

# We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

5,600

Open access books available

138,000

International authors and editors

170M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index  
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?  
Contact [book.department@intechopen.com](mailto:book.department@intechopen.com)

Numbers displayed above are based on latest data collected.  
For more information visit [www.intechopen.com](http://www.intechopen.com)



# Inner Navigation and Theta Activity: From Movement to Cognition and Hypnosis According to the Sphere Model of Consciousness

*Patrizio Paoletti, Tal Dotan Ben-Soussan and Joseph Glicksohn*

## Abstract

EEG theta (4–7 Hz) activity is closely related to hypnosis and hypnotic analgesia, as well as to meditation and absorption. Research further indicates that theta oscillatory power is involved in different cognitive functions, such as spatial navigation, memory, creativity, and divided attention. The current manuscript will provide a synthesis of current knowledge regarding the importance of theta's different roles in relation to hypnosis and their connections to movement. Indeed, several movement paradigms, such as Quadrato Motor Training, have been found to modulate theta activity, significantly improving cognition and emotional well-being. The utility of such movement paradigms as a therapeutic vehicle closely related to hypnosis, and the underlying characteristics allowing these neuromodulations, will be discussed. Finally, the relationships between diagonal movement and other psychological phenomena, especially intentionality, attention, and the Sphere Model of Consciousness, will be highlighted.

**Keywords:** hypnosis, meditation, movement, theta, EEG, Sphere Model of Consciousness

## 1. Introduction

Considering the many positive effects of hypnosis, such as relief from chronic pain [1, 2], the ability to enhance hypnotizability has considerable clinical utility. Hypnosis can be defined as an altered state of attention, receptivity, and concentration during which the hypnotized person is immersed in a suggestion [3–5]. Hypnosis can modulate perceptual, motor, emotional, and cognitive processes by producing changes in subjective experience and in behavior, such as greater relaxation, changes in perception of the body and/or of the environment, and increased imagination [6–8]. While neurophysiological data may not completely resolve the debate around hypnosis as an altered state of consciousness (ASC) [9, 10], they do offer interesting clues regarding the role that intentionality and specific types of attention may play in hypnosis. Furthermore, the debate about hypnosis as an ASC could benefit from a reframing in light of current theories of consciousness, particularly the Sphere Model of Consciousness (SMC).

The Sphere Model of Consciousness developed by Paoletti [11–15] suggests that every experience of consciousness can be phenomenologically described as a movement within a spherical matrix. As will be illustrated in Section 4, the model provides that intentionality could be a means through which one can move from Narrative to Minimal Self and this, in turn, could allow deeper hypnotizability as well as other phenomena related to hypnosis, such as a reinterpretation of the nociceptive input underlying pain [16].

### **1.1 Movement and hypnosis**

While different theories of hypnosis share the assumption that a hypnotic response is automatic and feels like it is happening by itself [17, 18], they do not necessarily agree on the level of intentionality and cognitive control processes that are involved. For instance, the response expectancy theory claims that expecting a behavior to happen can elicit that particular behavior; therefore, suggestions can be implemented without the involvement of intentional executive systems [19, 20]. However, expectations cannot fully account for the variance in hypnotic responding [21, 22], which is indicative of trait differences in both hypnotizability [23] and in hypnotic depth [24].

In parallel to intentionality and volition, there is a close connection between hypnosis and movement. Hypnosis may help patients to better achieve tasks of motor imagination and alter activity in the motor cortex [5]. In addition, while some argue that eye movement desensitization and reprocessing (EMDR) and hypnosis are qualitatively different, the two are often used in conjunction in therapy [25–27].

But what is the exact nature of the relationship between movement and hypnosis, and what are the possible mediating electrophysiological mechanisms between inner and outer movements and hypnosis? These are the main questions that will be addressed in this chapter. Specifically, we will discuss the possible underlying neuronal mechanisms mediating both movement and hypnosis, with a specific focus on theta activity. What we term “inner movements” and their relation to theta activity will be discussed in Section 2, focusing on hypnosis, meditation, and perceptual deprivation. This will be followed by external movement practices and their relation to such “inner movement.” Consequently, we will embed our discussion within the framework of the Sphere Model of Consciousness [15] giving special attention to the Minimal Self and Narrative Self (for review see [28]). Briefly, the Minimal Self has a short temporal extension and is endowed with a sense of action, property, and first person nonconceptual content, while the Narrative Self involves personal identity and continuity through time and includes conceptual content. The SMC specifies the addition of a third state, called Overcoming of the Self, in which all sense of self disappears. Overcoming of the Self, which is parallel to consciousness without contents, has only recently been the subject of neuroscientific studies [29, 30]. It can further be compared with self-transcendence, absorption, and nondual states [31, 32].

