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Review article

Volitional mental absorption in meditation: Toward a scientific understanding of advanced concentrative absorption meditation and the case of jhana

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A B S T R A C T

Meditation has been integral to human culture for millennia, deeply rooted in various spiritual and contemplative traditions. While the field of contemplative science has made significant steps toward understanding the effects of meditation on health and well-being, there has been little study of advanced meditative states, including those achieved through intense concentration and absorption. We refer to these types of states as advanced concentrative absorption meditation (ACAM), characterized by absorption with the meditation object leading to states of heightened attention, clarity, energy, effortlessness, and bliss. This review focuses on a type of ACAM known as jhana (ACAM-J) due to its well-documented history, systematic practice approach, recurring phenomenological themes, and growing popularity among contemplative scientists and more generally in media and society. ACAM-J encompasses eight layers of deep concentration, awareness, and internal experiences. Here, we describe the phenomenology of ACAM-J and present evidence from phenomenological and neuroscientific studies that highlight their potential applications in contemplative practices, psychological sciences, and therapeutics. We additionally propose theoretical ACAM-J frameworks grounded in current cognitive neuroscientific understanding of meditation and ancient contemplative traditions. We aim to stimulate further research on ACAM more broadly, encompassing advanced meditation including meditative development and meditative endpoints. Studying advanced meditation including ACAM, and specific practices such as ACAM-J, can potentially revolutionize our understanding of consciousness and applications for mental health.

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1. Introduction

The practice of meditation has existed for thousands of years [1]. Siddhartha Gautama, known as the Buddha, used meditation in combination with a comprehensive teaching system and tools to guide his disciples to "awakening", sometimes referred to as enlightenment. This awakening is often described as a profound shift in consciousness, leading to a profound understanding of the nature of existence and liberation from suffering. Modern-day elements of meditation have incorporated elements from meditative traditions, notably Buddhism, and have been effectively integrated into various clinical settings [2]. Some examples of these interventions and integrations include mindfulness-based interventions, such as Mindfulness-Based Stress Reduction [3], Mindfulness-Based Cognitive Therapy [4], and Mindfulness-Oriented Recovery Enhancement [5]. Research in contemplative science, centered on the study of contemplative practices including meditation and mindfulness, has consequently grown exponentially over the last several decades [6].

The field of contemplative science has reached some degree of maturity since its inception. However, researchers have largely ignored the deeply concentrated states of altered consciousness that are thought to become accessible from the long-term, intensive, and directed meditation practice. We call such states advanced meditation. Advanced meditation is a crucial aspect of a larger psychologically transformative development of health and well-being through meditative practices, which may be collectively referred to as meditative development [7]. At the culmination of meditative development, one will find certain meditative endpoints. These endpoints could be represented in various forms, including cessation events that trigger profound clarity and openness to the meditator [8,9].

One class of advanced meditation is characterized by advanced concentrative absorption. We call this advanced concentrative absorption meditation (ACAM). Practitioners of ACAM focus their attention on a specific meditation object [10], seeking an absorption with the meditation object that leading to states of heightened attention, clarity, high energy, effortlessness, and bliss [11]. ACAM can be found in many spiritual and contemplative traditions [12], including Theravada Buddhist jhana meditation emphasizing progressive states of bliss, happiness, and heightened awareness [1], Carmelite tradition in which nuns describe experiences of union with God while in prayer [13], Islamic Sufi meditation states of ecstasy [14–16], and Jewish contemplative traditions that involve states of immense concentration [17]. While these diverse contemplative and spiritual traditions differ in their underlying philosophies and techniques, these practices may lead to similar induced states of immense absorption and self-generated bliss [11]. Our contention is that understanding ACAM is a core task for advancing contemplative science, especially the understanding of meditation, and that this understanding will provide increasingly valuable insights into body-brain-mind connections, cognition, emotion, and fundamental features of consciousness. More importantly, ACAM can allow individuals to experience states free of psychological suffering where the mind is profoundly peaceful and blissful. ACAM and advanced meditation more broadly has the potential to advance human flourishing and alleviate psychological suffering [18]. However, there is a need for further research that directly compare and explicate the relationships between ACAM and their phenomenology and psychology among different types of ACAM, such as those listed in this paragraph. Comparative phenomenology will be crucial for future research aiming to understand the distinctions or similarities in ACAM across diverse contemplative traditions.

In this review, we focus on using modern scientific frameworks, specifically within cognitive neuroscience and psychology, to understand and characterize jhana meditation (*jhāna* in Pali, the liturgical language of Theravada Buddhism, or *dhyāna* in Sanskrit), and to propose future directions for their study. We use the term ACAM-J to denote jhana states and highlight jhana meditation and its related taxonomy. Considering the well-documented history of ACAM-J, the availability of systematic approaches to practicing ACAM-J, recurring themes in reported phenomenology, and the popularity of mindfulness meditation among contemplative scientists and more generally in mainstream media and society, we chose to focus on ACAM-J in this review. There are some attempts to give precise and rigorous definitions of these states in ways that lend themselves well to neuroscientific investigations [19–22]. Nonetheless, we also include historical context and terms to provide a reference for the secular and scientific terms we use in this paper. We first provide brief background and characterization of ACAM-J in terms of their phenomenology and experiential boundaries. This is followed by a review of empirical studies of ACAM-J, primarily from several early and recent neuroimaging studies. We then discuss the broader relevance of ACAM-J within meditation and mindfulness, contemplative sciences, and cognitive psychology. In this sphere, we discuss ACAM-J in relation to attention, reward processing, and consciousness, as well as potential applications and health- and performance-related benefits of ACAM-J in both cognitive sciences and within clinical settings. Finally, we examine possible theoretical models and frameworks for understanding ACAM-J.

2. The eight ACAM-J

ACAM-J are deeply concentrated and progressive states of altered perception achieved through intense concentration on or 'absorption' into a meditation object, resulting in a profound unification of the mind and object and the dissolution of spontaneous mental content [1,23–25]. ACAM-J can be characterized into two overarching types of states: the first set of ACAM-J are known as the "form ACAM-J" (*rūpa jhānas*, in Pāli), and the second set are the "formless ACAM-J" (*arūpa jhānas*). Within each set are four progressive states, resulting in eight ACAM-J that systematically unfold from the first to the eighth [1]. The depth of ACAM-J is determined by the meditation object and the balance of several mental factors described later [25].

It is not the purpose of this review to describe the previously reported methods for experiencing, and the phenomenology of, ACAM-J in detail. Instead, here we provide sufficient information about these states so that readers can understand their relation to existing neuroscientific evidence and their relevance to other cognitive and affective processes. ACAM-J have been previously described in greater detail elsewhere [11,20,23,26–28], and it is important to note that the account of ACAM-J may differ according to the different traditions or schools they were formulated within. The description below represents a synthesis of the eight ACAM-J, aiming to provide a general overview useful for understanding existing neuroscientific work.

