Mindfulness (2023) 14:1088–1101
https://doi.org/10.1007/s12671-023-02101-y

ORIGINAL PAPER

Uniting Contemplative Theory and Scientific Investigation: Toward a Comprehensive Model of the Mind

Malcolm J. Wright[1] · **Joseph L. Sanguinetti**[2] · **Shinzen Young**[2] · **Matthew D. Sacchet**[3]

Accepted: 28 February 2023 / Published online: 10 April 2023

Abstract

Objectives Research into meditation-related emergent phenomenology is advancing, yet progress is hampered by significant incongruities between meditator self-reports and objective measurements (e.g., of brain states). We address these incongruities by developing and demonstrating the potential of contemplative theory to support scientific investigation.

Method Our approach is to translate key theories from Buddhist contemplative traditions into scientific terms, and then systematize these translations as a functionalist model of the mind—the Thin Model—able to inform scientific inquiry.

Results Buddhist doctrine is shown to be consistent with objective descriptions of mental function, and the Thin Model derived from these translations demonstrates immediate explanatory power. The nested nature of the model allows explanations to be restricted to the specific problem being studied. The model enables connection of complex higher-level phenomena, such as self-reports of mental states, to complex lower-level phenomena, such as empirically measured brain states. This connection does not require simplistic assumptions to be made. A detailed demonstration illustrates how the model can convert subjective accounts of the ecstatic meditative states known as *jhānas* into testable neuroscientific hypotheses.

Conclusions We provide an account of contemplative theory that is amenable to scientific investigation. Our approach, exemplified in the Thin Model, offers immediate explanatory power, allows meaningful dialogue between different research traditions, and provides an organizing principle for explanations of mental phenomena. The Thin Model may also be relevant to other fields concerned with autonomous entities or the nature and operation of the mind.

Keywords Neuroscience · Contemplative science · Philosophy of mind · Emergent phenomenology · Mindfulness meditation · *Jhāna*

As mindfulness meditation and other contemplative traditions have become more widely practiced in western cultures, there are increasing reports of associated *emergent phenomenology*, that is, unusual subjective mental events with a spiritual, mystical, or energetic character that emerge from meditative practice. The nature of energetic phenomena is debated, so we offer a minimalist definition of these as somatic correlates of emotion. Emergent phenomenology is quite varied in nature and may be perceived either positively or negatively (Galante et al. 2023; Grof & Grof, 2017; Lindahl et al., 2020) yet is hardly understood in modern scientific terms. Empirical research remains at an early stage although it is growing. The scope and possible benefits of research into emergent phenomenology appear considerable due to likely interactions with outcomes in mental health, personal wellbeing, social adjustment, and even the development of social capital in the case of compassion-based practices. Concrete short-term benefits of research into emergent phenomenology may include improved diagnosis and treatment of spiritual crisis separately from mental illness and identification of risk factors for spiritual crisis within existing mindfulness meditation practice.

To date, relevant research on emergent phenomenology falls broadly into two somewhat disjunct research

✉ Malcolm J. Wright
m.j.wright@massey.ac.nz

[1] School of Communication, Journalism and Marketing, Massey University, Auckland, New Zealand

[2] SEMA Lab, Center for Consciousness Studies, University of Arizona, AZ, Tucson, USA

[3] Meditation Research Program, Department of Psychiatry, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA

traditions—studies of contemplative practice using social science methods (including depth interviews, case studies, and surveys) and studies of neurobiology using brain imaging and sometimes medical intervention (including application of psychedelic substances and transcranial stimulation). Some work has sought to connect the two research traditions, for example, by investigating neurobiological correlates of subjective reported meditative states (Berkovich-Ohana, 2017; Hagerty et al., 2013). As emergent phenomenology can be assumed to have neurobiological origins involving multiple brain structures, contemplative training that leads to emergent phenomenology may activate large-scale brain networks including those involved in associative memory and other cognitive processes, as well as immune and endocrine responses including production of particular molecular markers (e.g., hormones). These brain structures likely interact in complex ways including through a hierarchy of sensory and conceptual processing. Thus, relating emergent phenomenology, or indeed any subjectively reported mental event, to neuroimaging including electroencephalography (EEG) or functional magnetic resonance imaging (fMRI) is a non-trivial task.

A further constraint to investigating empirical correlates of subjectively reported mental phenomena is the apparent incommensurability of modern science with contemplative—including mystical, philosophical, religious, and spiritual—traditions that provide the source materials for meditation. Yet, it is possible to see each contemplative tradition as simply expressing a particular frame of reference, a preferred language, and a particular mode of cultural expression. That is, we believe that translation of contemplative theory into terms suitable for scientific inquiry is possible, and that such translation may help to address the challenges referenced above. The present work attempts this task of translation, drawing on the case of Buddhist doctrine to develop a model of mental function. First, Buddhist doctrine is explained in terms consistent with scientific inquiry. Then, from this explanation, a summarized functional model of the mind is developed to provide explanations and generate hypotheses about autonomous entities such as humans. This model is intermediary, sitting between contemplative and scientific modes of thinking, consistent with both, yet avoiding the need to subordinate either to the other. The ability of the model to explain phenomena and generate testable hypotheses is illustrated through brief examples. These illustrations are not intended to claim priority for the developed model over other models, but rather to establish its competitiveness as a scientific theory, thereby demonstrating that deeper understanding of contemplative traditions has the potential to advance rather than hinder scientific inquiry into the mind.

Development of a functional model of the mind is certainly quite ambitious, yet Buddhist doctrine on mental function arguably provides the basis for such a project. It is Buddhist doctrine upon which many contemplative practices and indeed mindfulness meditation techniques are based (Kabat-Zinn, 2003) and emergent phenomenology such as ecstatic states or altered perceptions of self and reality are expected to arise from the application of Buddhist meditation techniques (Lindahl, et al., 2020). It is therefore reasonable to expect that Buddhist models of mental function may prove useful in developing testable hypotheses about the arising of emergent phenomenology.

Some descriptions of brain function in neuroscience and psychology already appear to correspond to key aspects of Buddhist thinking. For example, investigators have noted that Buddhist notions of not-self may map neatly onto neuroscientific understandings of self-related processes in the brain (Dahl et al., 2015), while long-term meditators have been found to self-induce high-amplitude gamma activity that facilitates neural change, consistent with Buddhist notions of mental training (Lutz et al., 2004). Other work has taken steps toward explanatory schemas of mental or biological function influenced by Buddhist doctrine. This includes recognition that cognition involves bodily as well as brain processes (Varela et al., 1992), that living entities can be described in terms of autopoietic systems, that is sustaining and maintaining their own organization through internal processes (Maturana & Varela, 1991), and that meditative experiences can be grouped into a phenomenological matrix potentially explainable by various neural networks (Lutz et al., 2015).

By digging deeper into Buddhist doctrine, we hope to go further than prior work toward the goal of developing a functional model of mind consistent with modern science. Source materials are principally the Buddhist collection of *suttas* (teachings) recorded in the scriptural language of *Pāli* and known as the *Pāli Canon*. These are obtained from a translated anthology of *suttas* (Ṭhānissaro, 2017), further identified with conventional scriptural numbering (e.g., DN 2; MN 118; SN 12:2), and supplemented by the Theravadan Buddhist Abhidhamma commentarial tradition represented by ancient (Buddhaghosa, 2010) and modern (Ingram, 2018) syntheses.

We proceed by (i) outlining key ideas from Buddhist doctrine on the mind and self in terms consistent with scientific inquiry, (ii) combining these ideas into a simple yet flexible functional model of an autonomous entity, (iii) highlighting several ways the model can be applied to provide explanatory power, and, (iv) demonstrating the ability of the model to generate an empirical neurobiological research agenda, using as a case study the ecstatic meditative states known in the *Pāli Canon* as *jhānas*.