### **1.2 Electrophysiological measures and hypnosis**

Neural oscillations are divided into different frequency bands: both theta (4–7 Hz) and alpha (8–12 Hz) bands are associated with working memory and attention, while the gamma band (30–70 Hz) is associated with functions that include long-term memory storage and retrieval, as well as perceptual processing [33–35]. An increase in theta activity, quantified as spectral power, both frontally and globally, is a hallmark of hypnotic states [36], trance [37], meditative states [38–40], states of absorption [40], and of hypnotizability ([41]; but see [42] for an opposing view). Importantly, frontal theta activity correlates negatively with

default mode network (DMN) activity [43], which is typically active during task-free resting states and is thought to represent neural processing related to mind-wandering [44, 45]. Keeping in mind that the DMN activity is automatic and is thus considered nonvoluntary, it is not surprising that electrophysiological studies based on predictive coding models<sup>1</sup> have focused mostly on theta activity [49, 50].

In addition, while hypnosis and hypnotizability are thought to be mediated electrophysiologically by theta activity and behaviorally by relaxation [51, 52], it is still under debate whether all hypnosis is actually autohypnosis (see for a review [53]), since motivation seems to play a central role in the process. For example, being motivated to participate in a hypnotic session and having a positive attitude about it correlates with the success of the hypnotic response and the effectiveness of the hypnotic experience [54]. This suggests that the levels of intentionality and attention could be related to the levels of hypnosis and participant susceptibility. Seemingly paradoxical, there may be a voluntary “letting go” that occurs in the hypnotic process [13, 55] related to *Overcoming of the Self*, which will be discussed further in Section 4.

At the electrophysiological level, it has been suggested that slow wave oscillations facilitate responses to suggestion, which in turn may help to explain the known variability in hypnotic responding between individuals [56]. This has been supported by findings of significantly higher levels of baseline theta activity in highly hypnotizable participants relative to those scoring “low” on hypnotizability [36, 57–61] and a tendency for hypnotic inductions to result in increases in theta activity, especially among highs [36, 62, 63].

Notably, an increase in both theta activity and alpha activity was reported among proficient meditators during meditation ([39], p. 191; [64]) and at rest ([39], p. 190), but not among those assessed for hypnotizability ([65]; note, however, that in their review, these authors only discuss the lack of a systematic relationship with alpha activity). However, the authors clarify that this increase in theta activity among proficient meditators was “the frontal midline theta generated by the anterior cingulate, dorsal, and medial prefrontal cortices” and not the “theta typically seen at the transition from Stage I to Stage II sleep...[which] originates from more widespread source” ([39], p. 202). Thus, some evidence suggests that the notion that a meditative state is essentially a hypnagogic state (the transitional state between wakefulness and sleep) or even sleep itself [66] should be replaced by the notion that a meditative state can be an intentionally prolonged hypnagogic state ([67], pp. 99–100; [68], p. 403; [69], p. 158); this, itself, would be considered to be a trance state [70]. Furthermore, as Holroyd ([71], p. 115) suggests, “a distinction is drawn between low range theta (4–6 Hz) which is associated with reverie and high range theta (5–7 Hz) which, in the frontal cortex area, is associated with loss of executive control.” Mitchell, McNaughton, Flanagan, and Kirk ([72], p. 179) also suggest, “The meditation data make it possible that FM [frontal-midline]-theta is a sign that attentional resources are more internally than externally focused.” Turning to change in gamma activity in the low range (25–45 Hz) in these states, there is a

