Imag(in)ing the Buddhist Brain

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MINDFULNESS AND THE COGNITIVE NEUROSCIENCE OF ATTENTION AND AWARENESS

by Antonino Raffone, Angela Tagini, and Narayanan Srinivasan

Abstract. Mindfulness can be understood as the mental ability to focus on the direct and immediate perception or monitoring of the present moment with a state of open and nonjudgmental awareness. Descriptions of mindfulness and methods for cultivating it originated in eastern spiritual traditions. These suggest that mindfulness can be developed through meditation practice to increase positive qualities such as awareness, insight, wisdom, and compassion. In this article we focus on the relationships between mindfulness, with associated meditation practices, and the cognitive neuroscience of attention and awareness. Mindful awareness is related to distributed attention, phenomenal consciousness, and momentary self-awareness, as characterized by recent findings in cognitive psychology and neuroscience as well as in influential consciousness models. Finally, we outline an integrated neurocognitive model of mindfulness, attention, and awareness, with a key role of prefrontal cortex.

Keywords: attention; consciousness; meditation; metacognition; mindfulness; neuroimaging; prefrontal cortex; self-awareness

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Mindfulness

Mindfulness usually is defined as open mental presence and attention to the experiences occurring in the present moment, in a nonjudgmental or accepting way (Kabat-Zinn 1990). It can be contrasted with states of mind in which attention is focused elsewhere, including fantasy, planning, reliving memories, and behaving automatically without awareness of one's actions (Brown and Ryan 2003). Descriptions of mindfulness and methods for cultivating it originate in Eastern spiritual traditions, which suggest that mindfulness can be developed through meditation practice and that increases in positive qualities such as awareness, insight, wisdom, and compassion are likely to result (Goldstein 2002; Kabat-Zinn 2000). In particular, the notion of mindfulness is central in Buddhist teachings on the importance of consciousness (Hayes and Wilson 2003). It describes a virtue to be cultivated by meditation and practice in everyday life and refers to an alert and open mode of perceiving and monitoring all mental content, including perceptions, sensations, cognitions, and affects.

Traditional mindfulness meditation practices recently have been adapted and incorporated into several interventions that are now widely available in medical and mental health settings (Kabat-Zinn 1982; 1990; Hayes, Strosahl, and Wilson 1999; Marlatt and Gordon 1985; Segal, Williams, and Teasdale 2002). Moreover, within the past decade, self-report questionnaires for the assessment of mindfulness have begun to appear in psychological literature (Baer, Smith, and Allen 2004; Baer et al. 2006; Brown and Ryan 2003; Buchheld, Grossman, and Walach 2001; Feldman et al. 2004).

With reference to mindfulness-based Buddhist meditation (Cahn and Polich 2006; Lutz et al. 2008), D. J. Siegel (2007) has suggested a distinction between three different forms of awareness: (1) a *receptive* or *mindful awareness*, with openness to whatever "comes to mind in the moment," which has been shown to create a state of flexibility in self-regulation enabling an individual to profoundly shift out of habitual ways of adapting and reacting (Kabat-Zinn 2003); (2) a *self-observational awareness*, accompanied by reflective self-observation, including the metacognitive investigation of one's mental processes; the integration of this self-reflective state with receptivity is characterized by *curiosity*, *openness*, *acceptance*, and *love* (COAL); and (3) a *reflexive awareness*, implying a more immediate capacity of the mind to know itself, without effort and words, leading to an understanding of the nature of *awareness of awareness*.

In this article we relate mindfulness to processes of attention, consciousness, and self-awareness on the basis of findings and models in the fields of cognitive psychology and neuroscience. Our aim is to outline an integrated model of mindfulness, attention, and awareness. To this end, we review the distinction between focused and distributed attention, which may characterize mindfulness-based cognition. Relevant literature indicates a bias toward focused attention, whereas distributed attention, which appears to be closely related to mindfulness processes, is only marginally considered in recently developed consciousness models. Further, we discuss the interactions between attention and consciousness with reference to the influential global-workspace model (Baars 1998; Dehaene et al. 2006), and the distinction between phenomenal and access consciousness, as well as their interactions with focused and distributed attention. In particular, we relate the notion of phenomenal consciousness (Block 1995; 2007) to mindfulness.

Because mindfulness usually is cultivated in meditation, we attribute attentional and conscious processes to the two main categories of meditation, open monitoring or mindfulness-based meditation, in the light of recent psychological and neuroscientific investigations. In order to include the "self" in awareness in our considerations, we subsequently discuss the distinction between narrative or objective selves and momentary subjective self, which seems to be strongly related to mindfulness. Finally, we outline an integrated neurocognitive model of mindfulness, attention, and awareness, with the prefrontal cortex playing a key role.

Focused and Distributed Attention

It has been argued that focused attention is necessary for awareness (Crick 1994; Mack and Rock 1998; Posner 1994; Rensink, O'Regan, and Clark 1997). Without focused attention, the contents in visual short-term memory would be overwritten by subsequent stimuli (Rensink 2002). The process of selecting information from the visual field for identification and awareness has been conceived in terms of a spotlight (Posner 1980) or zoom lens (Eriksen and Yeh 1985). Selective attention is thought of as a process that focuses on a particular location in space, a specific object, or a feature of a whole object. Features obtained through preattentive processes are combined or bound together through focused attention enabling object identification (Treisman and Gelade 1980). Focused attention results in faster or enhanced identification of objects (Carrasco, Ling, and Read 2004).

It also is possible that attention is more diffused or distributed across the visual field or across all objects in the visual field. The focused/distributed nature of attention can be manipulated voluntarily or through specific tasks. It is possible to manipulate the degree of attention by manipulating the load or task difficulty, with more distributed attention occurring in low-load conditions and more focused attention in high-load conditions (Srinivasan et al. 2009; Theeuwes, Kramer, and Belopolsky 2004). Anne Treisman (2006) has argued that these two types of distinct attentional processes are linked to differences in the nature of the information processed. Thus, focused attention is associated with the detailed analysis of specific features and objects, and distributed attention is linked to the global properties of a scene.

Focused attention and distributed attention therefore differ as a function of the information processed and differences in awareness. They also are associated with differences in evaluative processing, such as the processing of emotional information. Positive emotions and processing positive emotional information are linked to distributed attention; negative emotions and the processing of negative emotional stimuli are associated with focused attention. Douglas Derryberry and Marjorie A. Reed (1998) have argued that arousal during negative states is linked to a constriction of the attentional focus, which results in information outside the focus not being processed. In contrast, positive emotions have been connected to a broadening of the scope of attention (Fredrickson 2004). Differences in the scope of attention also result in large-scale changes in behavior (Förster et al. 2006; Förster and Higgins 2005). Global processing and distributed attention have been linked to approach behavior, and local processing and focused attention to avoidance behavior (Förster et al. 2006).