Brief Overview of Buddhist Doctrine on the Mind and Self

Buddhist practices have much in common with the Idealist movement in philosophy (Finnigan, 2017), in that their subject is normally restricted to perceptual data; that is, the study of mental processing of changeable data received through sense organs, rather than the study of enduring separate objects in the external world. This does not necessarily deny the existence of an external material world, but rather simply indicates that contemplative techniques provide no such knowledge directly. Instead, contemplative knowledge of mental function and creation of the sense of self is principally a matter of studying perceptual processing, including processing of internally retrieved or internally created sense data.

In developing an account of mental function, we draw on three main inter-related Buddhist doctrines that address aspects of perceptual processing, as described in the *Pāli Canon* and prominent in the Theravadan Abhidhamma tradition. First, the doctrine of the Five Aggregates of Clinging (Ṭhānissaro, 2017, SN 22:48) describes five elements that make up a human being, conventionally translated as form (or matter), feeling, perception, mental activity, and consciousness. Second, the doctrine of the Six Sense Consciousnesses (Ṭhānissaro, 2017, MN 137) details the operation of the familiar senses of sight, hearing, taste, touch, and smell, plus an internal mind sense. Third, the doctrine of Dependent Origination (DO) (Ṭhānissaro, 2017, SN 12:2) describes the 12 steps by which humans process perceptual data, leading to the experience of a separate enduring self, as well as the suffering or stress attached to that sense of self. All three doctrines are discussed in detail below.

These doctrines are interdependent in that each draws upon explanations provided by the others. This interdependence is not a simple relationship, as Buddhist thought regards all phenomena as dependently originating from complex interactions between various causes and conditions and ceasing when those causes and conditions no longer support the phenomena (Ṭhānissaro, 2017, SN 12.61; and repeated throughout the *Pāli Canon*). Thus, relationships within and between the three doctrines are expected to be non-linear and multi-casual, with a variety of feedback loops.

Taken together, Buddhist doctrines have considerable explanatory power. The Five Aggregates of Clinging provide a rough sketch of an autonomous entity with cognition arising from interactions between a variety of distributed systems. The Six Sense Consciousnesses flesh out details of one part of this sketch and provide additional avenues to decompose and explain sensory phenomenology. DO describes a goal-seeking and feedback mechanism that completes the model of an autopoietic mind, sustaining and maintaining its own organization through internal processes, as well as giving an account of how self-awareness develops from perceptual data.

This may seem a surprisingly impressive achievement for an apparently religious tradition, yet Buddhist contemplatives have been developing doctrines around first-person accounts of mental experience and in tandem developing approaches for others to experience the same, for thousands of years. It is therefore reasonable to expect that the extensive knowledge accumulated in Buddhist traditions will continue to be a valuable source for insights into the mind. We now turn to examine the core doctrines of interest in more detail.

The Five Aggregates of Clinging

In the Buddhist scriptural language *Pāli*, the Five Aggregates of Clinging are *Rūpa*, *Viññāna*, *Saññā*, *Vedanā*, and *Sankhāra* (SN 22:48). As noted above, *Rūpa* is usually translated as "form" and refers in this context to the physical body. *Viññāna* is usually translated as "consciousness" but may also be translated as "divided knowing," defined as knowledge of a world (object) separate from the biographical self (subject). *Saññā* is perception, in the sense of discrimination or recognition of objects. *Vedanā* is feeling tone, or the valence of a reaction being positive, negative, or neutral. *Sankhāra* are volitional tendencies that arise from habitual patterns of bodily action and thought. Buddhist doctrine states that we mistakenly believe these five aggregates to be the "self" and that this mistake leads on to suffering or stress. Stress arises as ignorance about the true nature of perceptual reality entices us into harmful obsessions toward "external" objects in relation to our "self," whereas both are really just internally generated concepts overlaid onto sense data (Ṭhānissaro, 2017, MN 22; Ṭhānissaro, 2017, SN 12:2). We present the aggregates in non-traditional order to aid our later account of mental functioning (Table 1).

Notwithstanding Buddhist doctrine, it is obvious that the Five Aggregates of Clinging sketch out some preliminary requirements for an autonomous entity, with the components of material form, knowledge of self and other, recognition of objects, basic evaluations of sensory input, and pre-programmed sets of action tendencies in response to perceptions. The doctrine is consistent with ideas of embodied cognition (Varela et al., 1992) as it describes multiple interactions between mental and physical processes to support cognitive activity. Such a brief sketch is nonetheless clearly just a starting point for theoretical development and remains incomplete due to two omissions. The first is some form of goal orientation and feedback learning mechanism, and this

Table 1 The Five Aggregates of Clinging

Pāli	Present interpretation (alternate traditional translation)
Pañcupādānakkhandhā	Five Aggregates of Clinging
Rūpa	Form (matter)
Viññāna	Divided knowing (consciousness)
Saññā	Discrimination or recognition of objects (perception)
Vedanā	Feeling tone (feeling, sensation)
Sankhāra	Volitional tendencies that arise from habitual patterns of bodily action, thought, and perceptions (mental activity, mental formations)

Sankhāra may be interpreted differently between schools of Buddhist thought, including as physical and mental contractions, karmic potentials, volitional tendencies, and the integration of perceptual data into coherent frames of experience. Similar variations in interpretation may apply to Viññāna, Saññā, and Vedanā. The potential for disputes is resolved by seeing competing interpretations as nested components of the larger Aggregate

is provided by the doctrine of DO (Ṭhānissaro, 2017, SN 12:2). The second is a strategy for fleshing out this brief working model into far greater detail as needed, discussed next and then illustrated through deeper examination of the doctrine of the Six Sense Consciousnesses.

Although the doctrine of the Five Aggregates of Clinging appears simplistic, it does in fact refer to "aggregates" or "heaps" of clinging. That is, each of the five aggregates is a shorthand functional description for a complex set of phenomena normally observed at a particular level of aggregation. In fact, Buddhist meditation techniques are available to interrogate each aggregate in progressively more detail, while the practice of insight meditation overtly requires the noticing of increasingly fine details of experience (Ingram, 2018; Mahāsī, 1978).

The Five Aggregates of Clinging could perhaps be seen as fractals, shapes made of parts similar to the whole in some way, such that similar levels of complexity are observed at differing levels of aggregation. Fractals are common in nature (Mandelbrot, 1982) and widely observed in human biology including in the respiratory and vascular system, central nervous system, and DNA (Stanley et al. 1994), as well as proteins (Enright & Leitner, 2005), heartbeat (Ivanov et al., 1999), and fMRI signals (Ciuciu et al., 2012). Fractals can reasonably be expected to apply to mental function as well. For example, the fractal nature of emotion is apparent in drilling down from self-reports of emotion; to emotional processing of sensory input by the limbic system; to the study of specific brain structures involved in the limbic system such as the hypothalamus, thalamus, amygdala, and hippocampus; to examining the interior structure of the thalamus; and even down to the organization of clusters of neurons (e.g., Barson et al., 2020).

However, mathematical definitions of fractal morphology are contested, and the present work does not intend a formal mathematical treatment. Therefore, we simply note the Five Aggregates of Clinging are consistent with some accounts of fractal morphology in that they can be easily defined, have a nested structure with similarities in organization at multiple scales, and can be elaborated through recursive descriptions, but cannot easily be described at a local level as they have a fine structure with close-to-zero size at the smallest dimension (Falconer, 2004). Importantly, given a specific research agenda, as illustrated by the example of emotional processing above, each Aggregate need only be investigated to the extent required for explanation of the phenomena being studied.