The first ACAM-J (ACAM-J1; first of the form ACAM-J) is experienced with the presence of applied focus (directing focus onto the ACAM-J object; directed attention), sustained focus (fixing attention on to the ACAM-J object; sustained attention), bliss (physical excitement from being with the ACAM-J object, high rewards, and arousal), happiness (mental ease from letting go of counterfactual processing; happiness), and single-pointedness (the only object of mental activity is the ACAM-J object), known as the five ACAM-J factors [27]. ACAM-J factors in the context of ACAM-J have specific definitions. Directed attention and sustained attention refer to attention toward the phenomenology of ACAM-J1. Similarly, bliss and happiness are emotional states that occur specifically from meditation on the ACAM-J object [25]. Finally, single-pointedness refers to complete awareness and attention on that object [27,29]. Due to the lack of consensus on their corresponding phenomenology, we retain the English translation of the ACAM-J factors while also providing a modern equivalent term to aid an initial modern scientific and phenomenological interpretation of these terms [11,30]. See Table 1 for a list of Pali and English terms used to describe ACAM-J phenomenology.

To experience ACAM-J1, the meditator must first be able to disengage from the five mental hindrances temporarily [27,29] and develop the ACAM-J factors [29,31]. The five mental hindrances are sensual desire (involvement with phenomenology of the five senses; attention to the phenomenology of the senses), ill will (negative thoughts towards oneself, others, and the meditation object; negative mental contents), sloth and torpor (state of lethargy and drowsiness; clouding of consciousness), restlessness and remorse (state of mind wandering and remorse), and doubt (about the teachers, the teachings, or self-doubt). These hindrances are mental factors characterized by framing responses to and evaluation of external stimuli are framed in relation to a sense of "self" and are obstacles to the success of experiencing ACAM-J1 [27,28,32,33]. See Table 2 for more details on the five mental hindrances.

Central to inhibiting the five mental hindrances and learning ACAM-J are the five mental attributes and seven mental factors of enlightenment [25]. Briefly, the five mental attributes–faith, effort, mindfulness, concentration, and wisdom– are five mental factors that are said to help the meditator maintains focus on the meditation object [24,25]. In contrast, the seven mental factors of enlightenment are mindfulness, investigation of phenomena, effort, bliss, tranquility, concentration, and equanimity [24,25]. As mentioned in "Fire Discourse" of the *Samyutta Nikaya*, investigation of phenomena, bliss, and energy are said to counter sloth and torpor, while tranquility, concentration, and equanimity are said to remedy restlessness and regain mindfulness [34]. Additionally, mindfulness balances the other factors. With these factors, mental state could be calm, balanced, and focused on the meditation object, reducing the activity of the five mental hindrances while enhancing the ACAM-J factors. See Table 2 for more details on the five mental attributes and seven mental factors of enlightenment.

Various traditions and schools have different interpretations of, and techniques for teaching, ACAM-J [1,23,35,36]. Some schools mainly focus on the ACAM-J factors [23,24,29] while others use a *nimitta* (Pali term for mental image) for access and involve very deep absorption [27,37]. Nimitta is often described as a bright light, disc, point, or pattern seen in the mind, and may take various forms such as thigles (rainbow spheres), diffuse glows at the periphery, intricate afterimages, or internal mental representations of physical phenomena. In traditions emphasizing the nimitta (e.g., taught by Pa Auk Sayadaw), it is considered a sign of deepening concentration and anchors the progression of ACAM-J from initial stages of concentration to the deeper absorption states (i.e., ACAM-J). While others may suggest a connection between sensory deprivation and perceptual isolation [38], particularly in relation to ACAM-J phenomenology in some traditions [24,25], the mechanisms and neural correlates associated with the nimitta remain unclear [22]. Hence, further conceptual and empirical investigations are required to understand the significance of the nimitta in ACAM-J and the different types of absorptions [1].

The eight ACAM-J typically occur in progressive stages. To arrive at the next ACAM-J (e.g., from ACAM-J1 to ACAM-J2), some quality/qualities associated with the given ACAM-J are relinquished or transformed, enabling falling into the subsequent deeper

Table 1
Dissolution and emergence of mental activity in the first four form advanced concentrative absorption meditation states of jhana (ACAM-J) and subsequent four formless ACAM-J.

ACAM-J	Dissolved mental activity	Emerged mental activity
Form ACAM-J		
First ACAM-J (ACAM-J1)	Sensual desire (*kāmacchanda*)	Directed attention (*vitakka*)
	Ill will (*vyāpāda*)	Sustained attention (*vicāra*)
	Sloth and torpor (*thīna-middha*)	Joy (*pīti*)
	Restlessness and remorse (*uddhacca-kukkucca*)	Happiness (*sukha*)
	Doubt (*vicikiccha*)	One-pointedness (*ekaggatā*)
Second ACAM-J (ACAM-J2)	Directed attention (*vitakka*)	Joy (*pīti*)
	Sustained attention (*vicāra*)	Happiness (*sukha*)
		One-pointedness of the mind (*ekaggatā*)
Third ACAM-J (ACAM-J3)	Bliss (*pīti*)	Happiness (*sukha*)
		One-pointedness of the mind (*ekaggatā*)
Fourth ACAM-J (ACAM-J4)	Happiness (*sukha*)	One-pointedness of the mind (*ekaggatā*)
		Equanimity (*upekkha*)
Formless ACAM-J		
Fifth ACAM-J (ACAM-J5)	–	Base of boundless space (*ākāsānañcāyatana*)
Sixth ACAM-J (ACAM-J6)	Base of boundless space (*ākāsānañcāyatana*)	Base of boundless consciousness (*viññāṇañcāyatana*)
Seventh ACAM-J (ACAM-J7)	Base of boundless consciousness (*viññāṇañcāyatana*)	Base of nothingness (*ākiñcaññāyatana*)
Eighth ACAM-J (ACAM-J8)	Base of nothingness (*ākiñcaññāyatana*)	Base of neither perception nor nonperception (*nevasaññānāsaññāyatana*)

Table 2

Five mental hindrances, five mental attributes, and seven mental **factors of enlightenment associated with the development of ACAM-J.** The five mental hindrances are characterized by framing responses to and evaluation of external stimuli are framed in relation to a sense of "self" and are obstacles to the success of experiencing ACAM-J. In contrast, the five mental factors and seven mental factors of enlightenment are mental qualities that are said to help the meditator maintains focus on the meditation object.

Category	Factor	Definition
Five mental hindrances	Sensual desire (*kāmacchanda*)	Attending to the phenomenology of the five senses
	Ill will (*vyāpāda*)	Broad general term for negative mental contents such as self-deprecation, rumination, and anxiety
	Sloth and torpor (*thīna-middha*)	State of lethargy and drowsiness that hinders attention to the meditation object
	Restlessness and remorse (*uddhacca-kukkucca*)	State of mind wandering and remorse Restlessness is a state of mind wandering while remorse is a state of worry or regret from past wrongdoing
	Doubt (*vicikiccha*)	Lack of confidence in the teacher, teachings, and oneself
Five mental attributes	Faith (*saddhā*)	Strong faith in the teachings
	Effort (*vīriya*)	Strong effort
	Mindfulness (*sati*)	Strong mindfulness on the meditation objects
	Concentration (*samādhi*)	Strong concentration on the meditation objects
	Wisdom (*paññā*)	Understanding about the meditation objects
Seven mental factors of enlightenment	Mindfulness (*sati*)	Remembers the meditation object and discerns it repeatedly
	Investigation of phenomena (*dhamma-vicaya*)	Understands the meditation object comprehensively
	Effort (*vīriya*)	Brings the enlightenment factors together and balances them on the meditation object
	Bliss (*pīti*)	Gladness of the mind
	Tranquility (*passaddhi*)	Tranquility of the mind and associated mental factors
	Concentration (*samādhi*)	One-pointedness of the mind on the meditation object
	Equanimity (*upekkhā*)	Evenness of the mind that neither becomes excited nor withdraws from the meditation object

ACAM-J states [39]. During the progressive unfolding of ACAM-J, the level of attention on the ACAM-J object becomes increasingly deeper, and the meditator enters increasingly deeply concentrated states of altered consciousness that are less and less impacted by external stimuli. Additionally, the previous ACAM-J should be mastered before learning the next ACAM-J. By mastery, the meditator can enter, maintain and exit from the ACAM-J as long as the meditator wills it [25].