Differences in attention therefore may be connected to differences in awareness. Observers often report that they see more than they are able to report or that they sense a change without being able to verbalize it (Block 2007; Rensink 2004; Sperling 1960). These phenomenal experiences may be the result of distributed attentional processes rather than focused attentional processes, the latter of which are required for verbal reports. Manipulating attention also results in changes in awareness, as measured by color after-images. After-images also have been found to be shorter in low-load conditions linked to a broad scope of attention when compared to high-load conditions (Srinivasan and Hanif in press; Srinivasan and Gupta 2010). In addition, changes in the scope of attention associated with a central task resulted in differences in after-image duration of a peripheral inducer (Baijal and Srinivasan 2009). These results suggest that focused and distributed attention produce different effects on awareness. We consider this aspect in depth in the next section with reference to Ned Block's (2007) distinction between phenomenal consciousness and access consciousness, which may be related to differences in attentional processes.

Interactions between Attention and Phenomenal and Access Consciousness

One of the currently most influential theories of human consciousness, with fundamental implications for addressing the neural correlates of consciousness, is Bernard Baars's global-workspace theory (Baars 1983; 1998; 2002; Baars, Ramsoy, and Laureys 2003). This theory holds that conscious perception enables access to widespread brain sources in terms of *broadcasting*, whereas unconscious processing involves brain areas processing information in a substantially segregated or modular fashion. According to Baars, consciousness, although limited in capacity at any given time, provides a gateway to extensive unconscious knowledge sources in the brain, thus creating the conditions for global access in cerebral information processing. Baars's theory has been revisited in a neuronal global-workspace framework by Stanislas Dehaene and collaborators (Dehaene, Karszberg, and Changeux 1998; Dehaene et al. 2006).

Block uses the global-workspace framework to characterize the distinction between *phenomenal consciousness* and *access consciousness* (Block 1996; 2005; 2007). According to Block, phenomenally conscious content is what differentiates between experiences such as red and green, whereas access-conscious content is information that is "broadcast" in the global workspace. Specifically, Block characterizes access-conscious contents in terms of information that is available to the brain's "consumer" systems: memory, perceptual categorization, reasoning, planning, evaluation of alternatives, decision making, voluntary direction of attention, and, more generally, the rational control of action.

Given that when we view a complex visual scene we experience a richness of content that seems to go beyond what we can report, Block proposes a distinct state of phenomenal consciousness prior to global access or global-workspace broadcasting. Block's proposal is also based on the report of participants in experiments with George Sperling's (1960) iconic memory paradigm who claimed to see the whole array of flashed letters, although they later could report only one subsequently cued row or column. Along these lines, it has been suggested that access consciousness is related to (relatively) *stable* working memory representations and phenomenal consciousness to a *transient* iconic memory (Block 2007; Lamme 2003).

One of the less controversial aspects in the field investigating the neural correlates of consciousness is the necessity of top-down or endogenous attention for conscious access (Block 2007; Dehaene et al. 2006; Lamme 2003). The vast majority of neuroscientific studies on top-down attention have involved orienting to sensory events, and in particular visual events. In these areas of investigation a basic distinction is suggested between those brain areas that are influenced by acts of orientation (*sites*) and those that are a part of an attentional orienting network itself, thus the *sources* of the orientation (Posner and Fan 2004).

It recently has been shown that endogenous attentional orienting (for selective attention) is guided by the prefrontal cortex, with a key role being played by oscillatory synchrony in the beta oscillatory range (Buschman and Miller 2007). The superior parietal lobe seems to be critical for voluntary shifts of attention following a cue (Corbetta et al. 2000). This brain area seems to be part of a larger network that includes frontal eye fields and the superior colliculus (Corbetta 1998). The region is active as well when attention is voluntarily moved from location to location in visual search. Also, the pulvinar, a thalamic-nucleus, appears to be crucial in endogenous visual orienting tasks that may be related to the access of the ventral information-processing stream (see Bundesen, Habekost, and Kyllingsbaek 2005). With reference to these sites, orienting to target motion influences area MT (middle temporal) (V5), while orienting to target color influences area V4 (Corbetta et al. 1991). This principle of activation of brain areas also extends to higher-level visual input, as shown by the evidence that attention to faces influences activity in the face-sensitive area of the fusiform gyrus (Wojciulik, Kanwisher, and Driver 1998).

We hypothesize that endogenous (top-down) attention is generated by *dynamic links* established between adaptive coding neurons in the prefrontal cortex, which are highly adaptable and may be driven by many different kinds of input via a dense network of associative synapses (Duncan 2001), and a set of frontal, parietal posterior and thalamic nuclei involved in endogenous attentional orienting (Bundesen, Habekost, and Kyllingsbaek 2005; Posner and Petersen 1990). This framework (see also Raffone and Srinivasan 2009) suggests that when a certain conscious access operation demands a high number of dynamic links with adaptive coding neurons, the endogenous attention resources available for other processing are reduced. This reduction would become evident in the inattentional blindness phenomenon, which occurs when a perceptually salient stimulus, even if presented within the fovea for a long duration, does not access visual awareness when subjects are engaged in intense mental activity such as detecting certain stimuli or counting (Simons and Chabris 1999).

As considered above, Dehaene and colleagues (2006, for example) stress that top-down (selective) attention is necessary for access to consciousness. However, in their neuronal global-workspace model it is unclear where this top-down attention derives from. This uncertainty may suggest a homunculus-like structure or process projecting a top-down attentional bias toward intended representations in perceptual maps. Our proposal here is that endogenous attention is potentially an ongoing open-field process that is primarily *distributed* and related to the ongoing phenomenal consciousness.

As Antonino Raffone and Narayanan Srinivasan (2009) suggest, when a task is to be performed or some information needs to be accessed in consciousness, the usually distributed endogenous attention becomes focused or selective. Thus, a goal-based task setting makes endogenous attention selective (Desimone and Duncan 1995; Maia and Cleeremans 2005). Such a task-based setting can be encoded within the adaptive coding prefrontal population itself (Duncan 2001; Duncan and Miller 2002). On a trial-by-trial basis this endogenous attention selectivity can be implemented by transient dynamic links between adaptive coding neurons and fronto-parieto-thalamic neurons (for example, in the parietal posterior cortex and in the pulvinar), which have been shown to be involved in top-down attentional orienting (Bundesen, Habekost, and Kyllingsbaek 2005;

Buschman and Miller 2007; Posner and Petersen 1990). One of the main assumptions of the neuronal global-workspace model (Dehaene et al. 2006; Gaillard et al. 2009) is that conscious sensory information must be *explicitly represented* by neuronal firing in perceptual networks coding for the specific features of the conscious percept. As a consequence, conscious access processes based on endogenous attention selectivity may be mediated by a *chain* of dynamic links established between adaptive coding neurons and such perceptual networks via fronto-parieto-thalamic neurons.