The Aggregates may be perceived at higher as well as lower levels of structure. Thus, although our focus is on the moment-to-moment operation of an entity, traditionally inclined Buddhist readers may wish to apply concepts such as consciousness for example to a higher level of temporal aggregation, showing some kind of continuity across longer periods than just a single moment. This point is discussed later in the context of rebirth. Nested thinking also invites consideration of higher levels of social aggregation, such as genetic or social groupings, as tractable to analysis, although this point is not addressed in the current work.

The Six Sense Consciousnesses

The consciousness aggregate provides an excellent example of the nested nature of the Five Aggregates of Clinging, and how each element may be developed in much greater depth. In Buddhist doctrine, the consciousness aggregate provides knowledge of a world separate from the self (that is divided knowing), derived from the six sense bases (sight, sound, touch, taste, smell, and mind), with each sense base further decomposed into the sense object, the sense organ, and the sense consciousness or act of cognizing the sense object (Ṭhānissaro, 2017, DN:22). Further decomposition is possible, using either modern scientific or Buddhist thought. For example, sight consciousness can be understood to involve a variety of lower-level components including (i) detection of different parts of the sense field; (ii) identification of color; (iii) imputation of missing data (e.g., in the blind spot over the

optic nerve); (iv) overlaying further senses of direction, distance, and volume; (v) perceiving boundaries around groups of perceptions; (vi) applying object recognition at varying levels of processing to those groups; and then (vii) enabling some kind of reaction by the body or mind. So, while at the highest level of processing, the consciousness element provides divided knowing—cognizing an object that is separate from the knower, this knowing is in turn supported by a nested structure of related sensory systems and sensory processing operating in a more or less autonomic fashion.

One of the aims of Buddhist meditation is to crack open the autonomic operation of sensory processing to enable greater flexibility about how perceptual data is aggregated and acted upon. In the case of the sight sense, relevant techniques include close observation in real time of many of the factors described above, such that each is seen clearly and separately, rather than being autonomically integrated into the sense base of sight without noticing how this visual integrative process operates (Ingram, 2018). Buddhist practices targeting the sight sense may involve (i) seeing mind-generated lights or complex glowing objects, (ii) perceiving grids or geometric patterns overlaid on the sensory field, (iii) visualization of entities that are not physically present, (iv) enhanced perception of the sense of volume, (v) collapsing of the sense of distance to phenomena, (vi) collapsing the sense of separateness from phenomena, and (vii) deconstructing perceived objects into packets of more-or-less raw sense data (Ingram, 2018). The result of these practices is typically an increase in the perceived clarity of the visual world, but also improved control over how the meditator relates to and reacts to objects that are visually perceived (Young, 2016). Other techniques are available to address the other five senses, investigating the nested structure of sensory processing related to sound, touch, taste, smell, and mind.

The Cycle of Dependent Origination

Seeking more control over reactions to sense data is part of the broader Buddhist project of clearly seeing and then undoing the Cycle of Dependent Origination (DO). DO describes how the autonomic default mode processing of perceptual data leads to unsatisfactoriness or stress, also translated as suffering (Ṭhānissaro, 2017, MN 22). Traditionally, DO consists of 12 steps. In the scriptural language of *Pāli* these are *Avijjā*, *Sankhāra*, *Viññāna*, *Nāmarūpa*, *Salāyatana*, *Phassa*, *Vedanā*, *Tanhā*, *Upādāna*, *Bhava*, *Jāti*, and *Jarāmarana* (Ṭhānissaro, 2017, MN 12:2). We translate these terms as (i) a delusional interpretation of perceptual data, (ii) volitional tendencies, (iii) divided knowing, (iv) conceptual schema, (v) consciousness of perceptual data, (vi) recognition, (vii) feeling tone, (viii) desire, (ix) obsession, (x) behavioral programming, (xii) arising of the qualia of self, and (xii) stress. Alternative translations of these terms can be found in Table 2.

While this is an apparent linear progression of stages, DO is by no means linear, instead being a summation of complex, iterative and indeed nested causes and conditions (Ṭhānissaro, 2017, MN 22; Ṭhānissaro, 2017, SN12:61). Thus, any explanation given of DO should be seen as simply highlighting one thread through a complex causal network that may operate at different levels of aggregation with rich interdependencies. Nonetheless any individual elaboration of the doctrine should, by induction, give an appreciation of other ways that DO can manifest in different situations.

Traditional translations of DO include consciousness both as *Viññāna* (consciousness) and *Salāyatana* (the Six Sense Consciousnesses). Difficulties in discriminating between the two concepts encourage the conclusion that *Viññāna* is somehow ineffable. An alternate view is that while both

Table 2 Dependent origination

Pāli	Present interpretation (traditional translation)
Paṭiccasamuppāda	Dependent origination
Avijjā	Delusional interpretation of perceptual data (ignorance)
Sankhāra	Volitional tendencies that arise from habitual patterns of bodily action, thought, and perception (mental activity, formations)
Viññāna	Divided knowing (consciousness)
Nāmarūpa	Conceptual schema (name and form)
Salāyatana	Consciousness of perceptual data (six sense bases, six consciousnesses)
Phassa	Recognition (contact)
Vedanā	Feeling tone (feelings, sensations)
Tanhā	Desire (craving, thirst)
Upādāna	Obsession—passion obsession or resistance obsession (clinging, attachment, grasping)
Bhava	Behavioral programming (becoming)
Jāti	Arising of the qualia of self (rebirth)
Jarāmarana	Stress from perceived threats to sense of self (old age and death, pain and lamentation, suffering, angst)

are part of the same consciousness Aggregate, they perform clear and distinct functions; thus, it is possible to translate *Viññāna* as divided knowing (the literal meaning in *Pāli*) or biographical perception of a distinct self, separate from external objects. Conversely, *Salāyatana* is the consciousness of perceptual data provided by the sense organs and processed through the sensory cortices.

For the purposes of the current work, DO can usefully be recast into a more tractable form through division into four stages: (i) the ultimate source of the feelings of stress, (ii) the basis by which perceptual data is processed, (iii) the reaction to perceptual data, and (iv) the destructive cycle of behavioral reinforcement (or learning) and self-perception that results. The first stage has a single element, often translated as "ignorance," meaning the delusional view of the world as consisting of enduring and meaningful separate objects, rather than ephemeral packets of sense data to which we apply conceptual overlays. This delusional view profoundly affects the construction and operation of the mind, and as such is seen as the ultimate source of the feelings of stress (Ṭhānissaro, 2017, SN 12:2).

The second stage, the basis by which perceptual data is processed, involves input into the mind exclusively through the six sense-bases (Ṭhānissaro, 2017, MN 22). That is, the mind has nothing to work with other than data presented by the organs responsible for sight, sound, touch, taste, smell, and mind (the mind sense organ can conveniently be seen as an aggregate of memory stores, retrievals, imagined experiences, and related processes). The mind organizes and reacts to these perceptual data according to previously developed volitional tendencies or patterns of reactive predispositions embedded in the body-mind system. This process is supported by divided knowing, being the separation of perceptual data into subject and object, or self and other, and by the application of a pre-existing conceptual schema to recognize specific objects. The interdependent nature of these elements should be rather obvious as sensory input, perception of a separate self, a conceptual schema, and volitional tendencies all clearly involve a multitude of nested neurobiological systems. For example, processing sense data to the point of recognition involves multiple hierarchical levels of neural processing to assign color, direction, distance, object boundaries, implied shape, missing data, conceptual overlays, and to make associations with contemporaneous inputs from other senses; hence recognizing a leaf in your hand, for example, or a cat in your lap.