During ACAM-J1, meditators report experiencing physical pleasure that pervades throughout the entire physical body [27]. During this state, applied and sustained attention are still active. Once ACAM-J attention stabilizes and ACAM-J1 has been mastered, applied and sustained attention are somewhat unsatisfying. ACAM-J meditators then drop sustained and applied attention and reach ACAM-J2, bliss. ACAM-J3 is experienced when bliss has become unsatisfying and has subsided, and only happiness (mental ease and contentment) remains. At this point, mindfulness becomes very stable and associated with heightened equanimity. When happiness is unsatisfying and abandoned, ACAM-J4 is reached with equanimity remaining with the most stable concentration among ACAM-J1 to ACAM-J4 [25]. See Table 1 for details of the form ACAM-J.

In the next four ACAM-J (ACAM-J5 to ACAM-J8), consciousness and perception become highly refined while the meditator is in a deeply equanimous state [27]. ACAM-J5 to ACAM-J8 are non-ordinary perceptions of space and consciousness in which sensations, cognitive processing, and narrative processing are extremely inhibited [40]. ACAM-J5 and ACAM-J6 have the adjective *boundless* because the object of meditation is space, which is perceived as boundless and infinite. This type of phenomenology is key to understanding the phenomenology and perception of ACAM-J5 to ACAM-J8. The major difference between ACAM-J1 to ACAM-J4 and ACAM-J5 to ACAM-J8 is the point of focus of the ACAM-J. Since the point of foci in the form ACAM-J are still on the ACAM-J object, it is still conceptualized (i.e., it has a representation or form) as compared to the formless ACAM-J, which cannot be represented conceptually [24]. Thus, while the awareness of the body becomes very focused on a single point during form ACAM-J, awareness of the body falls away in the formless ACAM-J. Below we describe the phenomenology of the formless ACAM-J in brief.

ACAM-J5 is sometimes described as *base of boundless space* in which space is simultaneously perceived as boundless and empty. ACAM-J6 is sometimes called *base of boundless consciousness,* in which the perception of space disappears and is replaced with the perception of consciousness. Similarly, in ACAM-J7 (*base of nothingness*), the perception of boundless consciousness disappears, and only a very subtle perception of nothingness remains. Finally, in ACAM-J8 (called *base of neither perception nor nonperception*), only a very subtle form of perception that is sometimes seen as indescribable with words [27], but sometimes as relinquishing nearly, but not *quite* all recognition of phenomena [28]. Building upon the abundant ancient knowledge about ACAM-J is crucial to advance the contemplative science of advanced meditation. This can be achieved through thorough theoretical and empirical research that characterizes ACAM-J of Theravada Buddhism and similar states of absorptive bliss found in other traditions using modern and scientific languages. Such investigations will pave the way for deeper understanding and progress in contemplative practices.

3. Empirical evidence for ACAM-J

3.1. Phenomenological study

Very few psychological studies on ACAM-J have been conducted to date. To our knowledge, only one study has attempted to unravel the phenomenology of dhyana [11]. Dhyana, in the sense that the author used the term (effortless focus on a meditation object and related experiences such as bliss and happiness), arguably overlaps with the Theravada account of ACAM-J outlined above. While the author refers to the state investigated as access concentration, this state may be distinguished from ACAM-J by considering whether the ACAM-J factors are present. Considering the experiences reported, the experiences involved ACAM-J factors beyond effortless focus such as bliss and happiness. Generally, the article may be understood as a description of the maturation of access concentration into ACAM-J1 and ACAM-J2 and adds insight into especially into the maturation of effortless focus through balancing effort and letting go.

The author conducted a micro-phenomenological investigation of focused attention practice for 45 h over nine days [11]. The inquiry studied the phenomenology of the entire process from before entering ACAM-J to after exiting the ACAM-J. It was reported that with stronger focus and calmness over the days, the meditator could enter ACAM-J intentionally. Intentionality is vital for ACAM-J as it signifies mastery over access, cessation of competing mental processes, and stabilization of ACAM-J. Primary and secondary features of ACAM-J were also reported, that is, the primary features that were always present during ACAM-J, and the secondary features that were occasionally present during ACAM-J. For example, attention, will, directionality, energy, and wakefulness were found to be primary features, and insights and reflections, visual and auditory experiences, a variety of sensations and emotions, 'atmosphere', defined as the mood that is mixed with meaningful context, and cohesion, described as a feeling of interweaving of all features and consciousness, were identified as secondary features. This study provided initial insight into the potential for the phenomenological study of ACAM-J. However, this prior investigation was only a case study of a single adept meditator. Completing larger studies with additional participants would strengthen the analytical and conceptual framework developed in this prior study. Another limitation is that the meditator could not traverse all ACAM-J volitionally, thereby limiting a comprehensive phenomenological assessment [11].

Another central limitation of the study is the lack of reporting of the phenomenology of the nimitta, a key feature that determines if an individual's level of concentration is approaching the level of ACAM-J in some traditions. While the author mentioned phenomenology related to the nimitta (e.g., visual, sensations), a lack of discussion in relation to the nimitta prevents a thorough investigation of this crucial aspect of ACAM-J experience [24,25]. Understanding the qualities and variations of the nimitta could help differentiate between less-developed absorption and ACAM-J, provide more robust understanding of the meditative process, and contribute to the accurate characterization of ACAM-J. Finally, the several processes and phenomenology related to ACAM-J such as the five mental attributes, and five mental hindrances were not explored in this study. Moreover, given that mastery of the previous ACAM-J is emphasized before learning the next ACAM-J, a thorough understanding of the phenomenology of mastery would enable precise modern understanding of ACAM-J [25].

3.2. Neuroscientific studies

3.2.1. First study: Hagerty et al. (2013) functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) case study

Only four human neuroscience studies have been conducted on ACAM-J. The first study was a fMRI-EEG case study of a single adept meditator [21]. The investigators recruited a long-term Buddhist meditation practitioner trained in the *sutta*-style ACAM-J tradition of Ayya Khema, who had completed approximately 6000 h of formal meditation practice. The *sutta*-style ACAM-J mainly based the ACAM-J practices on the direct teachings of the Buddha as found in Buddhist Theravada suttas, a Pali term for Buddhist scriptures [24]. The participant was asked to meditate and access ACAM-J from ACAM-J1 to ACAM-J8, then return to ACAM-J1 stepwise. Transitions between ACAM-J were indicated using button presses. The investigators used general linear models to examine blood-oxygen-level-dependent signal changes in pre-defined brain regions between conditions and including a comparison of ACAM-J. The investigators expected deactivation in regions associated with visual, auditory, language, and orientation, increased activation in the anterior cingulate cortex (ACC), orbitofrontal cortex (OFC), and nucleus accumbens (NAcc). Finally, they hypothesized no change in activation in the motor cortex, somatosensory cortex, and cerebellum to rule out an alternative hypothesis that the reward system is activated due to subtle rhythmic movements rather than ACAM-J.