Finally, we hypothesize that there is a trade-off between distributed endogenous attention (related to phenomenal consciousness) and focused endogenous attention (related to access consciousness). In turn, broadcasting and the self-sustained neural operations for conscious access can provide a dynamical bias for the selective allocation of endogenous attention.

Focused Attention and Open Monitoring in Meditation

Focused and distributed attention, as well as phenomenal and access consciousness and their interactions, are central to meditation as a fundamental method to cultivate mindfulness. Meditation can be conceptualized as a family of complex emotional and attentional regulatory practices in which mental and related somatic events are affected by engaging a specific attentional set. Many recent behavioral, electroencephalographic, and neuroimaging studies have revealed the importance of investigating states and traits related to meditation in order to achieve an increased understanding of cognitive and affective neuroplasticity, attention, and self-awareness, as well as for their possible clinical implications (Cahn and Polich 2006; Lutz et al. 2008).

The regulation of attention is a central feature of different meditation methods (Davidson and Goleman 1977), and meditation practices can be usefully classified into two main styles—*focused attention* (FA) and *open monitoring* (OM)—depending on how the attentional processes are directed (Cahn and Polich 2006; Lutz et al. 2008). In the FA (concentrative) style, attention is focused on a given object in a sustained manner. The second style, OM (mindfulness-based) meditation, involves the nonreactive monitoring of the content of ongoing experience, primarily as a means to become aware of the nature of emotional and cognitive patterns.

Focused Attention Meditation. Apart from sustaining the attentional focus on an intended object, FA meditation also implies the regulative skills of monitoring the focus of attention, detecting distraction, disengaging attention from the source of distraction, and (re)directing and refocusing on the object (Lutz et al. 2008). FA meditation techniques involve observing the experiential field by allowing thoughts and sensations to arise and pass without clinging to them, maintaining attention on an object or bringing it back to the specific object of concentrative (or focused) awareness, in order to develop an internal witnessing observer (Cahn and Polich 2006). Note that this witnessing observer resembles the operations of mindfulness, even if with a focused attention. The attentional and monitoring functions of FA meditation have been related to dissociable systems in the brain involved in conflict monitoring as well as general selective and sustained attention (Corbetta and Shulman 2002; Lutz et al. 2008; Weissman et al. 2006).

The practice of FA meditation leads to reduced effort in sustaining the focus on an intended object. Expertise in FA meditation leads to a greater monitoring ability to detect arising distractions or mind wanderings, thus implying reduced cognitive efforts during practice (Lutz et al. 2008).

In Buddhist texts consciousness is described as a momentary collection of mental phenomena or distinct moments of consciousness (von Rospatt 1995). In these texts it is asserted that the continuum of awareness is characterized by successive moments, or *pulses*, of cognition (Wallace 1999). On the basis of a view of consciousness as consisting of sequences of discrete events (see also Poeppel 1997; VanRullen and Koch 2003), Alan Wallace (1999) argued that the degree of focused *attentional stability* during FA meditation increases in relation to the proportion of ascertaining to unascertaining moments of cognition of the intended object. In this view, a continuum of perceptual experience consists of nonascertaining cognition, as objects *appear* to this inattentive awareness but are not *ascertained*—that is, they are outside the domain of perceptual awareness (Lati Rinbochay 1981; Wallace 1999).

As attentional stability increases, a reduced number of moments of ascertaining consciousness are focused on perceptual objects other than the intended object, thus resulting in a homogeneous series of moments of ascertaining perception or perceptual awareness of the chosen object. The degree of *attentional vividness* during this process corresponds to the ratio of ascertaining to nonascertaining moments of cognition; the higher the frequency of ascertaining perception, the greater the vividness (Wallace 1999). In FA meditation practice, high attentional stability and vividness are achieved in a mental state of concentrated calm or serene attention, denoted by the word *samatha* (with the literary meaning of "quiescence") in the Buddhist contemplative tradition (Wallace 1999). Wallace observes that the development of attentional stability may be likened to mounting a telescope on a firm platform, while the development of attentional vividness is like polishing the lenses and bringing the telescope into clear focus.

A study with a binocular rivalry paradigm showed that Tibetan Buddhist monks were able to perceive a stable, superimposed percept of two dissimilar, competing images presented to separate eyes for a longer duration both during and after FA meditation but not during and after a form of compassion (emotional OM) meditation (Carter et al. 2005). This extreme increase in perceptual dominance duration suggests that extensive training in FA meditation improves the ability to sustain attentional focus and awareness on a particular object.

Recently, an fMRI study investigated the neural correlates of FA meditation in experts (following Tibetan Buddhist traditions) and novices, with a meditation focus on an external visual point (Brefczynski-Lewis et al. 2007). FA meditation compared with a rest condition was associated with the activation of multiple brain regions involved in monitoring, such as the dorsolateral prefrontal cortex, attentional orienting (for example, the superior frontal sulcus and intraparietal sulcus), and attention engagement (visual cortex). Srinivasan and Shruti Baijal (2007) used the mismatch negativity (MMN) paradigm, an indicator of preattentive processing, to investigate the effects of FA (Sudarshan Kriya Yoga) meditation. Meditators were found to have larger MMN amplitudes than nonmeditators. The meditators also exhibited significantly increased MMN amplitudes immediately after meditation, suggesting transient meditation-related state changes. These findings suggest that FA meditation practice enhances preattentive perceptual processes, enabling enhanced change detection in auditory sensory memory.

Transcendental meditation (TM) can be broadly included in the FA meditation category, as its practice centers on the repetition of a mantra. However, TM primarily emphasizes the absence of an effort to maintain concentration and the development of a witnessing, thought-free "transcendental awareness" or "pure consciousness." Maharishi Mahesh Yogi, who introduced TM—which is derived from the Vedic tradition of India—to the West, characterized the experience of pure consciousness as deriving from consciousness turning back on itself, abandoning its identifications with things of the mental and material world and achieving an integrated state. Pure consciousness is thus regarded as "pure" in the sense that it is free from the contents of knowing. It is a state of consciousness in which the individual experiencing it is fully aware or conscious and the "content" of consciousness becomes awareness itself (Arenander and Travis 2004). TM meditation practitioners report that the absence of any concentration or effort unfolds experiences of "unboundedness" and the "loss of time, space and body sense." These "pure consciousness" or "thoughtless awareness" experiences are associated with profound physical relaxation, marked by spontaneous breath quiescence and global, high-amplitude, slow-frequency (alpha) EEG patterns that are generally highly coherent across frontal leads (Arenander and Travis 2004; Travis and Pearson 2000; Travis and Wallace 2000). A similar reference to a pure or *intuitive awareness* can be found in Buddhism, as reflecting a "non-self" mental state, which, however, is associated with a mindfulness-based insight meditation (Sumedho 2004).