Due to ignorance about the nature of sense data, most people process perceptual data with the erroneous view that we humans have a separate internal essence that interacts directly with and somehow possesses objects in the material world. To emphasize again why this view is erroneous, consider that even if we were to directly grasp external material phenomena, instead of just perceptual data, recognition of objects would still be fundamentally arbitrary and dependent on the individual's conceptual schema, which is itself inherently mutable. One person's biohazard trash heap may be another person's treasured archaeological record – but only after that other person has received archaeological training.

The third stage, the reaction to perceptual data, commences with the act of recognition described above. Following recognition, a feeling tone is evoked in reaction to some biological drive or prior learning such as encoding of past experiences with similar stimuli. The feeling tone may have a positive valence, a negative valence, or a neutral valence. Next, a more action-oriented desire for the presence or absence of the recognized object may be triggered. This process has clear parallels to the approach-avoidance framework in psychology, as a positive feeling tone and associated desire for presence is clearly appetitive, whereas a negative feeling tone and associated desire for absence is clearly aversive. Research has further linked the approach-avoidance framework to specific neural regions, including the amygdala and anterior prefrontal cortex, as well as production of testosterone and cortisol, highlighting the similarly nested nature of these analogous psychological and neurobiological concepts (Kaldewaij et al., 2016).

Following the feeling tone and associated desire, an obsession may arise. This may be a passion obsession, associated with desire for the presence of the object, or a resistance obsession, associated with desire for the absence of the object (Ṭhānissaro, 2017, MN 44). Obsession is also variously translated as clinging, attachment, or grasping. Buddhist doctrine attacks suffering at the point of desire, but it is not just any desire—rather, it is the desire "accompanied by passion and delight, relishing now here and now there" (Ṭhānissaro, 2017, SN 56:11; Ṭhānissaro, 2017, MN 22). In other words, it is desire accompanied by an obsession that leads on through the chain of DO.

The fourth stage, the destructive cycle of behavioral reinforcement and self-perception, responds to desire accompanied by an obsession through programming new or reinforced volitional tendencies. This process, also called becoming, represents the encoding of feedback in response to environmental stimuli, and thus completes an autopoietic process that maintains the mind within environmental constraints. The resulting volitional tendencies are sometimes called *karma* as they will only be given expression through future events.

Behavioral programming, in response to desire accompanied by an obsession, leads on to rebirth or the epiphenomenon of the arising of a distinct sense of self—the qualia of self, as it were. From the qualia of self comes all the stress and angst of threatened erosion of personal possessions, youth, family, intelligence, health, wealth, enjoyment, and all other things erroneously bound into that sense of self. Thus, it is the process of behavioral programming, under

certain conditions, that is the key cause and condition of the sense of self and associated stress (Ṭhānissaro, 2017, SN 12:2; Ṭhānissaro, 2017, MN 22). Note, however, that the sense of self and associated stress is not required for maintenance of a viable entity.

As noted earlier, the Five Aggregates of Clinging thus provide a rough sketch of an autonomous entity with cognition arising from multiple interactions between mental and physical processes. The Six Sense Consciousnesses demonstrate the nested structure of this sketch and show how it can be fleshed out according to need. DO then describes a goal-seeking and feedback mechanism that completes the working model of an autopoietic mind, as well as giving an account of how self-awareness develops from sensory awareness. The net result is a surprisingly complete model of the mind and self with considerable explanatory potential.

A Thin Model of the Mind and Self

By giving a reasonably comprehensive account of relevant Buddhist doctrine we demonstrate the depth of intellectual resource that can be drawn on, as needed, to develop ideas about mental function. However, the richness and depth of Buddhist doctrine, and the historical and cultural context from which it is developed, are somewhat disjunct from modern scientific traditions. Thus, it is useful to significantly simplify, update and contextualize Buddhist doctrine as we have done above. This has resulted in the presentation of a coherent body of thought about mental functioning that can be used in turn to inform development of a simple functional model of the mind. This simple model is referred to here as the Thin Model, as it provides a basic scaffold on which more complex theories can be built according to the needs of the problem being studied.

Core Model

First, we propose some axioms to inform interpretation of the Thin Model.

1. The model is materialist, in that descriptions are intended to be consistent with, or at least directly testable by, materialist approaches from the neurosciences and other empirical disciplines.
2. The model is functionalist, in that core elements are not expected to correspond directly to specific neurobiological processes, but rather to represent the aggregate output of a variety of interacting nested processes.
3. The model is reductionist, in that functional elements are in principle reducible to the interactions of neurobiological processes, and materialist descriptions are in principle related to sense data descriptions.
4. The model is recursive, in that it can be further developed through accounts of content and interactions of core elements at different levels of aggregation.
5. Buddhist doctrine provides a key source for further insights into the development of the Thin Model.

The elements of an autonomous entity in the Thin Model are then:

a A *form* capable of some degree of ongoing interaction with the environment.
b A set of innate or learned *guidelines* (goals and predispositions) that guide actions and responses.
c *Sense organs* that allow perception of the environment.
d A database of *concepts* that allow sense data to be perceived as objects.
e *Recognition* of sense data as being concepts contained within the guidelines.
f *Action tendency* arising from processing concepts and guidelines to set behavioral priorities.
g A *feedback mechanism*, that allows guidelines to be updated from experience.
h Optionally, a *qualia of self*. This element is optional as it may only be an epiphenomenon of human behavioral programming, rather than a strict requirement for all entities potentially described by the Thin Model.

The model is sufficient to meet the definition of an autopoietic system as a "network of processes that produces the components that reproduce the network, and that also regulates the boundary conditions necessary for its ongoing existence as a network" and also the definition of a cognitive system as one in which "sensory inputs serve to trigger actions in a specific way, so as to satisfy a viability constraint" (Bourgine & Stewart, 2004).

Examples of Explanatory Power

One advantage of the Thin Model is that it is species neutral. That is, the model makes no assumptions that entities need be human, animal, or even biological, yet still provides an explanatory framework to enable discrimination of qualities between entities.

To take humans as an example, the core elements for an autonomous entity can be seen as respectively: (i) form: the human body; (ii) guidelines: genetic predispositions and learning from the environment including both classical (Pavlov, 1927) and operant (Skinner, 1938) conditioning; (iii) sense organs: the six sense organs; (iv) concepts: semantic memory (Tulving & Donaldson, 1972); (v) recognition: matching sense

data to semantic memory in either working memory (Baddeley, 2010) or the subconscious (Chong et al., 2014); (vi) action tendency: systems for problem solving and decision-making, including both subconscious emotional processing (Damasio, 1994) and problem solving using working memory (Baddeley, 2010); and (vii) feedback mechanisms: encoding of memories (Tulving & Donaldson, 1972), emotional markers (Damasio, 1994), and conditioning (Pavlov, 1927; Skinner, 1938) to guide future behavior, as well as emendation of guidelines found to lead to unsatisfactory outcomes.

In contrast, microorganisms may have form, biological drives that represent guidelines, sense organs, and autonomic action tendencies; however, they lack a conceptual schema, a process for recognition of sense data or any form of feedback other than natural selection. Thus, microorganisms are not autonomous entities by this definition. In contrast, mammalian quadrupeds are clearly autonomous entities but have less capacity than humans for developing action tendencies due to reduced elaboration and problem-solving ability using working memory, and less capable feedback mechanisms for encoding experience through conceptual memories, and may or may not have a qualia of self. This last point is important, as the absence of a qualia of self may affect ethical conclusions about acceptable treatment.

Similar analysis using the Thin Model could easily be undertaken for industrial robots, software operating systems, iPhones, insects, and specific mammals or hominids, or even fictional intelligent interstellar gas clouds (as imagined by Hoyle, 1957), or indeed any kind of entity that may be encountered or speculated upon.