Hagerty et al.'s results included reduced activation in visual and auditory processing brain regions, as well as language, somatosensory, and posterior-parietal areas during ACAM-J, compared to being at rest (a condition during scanning where the participant is not doing any explicit experimental task) and compared to access concentration. They also reported increased activation in the NACC, OFC, and ACC. A similar pattern was observed in the acquired EEG data; electrodes AFz, Fz, FCz (scalp locations of ACC), FP1, and FP2 (scalp locations of OFC) displayed greater gamma power. The largest change in gamma power was observed in the OFC, followed by the ACC. Their results confirmed hypotheses that these regions are associated with states of ACAM-J, including decreased external awareness, internal verbalization, and boundary sense.

The reported increased activation in the ACC during ACAM-J could have reflected greater attentional processes [41–44], state prediction, and monitoring [45,46]. In contrast, increased activation in the NAcc and OFC during ACAM-J, specifically during ACAM-J2, compared to rest and access concentration control conditions is suggestive of the selection of motivationally relevant events [47]. The NAcc may be involved in translating the experience of pleasure and bliss in ACAM-J2 to focus on the phenomenology [48], while increased activation in the OFC may be related to encoding learning associations of pleasure and bliss with ACAM-J2 [49]. Hagerty et al. also reported deactivation of the NAcc but not the OFC during ACAM-J3, suggesting that the NAcc is not required to maintain the positive affect of ACAM-J3. While phenomenological correlations were not conducted in this study, we speculate that "letting go" of bliss in ACAM-J2 led to a deeper unfolding and refinement of positive affect, leading to ACAM-J3. In other words, the NAcc may not be required to motivate the experience of positive affect in ACAM-J3, leading to its deactivation in ACAM-J3.

3.2.2. Second study: DeLosAngeles et al. (2016) EEG study on meditative absorption states

In an EEG study, researchers instructed 12 meditators and 12 matched non-meditators to enter meditative absorption states using specific instructions for each state [19]. They asked participants to focus their breaths on different body parts for each meditative absorption state. For example, participants were instructed to watch the breath at the nostrils during the first absorption state, the torso during the second, the in-breath at the navel during the third, the out-breath at the navel during the fourth, and conceptually think about space or feel the vast space during the formless states. These instructions were given aurally during meditation.

The authors conducted power spectra analyses on delta, theta, alpha, beta, and gamma frequency bands. They found monotonic depth-related power increases in the major principal component of the theta band, but monotonic depth-related power decreases in the beta band and the second component in the gamma1 band. Furthermore, they reported that these changes occurred in the fronto-temporal and parietal for theta and central for beta and gamma1 bands, suggesting that deeper states of meditation are accompanied by stronger cognitive control and attention [50–53].

3.2.3. Third study: Dennison (2019) EEG study of experienced meditators

The third study to use human neuroscience methods to investigate ACAM-J was an EEG study conducted on twenty-nine experienced *samatha* (in Pāli, means tranquility) meditators with varying degrees of experience with ACAM-J [20]. While Dennison (2019) did not test as many hypotheses as Hagerty et al. (2013), Dennison hypothesized that the EEG metrics would be related to the phenomenology of ACAM-J, particularly the goal of inhibiting default sensory and narrative processing.

Dennison reports three paroxysmal features in their data: spindles, infraslow waves, and spike-waves. Spindles (bursts of coherent brain activity) were found in occipital, temporal, parietal, and limbic areas at lower frequencies (lower alpha and theta), with a lower frequency range between experienced meditators [20]. Dennison explains that other states of attention disruption exhibited similar characteristics and further elaborated that the meditation or ACAM-J spindles could represent a disruption to the cortical networks sustaining the default mode of human consciousness. Moreover, he further stated that the spindles might represent the dorsal and ventral attentional networks supporting sustained and applied thought. A more interesting finding that Dennison reported was dominant infraslow waves (brain rhythms with frequencies below 0.1 Hz) in the midline, followed by frontal and occipital regions and temporal regions. According to Dennison, ACAM-J can be distinguished based on patterns of spindles and infraslow waves that are unique and different from other states of consciousness such as sleep or epilepsy. However, this finding remains to be replicated. Finally, heavy spike-waves were seen in the occipital regions, which the author suggest being a disruption of the self-referent cortico-thalamic loop. Spike-waves are spikes with very short duration and sharp-pointed peak duration of 20–70 ms, followed by a wave component [54]. Heavy spike-waves in the occipital regions suggest a destabilization of the thalamocortical feedback loops when the narrative self is inhibited during ACAM-J. The study by Dennison (2013) revealed remarkable changes in neurophysiological signals during ACAM-J, reflecting a profound disruption and inhibition of default and narrative processing, resulting in a volitional change of consciousness.

3.2.4. Fourth study: Yang et al. (2024) functional magnetic resonance imaging (fMRI) and neurophenomenology case study

The fourth fMRI case study conducted by our research team investigated the neurophenomenology of ACAM-J using an ultra-high magnetic field strength of 7 T, spanning 5 days and 27 sessions [22]. This research stands as the most comprehensive and extensive exploration of ACAM-J from a neuroscientific perspective to date, encompassing quantification of activity across the cortex, subcortex, brainstem, and cerebellum. We recruited a long-term meditator who had over 25 years of *sutta*-style ACAM-J experience at the point of data collection. The participant followed his standard ACAM-J sequence and progressed through the ACAM-J, and indicated entry into each ACAM-J with a button press. Two tasks, a memory task, and a counting task, were used as control conditions to contrast brain activity against ACAM-J. Moreover, the participant also rated several ACAM-J phenomenology, including attentional qualities, intensity of ACAM-J, and ACAM-J qualities. Regional homogeneity (ReHo) was computed as an index of brain activity, and linear mixed models were used to identify ReHo trends across ACAM-J and ReHo differences between ACAM-J and the control conditions. Finally, correlational analyses were conducted to identify phenomenological correlations with brain activity.

The results indicated positive linear trends in temporal, visual, OFC, dorsal thalamus, putamen, periaqueductal gray (PAG), cerebellum, and negative linear trends in the prefrontal cortex, caudate, and ventral thalamus. Moreover, there were also quadratic and cubic trends, mostly negative, in similar regions, signifying the complexity of meditative development [7]. The comparisons between meditative and non-meditative states of cognition revealed a reorganization of brain activity from the posterior (including areas like the visual cortex and precuneus) to the anterior regions (such as the anterior cingulate cortex and medial prefrontal cortex). This was indicated by negative ReHo values shifting from the posterior regions during ACAM-J1 to the anterior regions during ACAM-J5. Additionally, changes in non-cortical regions were observed, including increased ReHo and decreased ReHo in nuclei of the thalamus, putamen, caudate, hippocampus, reticular formation, other brainstem nuclei, and cerebellum, when comparing different ACAM-J milestones with the control conditions. In correlational analyses, the authors demonstrated that attentional qualities were positively associated with ReHo in the posterior cortices and negatively associated with ReHo in the anterior cortices, further demonstrating the anterior-posterior re-organization of the brain during ACAM-J. Finally, intensity of mental ease and equanimity were positively associated with ReHo in the visual cortex while negatively associated with the prefrontal cortex, and intensity of formlessness was predominantly negatively correlated with ReHo in the brainstem.