Interestingly, Semir Zeki (2003) considers a similar construct of unified or pure consciousness in his hierarchical theory of consciousness. Zeki's theory includes three hierarchical levels of consciousness: the level(s) of micro-consciousness, the level(s) of macroconsciousness, and unified consciousness. With reference to Immanuel Kant (1996), Zeki regards this pure, unified, or "transcendental" consciousness as consciousness of oneself as a perceiving person, which can be considered a meta-awareness or "being aware of being aware." Zeki places this process at the apex of the hierarchy of consciousnesses and remarks that it is the only form of consciousness that can be described in the singular person.

Open Monitoring Meditation. Open monitoring (OM) meditation does not involve an explicit attentional focus and therefore does not seem to be associated with brain areas implicated in sustained or focused attention. Instead it involves brain regions implicated in vigilance, monitoring, and disengagement of attention from sources of distraction from the ongoing stream of experience (Lutz et al. 2008). OM practices are based on an attentive set that is characterized by an open presence and a nonjudgmental awareness of sensory, cognitive, and affective fields of experience in the present moment, and involves a higher-order (meta-) awareness of ongoing mental processes (Cahn and Polich 2006). The cultivation of this reflexive awareness in OM meditation is associated with a more vivid conscious access to the rich features of each experience and enhanced metacognitive and self-regulatory skills (Lutz et al. 2008).

Unlike FA meditation, OM meditation does not entail attentional biases resulting in selection and deselection processes. Therefore, in OM meditation cognitive monitoring is reflected in an open-field capacity to detect arising sensory, feeling, and thought events within an unrestricted "background" of awareness, without a grasping of these events in an explicitly selected foreground or focus. In the transition from an FA to an OM meditative state, the object as the primary focus is gradually replaced by an "effortless" sustaining of an open background of awareness without an explicit attentional selection (Lutz et al. 2008). In the next sections we return to the constructs of open monitoring and of a background of awareness as revealed through OM meditation, with reference to metacognitive consciousness.

In contemplative practice, as in the Buddhist tradition, attentional stability and vividness (acuity), as developed in FA meditation, are regarded as necessary for deep and reliable introspection to take place, as in the practice of *vipassana* (insight) OM meditation. As indicated by Wallace (1999), the eminent Tibetan Buddhist contemplative and philosopher Tsongkhapa (1357–1419) highlighted the importance of attentional stability and vividness for the cultivation of contemplative insight by referring to an oil lamp, which is both radiant and unflickering and, with its light, allows shapes on a tapestry to be observed in detail and vividly at night. When the light is dim or the wind induces flickering the perception of shapes is lost.

In the Buddhist contemplative tradition, introspection, as performed in OM insight meditation, is regarded as a form of metacognition, thus raising the question of whether it is possible for the mind to observe itself. Buddhists generally assert that at any moment in time the same intentional object constitutes both the content of consciousness and its associated mental processes (Vasubandhu 1991). Because consciousness is by definition single and unitary, the problem of whether it is possible for the mind to observe itself arises (Wallace 1999). In this respect, Buddha seems to have asserted that the mind cannot observe itself, just as a sword cannot cut itself and a fingertip cannot touch itself; nor can the mind be seen in external objects of the senses or in sense organs (*Ratnacutasutra*, cited in Shantideva 1971; Wallace 1999).

To avoid an infinite regress in terms of an observing observer and an observer who is observing the observing observer, the eighth-century Indian Buddhist contemplative Shantideva suggested that instead of metacognition occurring simultaneously with cognition, a *recollection* of past moments of consciousness takes place. In Shantideva's view, when a certain event is remembered, the event and the subject perceiving it are recalled. The subject and object are recalled as an integrated, experienced event, in which the subject is retrospectively identified as such. Shantideva denies that it is possible for a single cognitive process to take itself as its own object (Dalai Lama 1994; Shantideva 1997; Wallace 1999).

This view of metacognition and conscious access may be thought to converge with the contemporary connectionist approach to metarepresentation, in terms of the production of representations that are then fed back to the same constraint satisfaction network as input (Rumelhart et al. 1986), or, more generally, with the creation of representations that are then available for reprocessing to the same network, thus implementing a (meta) representational and (recursive) processing cycle that could be regarded as the parallel distributed processing basis of the "stream of thought" (Maia and Cleeremans 2005).

Behavioral studies have shown a more distributed attentional focus (Valentine and Sweet 1999), enhanced conflict monitoring (Tang et al. 2007), and reduced attentional blink or more efficient resource allocation to serially presented targets (Slagter et al. 2007) in OM meditators. Specifically, Heleen Slagter and collaborators (2007) found that three months of intensive OM meditation lead to an observable reduction of elaborative processing of the first of two target stimuli (T1 and T2) presented in a rapid stream of distractors, as indicated by a smaller T1-elicited P3b, a brain potential index of resource allocation. Remarkably, such a reduction in resource allocation to T1 was associated with improved detection of T2.

Slagter and colleagues' study indeed suggests that intensive training in OM meditation may result in the development of efficient attentional regulative skills to flexibly engage and disengage from target stimuli in a given task.

Antoine Lutz and collaborators (Lutz et al. 2004) found a high-amplitude pattern of synchrony in the gamma oscillatory band in expert meditators during an emotional version of OM meditation (nonreferential compassion or "loving kindness" meditation). In that study, compared with a group of novices, the expert meditators (with a mental training of 10,000 to 50,000 hours over time periods ranging from fifteen to forty years) self-induced higher-amplitude sustained gamma band oscillations and long-range phase synchrony, especially over lateral fronto-parietal electrodes, during meditation. This pattern of gamma band oscillations and synchrony was also significantly more pronounced in the baseline state of the long-term practitioners compared with the novices, thus suggesting a neuroplasticity-based transformation in the default brain mode of the expert meditators.

The Twofold Nature of Awareness of Self

Since William James (1890), two main forms of awareness of self have been characterized in psychology and in more recent years in cognitive neuroimaging. James posited that the self, rather than being a unitary entity, needed to be construed in terms of an *I*, as the subjective self and causal agent, and a *Me*, the objective sense of self that is a constituent of the self-image. In James's view, the I is closely related to and based upon the body and its ownership. Authors from different theoretical perspectives have concurred with James on the distinction between I and Me (for example, Freud 1959; Mead 1934; Piaget 1954). Given the centrality of the I-related or momentary self-awareness to characterize mindfulness and related cognition, and of self-related processing for conscious access, in this section we synthetically focus on empirical evidence and theories on the distinction between I and Me in awareness.