Another application is to interrogate concepts such as consciousness or intelligence. Consciousness is often defined as the state of being aware of and responsive to surroundings, but how do we differentiate between different types of organisms or indeed between humans and responsive robots or computer software? Without reviewing the extensive literature in this area, we simply note that the Thin Model allows discrimination depending on the degree of recognition, the action tendency arising from the processing of concepts and guidelines, and the operation of feedback mechanisms. This could easily be developed into, say, a four-stage working classification of consciousness as being progressively (i) aware of and responsive to the environment, (ii) aware of and responsive to judgmental processes that affect action tendency, (iii) aware of and responsive to feedback and learning that affect judgemental processes, and (iv) aware of and responsive to the autonomous entity emerging from these various constituent elements.

If intelligence is taken as "the ability to apply knowledge to manipulate one's environment" (Merriam-Webster, n.d.), then it becomes immediately clear from the Thin Model that this is an embodied, multidimensional, and contextual process. Successful thoughtful action will depend on the contextual usefulness of prior guidelines and concepts, efficient operation of recognition, processing of perceptual data according to concepts and guidelines to form an action tendency, and the ability to update guidelines and concepts based on feedback from experience. The action tendency in turn may be influenced by a set of subsystems that include emotional processing, snap judgments from rapid associations to accessible memories, and extended deliberative thought. The term "intelligence" may therefore invite an unhelpful reification of the application of knowledge to manipulate one's environment, obscuring the complex processes revealed by the Thin Model.

Finally, as the Thin Model is based on the Buddhist project to be liberated from stress (also known as awakening or enlightenment), it should be expected to give some account of that problem and its solution. Very briefly then, we can translate the Buddhist project into the Thin Model as follows. First, we misperceive the world as our concept database adopts the premise that things in the world are enduring separate objects, instead of allowing their recognition as fluctuating processes that emerge from complex inter-related conditions. Second, we develop an action tendency to erroneously grasp after these imaginary enduring objects, and as the recognition of data from our sense organs does not correspond to our erroneous expectations, we have an inherent mismatch that leads to ongoing negative mental feedback, experienced as stress. In the human condition, this feedback occurs not just from behavioral action tendencies, but also from cognitive action-oriented deliberation. The result is a vicious cycle as the feedback mechanism constantly prods us toward impossible expectations, with inevitable failure leading to even more negative feedback, much of this occurring at a subconscious level of generalized angst. The solution is first to calm down the feedback mechanism through a focus on moral behavior (calm), then to develop sufficient cognitive control and discrimination to recognize the elements that support the feedback process (concentration), and finally to work with each element to understand its nature (insight) and thus gain enough control to pause the autonomic aspects of the process, thereby allowing reprogramming of concepts and neurobiological rewiring of sense organs, recognition, action tendency, and feedback mechanisms to stop the default grasping after imaginary concepts. The feedback mechanism then becomes subject to thoughtful control and operates calmly without creating enduring stress. While the process of getting to this point is associated with various blissful and ecstatic states, these are not the end goal. The Buddha said clearly, "Both formerly and now, it is … stress that I describe, and the cessation of stress." (Ṭhānissaro, 2017, SN 22:86).

These examples demonstrate the scope of the Thin Model, and the capacity of the model to support a progressive multi-disciplinary research program into the

mental function of all kinds of entities. The examples are of course too brief to provide more than an indication of fruitful research areas, and do not advance to the level of testable hypotheses. Therefore, to demonstrate how testable hypotheses may nonetheless be obtained, we develop a more detailed analysis applying the Thin Model to an example of emergent phenomenology, specifically the *jhānas*—the series of blissful meditative absorptions that are core elements of the Buddhist meditation training (Brasington, 2015; Buddhaghosa, 2010;).

Detailed Example—the Case of the *Jhānas*

The *jhānas* are widely described using standard language across the *Pāli Canon*, supplemented with guiding metaphors and detailed descriptions of mental factors active at various stages of practice (Brasington, 2015). Similar meditative absorptions have been reported in other religious traditions, particularly Hindu but also Christian (Avila, 2004) and Islamic traditions (Kugle, 2012). For reasons of space, our analysis is restricted to four *rūpa* (with form) *jhānas* described in Buddhist tradition, and not the *a-rūpa* (formless) *jhānas* or other absorptions described in either Buddhist or non-Buddhist traditions. Our initial descriptions draw heavily on the experience and scholarship of Leigh Brasington (Brasington, 2015). For closer examination of the original sources, also see DN 2 (Ṭhānissaro, 2017, DN: 2) for a rich description of *jhāna* phenomenology, including the series of traditional metaphors, and MN 111 (Ṭhānissaro, 2017, MN 111) for very precise and detailed descriptions of all the mental factors accessible in each *jhāna*.

To experience *jhāna*, the recommended procedure starts with standard instructions to find a secluded spot, sit cross legged, and focus on an object of concentration (Brasington, 2015; Ṭhānissaro, 2017, MN 118). The meditator should stay ardent and alert (not dull or "zoned out"), while allowing the Five Hindrances of greed, hatred, restlessness, sloth/torpor, and doubt to subside so that single-pointed concentration becomes established. While MN 111 (Ṭhānissaro, 2017, MN 111) describes many mental components that may be present during *jhāna*, most descriptions in the *Pāli Canon* and *Abhidhamma* commentary refer to a subset of *jhāna* factors being principally *vitakka* (initial concentration), *vicāra* (sustained concentration), followed by *pīti* (physical rapture or zest), *sukha* (happiness or bliss), and *upekkhā* (equanimity). These *Pāli* terms are difficult to translate precisely and are subject to some disputes over meaning. Acknowledging this context, we will do our best to provide a clear sense of the *jhānas* for non-adepts.

In the first *jhāna*, the meditator is advised to locate pleasurable sensations at some specific location within the body, and then "spread" these pleasurable sensations (that is, expand them to encompass adjacent areas) until they suffuse the entire body. The traditional metaphor is that the body becomes like a ball of soap powder thoroughly saturated and moisture laden, permeated, but not dripping. The meditator concentrates attention on these pleasurable feelings so that they strengthen into zest, but in broader awareness notices the associated feelings of happiness. In this first *jhāna*, deliberative thinking continues.

In the second *jhāna*, deliberative thinking fades away and the balance of experience shifts from a predominant experience of zest toward a predominant experience of happiness. The traditional metaphor is of an ever-refreshed cool spring that upwells and thoroughly permeates a lake of water. In the third *jhāna*, zest fades completely away to leave happiness as the only object of attention. The traditional metaphor is of a lotus plant sitting immersed in a pool of water with its head just below the surface, so that it is permeated with water from its head to its tip, and flourishes submerged in the water. In the fourth *jhāna*, even happiness subsides to result in emotional equanimity with a pure and bright awareness directed outward without a specific focus. The traditional metaphor is of the meditator being completely covered by a white sheet.

A common method to successfully experience *jhānas* is to ensure that once the absorptions start to arise the meditator makes the *jhāna* itself the object of concentration (Brasington, 2015). This creates a feedback loop and state of flow that maintains the absorption. Meditators progress to the next *jhāna* as they find the predominant factor of each successive *jhāna* unsatisfactory, and this transition typically occurs on the outbreath. See also MN 118 (Ṭhānissaro, 2017, MN 118) for access to zest and happiness with breath meditation independently of *jhāna*.

