



## Disentangling the neural mechanisms involved in Hinduism- and Buddhism-related meditations



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### ABSTRACT

The most diffuse forms of meditation derive from Hinduism and Buddhism spiritual traditions. Different cognitive processes are set in place to reach these meditation states. According to an historical-philological hypothesis (Wynne, 2009) the two forms of meditation could be disentangled. While mindfulness is the focus of Buddhist meditation reached by focusing sustained attention on the body, on breathing and on the content of the thoughts, reaching an ineffable state of nothingness accompanied by a loss of sense of self and duality (*Samadhi*) is the main focus of Hinduism-inspired meditation. It is possible that these different practices activate separate brain networks. We tested this hypothesis by conducting an activation likelihood estimation (ALE) meta-analysis of functional magnetic resonance imaging (fMRI) studies. The network related to Buddhism-inspired meditation (16 experiments, 263 subjects, and 96 activation foci) included activations in some frontal lobe structures associated with executive attention, possibly confirming the fundamental role of mindfulness shared by many Buddhist meditations. By contrast, the network related to Hinduism-inspired meditation (8 experiments, 54 activation foci and 66 subjects) triggered a left lateralized network of areas including the postcentral gyrus, the superior parietal lobe, the hippocampus and the right middle cingulate cortex. The dissociation between anterior and posterior networks support the notion that different meditation styles and traditions are characterized by different patterns of neural activation.

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### 1. Introduction

The most diffuse forms of meditation draw inspiration from religious traditions, in particular Hinduism and Buddhism, both originated in India several centuries BC. One of the most ancient texts dealing with meditation is the *Yoga sutra*. *Yoga-Sutra* is a collection of 196 brief phrases attributed to Indian physician and mystic Patañjali (II BC) which provides a description of the main meditation practices developed within ancient Hinduism. *Yoga* summarizes all the techniques of asceticism and meditation developed in ancient Hinduism (Klostermaier, 1998). According to Patañjali, *Yoga* enables the “suppression of the fluctuations and modifications of the mind” (*Yoga-sutra* 1,2) (Taimni, 1961). Such a goal can be reached through: (i) voluntary inhibition of sensory

activities (*pratyahara*), preceded by specific muscular postures (*asana*) and breathing regulation (*pranayama*); (ii) focusing on a particular object (e.g., the navel or the heart), with the aim of suppressing mind wandering (*dharana*) and (iii) switching from concentration on a single object of consciousness to complete absorption in meditation (*dhyana*), a condition leading to an ineffable state of nothingness accompanied by a loss of sense of self and duality (*samadhi*) (Feuerstein, 1996; Nash & Newberg, 2013). The Sanskrit term *samadhi*, literally meaning “putting together”, has been translated in European languages as an empty state of pure consciousness with no phenomenological content (Mishra, 1959; Nash & Newberg, 2013). *Samadhi* has been then translated as *enstasis*, a Greek term reflecting the emptying of consciousness, in which imagination and illusion are definitely suppressed (Eliade, 1969). According to Eliade, the meaning of *samadhi* has to be differentiated from hypnotic trance (Eliade, 1969), a condition reflecting the blocking of the mental flow, which is well known in the ancient Indian world, which could well be compared with the deeper stages of sleep (Cahn & Polich, 2006; Varela, 1997). Recently this concept

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has been classified as an enhanced non-cognitive/non-affective state (NC/NA) ((Nash & Newberg, 2013), see pages 7–8).

Several neuro-imaging studies have investigated the neural correlates of different forms of meditation that are usually referred to as *Hinduism meditations*. Relaxation meditation (Yoga Nidra) activated the hippocampus and posterior areas related, as argued by the authors, to mental imagery, and deactivated structures supporting the executive control network system (i.e., dorso-lateral prefrontal cortex (PFC), anterior cingulate gyri, striatal and thalamic regions) (Lou et al., 1999). The passive observation of breathing and mental repetition of a mantra activated the putamen, midbrain, anterior cingulate cortex (ACC) and hippocampal/parahippocampal formation (Lazar et al., 2000). Chanting meditation, a form of meditation deriving from Kundalini yoga, activated language areas (i.e., left fronto-temporal region) and deactivated the left posterior parietal lobe (a region known to control spatial orientation), the left medial occipital lobe and the right inferior temporal gyrus (Khalsa, Amen, Hanks, Money, & Newberg, 2009). Silent mantra meditation activated the hippocampi/parahippocampal area, the middle cingulate cortex (MCC) and the precentral cortex bilaterally (related to awareness of bodily sensations and involvement in body positions and execution) (Engstrom, Pihlgard, Lundberg, & Soderfeldt, 2010) and, in another study, the inferior frontal gyrus, which seems to reflect a relaxed mode of mental activity (Davanger, Ellingsen, Holen, & Hugdahl, 2010). “OM” chanting meditation deactivated the limbic system (Kalyani et al., 2011). Finally, *Kirtan Kriya*, a traditional kundalini yoga practice introduced in the West by Yogi Bhayan in the late 1960s (Nash & Newberg, 2013) activated the medial PFC and left caudate nuclei and deactivated the left superior occipital and inferior parietal cortex, as well as the right inferior occipital cortex (Wang et al., 2011). *Shabad Kriya*, which is thought to provoke higher absorption, deactivated the medial PFC and the ACC (associated with attention regulation and stress response), as well as the parietal areas (associated with spatial processing and feelings of connectedness) (Wang et al., 2011). In sum, given these discrepancies between studies, it would be useful to investigate whether Hinduism-inspired meditation techniques share some common activations.