More recently, related to James's view, Shaun Gallagher (2000) defined the "minimal self," a *prereflective* aspect of the self corresponding to the personal pronoun *I*. The minimal self corresponds to a sense of being the immediate subject of experience in the present and to taking on a first-person perspective. As such it is also the source of thought and action and provides an ecological sense of body ownership, which can be selectively impaired in asomatagnosia (lack of awareness of the condition of all or part of one's body), and agency in active behavior. The sense of agency can be conceived in terms of a *momentary awareness*, as when performing an action this action is experienced as one's own and under one's control. In contrast to the minimal self, Gallagher also defined a *reflective* "narrative self," or autobiographical self (Damasio 1999), representing the third-person perspective. It is extended in time and creates a subjective feeling of identity and continuity throughout time, linking past, present, and future.

Baars (1998; 2002) hypothesized that conscious events involve self-systems in the brain, in particular a "narrative interpreter" in the left hemisphere (with prefrontal cortex involvement). Metaphorically, this interpreter would operate as a stage director in a theater. Baars particularly referred to Michael S. Gazzaniga's (1985) findings with split-brain patients and argued that the two hemispheres might each possess an "observer" of the respective conscious flow of visual information.

To address the issue that conscious perception may entail a dialogue between specific self-related prefrontal regions (stage director or executive interpreter) and sensory cortex (Baars, Ramsoy, and Laureys 2003), brain activity patterns produced by a demanding sensory categorization task were compared to those engaged during self-reflective introspection, using similar sensory stimuli (Goldberg, Harel, and Marach 2006). The results showed a complete segregation of the two brain activity patterns, thus challenging Baars's hypothesis of an involvement of self-related observerlike prefrontal regions in perceptual awareness. Moreover, areas characterized by enhanced activity during introspection exhibited a robust inhibition during the demanding perceptual task, thus suggesting that self-related brain activities are not necessarily implied during sensory perception and that they can be suppressed. Interestingly, Goldberg and colleagues relate their findings to the Zen Buddhist view on selflessness:

> . . . the picture that emerges from the present results is that, during intense perceptual engagement, all neuronal resources are focused on sensory cortex, and the distracting self-related cortex is inactive. Thus, the term "losing yourself" receives here a clear neuronal correlate. This theme has a tantalizing echoing in Eastern philosophies such as Zen teachings, which emphasize the need to enter into a "mindless," selfless mental state to achieve a true sense of reality. . . . (2006, 337)

Baars's global-workspace theory (1998; 2002) also posits that unconscious or "contextual" brain systems play a role in shaping conscious events, acting like a backstage in a theater. Contextual systems in the brain include the dorsal pathway for visual processing, whereas the ventral visual pathway produces sensory "contents" (Milner and Goodale 2008). Further, Baars noticed that parietal neglect, a syndrome characterized by an altered spatial framework for vision, often is accompanied by anosognosia, a loss of awareness of one's body space. Here we note that such contextual systems associated to body and space awareness can be regarded as aspects supporting momentary self-awareness, or I-awareness, whereas the "stage director" in Baars's metaphor may be related to Me-awareness. Interestingly, Baars's theory regards brain systems related to I-awareness as unconscious, whereas conscious access is associated to brain patterns that ultimately are related to a narrative self.

A recent neuroimaging study by Norman A. S. Farb and colleagues (2007) was designed to characterize the neural bases of two forms of self-awareness: extended self reference, linking experiences across time, and momentary self-reference, centered on the present moment. Specifically, these researchers investigated the monitoring of enduring traits (narrative focus, NF) and momentary experience (experiential focus, EF) in both novice participants and those having attended an eight-week course in mindfulness meditation, a program that trains participants to develop focused attention on the present moment. In novices, EF resulted in focal reductions in self-referential "cortical midline structures," including medial prefrontal cortex, which are brain regions associated with NF. In trained participants, EF yielded more pronounced and pervasive reductions in medial prefrontal cortex activation and increased engagement of a right lateralized network including the lateral prefrontal cortex, the insula and the inferior parietal lobule. Following mindfulness training, EF resulted in a shift of activation from both the ventromedial prefrontal cortex and the amygdala toward more lateral prefrontal regions, supporting a more objective and self-detached analysis of interoceptive (insula) and exteroceptive (somatosensory cortex) sensory events, rather than their subjective or affective self-referential evaluation.

The functional connectivity analyses in the study by Farb and colleagues showed a strong coupling between the right insula (associated with momentary self-awareness) and the medial prefrontal cortex (associated with narrative self-awareness) in novices, which was uncoupled in the mindfulness group. These functional connectivity results suggest that a default mode of self-awareness may depend on habitual coupling between regions in medial prefrontal cortex supporting cognitive-affective representations of the self, and more lateral viscerosomatic neural representations of body state. Taken together, the findings suggest a fundamental neural dissociation between the self across time (Me) and in the present moment (I) and that these two forms of self-awareness, which normally are integrated, can be dissociated through attentional or mindfulness-based training. Thus, this kind of training allows for a distinct experiential mode in which body sensations, thoughts, and feelings are viewed as less integral to the extended self and treated as transient mental events that can be simply observed in the present moment (see also Williams et al. 2007).

Toward an Integrated Neurocognitive Model of Mindfulness, Attention, and Awareness

On the basis of the preceding sections, mindfulness can plausibly be related to distributed attention and phenomenal consciousness as well as to I-related self-awareness. In an OM or mindfulness-based meditation scenario, attention and monitoring functions are nonselective or open-field, inclusive of external sensory fields and of internal thoughts and feelings. In light of what we have argued about the primary nature of endogenous attention, OM meditation can be conceived as the context for the most direct manifestation of distributed endogenous attention, not bound to goal-related task settings that induce a selective or focused allocation of attentional resources. The notion of mindfulness may provide a unifying construct for endogenous attention, monitoring, and executive control functions (Raffone and Srinivasan 2009).

During FA meditation, even if the endogenous attention focus on a chosen object is sustained, other events arising in sensory and thought (feeling)-related fields typically are noticed in the "background" (Cahn and Polich 2006; Lutz et al. 2008). This background phenomenal awareness can be explained in terms of transient resonant assemblies in the brain that may coexist with a global workspace assembly or dynamic core (Tononi and Edelman 1998) assembly for "foreground" conscious access. Block (2007) has suggested a similar mechanism for phenomenal consciousness, in terms of losing neuronal coalitions in posterior associative (for example, parietal posterior) cortex, maintained in parallel with a winner-take-all global workspace coalition for access consciousness.

