperature, and bodily movements. Such measurements, combined with measurements of “resting”-state brain activity, are crucial for determining how *nirodha samāpatti* may qualitatively differ from deep sleep or comatose states,

and presents a fundamentally different altered state of awareness, which would have large implications for current scientific theories of consciousness. Moreover, (neuro) physiological measures can also reveal to what extent practitioners can precisely sustain the state for the intended duration,<sup>m</sup> the precise beginning and end time of the state, and if this state can be characterized as an unusual hypometabolic state, that possibly shares characteristics with torpor in other mammals, and how long it may take for such a state to arise. Finally, this approach may also shed light on the extent to which *nirodha samāpatti* is stable over time at the (neuro)physiological level, or, for example, still contains remnants of the regular sleep cycle.

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## 10 Conclusion

We find the study of cessations—rare states of internally induced transitions from consciousness to unconsciousness—promising for the future of cognitive neuroscience, much in the same way as externally induced events have provided insights into the nature of the mind and brain (e.g., brain traumas, unusual psychiatric conditions, comatose, and drug-induced states, and so on). To this end, there are advanced meditators who are uniquely able to consistently and safely induce these states under laboratory conditions. Our initial results reveal that meditative cessations show similar results to propofol and ketamine induced states of unconsciousness, and we have presented an initial theoretical explanation for how meditation can gradually abate hierarchical predictive processing until cognition and experience ceases. We also believe that the science of cessations will provide new insights for our understanding of the nature of consciousness—and possibly even the hard problem (Chalmers, 2017). Unlike anesthesia or trauma induced states of unconsciousness, the specific events surrounding a cessation are introspectively available to meditators retrospectively and can be induced successively many times, thereby affording repeated measurements with minimal side effects. Taken together, this may increase the quality of our “microscope” on the neurophenomenological constituents of (altered states of) experience and consciousness itself, without the confounding element of a drug or other invasive procedure.

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<sup>m</sup>Interestingly, in our study (unpublished; RL, HB, HS), the participant intended to enter NS for 90 min. During NS, the researchers noted no perceptible eye and body movements. Moreover, the EEG, respiration, and heart rate appeared to remain unchanged for the entire 90 min. After roughly 90 min, the researchers observed a notable increase in heart rate (i.e., an increase of 10 beats per minute) as well as changes in the EEG and EOG (e.g., first indication of eye movements appeared at around 90 min). The participant opened their eyes after 104 min and indicated that they were fully awake. Clearly, such an observation requires careful replication and a more rigorous design, nevertheless, this first observation highlights a curious potential capacity associated with NS—to wake up out of cessation automatically, after a prespecified time, via simply the intention to do so.

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