The findings from Yang et al. (2024) suggest that ACAM-J is related to a posterior–anterior cortical differentiation that reflects cortical hierarchy of the brain from early sensory to higher-order transmodal cortices [55]. The involvement of the thalamic and brainstem nuclei also suggest their significance during affect and arousal generation during ACAM-J. The brainstem, and more specifically, the ascending reticular activating system (ARAS), connects to the cortex through the thalamus [56] and plays a critical role in regulating consciousness, wakefulness, and arousal [57–61]. One of the key functions of the brainstem [62,63] and thalamus [64–67] is to process and filter incoming sensory information, allowing important sensory information to pass through to maintain coherent perception of the world. Decreased brainstem activity during deeper ACAM-J is suggestive of reduction in sensory processing [62,63] and regulation of emotion and arousal [68–71]. The dynamic changes in thalamic activity may also be related to alterations in sensory-gating to Refs. [72,73] and from the cortex [74], and the deconstruction of consciousness during ACAM-J [66,67,75–77].

3.2.5. *Discussion of four neuroscientific studies*

The study of ACAM-J is a recent development in contemplative neuroscience. While most studies of meditation focused on more commonly studied topics like perception, cognition, emotion, and clinical applications [78–82], only four neuroscientific studies, to our knowledge, have examined the neural correlates of ACAM-J [19–22]. While the number of studies are limited, these studies indicated that ACAM-J involve a decrease in activity within areas associated with sensory processing, suggesting a common neurophysiological signature of ACAM-J, providing converging evidence of neurophysiological and functional correlates of ACAM-J [19–22]. Moreover, two studies reported changes in reward processing, possibly linked to the involvement of the reward systems [21,22]. One study further examined the potential roles of the thalamus and brainstem in the phenomenology of ACAM-J [22]. Various neuroimaging modalities have been utilized, with two EEG [19–21], one employed fMRI [21,22], and one fMRI-EEG study [21]. Notably, a decade was required to achieve methodological maturity for investigating of ACAM-J with fMRI using neurophenomenological methods [22,83]. While some studies have also examined states of consciousness similar to ACAM-J but referred to using a different names [13,84,85], we have omitted their discussion in this paper due to the difficulty of determining whether these states were ACAM-J or non-ACAM-J.

Although the studies demonstrated feasibility and reliability of investigating the neural correlates of ACAM-J, neuroscientific understanding of these states remains limited. This is partly due to the lack of eligible and available candidates who can reach these refined states of consciousness, more so in constricted research environments or an insufficient understanding of them. Additionally, conducting case studies on advanced meditative states like ACAM-J with only a single session may present challenges in ruling out alternative explanations for observed brain activity [21]. In a recent study, Ganesan and colleagues utilized a modified intraclass correlation to assess the within-subject reliability of brain estimates during ACAM-J [83]. They found that several brain regions, consistent with findings by Yang et al., exhibited strong within-subject reliability across multiple sampling sessions. Thus, employing repeated sampling methodologies, such as one proposed by Yang et al., could enhance the reliability of neuroimaging metrics of ACAM-J or other advanced meditation states [22].

The investigation of ACAM-J is further complicated by distinction in type, that we have categorized as “light”, “intermediate,” or “deeper”, each with its own operationalization and phenomenology. Although this paper does not delve into the distinctions or review the various subsets of individual ACAM-J, it is still important to acknowledge these differences. For instance, in the DeLosAngeles et al. study, the way in which the authors described ACAM-J were derived from a specific type of ACAM-J practice outlined in the Visuddhimagga, a manual encompassing the phenomenology and practice of the ACAM-J [86]. This particular style, referred to as the Visuddhimagga-style or “deep” ACAM-J, involves complete absorption in their ACAM-J object. During these states, sensory processing is inhibited and the meditator may be incapable of receiving new instructions during transition sequences [27,28,86].]. However, the progression of these states reported by the authors align more with a “light” ACAM-J that entails ongoing engagement with sensations. In contrast, participants from two studies by Hagerty et al. [21] and Yang et al. [22] practiced the sutta-style ACAM-J, while ACAM-J style of participants in Dennison’s study [20] were not explicitly mentioned, but it can be inferred that they practiced a deep or Visuddhimagga-style ACAM-J, as Dennison is a proponent of this kind of ACAM-J [87], which utilizes a nimitta for entry into ACAM-J. In other words, three out of four studies were “intermediate” ACAM-J while the fourth (Dennison’s study) could be a “deeper” ACAM-J.

Although sutta-style and Visuddhimagga-style ACAM-J exhibit distinct phenomenological characteristics, they both share a common trait of stabilizing attention beyond typical everyday experiences. Despite their differences, understanding their neurophenomenology remains valuable and informative, particularly in the context of neuroscientific investigations. Therefore, it is utmost crucial for future on ACAM-J studies and advanced meditation more generally to indicate the meditative traditions practitioners come from and include a comprehensive account of the phenomenology of each state. This practice is crucial for accurately distinguishing between the depths of ACAM-J experiences. Failure to attend to phenomenological nuances in research risks misrepresenting ACAM-J phenomenology, thus producing findings of limited utility or potentially misleading conclusions.

The inclusion and proper utilization of control groups or conditions are crucial in advanced meditation studies. One study included a meditation-naïve control group [19], one included a resting-state control condition [21], one included two non-meditative control conditions [22], and another did not include and comparison groups or states [20]. The comparison of ACAM-J to a resting-state condition conducted by Hagerty et al. [21] may not be ideal as experienced meditators may naturally dwell in meditative during so-called rest, when not engaged in other mental activities [88]. This complicates the interpretation of results if the resting state itself is not truly “restful” but instead heavily involves some level of meditative activity. Comparatively, while Yang et al. included two non-meditative tasks that were thought to actively engage the participant in the task while avoiding the potential confound of spontaneous meditation during rest, the participant still reported the experience of several aspects of advanced meditative states during the control tasks [22]. Thus, future studies need to consider the suitable control groups or conditions to maximize the contrast between ACAM-J and non-ACAM-J or other cognitive states.

While advanced meditators can perceive subtle phenomenological changes during deeper ACAM-J, the challenge arises in accurately indicating transitions in deeper ACAM-J (e.g., ACAM-J6 to ACAM-J7, ACAM-J7 to ACAM-J8). These states are exceptionally subtle and similar, are susceptible to disruption by even the faintest thoughts or sensations [25]. The case study participant from Yang et al.'s study [22] was unable to indicate transitions from ACAM-J6 to ACAM-J8, but the participant from Hagerty et al. was able to, although the fMRI recording stopped due scanner memory limitations [21]. Therefore, factors such as MRI sounds or individual differences must be considered in designing such studies.

Finally, only one study included a neurophenomenological analysis of ACAM-J [22]. While Hagerty et al. (2013) revealed that brain activations were associated with the theoretical phenomenology of ACAM-J, phenomenological data was not collected to support their claim. Neurophenomenological analysis is vital for research like advanced meditation as these neurophenomenology has thus been proposed as an effective method to study these non-ordinary states of consciousness [89,90]. Phenomenology of altered states of consciousness such as ACAM-J cannot be captured fully by pre-defined questionnaires. Moreover, neurophenomenology can provide an important taxonomy and cognitive activities involved in ACAM-J, thus offering new research avenues into the modern classification of phenomenology of ACAM-J, including the necessity of the nimitta in experiencing ACAM-J [30].