Related to the findings of Lutz and colleagues (2004), transient oscillatory coherence in the gamma band may play a crucial role in the reversible binding and unbinding of large-scale dynamic or resonant neural assemblies in OM meditation (see also Lutz et al. 2008). Thus, a mechanism based on transient dynamic assemblies may be involved in OM meditation as related to an open background awareness of rapidly changing experience contents (Lutz et al. 2008). A more efficient binding (dynamic linking) and unbinding of neural assemblies, encoding for serially presented targets, may explain the reduced attentional blink observed by Slagter and colleagues (2007). A transition from transient assemblies for phenomenal consciousness to more stable or self-sustained assemblies for access consciousness would be possible at any time, however, by endogenous attention driving an extended brain broadcasting process, related to a complementary introspective or investigative stance in (insight) OM meditation. Cognitive control processes (by inner speech or imagery, for example) can be used to reiterate broadcasting in this kind of sustained conscious access (Baars 1998).

As suggested by Farb and colleagues' (2007) findings, awareness of subjective or phenomenal aspects of experience in the present moment involves neuronal populations with responses marking transient body states—in particular, right lateralized exteroceptive somatic and interoceptive insular cortices (Craig 2004; Critchley et al. 2004; Damasio 1999). Somatic marker or momentary self-awareness areas have also been implied in OM or mindfulness-based meditation (Lutz et al. 2008). We suggest that the dynamic linking between such neuronal populations and adaptive coding neurons in prefrontal cortex is crucial for an I-related phenomenal awareness and to enable a transient brain broadcasting process necessary for that awareness (see also Raffone and Srinivasan 2009).

The high degree of response flexibility and intrinsic as well as extrinsic synaptic recurrency of the large population of adaptive coding neurons in prefrontal cortex may enable *metacognitive consciousness* abilities (Raffone and Srinivasan 2009). This metacognitive consciousness, which can be related to the self-observational aspects of mindfulness, may refer either to being aware of an object or to the subjective experience of cognition of an object, that is, an external stimulus or thought or feeling state. In our view, this metacognitive consciousness is "transversal" to any form of awareness based on the subject-object cognitive duality, whether it refers to an external or internal object per se (first-order consciousness) or to the subjective or phenomenal experience of such an object (second-order consciousness). As such, the intrinsic dynamic links within the adaptive coding population in prefrontal cortex also can be nonreferential, that is, related to a third-order consciousness, going beyond the cognitive subject/object duality, as the "awareness of being aware" (Arenander and Travis 2004; Zeki 2003).

In our view, this transcendent awareness may be developed only through meditation-based intuition and thus also can be characterized as an *intuitive awareness* (Sumedho 2004) or as the *reflexive awareness* facet of mindfulness (Siegel 2007). Because intrinsic and extrinsic dynamic links in and beyond the adaptive coding population in prefrontal cortex are likely to interact at any time, this intrinsically unified consciousness can reflect itself as referential and context-dependent metacognition and neural operations underlying access and phenomenal consciousness, with related endogenous attention dynamics. These interdependent processes may characterize the unfolding of the differentiated and yet integrated facets of mindful awareness.

NOTE

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References

Arenander, A., and F. T. Travis. 2004. "Brain patterns of self-awareness." In *Self-Awareness Deficits*, ed. B. Beitman and J. Nair. New York: W. W. Norton.

Baars, Bernard J. 1983. "Conscious contents provide the nervous system with coherent, global information." In *Consciousness and Self-regulation*, ed. R. J. Davidson, G. E. Schwartz, and D. Shapiro, 41–79. New York: Plenum.

———. 1998. "Metaphors of consciousness and attention in the brain." *Trends in Neurosciences* 21:58–62.

———. 2002. "The conscious access hypothesis: Origins and recent evidence." *Trends in Cognitive Sciences* 6:47–52.

Baars, Bernard J., T. Z. Ramsoy, and S. Laureys. 2003. "Brain, conscious experience and the observing self." *Trends in Neurosciences* 26:671–75.

Baer, R. A., G. T. Smith, and K. B. Allen. 2004. "Assessment of mindfulness by self-report: The Kentucky Inventory of Mindfulness Skills." *Assessment* 11:191–206.

Baer, R. A., G. T. Smith, J. Hopkins, J. Krietemeyer, and L Toney. 2006. "Using self-report assessment methods to explore facets of mindfulness." *Assessment* 13:27–45.

Baijal, Shruti, and Narayanan Srinivasan. 2009. "Types of attention matter for awareness: A study with color afterimages." *Consciousness and Cognition* 18:1039–48.

Block, Ned. 2007. "Consciousness, accessibility, and the mesh between psychology and neuroscience." *Behavioural and Brain Sciences* 30:481–548.

Brefczynski-Lewis, J. A., A. Lutz, H. S. Schaefer, D. B. Levinson, and R. J. Davidson. 2007. "Neural correlates of attentional expertise in long-term meditation practitioners." *Proceedings of the National Academy of Sciences, U.S.A.* 104:11483–88.

Brown, K. W., and R. M. Ryan. 2003. "The benefits of being present: Mindfulness and its role in psychological well-being." *Journal of Personality and Social Psychology* 84:822–48.

Buchheld, N., P. Grossman, and H. Walach. 2001. "Measuring mindfulness in insight meditation (Vipassana) and meditation-based psychotherapy: The development of the Freiburg Mindfulness Inventory (FMI)." *Journal for Meditation and Meditation Research* 1:11–34.

Bundesen, C., T. Habekost, and S. Kyllingsbaek. 2005. "A neural theory of visual attention: Bridging cognition and neurophysiology." *Psychological Review* 112:291–328.

Buschman, T. J., and E. K. Miller. 2007. "Top-down versus bottom-up control of attention in the prefrontal and posterior parietal cortices." *Science* 315:1860–62.

Cahn, B. R., and J. Polich. 2006. "Meditation states and traits: EEG, ERP, and neuroimaging studies." *Psychological Bulletin* 132:180–211.

Carrasco, M., S. Ling, and S. Read. 2004. "Attention alters appearance." *Nature Neuroscience* 7:308–13.

Carter, O. L., et al. 2005. "Meditation alters perceptual rivalry in Tibetan Buddhist monks." *Current Biology* 15:R412–13.

Corbetta, M. 1998. "Frontoparietal cortical networks for directing attention and the eye to visual locations: Identical, independent, or overlapping neural systems?" *Proceedings of the National Academy of Sciences, U.S.A.* 95:831–38.

Corbetta, M., J. M. Kincade, J. M. Ollinger, M. P. McAvoy, and G. L. Shulman. 2000. "Voluntary orienting is dissociated from target detection in human posterior parietal cortex." *Nature Neuroscience* 3:292–97.

Corbetta, M., F. M. Miezin, G. L. Shulman, and S. E. Petersen. 1991. "Selective and divided attention during visual discriminations of shape, color, and speed; functional anatomy by positron emission tomography." *Journal of Neuroscience* 11:2383–2402/

Corbetta, M., and G. L. Shulman. 2002. "Control of goal-directed and stimulus-driven attention in the brain." *Nature Review Neuroscience* 3:201–15.