---

<sup>1</sup> Predictive coding suggests that the brain generates hypotheses about the possible causes of forthcoming sensory events and that these hypotheses are compared with incoming sensory information and enables the motor system to “select appropriate responses” before an anticipated event is realized [46]. Similarly, predictive timing can be defined as the “process by which uncertainty about ‘when’ events are likely to occur is minimized in order to facilitate their processing and detection” [47]. At the neurophysiological level, anticipating sensory events resets the phase of delta and theta activity before the stimulus occurs [47]. Llewellyn [48] argues that REM dreaming has an elaborative role for encoding during sleep, suggesting that REM dreaming constitutes prospective coding because elaborative encoding enables inferences which, in turn, generate predictions.

decrease in frontal power [73] and an increase in posterior power [38, 73] and/or a decrease in central power [40].<sup>2</sup>

It is noteworthy, then, that an increase in theta activity during hypnotic induction has been found in various studies ([36, 56, 62, 63]; for review, see [78]. From [79]). Frontal theta has been found to increase with working memory load, indicating a role of theta oscillations in working memory maintenance (for review, see [43]). Theta activity increases with increasing task demands and is related to orienting, attention, memory, and affective processing mechanisms [35, 80]. Theta activity is highest at frontal midline electrodes in the resting state, indicating that the frontal theta rhythm is also detectable during rest conditions [81].

While hypnosis has been most closely linked to power in the theta band, reports suggesting changes also in gamma activity have been considered [56]. Jensen et al. [56] proposed a link between theta oscillations and hypnosis, whereby theta oscillations facilitate hypnotic responding. They further speculated that theta-gamma phase-locked oscillations may provide a physiological explanation for hypnosis by suggesting the linking of limbic and neocortical circuits [56]. However, gamma activity is known to be at possible risk of contamination from muscular activity [82] or saccade-related spike potentials (SP) due to eye movements [83].

While acknowledging that theta is associated with a large number of cognitive activities and states (including, among others, attention, orienting, decision-making, feelings of drowsiness, and emotional arousal, as noted above), it is important to emphasize that the most commonly identified roles for theta are those concerned with declarative memory coding and retrieval (for a review, see [78]) and navigation, such as maze navigation [84–86]. In parallel to navigation in the external environment, which is electrophysiologically mediated mostly by theta activity [84–86], we will suggest that:

1. Hypnosis and other “internal movement” paradigms may be regarded as mental navigation.
2. Hypnosis can be compared with external movement and navigation in space [82].
3. Internal movement paradigms, such as hypnosis and meditation, are electrophysiologically mediated, among other bands, by theta activity and require greater intentionality and attention [15].

The following section will introduce several “internal movement” techniques related to both hypnosis and meditation, as well as absorption and theta activity.

## **2. Inner movement**

### **2.1 Hypnosis and absorption**

Trait absorption has relevance for the study of imagery, hallucinatory or pseudo-hallucinatory experiences of altered states of consciousness, and

---

<sup>2</sup> It is noteworthy to remember that in many conditions, gamma power is phase-locked to theta activity and that both work in coordination of hippocampal networks during both waking and REM sleep [74, 75]. In addition to gamma, also beta activity is evident during both waking and REM sleep [76]. Gamma activity is further related to sensory perception, problem-solving, and memory and is thought to contribute to “binding” of sensory information (for review see [76]) and problem-solving with insight [77].

elaborate imagination [87–89]. Individuals scoring high on trait absorption will have a markedly different experiential profile compared to those scoring low on trait absorption [89, 90], and these two groups will perform differently on tasks of attentional demand [91, 92]. The overlap between high trait absorption and (1) high hypnotizability [23, 93, 94] and (2) proficiency in meditation [95] may indicate that the correlation between the two is either “significant only when both scales are administered in the same context, thus allowing the subjects to become aware that the experimenter expected to find an association between them” ([96], pp. 849–850; see also [97], but also [98], who do not find such a context effect), or the position we support that “absorbed attention may be an important prerequisite for successful long-term practice of meditation” ([69], p. 188), and that “a deeper state of absorption seems to facilitate the entrance to a deeper ASC” ([99], pp. 126–127).