The *jhānas* and their factors can be experienced at various strengths (Brasington, 2015; Buddhaghosa, 2010). For example, single-pointed concentration can involve calm non-distraction and consistent focus on the chosen object, or it can progress to no longer being aware of the sensations of the body like a reader lost in a book, or even to the point that sensations of the body cease to manifest at all, leaving a blank spot in awareness. There are also well-documented grades of zest ranging from mild buzzing and passing showers of joy all the way up to almost unbearably strong ecstasies (Brasington, 2015; Buddhaghosa, 2010). Happiness is less discussed in the traditional sources, although variation in strength and quality leads to the use of various near synonyms such as bliss, joy, pleasure, gladness and even rapture as a translation of *sukha*. The more subtle glow of equanimity can encompass all kinds of visual phenomena up to the perception of extremely bright white lights (the famous "inner light" or *nimitta* in the *Abhidhamma* tradition) and can be a jumping-off point for cultivating more detailed visionary experiences of various kinds known as *iddhis*.

Extant research allows some speculations about neurobiological correlates of the *jhānas*. Entry to *jhānas* involves calming bodily formations followed by the arising of zest and happiness. One *Sutta* clearly states that these bodily formations consist of the in–out breath (Ṭhānissaro, 2017, MN 44). This seems incongruously over-simplified—reducing the body to nothing but the breath to explain the effects of *jhāna*. Yet, the in–out breath has been linked to the autonomic nervous system (Tang et al., 2009; Telles et al., 2013; Zaccaro et al., 2018), with deep slow relaxed breathing known to influence autonomic and pain processing (Busch et al., 2012), emotional regulation (Sarkar, 2017), and the activation of both sympathetic and parasympathetic nervous systems (Busch et al., 2012; Jerath et al., 2006; Sinha et al., 2020). Zest and happiness may therefore be somewhat intuitively related to regulation of the autonomic nervous system followed by activation of the somatosensory and parasympathetic components of the peripheral nervous system. Similarly, metaphors of the welling up of a spring within a lake and the permeation of an entire lotus plant with water invite contemplation of the central nervous system sitting within a broader pool of peripheral activity. There is some evidence in support of such comparisons. Connections of the peripheral and central nervous systems in are obvious in Tibetan Buddhist Tummo meditation, with visualization of a flame rising from below the navel with each breath to eventually reach the top of the head, while experiencing sensations of heat in the spine (Kozhevnikov, et al., 2013). Related Hindu practices seek to awaken energy changes around the spine and are well known, even notorious, for resulting in uncontrolled raptures (Sannella, 1987).

Nonetheless, evidence on the role of the peripheral and central nervous systems in *jhānas* is rather scattered and incomplete, and the comparisons above are fairly intuitive. Can the analysis be improved through application of the Thin Model? The principle of nested analysis suggests that the components of the entity that gives rise to *jhānas* need only be elaborated to the extent required for explanation. For this set of explanations, we draw particularly on the components of form, sense organs, action tendency, and feedback mechanisms as the basis for the explanatory account, and to a lesser extent on recognition as additional mental activity. This allows an explanation as follows.

Single-pointed concentration sufficient to access *jhānas* arises from cognitive control over action tendency to allow the direction of attention and the consequent fading of distraction. This enables calming of form (body) and feedback mechanisms, allowing the peripheral nervous system (a subsystem of form) to become more salient. The increased salience allows triggering of pleasurable physical functions associated with the peripheral nervous system that are normally less easily accessible, and these provide a reward that gives targeted feedback to support ongoing concentration (action tendency). This feedback loop may interact with sympathetic nervous system components such as sexual function to alter the nature of the zest that is experienced, perhaps explaining why some raptures can become unbearably ecstatic; for example, St. Teresa of Avila records such a rapture as follows:

> I saw in his hand a long spear of gold, and at the iron's point there seemed to be a little fire. He appeared to me to be thrusting it at times into my heart, and to pierce my very entrails; when he drew it out, he seemed to draw them out also, and to leave me all on fire with a great love of God. The pain was so great, that it made me moan; and yet so surpassing was the sweetness of this excessive pain, that I could not wish to be rid of it. The soul is satisfied now with nothing less than God. The pain is not bodily, but spiritual; though the body has its share in it. It is a caressing of love so sweet which now takes place between the soul and God, that I pray God of His goodness to make him experience it who may think that I am lying. (Avila, 2010)

The activation of subsystems related to form may spread to parts of the body through the central nervous system and particularly the spine. As absorptions in zest and happiness progress, they occupy increasing amounts of mental function, drawing attention away from other cognitive elements so calming the sense organs and the recognition process thus eroding competing feedback loops that were consciously or subconsciously operating. This increasing mental quiet enhances access to additional feedback and reward systems in the brain, further calming the mind and body and sustaining the absorption. As zest and happiness fade attention moves away from an internal focus on pleasurable aspects of form to a residual non-specific equanimity of calmness without attention to form. With the substantive calming of most bodily and mental activity, the eye-sense organ no longer subtly strives to process other input, the non-specific general glow of being covered by a white sheet may be a manifestation of white noise in that organ. Should this white noise become caught in an attentional feedback loop, the light may become rather bright.

Given this functional description, we can generate a coherent set of testable hypotheses. These hypotheses may be psychological or neurobiological depending on the nested level of the Aggregate examined. One example set of hypotheses follows. Progress through the *jhānas* may occur through (i) changes to the modulation and connectivity of brain systems involved in cognitive control; (ii) increasing regulation of the autonomic nervous system through increasing regulation of breathing; (iii) achievement of calm through reduced activity in particular brain regions or changed emission of neuromodulators followed by (iv) awareness of somatic (zest—form) and parasympathetic (happiness—form); nervous system

phenomena followed by (v) activation of the central nervous system in the spine and brain, including for example activation of the ventral striatum or the release of opioids, dopamine, or related substances; (vi) fading of activation of the somatic nervous system and cognitive control, and then fading of the parasympathetic nervous system and sensory processing, perhaps with depletion of relevant neurotransmitters, leading to (vii) generally low levels of brain and nervous system activation, followed by non-specific activation of the visual cortex. These are all hypotheses that using modern neuroimaging may be directly tested. A summary of this progression from intuition to functional descriptions to testable hypotheses is provided below (Table 3).

We do not propose these ideas are necessarily correct explanations, but rather that they provide an example of how the Thin Model allows fresh approaches to emergent phenomenology, by converting intuitions and scattered evidence into a coherent and complete cognitive or neurobiological explanation. While the resulting hypotheses are not necessarily correct, they are testable. Most importantly, the Thin Model can be used to generate competing hypotheses, so that empirical work might examine, for example, whether jhānic absorptions are more associated with brain or body function or vary according to the absorption being studied.

Discussion

The self-reports emerging from meditation are familiar to contemplative traditions, but somewhat new to modern science which has largely eschewed the study of metaphorical descriptions of internal mental experiences. The problems that inspired the present work are how to (i) address the incongruities that are emerging between subjective reports and empirical studies of these phenomena, (ii) demonstrate that contemplative traditions need not be incommensurable with modern science, and (ii) provide a reasonably comprehensive theoretical framework to understand what occurs subjectively during meditation. Neuroscience has made progress in identifying some of the correlates of specific mental states; yet those findings are isolated and fragmentary and there remain tremendous obstacles in building neuroscientific research into a comprehensive modern science of being that could reconcile subjective self-reports and neural measurements.