In conclusion, while progress has been made in understanding the neural correlates and phenomenology of ACAM-J, there are still significant gaps in knowledge that need to be addressed. Future studies should strive for greater clarity by delineating between different styles of ACAM-J, using appropriate control groups or conditions, and utilizing neurophenomenological approaches to deepen our understanding of these states. While the studies are limited, ACAM-J research is a promising subfield in contemplative science with relevance and implications for meditation, contemplative sciences, and well-being (discussed in the next section). By addressing these challenges and advancing research methodologies, a strong scientific foundation of ACAM-J and advanced meditation more broadly can be established.

4. Relevance to meditation and contemplative sciences

The study of ACAM-J has several important implications within the field of contemplative sciences. Specifically, ACAM-J have the potential to enhance attentional-related processes by reducing narrative processing and strengthening equanimity and attention. Additionally, ACAM-J training can induce ecstatic states of bliss, which may facilitate positive affective change for the individual. Traditionally, ACAM-J are viewed to prepare the mind for insight; since the hindrances are removed, and the access to mental processes may increase due to ACAM-J, ACAM-J may facilitate and enhance cognitive processes. Additionally, typical mindfulness meditation practices are sometimes known as preparatory practices for advanced meditation such as ACAM-J [27]. Therefore, ACAM-J potentially links meditative practices from novice mindfulness meditators to advanced insight meditators, making is position a bridge between typical modern mindfulness practices and advanced meditative practices. Given these possible benefits and implications, ACAM-J may be valuable and conducive to psychological intervention. Below, we describe the relevance of ACAM-J research to the study of human consciousness, attention, reward processing, clinical applications, and other applications in health and performance.

4.1. *Human consciousness*

ACAM-J provide unique possibilities to investigate the plasticity of the human brain and roles of different brain regions and networks involved in the generation and maintenance of altered states of consciousness [91–94]. Comparing the neural correlates of ACAM-J to other states of consciousness, such as the default mode of consciousness or psychedelic states can reveal common and unique features of different states of consciousness, their underlying neural mechanisms, and representations. For instance, the ability to generate bliss states simply by focusing attention on an object can provide insight into how consciousness changes with attention and the mechanisms involved [20–22]. Moreover, ACAM-J, where counterfactual and temporal depth of processing diminishes [28,40], informs the breakdown of layers of consciousness in which advanced stages of meditation may deconstruct a unified conscious space [75,76]. As such, studying ACAM-J will enable researchers to better understand the neural and cognitive mechanisms that underlie conscious experience and the relationship between consciousness and the self.

4.2. *Attention and narrative processing*

Attention is a fundamental cognitive function that underpins many other ones, such as working memory and executive functioning [95,96]. In contemplative sciences and also ACAM-J, attention and narrative processing share a dynamic relationship. When the five aggregates and narrative processing dominate the mind of the meditator, attention is weakened. In contrast, attention is strengthened when narrative processing weakens [27,28,40,97]. Central to the development of ACAM-J applied and sustained attention, two of the five ACAM-J factors. According to Theravada Buddhism, these factors, together with, effort, mindfulness, concentration, tranquility, and equanimity, are crucial for developing attention and minimizing the impact of narrative processing and the five aggregates on attention [24,25]. ACAM-J may reduce narrative processing and biases in perception of sensory stimuli by attenuating overestimated priors and prediction errors [40].

Consistent evidence has shown that mindfulness-based training improves executive functions, specifically inhibition, working memory updating, and set shifting [98]. Experienced meditators exhibited improved attention, working memory, and cognitive flexibility compared to non-meditators [99]. Moreover, changes in functional connectivity in the frontoparietal, salience, and default mode networks during meditation are associated with increased attention and reduced occurrences of mind-wandering and self-referential processing [100]. The default mode network has long been associated with the construction of a self, and ACAM-J is hypothesized to deconstruct the qualia of the self [97] by reducing activations in the default mode network [101] and reducing predictive processing [40]. Recent evidence has also shown that reduced activations in the medial prefrontal cortex, a central hub of the default mode network related to narrative processing, during ACAM-J is associated with greater attentional qualities [22].

ACAM-J may disrupt neural functions related to internal monologue, enabling attention to remain more focused and resist distractions of unrelated thoughts or concerns. ACAM-J meditators may then be less likely to perceive phenomena solely based on past experiences or assumptions, allowing for a more accurate and open-minded perception of the present moment. In practical terms, the meditator may find it easier to maintain attention on their chosen object of focus without distractions from biased perception or unexpected deviations from expectations. In summary, ACAM-J offers a potential mechanism to improving attention and reducing distractive narrative processing.

4.3. Motivation, reward processing, and arousal

Reward processing is vital for many typical human behaviors and social interactions, including intrinsic motivation and satisfaction [102]. According to traditional and anecdotal accounts of ACAM-J, the experience of bliss and happiness from ACAM-J2 and ACAM-J3 may allow meditators to feel a surge of energy and enthusiasm towards their goals and aspirations, and provide a deep sense of contentment and satisfaction [24,25,27,28,32]. We speculate that this process may be mediated by activity in the limbic regions, specifically the OFC and NAcc. The OFC is known to integrate information to guide adaptive behavior [103] while the NAcc is involved in action selection, integrating cognitive and affective information processed by frontal and temporal lobe regions to modulate motivationally-guided behavior [48]. The possible involvement of the PAG during ACAM-J in regulating arousal and autonomic signals that arise from other key affective regions further strengthens the role of ACAM-J in reward processing and arousal [104]. The involvement of the OFC and NAcc, and potentially the PAG, in ACAM-J2 and ACAM-J suggests that ACAM-J may significantly impact reward processing [21,22], potentially influencing emotions, motivations, and behaviors in a positive manner.

Recent evidence has shown that mindfulness meditation training can decrease loneliness [105], and increase daily positive emotion in novices [106]. Moreover, meditators have shown improved social skills such as perspective-taking and empathic concern compared to non-mediators [107]. We speculate that this may be attributed to self-transcendence experienced during ACAM-J [108]. Together, while preliminary at best due to limited studies on ACAM-J, current evidence suggest that ACAM-J has the potential to enhance intrinsic motivation and social interactions due to brain activity changes in regions associated with reward processing and arousal.

4.4. Clinical relevance and applications in health and performance

According to Theravada Buddhism, a crucial element in ACAM-J is developing insight and clarity into the nature of reality [27,28,32,33]. Putting aside spiritual relevance, ACAM-J may be helpful within contexts of psychological therapy, providing a unique position of clinical significance. As ACAM-J induces states of immense concentration and absorption, once an individual arrives at an ACAM-J, traditional and anecdotal accounts suggest that they may exit the state and stay in a post- ACAM-J state of clarity and bliss for several minutes to days [27,28,32,33]. Individuals in this state are thought to be more attentive, clear, satisfied, and peaceful, allowing them to potentially engage in therapy more effectively, developing insight into mental and behavioral patterns underlying psychological suffering [109]. Meditation is associated with life goals and values through decentering, describing, and non-judging facets of mindfulness [110]. ACAM-J may strengthen these qualities, making them potentially useful for overcoming psychological suffering during therapy sessions.