Craig, A. D. 2004. "Human feelings: Why are some more aware than others?" *Trends in Cognitive Sciences* 8:239–41.

Crick, F. 1994. *The Astonishing Hypothesis.* New York: Scribner's.

Critchley, H. D., S. Wiens, P. Rotshtein, A. Ohman, and R. J. Dolan. 2004. "Neural systems supporting interoceptive awareness." *Nature Neuroscience* 7:189–95.

Dalai Lama. 1994. *Transcendent Wisdom: A Teaching on the Wisdom Section of Shantideva's Guide to the Bodhisattva Way of Life*. Trans., ed., and annot. B. A. Wallace. Ithaca, N.Y.: Snow Lion.
Damasio, A. 1999. *The Feeling of What Happens: Body and Emotion in the Making of Consciousness*. New York: Harcourt, Brace.
Davidson, R. J., and D. J. Goleman. 1977. "The role of attention in meditation and hypnosis: A psychobiological perspective on transformations of consciousness." *International Journal of Clinical and Experimental Hypnosis* 25:291–308.
Dehaene, Stanislas, M. Kerszberg, and J. P. Changeux. 1998. "A neuronal model of a global workspace in effortful cognitive tasks." *Proceedings of the National Academy of Sciences, U.S.A.* 95:14529–34.
Dehaene, Stanislas, J. P. Changeux, L. Naccache, J. Sackur, and C. Sergent. 2006. "Conscious, preconscious, and subliminal processing: A testable taxonomy." *Trends in Cognitive Sciences* 10:204–11.
Derryberry, Douglas, and Marjorie A. Reed. 1998. "Anxiety and attentional focusing: Trait, state and hemispheric influences." *Personality and Individual Differences* 25:745–61.
Desimone, R., and J. Duncan. 1995. "Neural mechanisms of selective visual attention." *Annual Review of Neuroscience* 18:193–222.
Duncan, J. 2001. "An adaptive coding model of neural function in prefrontal cortex." *Nature Reviews Neuroscience* 2:820–29.
Duncan, J., and E. K. Miller. 2002. "Cognitive focusing through adaptive neural coding in the primate prefrontal cortex." In *Principles of Frontal Lobe Function*, ed. D. Stuss and R. T. Knight, 278–91. New York: Oxford Univ. Press.
Eriksen, C. W., and Y. Yeh. 1985. "Allocation of attention in visual field." *Journal of Experimental Psychology: Human Perception and Performance* 11:583–97.
Farb, N. A. S., Z. V. Segal, H. Mayberg, et al. 2007. "Attending to the present: Meditation reveals distinct neural modes of self-reference." *Social Cognitive and Affective Neuroscience* 2:313–22.
Feldman, G. C., A. M. Hayes, S. M. Kumar, and J. M. Greeson. 2004. Development, factor structure, and initial validation of the Cognitive and Affective Mindfulness Scale. Unpublished manuscript.
Förster, J., R. S. Friedman, A. Özelsel, and M. Denzler. 2006. "Enactment of approach and avoidance behavior influences the scope of perceptual and conceptual attention." *Journal of Experimental Social Psychology* 42:133–46.
Förster, J., and E. T. Higgins. 2005. "How global versus local perception fits regulatory focus." *Psychological Science* 16:631–36.
Fredrickson, B. L. 2004. "The broaden and build theory of positive emotion." *Philosophical Transactions: Biological Sciences (The Royal Society of London)* 359:1367–77.
Freud, Sigmund. 1959. "Instincts and their vicissitudes." In *Collected Papers of Sigmund Freud*, ed. E. Jones, 317–85. New York: Basic Books.
Gaillard, R., S. Dehaene, C. Adam, S. Clémenceau, D. Hasboun, et al. 2009. "Converging intracranial markers of conscious access." *PLoS [Public Library of Science] Biology* 7:e1000061.
Gallagher, Shaun. 2000. "Philosophical conceptions of the self: Implications for cognitive science." *Trends in Cognitive Sciences* 4:14–21.
Gazzaniga, Michael S. 1985. *The Social Brain*. New York: Basic Books.
Goldberg, I. I., M. Harel, and R. Malach. 2006. "When the brain loses its self: Prefrontal inactivation during sensorimotor processing." *Neuron* 50:329–39.
Goldstein, J. 2002. *One Dharma: The Emerging Western Buddhism*. San Francisco: Harper Collins.
Hayes, S. C., and K. G. Wilson. 2003. "Mindfulness as a method and process." *Clinical Psychology: Science and Practice* 10:161–65.
Hayes, S. C., K. Strosahl, and K. G. Wilson. 1999. *Acceptance and Commitment Therapy: An Experiential Approach to Behavior Change*. New York: Guilford.
James, William. 1890. *The Principles of Psychology*. Vol. I. New York: Dover.
Kabat-Zinn, J. 1982. "An outpatient program in behavioral medicine for chronic pain patients based on the practice of mindfulness meditation: Theoretical considerations and preliminary results." *General Psychiatry* 4:33–47.

———. 1990. *Full Catastrophe Living: Using the Wisdom of Your Mind and Body to Face Stress, Pain, and Illness*. New York: Delacorte.

———. 2000. "Indra's network: The mainstreaming of Dharma practice in society." In *The Psychology of Awakening: Buddhism, Science, and Our Day-to-Day Lives*, ed. G. Watson and S. Batchelor, 225–49. North Beach, Maine: Weiser.

———. 2003. "Mindfulness-based interventions in context: Past, present, and future." *Clinical Psychology: Science and Practice* 10:144–56.

Kant, Immanuel. [1781] 1996. *Critique of Pure Reason* [Kritik der reinen Vernunft]. Trans. W. S. Pluhar. Indianapolis: Hackett.

Lamme, V. 2003. "Why attention and awareness are different." *Trends in Cognitive Sciences* 7:12–18.

Lati Rinbochay. 1981. *Mind in Tibetan Buddhism*. Trans. and ed. Elizabeth Napper. Valois: Gabriel/Snow Lion.

Lutz, A., L. Greischar, N. B. Rawlings, M. Ricard, and R. J. Davidson. 2004. "Long-term meditators self-induce high-amplitude synchrony during mental practice." *Proceedings of the National Academy of Sciences, U.S.A.* 101:16369–73.

Lutz, A., H. A. Slagter, J. D. Dunne, and R. J. Davidson. 2008. "Attention regulation and monitoring in meditation." *Trends in Cognitive Sciences* 12:163–69.

Mack, A., and I. Rock. 1998. *Inattentional Blindness*. Cambridge: MIT Press.

Maia, T. V., and A. Cleeremans. 2005. "Consciousness: Converging insights from connectionist modeling and neuroscience." *Trends in Cognitive Sciences* 9:397–404.