The trait-state approach to hypnosis [100] suggests that the *trait* of absorption will interact with situational *context* in producing *state* absorption or a hypnotic state of consciousness. Consider what Kihlstrom ([101], p. 366) terms the “canonical design for hypnosis research,” which “involves administering a standard hypnotic induction, or a control procedure, to subjects classified (on the basis of the standardized scales) as low, medium, or high in hypnotizability... Such a design permits assessments of both the correlates of hypnotizability (in the absence of hypnotic induction) and the effects of the induction procedure (independent of hypnotizability). Of particular interest, of course, is the interaction of these factors—i.e., how highly hypnotizable subjects behave following a hypnotic induction, compared to some control condition.” Replace hypnotizability with absorption (the two being modestly correlated), and one can see how those scoring high on absorption behave differently from those scoring low on absorption, in much the same manner. Note further, that “Although there is acceptance that there is a general trait of hypnotic susceptibility, as measured by conventionally used standardized scales... susceptibility is also modifiable... Additionally, hypnosis in susceptibles is not a unitary state ([102], p. 62). Hence, the trait-state approach must consider a dynamic, unfolding, modifiable, interaction.

Furthermore, one can investigate concomitant electrophysiological changes in theta power in this trait-state interaction. For example, Graffin et al. [103] concluded from their study that “that the high-susceptible individuals displayed a decrease in EEG theta activity from the baseline period immediately preceding the hypnotic induction to that immediately following the induction, whereas the low-susceptible individuals showed an increase in EEG theta activity. This is consistent with the view that the high- and low-susceptible individuals are indeed in different cortical states prior to and following the hypnotic induction, that is to say, the induction procedure itself would be assumed to differentially affect high- and low-susceptible individuals.” Kihlstrom ([101], p. 367) has a different take on this. He comments: “Graffin et al. interpreted the changes in theta as indicative of heightened concentration among hypnotizable subjects, but the fact that theta activity decreased in hypnotizable subjects and increased in insusceptible subjects suggests that, following the induction of hypnosis, both groups of subjects were actually in very similar cortical states.” Either way, what is important here is the interaction of trait with condition in producing these shifts in theta activity.

Given that theta activity can be indicative of either the induction of a hypnagogic-like state of consciousness (which, in the present context, is closely affiliated with both meditation and hypnosis), or of highly concentrated attention [104], such shifts in theta power can be indicative of either of these. Schacter ([104], pp. 74–75) warns us that “It is not yet known whether the two “classes” of psychological events related to theta activity are essentially different processes, or whether

they are different aspects of the same process ... This is a critical problem for future research. ...we might question whether it is plausible to accept that theta activity observed during zazen concentration in experienced meditators indexes psychological processes that are similar to those observed in college-age volunteers when concentrating on a mental arithmetic problem.” Thus, even though, as White, et al. ([105], p. 98) have noted, the “correlation between baseline theta and hypnotizability has been described as a robust finding in the literature, proposed to result from attentional differences between high and low susceptibility groups,” without a close analysis of how such theta activity is related to the actual performance of those scoring low or high on absorption, we will remain with the problem underlined by Schacter [104]. What is promising is that “findings showing differences between highs and lows in both the *patterns* of associations between EEG-assessed bandwidth activity and subjects’ phenomenological experience of hypnosis ... and in the brain *areas* (source locations) associated with theta and beta activity...” ([56], p. 44).

Speaking of beta, it was further found that the hypnotic depth and increased imagery and exceptionality of the hypnotic experience in highly suggestible individuals were related to fast frequencies, including beta and gamma, while the lows exhibited negative correlations between imagery on the one hand and theta and beta on the other [106].

In this context, it should also be kept in mind that beta oscillatory activity is likely to have a functional role in response selection, resembling attentional modulation of alpha activity [107]. Beta modulation was found also following “animal hypnosis,” also known as “tonic immobility” or “immobility reflex”.

The modulation depended on type of induction and session number [108, 109], supporting previous evidence that beta power has also been implicated in broader cognitive processes [107] in addition to movement and response inhibition [107].