The potential of ACAM-J to improve health and performance extends beyond clinical applications, and can be enhanced through neurotechnology. For instance, ACAM-J combined with neurofeedback can enhance attentional and awareness capacity and reduce narrative processing via modulation of brain activity [111,112]. Brain stimulation methods such as transcranial magnetic stimulation (TMS) or transcranial direct current stimulation (tDCS) can also be used with ACAM-J to facilitate access to ACAM-J1 for new practitioners. Brain stimulation methods have been shown to modulate specific brain regions and improve cognitive and behavioral processes [113–116]. Combining ACAM-J with neurotechnology may result in a synergistic effect, enhancing the benefits of both techniques to overcome obstacles during ACAM-J [117,118]. However, this remains to be tested empirically. Ultimately, ACAM-J offer a unique and powerful practice with great potential for clinical and neurotechnological applications.

The exploration of ACAM-J within the contemplative sciences and their potential clinical application offers a promising frontier for understanding human consciousness, attention, reward processing, and overall well-being. For example, investigating cognitive processes, phenomenology, neural mechanisms, and other factors contributing to the development, stabilization, and deepening of ACAM-J can provide greater insight into new models and mechanisms of well-being and intervention development. Such undertaking will develop a scientific understanding of ACAM-J, thus fostering a broader approach to studying this practice in cognitive psychology and cognitive neuroscience. Thus, ACAM-J represents a significant area of study with the potential to contribute to mental health therapies, improve cognitive and emotional functioning, and enrich our understanding of the dynamics between consciousness, the self, and the brain.

5. Integrated frameworks and models

We provide three possible and current frameworks or models within meditation research that may explain ACAM-J conceptually. These are the (1) many-to-(n)one model of the predictive mind; (2) RElaxed Beliefs Under pSychedelics (REBUS) and the anarchic brain model; and (3) connectome harmonics model.

5.1. The many-to-(n)one model of the predictive mind

The many-to-(n)one model of the predictive mind argues that meditation generally reduces the temporal depth within the predictive hierarchy [40]. According to this model, processes with greater temporal depth such as the narrative self are situated *higher* in the predictive hierarchy while processes with comparatively less depth such as sensory and interoceptive processes are placed *lower* [40]. Temporally thick processes involves predicting future states based on current sensory information and past experiences. The mind continuously generates prediction about the world, known as arising predictions, based on sensory input and past experiences. Meditation generally decreases the frequency of arising predictions and temporally "thick" predictions by reducing mind wandering and enhancing attention and interoceptive awareness [119]. Please see Laukkonen and Slagter for a full review of this model [40].

In the context of ACAM-J, the many-to-(n)one model of the predictive mind holds particular significance. During ACAM-J, meditators confine their attention towards the ACAM-J object, thereby reducing temporal depth and precision weights of narrative and spontaneous mental contents. Consequently, arising prediction tends to decrease. This immense concentration cultivates a profound sense of present-moment awareness and interoceptive sensitivity, facilitating ACAM-J. As ACAM-J deepen, the frequency of arising predictions and temporally thick predictions decreases, allowing immersion into deeper ACAM-J.

Recent evidence have supported this hypothesis, showing that focused-attention meditation reduces mind-wandering [120,121], and decreases activity in the default mode network, which is typically associated with self-referential processing [122]. The default mode network is believed to be located at the top of the processing hierarchy, involved with processes of the "self" [123]. The evidence presented by the four ACAM-J studies also aligns with this model, suggesting reduced arising predictions and the temporal depth of processing [21,22]. This is reflected by the strong activation in the ACC [21], posterior cortices, and reduced activations in the medial prefrontal cortex [22]. Moreover, the brainstem and thalamus appear to deconstruct narrative thoughts in deep ACAM-J, aligning with the many-to-(n)one model of the predictive mind [22]. By deconstructing the elements of the narrative self across ACAM-J, arising predictions and the predictive brain reduces, leading to deep ACAM-J (*base of neither perception nor nonperception*) and even towards an endpoint beyond ACAM-J, known in Theravada Buddhism "*cessation of feeling and perception*" [8]. As it is beyond the scope of this review to discuss *cessation of feeling and perception*, please refer to Laukkonen and colleagues for a detailed review [8]. In short, the many-to-(n)one model of the predictive mind may explain how ACAM-J reconfigures the predictive brain and mind, leading to the experience of the present moment and the deconstruction of processes in the higher levels of the predictive hierarchy.

5.2. RElaxed Beliefs Under pSychedelics (REBUS) and the anarchic brain model

The REBUS and the anarchic brain model of psychedelics posit that by relaxing high-level beliefs or priors, psychedelics open up bottom-up information flow, especially through the affective (sometimes called limbic) system, leading to another state of consciousness [93,123]. As a result, overestimated priors become down-weighted, and new information can flow in, enabling psychedelic therapy and intervention for mental illnesses [123].

Similarly, we suggest that ACAM-J may induce comparable states, marked by disruption of self-related processing [124] and increased brain entropy [125]. By disrupting self-related processing and increasing brain entropy, ACAM-J appears to relax overestimated priors, reducing default mode network activity while enhancing parietal network activity to enhance bottom-up perceptual processing [21,22,97]. This results in a higher entropic brain state and a mode of cognition characterized by heightened perceptual clarity and a more open awareness of the present moment. Recent evidence has shown that attentional qualities positively correlates with brain activity in the posterior cortices, and negatively with the prefrontal cortices, suggesting a release of deep overestimated priors and increased bottom-up processing [22]. This shift in brain state aligns with Buddhist theories, which describes a mode of cognition characterized by heightened perceptual clarity, open awareness, and sense of unity with the surrounding world [25,32,33].

In some traditions, ACAM-J is foundational to advanced insight meditation [27,28,32,33]. Advanced insight training is focused on perceiving the nature and dynamics of what are called the "three marks of existence," that is impermanence, non-self, and suffering [126,127]. This form of advanced insight meditation is thought to lead to deep mental states of clarity and tranquility [128]. By reducing overestimated priors from narrative processing, meditators are less biased by prior beliefs that modulate the current state. Therefore, meditators may have higher perceptual acuity on the nature and dynamics of the phenomenology they are observing during advanced insight meditation. This may be particularly relevant to psychology, specifically clinical psychology and psychiatry as ACAM-J may facilitate the dissolution of previously held beliefs and mental models [123]. Considering the similarities between ACAM-J and psychedelic states, the REBUS and anarchic brain model of psychedelics is an excellent framework for describing the mechanisms of ACAM-J.

5.3. Connectome harmonics model

Harmonic patterns of neural activity emerging from interacting brain regions can be used to explain the functional organization of the brain [129,130]. Connectome harmonics decompose cortical activity into harmonic modes of the human connectome. These harmonic modes are ubiquitous across natural phenomena, ranging from acoustic vibrations and electron orbits to animal coat patterns. Connectome harmonics have been proposed to be the fundamental building blocks of brain function, giving rise to neural activity patterns that underlie cognition and behavior. Although a relatively new theory and research is still in its infancy, there has been evidence that it may provide a valuable framework for understanding brain function and disorders. For example, connectome harmonics have been shown to consistently identify signatures of psychedelic states in lysergic acid diethylamide (LSD) and psilocybin with a shift from low-to high-frequency harmonics, corresponding to increasingly complex neural dynamics [91,92]. Both psychedelics and meditation induce states of altered consciousness, such as temporary states of self-loss or "selflessness" [124]. In the same way, the connectome harmonics model could be applied to study ACAM-J by studying how the harmonic modes of the brain change during meditation and how these changes may correlate with the experience and benefits of ACAM-J. In summary, the connectome harmonics model could provide a framework to understand brain dynamics and mechanisms of consciousness through ACAM-J.