Marlatt, G. A., and J. R. Gordon. 1985. *Relapse Prevention: Maintenance Strategies in the Treatment of Addictive Behaviors*. New York: Guilford.

Mead, G. H. 1934. *Mind, Self, and Society*. Chicago: Univ. of Chicago Press.

Milner, A. D., and M. A. Goodale. 2008. "Two visual systems re-viewed." *Neuropsychologia* 46:774–85.

Piaget, J. 1954. *The Construction of Reality in the Child*. New York: Basic Books.

Poeppel, E. 1997. "A hierarchical model of temporal perception." *Trends in Cognitive Sciences* 1:56–61.

Posner, M. I. 1980. "Orienting of attention." *Quarterly Journal of Experimental Psychology* 32:3–25.

———. 1994. "Attention: The mechanisms of consciousness." *Proceedings of the National Academy of Sciences* 91:7398–7403.

Posner, M. I., and J. Fan. 2004. "Attention as an Organ System." In *Topics in Integrative Neuroscience: From Cells to Cognition*, ed. James R. Pomerantz and Michael C. Crair, 31–61. Cambridge: Cambridge Univ. Press.

Posner, M. I., and S. E. Petersen. 1990. "The attention system of the human brain." *Annual Review of Neuroscience* 13:25–42.

Raffone, Antonino, and Narayanan Srinivasan. 2009. "An adaptive workspace model of metacognitive consciousness: Insights from neuroscience of consciousness and meditation studies." In *Progress in Brain Research: Attention*, Vol. 176, ed. N. Srinivasan, 161–80. Amsterdam: Elsevier.

Rensink, R. A. 2002. "Change Detection." *Annual Review of Psychology* 53:245–77.

———. 2004. "Visual sensing without seeing." *Psychological Science* 15:27–32.

Rensink, R. A., J. K. O'Regan, and J. J. Clark. 1997. "To see or not to see: The need for attention to perceive changes in scenes." *Psychological Science* 8:368–73.

Rumelhart, D. E., et al. 1986. "Schemata and sequential thought processes in PDP models." In *Parallel Distributed Processing: Explorations in the Microstructure of Cognition,* Vol. 2, ed. J. L. McClelland et al., 7–57, Cambridge: MIT Press.

Segal, Z. V., J. M. G. Williams, and J. D. Teasdale. 2002. *Mindfulness Based Cognitive Therapy for Depression: A New Approach to Preventing Relapse*. New York: Guilford.

Shantideva. 1971. *Siksa-samuccaya: A Compendium of Buddhist Doctrine*. Trans. from Sanskrit by C. Bendall and W. H. D. Rouse. Delhi: Motilal Banarsidass.

Siegel, D. J. 2007. *The Mindful Brain*. New York: Norton.

Simons, D. J., and C. F. Chabris. 1999. "Gorillas in our midst: Sustained inattentional blindness for dynamic events." *Perception* 28:1059–74.

Slagter, Heleen A., et al. 2007. "Mental training affects distribution of limited brain resources." *PLoS [Public Library of Science] Biology* 5, e138.

Sperling, George. 1960. "The information available in brief visual presentations." *Psychological Monographs: General and Applied* 74 (11): 1–30.
Srinivasan, Narayanan, and S. Baijal. 2007. "Concentrative meditation enhances pre-attentive processing: A mismatch negativity study." *Neuroreport* 18:1709–12.
Srinivasan, Narayanan, and R. Gupta. 2010. "Emotion-attention interactions in recognition memory for distractor faces." *Emotion* 10:207–15.
Srinivasan, Narayanan, and A. Hanif. In press. "Global-happy and local-sad: Perceptual processing affects emotion identification." *Cognition & Emotion*.
Srinivasan, Narayanan, P. Srivastava, M. Lohani, and S. Baijal. 2009. "Focused and Distributed Attention." In *Progress in Brain Research: Attention*, Vol 176, ed. N. Srinivasan, 87–100. Amsterdam: Elsevier.
Sumedho, Ajahn. 2004. *Intuitive Awareness*. Hemel Hempstead, U.K.: Amaravati Buddhist Monastery.
Tang, Y. Y., et al. 2007. "Short-term meditation training improves attention and self-regulation." *Proceedings of the National Academy of Sciences, U.S.A.*, 104:17152–56.
Theeuwes, J., A. F. Kramer, and A. V. Belopolsky. 2004. "Attentional set interacts with perceptual load in visual search." *Psychonomic Bulletin & Review* 11:697–702.
Tononi, G., and G. M. Edelman. 1998. "Consciousness and complexity." *Science* 282:1846–51.
Travis, F., and C. Pearson. 1999. "Pure consciousness: Distinct phenomenological and physiological correlates of 'consciousness itself.'" *International Journal of Neuroscience* 100:77–89.
Travis, F., and R. K. Wallace. 2000. "Autonomic and EEG patterns during eyes-closed rest and transcendental meditation (TM) practice: The basis for a neural model of TM practice." *Consciousness and Cognition* 8:302–18.
Treisman, Anne. 2006. "How deployment of attention determines what we see." *Visual Cognition* 14:411–43.
Treisman, A., and G. Gelade. 1980. "A feature-integration theory of attention." *Cognitive Psychology* 12:97–136.
Valentine, E. R., and P. L. G. Sweet. 1999. "Meditation and attention: A comparison of the effects of concentrative and mindfulness meditation on sustained attention." *Mental Health, Religion & Culture* 2:59–70.
VanRullen, R., and C. Koch. 2003. "Is perception discrete or continuous?" *Trends in Cognitive Sciences* 7:207–13.
Vasubandhu. 1991. *Abhidharma Kosabhasyam*. French trans. Louis de La Vallée Poussin; English trans. Leo M. Pruden. Berkeley, Calif.: Asian Humanities Press.
Von Rospatt, A. 1995. *The Buddhist Doctrine of Momentariness: A Survey of the Origins and Early Phase of This Doctrine up to Vasubandhu*. Stuttgart: Franz Steiner.
Wallace, Alan. 1999. "The Buddhist tradition of Samatha: Methods for refining and examining consciousness." *Journal of Consciousness Studies* 6:175–87.
Weissman, D. H., et al. 2006. "The neural bases of momentary lapses in attention." *Nature Neuroscience* 9:971–78.
Williams, M., J. Teasdale, Z. Segal, and J. Kabat-Zinn. 2007. *The Mindful Way through Depression*. New York: Guilford.
Wojciulik, E., N. Kanwisher, and J. Driver. 1998. "Covert visual attention modulates face-specific activity in the human fusiform gyrus: fMRI study." *Journal of Neurophysiology* 79:1574–78.
Zeki, Semir. 2003. "The disunity of consciousness." *Trends in Cognitive Sciences* 7:214–21.