## 2.2 Meditation

Meditators have been found to score higher on trait absorption than controls [95, 110]. In addition, increased theta and alpha power, reflecting activity of multifunctional neuronal networks and differentially associated with orienting, attention, memory, affective, and cognitive processing, is evident in meditators [80]. Altered theta and alpha activity has consistently been reported following meditation [111]. In fact, numerous studies conducted with Western meditators, usually having less than 10 years’ experience, have reported increased power and coherence in the alpha and theta frequency bands during meditation practice [39, 111, 112]. Increased gamma power has also been reported in studies with advanced meditative practitioners [38, 73, 113, 114].

Consistent with previous meditation research (for review see [115]), also Berman and Stevens [116] found increased delta (0–4 Hz), theta, and alpha activity during meditation. When differentiating between general meditation and nondual states (in which the participant transcends the separation between self and other), the opposite trend was observed for gamma, which was higher during the meditation sessions in entirety compared to the nondual state [116]. Similarly, Berkovich-Ohana et al. [73], who examined three levels of mindfulness expertise and controls, found that mindfulness practitioners generally exhibited reduced resting-state frontal low gamma power as compared to controls, as well as decreased resting-state gamma functional connectivity representing DMN deactivation in the long-term practitioners, suggesting a trait/long-lasting effect of reduced mind-wandering and self-related processing [73, 117]. In addition, creativity, as measured by ideational fluency and flexibility, which were higher in the long-term practitioners than

short-term practitioners and control participants, was negatively correlated with gamma interhemispheric functional connectivity [118]. Thus, one should keep in mind that different mediation techniques can produce different electrophysiological results, depending among others on the depth of the experience and the experimental design [116].

### 2.3 OVO Whole-Body Perceptual Deprivation (OVO-WBPD)

As we will see in the current section, studies examining perceptual movement, where movement is absent and stillness is the main feature, were also found to be related mostly on delta waves. While delta has historically been associated with sleep and pathological processes, it has recently been found to be related to both autonomic and metabolic processes, suggesting that it is involved in integration of cerebral activity with homeostatic processes, as well as in motivation and reward, as delta also increases during hunger, sexual arousal, and sustained pain [119]. Delta activity is further related to attention, salience detection, and subliminal perception, consistent with meditative states and absorption [116, 119, 120], such as in the case of Yoga Nidra [121]<sup>3</sup>.

In-line with previous research linking delta waves in meditative states [125], a recent study examined the effects of the OVO Whole-Body Perceptual Deprivation (OVO-WBPD) chamber effects on absorption in experienced meditators. The OVO, an altered sensory environment, is in the form of a human-sized egg (“uovo” means egg in Italian), within which the subject cannot easily perceive spatial coordinates. Based on the Sphere Model of Consciousness, the OVO-WBPD was specifically built with the aim of facilitating an immersive experience and an increased state of *presence* [11]. Ben-Soussan et al. [120], who studied participants who were instructed to “rest as best as they can” in the OVO chamber, found an increased state of absorption, which was accompanied by enhanced delta and lower theta activity, as well as beta (13–20 Hz) activity, peaking in the insula. These results may suggest an enhanced effort to sensory-integrate interoceptive signals.

In addition to the insula [120], theta was further linked to another main area of the salience network, namely, the anterior cingulate [126–131]. While DMN activity is negatively correlated with both hypnosis and theta activity [129–131], the salience network is thought to support the detection of subjectively important events and the mobilization of attentional and working memory resources in the service of goal-directed behavior [132–134].

<sup>3</sup> Yoga Nidra is defined as a “state in which an individual demonstrates all the symptoms of deep, non-REM sleep, including delta brain waves, while simultaneously remaining fully conscious [121]. In addition, it is important to note that while meditation spindles have similar amplitudes to those in sleep, all other parameters are significantly different, with more-experienced subjects displaying high-voltage slow waves reminiscent, but significantly different, to the slow waves of deeper stages of non-REM sleep [122]. In addition, they also differ from slow delta activity in anesthesia which is notably less rhythmic and coherent [122]. Most importantly, the main regions of interest are notably different to those in sleep [122, 123]. More specifically, the significant presence of limbic sources in meditation support the hypothesis of the effects of meditation on memory and spatial and temporal orientation, and consequently to the ventral and dorsal streams of attention and feeling- and salience-based, respectively [122]. The electrophysiological change induced by these type of training, together with the ability to remain consciously aware while producing delta waves, is believed to be associated with attaining a highly stabilized state of higher consciousness [121, 124] and the integration of transcendental experiences in both waking, dreaming, and sleeping [125].