5.4. Compatibility of the frameworks and models

ACAM-J are complex mental states that involve a wide range of cognitive, affective, and neural processes, which are difficult to capture using a single explanatory model or framework. While various models have been proposed to account for different aspects of ACAM-J, such as attentional control, sensory clarity, narrative processing, and awareness, no single model has fully explained the entire range of neural mechanisms and phenomenology of ACAM-J.

For example, the many-to-(n)one model of the predictive mind focuses on deconstructing narrative processing to which ACAM-J may be experienced [40]. This model suggests that ACAM-J can be understood as part of the 'fundamental structure' of the mind, as it deconstructs the elements that constitute the self, leading to just awareness without perceptual construal [97]. This view emphasizes the role of attentional control and the reduction of arising predictions, aligning ACAM-J with a deepened state of present-moment awareness and reduced narrative processing. In contrast, the REBUS and the anarchic brain model propose an alternative account of the neural mechanisms underlying ACAM-J. The model suggests that ACAM-J create more open awareness through relaxing overestimated priors, thus generating high rewards and arousal, leading to bliss and happiness from 'letting go' [21,22,97]. This model is congruent with heightened sensory clarity and a more open awareness, as it describes a shift towards more fluid and dynamic cognitive processes of ACAM-J.

Yet, these two models share a common feature of reducing the dominance of top-down cognitive processes, where high-level processes heavily influence perception and experience, to a state where lower-level sensory information can be experienced more directly without the overlay of complex cognitive operations. Both models suggest a kind of '*letting go*' of narrative thinking, very similar to the phenomenology of ACAM-J. Thus, these two models highlight a common neurocognitive mechanism where reductions in narrative processing leads to states of consciousness characterized by heightened sensory clarity and openness, such as ACAM-J.

Finally, the connectome harmonics model approaches ACAM-J from a structural-functional standpoint, proposing that the harmonic patterns in brain connectivity are the 'fundamental structure' upon which consciousness, including ACAM-J, is constructed [129,130]. This view might illuminate how shifts in neural connectivity patterns correlate with the rich phenomenology of ACAM-J, capturing the complexity of neural processes involved. Vastly different from the previous two models, the connectome harmonics model does not explicitly focus on predictive processing or priors for the phenomenology of ACAM-J. Yet, it offers a potential neurophysiological substrate for changes in brain dynamics during ACAM-J. For instance, the connectome harmonics model may be integrated into the prior two model to explain the neurophysiological substrate of the decrease in predictive processing and the relaxation of priors. However, this remains to be tested empirically.

It seems likely that a more comprehensive understanding of these states will require integrating multiple models and developing new theoretical frameworks that can account for the full range of cognitive, affective, and neural processes involved. We therefore propose that connectome harmonic metrics can be analyzed together with other neuroimaging metrics, such as brain activation, functional connectivity, and phenomenological reports to fully understand the mechanisms of ACAM-J. For example, changes in brain state dynamics from connectome harmonics may be associated with changes in brain activity in regions associated with awareness, attention, and narrative processing. These metrics may also be correlated with phenomenological changes during ACAM-J. Such an approach would be consistent with the emerging trend towards interdisciplinary research in contemplative neuroscience and could lead to important new insights into the nature of human consciousness. However, no models have yet, to our knowledge, been able to completely account for the altered states during deeper ACAM-J, specifically during the formless ACAM-J. Thus, further theoretical and empirical work need to be conducted to understand the phenomenology and mechanisms at deeper ACAM-J.

6. Future directions and conclusion

Research on ACAM-J is a highly underexplored area in contemplative neuroscientific research, compared to the extensive focus on mindfulness practices in predominantly clinical and more recently, non-clinical settings. In this paper, we have sought to address this gap in the literature by providing a comprehensive overview of ACAM-J, their unique characteristics, empirical research on their phenomenology, neural mechanisms, and their relevance to the larger context of consciousness, cognition, emotion, and clinical applications to date. By studying ACAM-J, we propose that it is possible to gain a deeper appreciation of the top-down malleability of consciousness and its contents.

Looking to the future, ACAM-J remain an underexplored area of inquiry. Despite the profound potential benefits of these refined states of consciousness, very few empirical studies have sought to illuminate the mental, neuronal, and neurophysiological changes that occur during ACAM-J [1,11,19–22]. Much of our understanding of ACAM-J phenomenology were derived from traditional contemplative texts [23,25–28,32–34,86]. The lack of research on ACAM-J could be due to inherent challenges in objectively measuring these states. Therefore, it is crucial to develop innovative research designs to examine these states. Toward this goal, we propose two methodologies: no-report paradigms and micro-phenomenology. No-report paradigms leverage neural activity to infer cognitive processes and consciousness during the examined state of consciousness, in this case, ACAM-J [131]. Indeed, this approach has already yielded promising results in previous studies [19–22]. By allowing participants to naturally access these refined states of consciousness without interference and pressure from researchers, no-report paradigms offer a valuable tool for investigating ACAM-J.

Micro-phenomenology is another methodology that holds great promise in uncovering the rich phenomenology of ACAM-J. Micro-phenomenology involves conducting carefully structured interviews to elucidate the experiential aspects of meditation and consciousness [132]. Given that meditators who practice ACAM-J can reflect on and deconstruct the multidimensional characteristics of these states as part of their training [28], micro-phenomenology offers a particularly fruitful avenue for inquiry. These multidimensional characteristics [11] should be explored rigorously as adverse effects may occur [133,134], whether they are actual adverse effects or effects that are part of a positive transformative process [135–137]. By exploring the multidimensional characteristics of the ACAM-J in detail, researchers can uncover mental aspects of ACAM-J that are conducive and healthy for developing these refined states of consciousness. This aligns well with guidelines such as the moral and upright mind required to for ACAM-J, as written in texts of ancient contemplative traditions [27,28]. Additionally, micro-phenomenology offers an opportunity to generate a modern scientific taxonomy to describe ACAM-J phenomenology, given the current lack of a standardized framework [11,30]. There is still considerable unanswered research questions on the cognitive processes and mechanisms contributing to ACAM-J; micro-phenomenology will help generate hypotheses about these processes.

In conclusion, the study of ACAM-J represents a promising avenue for the future of cognitive neuroscience research, with implications spanning many domains such as well-being, attention, emotion regulation, to consciousness. However, for advanced meditation research to reach maturity, including a comprehensive understanding of meditative development and meditative endpoints, it is necessary to carefully study appropriate participants and to employ rigorous empirical methods to investigate these advanced meditative states. By adopting neurophenomenological approaches, researchers can generate a more comprehensive and nuanced understanding of the psychological processes underlying ACAM-J and the corresponding subjective experiences. Ultimately, this line of inquiry can significantly contribute to the scientific understanding of consciousness and promote the development of contemplative practices that can enhance well-being and mental health.

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Winson F.Z. Yang: Writing – review & editing, Writing – original draft, Conceptualization. **Terje Sparby:** Writing – review & editing. **Malcolm Wright:** Writing – review & editing, Conceptualization. **Eunmi Kim:** Writing – review & editing. **Matthew D. Sacchet:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization.

Declaration of competing interest

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