We therefore point the way toward a comprehensive modern science of being by drawing on Buddhist doctrine interpreted in the light of modern understandings. The Thin Model offers immediate explanatory power, allows meaningful dialogue between different research traditions, and provides an organizing principle for explanations of mental phenomena. The Thin Model also allows intuitions to be developed into complete functional descriptions that in turn provide context often lacking in explanations of mental events, such as outlining likely antecedents and consequences, as well as acknowledging rich interdependencies and the emergence of phenomena at varying levels of aggregation. As such, the Thin Model has sufficient power and flexibility to match the complexity present in mental phenomena, yet sufficient simplicity to provide a useful basis for development of testable hypotheses. Simpler approaches, such as linear causal modeling, or moderated-mediation

Table 3 Translating intuitions to hypotheses using the Thin Model

Intuition: Concentration (e.g., on the breath) regulates the peripheral nervous system, allowing more control over of the central nervous system to generate ecstatic states, followed by a deep calm that enables sensory white noise to emerge		
Stage	Thin Model	Testable hypotheses
(i)	Control over action tendency	Changes to modulation and connectivity of systems involved in cognitive control
(ii)	Enabling concentration on breath and thus calming of form	Increasing regulation of the autonomic nervous system through increasing regulation of breathing
(iii)	Reducing the autonomic triggering of feedback mechanisms	Achievement of calm through reduced activity in particular brain regions or changed emission of neuromodulators
(iv)	Leading to clear observation of and access to those feedback mechanisms	Awareness of somatic and parasympathetic nervous system phenomena
(v)	Resulting in emergence of stronger feedback	Activation of the central nervous system in the spine and brain, including, for example, activation of the ventral striatum or the release of opioids, dopamine, or related substances
(vi)	As feedback monopolizes mental activity, there is growing calm in form, action tendencies and sense organs, and eventually in feedback mechanisms	Fading of activation of the somatic nervous system and cognitive control, and then fading of the parasympathetic nervous system and sensory processing, perhaps with depletion of relevant neurotransmitters
(vii)	With fading of feedback, there is a deep calm in many elements of the entity enabling observation of white noise in the sense organs	Generally low levels of brain and nervous system activation, followed by non-specific activation of the visual cortex

analysis, do not bear sufficient resemblance to the complex mental processes revealed by the Thin Model to offer similar expectations of explanatory power.

Limitations and Future Directions

The account of Buddhist thought given in support of our objectives will no doubt be subject to disagreements from other Buddhist scholars. There are a wide variety of views and practices in Buddhism, including extensive scriptural commentary, associated doctrinal disputes, and the alternative soteriological approaches of the Theravada, Mahayana, and Vajrayana traditions. As a result, competing interpretations will exist for many if not all elements of doctrine we discuss. Our aim is not to assert any doctrinal priority, but rather to illustrate how a self-consistent body of contemplative knowledge can yield useful insights in the neurobiological domain. The account can perhaps be seen as adequate to inform a simple model of the operation of the mind and self, which may in turn guide research in neuroscience and related sciences of the mind (possibly with results that then inform disputes among doctrinal accounts).

A particular point of doctrinal dispute may be the interpretation of rebirth, as there are differing views within Buddhism on whether rebirth refers to reincarnation after death and breakup of the body, moment-by-moment recreation of the self, or both. Our description accords with modern science in that it does not assume rebirth takes place in a non-contiguous body, time, and location. For our purposes, it is sufficient to take rebirth to be the ongoing process of moment-by-moment evolution of a single discrete organism, together with the constant rebirth of the sense (or qualia) of self.

However, traditionally inclined Buddhist readers might note that our account does not rule out other forms of rebirth occurring at different levels of temporal aggregation of DO, particularly given that modern science and philosophy do not yet provide a complete account of the origin of perceptual data, causation, time, space, or consciousness. Conversely, taking the perspective of contemporary science and medicine, nor does our account rule out biological birth being considered as regeneration and continuity (hence, rebirth) at the level of the family, ethnic group, or community, as the phenomenon of DO can also be applied at different levels of genetic or social aggregation.

Psychology researchers may also criticize elements of the Thin Model for imperfect alignment with or characterization of current theories in psychology. Again, we observe that our objective is not to summarize the current state of knowledge or assert a particular paradigm, but rather to demonstrate how ancient and modern knowledge can be combined to develop a useful approach to understanding both contemplative traditions and psychological or neurobiological phenomena.

The Thin Model offers a scaffold for further progress in three ways. First, it can be applied directly to develop explanations and applications across a whole range of phenomena. For example, emergent phenomena may be expected to interact with outcomes in mental health, personal wellbeing, and social adjustment, so the Thin Model may have immediate utility in these areas. Second, it provides a context to invite, and guide, detailed scientific investigation into each element of the model to better understand the operation of an autopoietic mind. Third, it introduces a new type of functional model of autonomous entities, mind, and self, and so may inspire others to develop improved models of the same type. The contestability of Buddhist doctrine or psychological theories in fact provides rich opportunities for development of the Thin Model. As the links between doctrine, theory and model are so clearly laid out, alternative views can easily be converted into new models with potential for improved problem-solving ability.

Given the explanatory power of the model, there is also an opportunity to interrogate problems in other fields. In fact, any field that involves consideration of autonomous entities, mental function, or conceptualization of being may find that modalities offered by the Thin Model will contribute to fresh explanations and new priorities for study.

Acknowledgements Thanks to Niffe Hermansson and Daniel Ingram for comments on an earlier version of this manuscript, and to Vanessa Cha for copyediting assistance on the final draft.

Author Contribution Malcolm J. Wright conceptualization, methodology, writing—original draft, writing—review and editing.
Joseph L. Sanguinetti validation, writing—review and editing
Shinzen Young validation, writing—review and editing
Matthew D. Sacchet conceptualization, supervision, writing—review and editing

Funding Open Access funding enabled and organized by CAUL and its Member Institutions

Data Availability This is a conceptual study; data availability is not applicable.

Declarations

Ethical Approval This is a conceptual study; ethical approval is not applicable.

Informed Consent This is a conceptual study; informed consent is not applicable.

Conflict of Interest The authors declare no competing interests.

References

Avila, S.T. (2004). *The interior castle*, (M. Star, Trans.). Riverhead.

Avila, S. T. (2010). *The life of Saint Teresa of Avila by herself*. Neeland Media.

Baddeley, A. (2010). Working memory. *Current Biology, 20*(4), R136–R140. https://doi.org/10.1016/j.cub.2009.12.014

Barson, J. R., Mack, N. R., & Gao, W. J. (2020). The paraventricular nucleus of the thalamus is an important node in the emotional processing network. *Frontiers in Behavioral Neuroscience*, *14*, 598469. https://doi.org/10.3389/fnbeh.2020.598469

Berkovich-Ohana, A. (2017). A case study of a meditation-induced altered state: Increased overall gamma synchronization. *Phenomenology and the Cognitive Sciences, 16*, 91–106. https://doi.org/10.1007/s11097-015-9435-x

Bourgine, P., & Stewart, J. (2004). Autopoiesis and cognition. *Artificial Life, 10*(3), 327–345. https://doi.org/10.1162/1064546041255557

Brasington, L. (2015). *Right concentration: A practical guide to the Jhānas*. Shambhala Publications.

Buddhaghosa, B. (2010). *Path of purification, (O Ñanamoli, Trans)*. Buddhist Publication Society.

Busch, V., Magerl, W., Kern, U., Haas, J., Hajak, G., & Eichhammer, P. (2012). The effect of deep and slow breathing on pain perception, autonomic activity, and mood processing—an experimental study. *Pain Medicine, 13*(2), 215–228. https://doi.org/10.1111/j.1526-4637.2011.01243.x

Chong, T. T. J., Husain, M., & Rosenthal, C. R. (2014). Recognizing the unconscious. *Current Biology, 24*(21), R1033–R1035. https://doi.org/10.1016/j.cub.2014.09.035

Ciuciu, P., Varoquaux, G., Abry, P., Sadaghiani, S., & Kleinschmidt, A. (2012). Scale-free and multifractal properties of fmri signals during rest and task. *Frontiers in Physiology, 3*, 186. https://doi.org/10.3389/fphys.2012.00186

Dahl, C. J., Lutz, A., & Davidson, R. J. (2015). Reconstructing and deconstructing the self: Cognitive mechanisms in meditation practice. *Trends in Cognitive Sciences, 19*(9), 515–523. https://doi.org/10.1016/j.tics.2015.07.001

Damasio, A. (1994). *Descartes' error: Emotion, reason and the human brain*. Putnam.