In *Buddhism*, too, a spiritual tradition derived from the teaching of Siddhārtha Gotama, the Buddha (about 485–405 BC), meditation is considered as a fundamental practice aimed at reaching liberation (Gombrich, 1995; Gombrich, 2009). According to the tradition, prince Siddhārtha was a *ksytria* (warrior) before starting his personal spiritual path that finally led him to “enlightenment”. He relinquished his life, became a *yogin*, was introduced to early Hinduism meditation techniques by two spiritual teachers, Alara Kalama and Udakka Ramaputta, and finally he himself became one of the most important spiritual teachers (Robinson & Johnson, 1997). It is thought that Siddhārtha learnt from his two teachers Hinduism meditation techniques aimed at reaching *Samadhi* (see above). However, according to the Buddha, *Samadhi* was a necessary but not a sufficient mental condition to reach the ultimate liberation (*nibbana*) from the illusion of the unchanging self, which, in his vision, could be described as an ever-changing flow of psychophysical phenomena void of any impermanent soul ((Gombrich, 2011), see pages 8–11).

Based on his experience, Buddha argued that the seeker of liberation had to reach the meditation state of *samadhi* in a mindfulness condition: “Observing nothingness, being mindful [of it]” (*Upasivamanavapucca*, 1070). It is held that “The Buddha taught that meditation must be accompanied by a careful attention to the basis of one’s experience – the sensations caused by internal and external objects – and eventually an insight into the nature of this meditative experience” ((Wynne, 2009), p. 109). Thus, the different forms of Buddhist meditation always involve to some extent both calming meditation practices (*samatha*) and mindfulness meditation

practices (insight meditation or *Vipassana*) (Flickstein, 2007; Lutz, Slagter, Dunne, & Davidson, 2008). All these different meditation forms can be defined as dynamic processes (different meditation states have indeed been described, see e.g., (Nash & Newberg, 2013; Tang, Rothbart, & Posner, 2012b). A unifying taxonomy for meditation proposed a distinction between three meditation methods based on: (1) the affective domain; (2) the cognitive domain; (3) the null domain (Nash & Newberg, 2013). According to this classification Buddhist meditation which tries to train mindfulness (*sammasati*) belongs to the second group, i.e., the cognitive domain, whereas, the meditation forms having as their main focus the “*samadhi*” use methods classified as “null domain”. In addition, in several Buddhist traditions, a third form of meditation, often referred to as “non-referential compassion”, is frequently cultivated (Lutz, Dunne, & Davidson, 2007). Although this form of meditation is somewhat different from mindfulness, as it is aimed at cultivating an intense state of loving-kindness to all the sentient beings, it also shares strong resemblances with this meditation practice. Indeed, this feeling of loving-kindness is associated to a state of mindfulness. Accordingly, loving-kindness meditation is considered by many authors and Buddhist masters as a variance of mindfulness meditation (Gunaratana, 1991; Kornfield, 2008; Lutz et al., 2007).

Several neuro-imaging studies addressed the neural correlates of Buddhist meditations and of meditations implicitly or explicitly derived from the Buddhist tradition. In long-term Buddhist practitioners, meditation associated with sustained attention activated the fronto-parietal attention network and deactivated regions related to conceptual thought and emotions compared to novices (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007). Loving-kindness/compassion meditation in expert meditators activated limbic areas and a network associated with processing mental states of other individuals (temporal lobes, temporo-parietal junction, medial PFC and posterior cingulate cortex), mainly in the right hemisphere; the most intense levels of compassion meditation activated the dorsal ACC, the somatosensory cortices and the right inferior parietal lobule in the medial-posterior part of the left insula (Lutz, Greischar, Perlman, & Davidson, 2009). Present moment awareness (experiential focus) deactivated mPFC areas and activated a right lateralized network involving the lateral PFC, the secondary somatosensory cortex, the inferior parietal lobule and viscerosomatic areas such as the insula in a group of novice meditators who had been trained in a mindfulness-based stress reduction (MBSR) program, a secular 8-weeks meditation program largely inspired by Buddhist practices (Kabat-Zinn, 1990) (as compared with controls) (Farb et al., 2007). Also, bilateral activation in the rostral anterior cingulate cortex and in the dorsal medial prefrontal cortex was observed in a group of Vipassana expert meditators as compared to novices (Holzel et al., 2007). Furthermore, mindfulness of breathing during word listening deactivated the default mode network in a group of Zen meditators as compared to novices (Pagnoni, Cekic, & Guo, 2008). The default mode network is a group of brain regions that are active when the brain is not engaged in task-induced activity and have been associated with self-referential processes (Buckner & Vincent, 2007). Moreover, the onset of breath-focused meditation increased the BOLD signal in the left and right putamen and the supplementary motor area, and decreased activation in the parieto-temporal cortex, posterior cingulate cortex and the right precuneus. Sustained meditation activated the head of the caudate nucleus bilaterally (Barentsen et al., 2010). Mindfulness meditation was also found to trigger a decrease in cortical midline structures associated with interoception (bilateral anterior insula, right medial prefrontal cortex and bilateral precuneus) and a significant increase in the right posterior cingulate cortex (Ives-Deliperi, Solms, & Meintjes, 2011). Some authors (Manna et al., 2010) studied a group of Theravada Buddhist monks who were experts in both *Samatha* and *Vipassana* meditations. *Samatha* triggered a wide

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