As in the case of perceptual deprivation, different meditative states have also been found to be related to decreased DMN activity [73, 135–137]. Similarly, hypnosis was found to be related to decreased DMN activity [138] and suspending habitual modes of attention and achieving refined states of meta-awareness [139]. In fact, hypnotic induction increased subjective ratings of attentional absorption and decreased ratings of mind-wandering. Moreover, these changes were associated with decreased DMN activity and increased activity in prefrontal attention networks [138].

### 3. External movement

As indicated above, according to Jensen et al. [78], hypnosis can be viewed as a use of suggestions for creating changes in thoughts, feelings, or behaviors when the clinician views the client as having enough theta power to be able to respond to those suggestions. Jensen indicates that “hypnotic strategies, then, could include (1) *any* strategy that enhances slow oscillations (using traditional hypnotic inductions, but also any technique that has been or is ultimately shown to increase slow oscillations) and/or being aware of behavioral signs indicating an increase in or adequate level of theta, coupled with (2) suggestions that enhance existing connections among neuron assemblies (e.g., those consistent with the subject experiencing of himself or herself with useful images or having a positive view of the future) or that create new ones” ([78], p. 15). It is, therefore, relevant to note that there is an increase in theta activity and a corresponding increase in either alpha activity or a global increase in spectral power (including within the alpha and theta bands) during exercise [140, 141]. Fascinatingly, there is even evidence of a higher degree of both alpha and theta activity during eyes-closed restful wakefulness in proficient athletes [142].

These converging lines of thought together with Dietrich [143, 144] support the connection between hypnosis, meditation, and acute exercise, which all result in prefrontal hypoactivation. Consequently, we now address the presence of increased theta activity following specifically structured bodily movement, focusing on several specific examples involving different degrees of diagonal movement.

#### 3.1 Diagonal movement

It has been suggested that rhythmical bilateral diagonal body movement improves motor and cognitive functions [145, 146], such as creativity and cognitive flexibility, similar to findings for hypnosis/mediation. However, no study that we are aware of has actually examined electrophysiological changes during diagonal body movements. The diagonal axis has the role of a metaphorical rule-breaker in relation to *the way of thinking*, as suggested by the definition of “diagonal thinking” as a mixture of logical (i.e., vertical) and creative (i.e., lateral) thinking [147]. Diagonal movements are widely used in disciplines based on whole-body movements such as tai chi, and recent paradigms such as Quadrato Motor Training, which will be discussed below.

Shapiro [148, 149], in her original description of EMDR, proposed that its directed eye movements mimic the saccades of rapid eye movement sleep (REM), known to be electrophysiologically related to synchronous theta waves [75, 150]. In addition, Stickgold [151, 152] proposed that the repetitive redirecting of attention during EMDR induces a neurobiological state similar to that of REM sleep. Additional study findings have supported the hypothesis that EMDR promotes the

transfer of episodic memory to semantic memory, which will then be consolidated during REM-like (4–6 Hz) states [153]<sup>4,5</sup>.

As mentioned above, activation of frontal areas and especially the anterior cingulate that occurs during hypnosis matches well with the behavioral changes occurring in hypnotic state, such as the intensification of focused attention (for review see [159]). Importantly, the anterior cingulate has known anatomical connections with the frontal eye field and supplementary eye field and thus plays a prominent role in regulating eye movements, such as maintenance of visual fixation and suppression of reflexive saccades [159]. For example, classical behavioral marker of hypnosis, namely, the *hypnotically induced stare*, is a glazed look in the eyes accompanied by a highly reduced eye blinking rate and inimitable changes in the patterns of eye movements and pupil size [159]. Pupil size was recently found to be closely related to a variety of cognitive processes, such as decision-making [160]. In turn positive correlations were only found in the high-gamma band (60–100 Hz) and were similar in both wake and sleep conditions.