Enright, M. B., & Leitner, D. M. (2005). Mass fractal dimension and the compactness of proteins. *Physical Review E, 71*(1), 011912. https://doi.org/10.1103/PhysRevE.71.011912

Falconer, K. (2004). *Fractal geometry: Mathematical foundations and applications*. Wiley.

Finnigan, B. (2017). Buddhist idealism. *Idealism: New Essays in Metaphysics* (pp. 178–199). Oxford University Press.

Galante, J., Grabovac, A., Wright, M. J., Ingram, D. M, Van Dam, N. T. Sanguinetti, J. L., Sparby, T., van Lutterveld, R., & Sacchet, M. D. (2023). A framework for the empirical investigation of mindfulness meditative development. *Mindfulness, in press.*

Grof, C., & Grof, S. (2017). Spiritual emergency: the understanding and treatment of transpersonal crises. *International Journal of Transpersonal Studies, 36*(2), 30–43. https://doi.org/10.24972/ijts.2017.36.2.30

Hagerty, M. R., Isaacs, J., Brasington, L., Shupe, L., Fetz, E. E., & Cramer, S. C. (2013). Case study of ecstatic meditation: fMRI and EEG evidence of self-stimulating a reward system. *Neural Plasticity*, *2013*, 653572. https://doi.org/10.1155/2013/653572

Hoyle, F. (1957). *The black cloud*. Heineman.

Ingram, D. M. (2018). *Mastering the core teachings of the Buddha: An unusually hardcore Dharma book* (revised and expanded). Aeon.

Ivanov, P. C., Amaral, L. A. N., Goldberger, A. L., Havlin, S., Rosenblum, M. G., Struzik, Z. R., & Stanley, H. E. (1999). Multifractality in human heartbeat dynamics. *Nature, 399*, 461–465. https://doi.org/10.1038/20924

Jerath, R., Edry, J. W., Barnes, V. A., & Jerath, V. (2006). Physiology of long pranayamic breathing: Neural respiratory elements may provide a mechanism that explains how slow deep breathing shifts the autonomic nervous system. *Medical Hypotheses, 67*(3), 566–571. https://doi.org/10.1016/j.mehy.2006.02.042

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: Past, present, and future. *Clinical Psychology: Science and Practice, 10*(2), 144–156. https://doi.org/10.1093/clipsy.bpg016

Kozhevnikov, M., Elliott, J., Shephard, J., & Gramann, K. (2013). Neurocognitive and somatic components of temperature increases during g-Tummo meditation: Legend and reality. *PloS ONE, 8*(3), e58244. https://doi.org/10.1371/journal.pone.0058244

Kugle, S. (2012). Sufi meditation manuals from the Mughal era. *Oriente Moderno, 92*(2), 459–489.

Lindahl, J. R., Cooper, D. J., Fisher, N. E., Kirmayer, L. J., & W. B. Britton (2020). Progress or pathology? Differential diagnosis and intervention criteria for meditation-related challenges: Perspectives from buddhist meditation teachers and practitioners. *Frontiers in Psychology, 11*, 1905. https://doi.org/10.3389/fpsyg.2020.01905

Lutz, A., Greischar, L. L., Rawlings, N. B., Ricard, M., & Davidson, R. J. (2004). Long-term meditators self-induce high-amplitude gamma synchrony during mental practice. *Proceedings of the National Academy of Sciences, 101*(46), 16369–16373. https://doi.org/10.1073/pnas.0407401101

Lutz, A., Jha, A. P., Dunne, J. D., & Saron, C. D. (2015). Investigating the phenomenological matrix of mindfulness-related practices from a neurocognitive perspective. *American Psychologist, 70*(7), 632. https://doi.org/10.1037/a0039585

Mahāsī, S. (1978). *Practical vipassana exercises*. Buddha Dharma Education Association Inc.

Mandelbrot, B. B. (1982). *The fractal geometry of nature*. W. H. Freeman & Co.

Maturana, H. R., & Varela, F. J. (1991). *Autopoiesis and cognition: The realization of the living*. Springer.

Merriam-Webster. (n.d.). Intelligence. In *Merriam-Webster.com dictionary*. Retrieved from https://www.merriam-webster.com/dictionary/intelligence. Accessed 6 Apr 2022

Pavlov, I. P. (1927). *Conditioned reflexes*. Oxford University Press.

Sannella, L. (1987). *The Kundalini experience: psychosis or transcendence?* (revised ed.). Integral Publishers.

Sarkar, A. A. (2017). Functional correlation between breathing and emotional states. *MOJ Anatomy & Physiology, 3*(5), 157–158. https://doi.org/10.15406/mojap.2017.03.00108

Sinha, M., Sinha, R., Ghate, J., & Sarnik, G. (2020). Impact of altered breathing patterns on interaction of EEG and heart rate variability. *Annals of Neurosciences, 27*(2), 67–74. https://doi.org/10.1177/0972753120950075

Skinner, B. F. (1938). *The behavior of organisms: An experimental analysis*. Appleton-Century.

Stanley, H. E., Buldyrev, S. V., Goldberger, A. L., Havling, S., Mantegna, R. N., Ossadnik, S. M., Peng, C. K., Sciortino, E., & Simons, M. (1994). Fractals in biology and medicine. In A. Pękalski (Ed.), *Diffusion processes: Experiment, Theory, Simulations. Lecture Notes in Physics (volume 438)* (pp. 147–178). Springer. https://doi.org/10.1007/BFb0031125

Kaldewaij, R., Koch, S. B. J., Volman, I., Toni, I., & Roelofs, K. (2016). On the control of social approach–avoidance behavior:

Neural and endocrine mechanisms. In M. Wöhr & S. Krach (Eds.), *Social behavior from rodents to humans.* Springer. https://doi.org/10.1007/7854_2016_446

Tang, Y. Y., Ma, Y., Fan, Y., Feng, H., Wang, J., Feng, S., Lu, Q., Hu, B., Lin, J., Li, J., Zhang, Y., Wang, Y., Zhou, L., & Fan, M. (2009). Central and autonomic nervous system interaction is altered by short-term meditation. *Proceedings of the National Academy of Sciences, 106*(22), 8865–8870. https://doi.org/10.1073/pnas.0904031106

Telles, S., Raghavendra, B. R., Naveen, K. V., Manjunath, N. K., Kumar, S., & Subramanya, P. (2013). Changes in autonomic variables following two meditative states described in yoga texts. *Journal of Alternative and Complementary Medicine, 19*(1), 35–42. https://doi.org/10.1089/acm.2011.0282

Ṭhānissaro, Bh. (2017). *Handful of leaves: An anthology from the Sutta Pitaka, revised edition.* Metta Forest Monastery.

Tulving, E. (1972). Episodic and semantic memory. In E. Tulving & W. Donaldson (Eds.), *Organization of Memory.* Academic Press.

Varela, F. J., Rosch, E., & Thompson, E. (1992). *The embodied mind: Cognitive science and human experience*. MIT Press.

Young, S. (2016). What is mindfulness? A contemplative perspective. In K. A. Schonert-Reichl & R. W. Roeser (Eds.), *Handbook of mindfulness in education* (pp. 29–45). Springer.

Zaccaro, A., Piarulli, A., Laurino, M., Garbella, E., Menicucci, D., Neri, B., & Gemignani, A. (2018). How breath-control can change your life: A systematic review on psycho-physiological correlates of slow breathing. *Frontiers in Human Neuroscience, 12*, 353. https://doi.org/10.3389/fnhum.2018.00353