Only a few recent studies have examined electrophysiological changes during diagonal movements. A rare pioneering study [161] has found increased frontal theta activity during the initiation of diagonal movement, compared to purely vertical movements, which were also studied. The increased frontal theta was possibly due to greater computational effort [86, 95, 140]. Source localization further showed that the increased frontal theta activity was generated in the middle frontal cortex. In addition, the authors found a biphasic pattern of frontoparietal alpha/beta modulations during vertical movements.

Rimbert et al. [5] reported modulation in sensorimotor beta and theta activity during real movement and motor imagery; Marson et al. [161] also found biphasic modulation of alpha activity related to the second part of vertical movements (*each movement was composed of two parts, a forward and comeback period, the biphasic response in the comeback period during vertical movement*). More specifically, the decreased alpha activity was observed immediately after the start of the comeback period, and, consequently, there was an increase in the same frequency band tied to the end of the movement. The decreased alpha activity observed immediately after the end of the second movement could reflect a decrease in internalized attention, as decreased alpha activity is classically related to decreased focus on internal states and amplified processing of environmental information through sensorial inputs,

<sup>4</sup> More specifically, as Pagani et al. [154] detail, delta activity is related to slow wave sleep, which in turn is related to transferring edited memories from the hippocampus to the neocortex, as well as to stimulating the integration of these into neocortical neuronal networks, while theta activity is related to REM sleep. Bilateral stimulation typical of EMDR causes immediate slowing of the depolarization rate of neurons from the dominant waking state frequency of around 7 Hz to about 1.5 Hz. Interestingly, as Pagani [154] further noted, animal research has demonstrated that low-frequency (5 Hz) stimulation can cause a depotentiation of amygdala AMPA receptors involved in the retention of traumatic memory and 900 stimuli at 1–5 Hz depotentiated synapses mediating memory, suggesting that memories aroused during therapy are reactivated, replayed, and encoded into existing memory networks. Interestingly, delta activity occurs as waves during bilateral stimulation in other frequency waves (such as beta) and is related to eye movements. Lastly, Pagani et al. [154] suggested that the consolidation of emotional memory in the neocortex during an EMDR session, which often results in a sudden symptoms disappearance, is associated with periods in which slow (1.5 Hz) and faster (theta-alpha) activity are elicited by the alternation of bilateral stimulation and improved cognition.

<sup>5</sup> Similarly to EMDR, also binaural beat, which requires bilateral stimulation, by presenting two slightly different wave forms to each ear via stereophonic headphones, thus generating a third “beat” frequency, was found to be related to hypnotic susceptibility and theta activity ([154–156], yet see [42]), suggesting in turn also complex dynamic interactions between the two hemispheres [157]. For example, beat frequencies in theta and alpha range both increased interhemispheric coherence selectively at alpha frequencies [158].

especially the visual system [159, 160]. Similar to Rimbert et al. [5], Marson et al. [161] further found post-movement beta rebound [162] between consecutive trials, namely, increased beta activity both in diagonal and vertical movements.

### **3.2 Quadrato Motor Training (QMT)**

Quadrato Motor Training is a mindful movement practice based on the Sphere Model of Consciousness. Participants are asked to move within a square (*quadrato*, in Italian), according to a specific sequence of instructions. QMT requires a high level of attention divided between the body and the spatial coordinates incorporated in the quadrato space, as well as silent waiting for the next instruction. Previous studies showed that QMT enhances theta activity and improves cognition (for a recent review, see [163, 164]). At the behavioral level, these changes have been associated with improvements in cognitive and psycho-emotional functioning [162, 165–167], considered important aspects of health and well-being.

What appears to make QMT different from other forms of physical activity is its impact on interhemispheric functional connectivity in the theta and alpha bands. In contrast to studies of other types of physical activity that focused on local changes in activity and have usually not reported changes in long-range connectivity, studies of healthy populations engaging in QMT have demonstrated both increased EEG power [168, 169] and coherence [170–173], especially in the theta and alpha bands. Indeed, both single sessions and protracted periods of QMT were found to result in increased intra- and interhemispheric functional connectivity in the theta and alpha bands [170–173]. Increased theta and alpha functional connectivity is thought to reflect improved cognitive functions and higher states of consciousness, due to better integration of information and communication across brain regions [174–176]. As such, these findings provide additional evidence relating to QMT's capacity to promote cognitive and psycho-emotional well-being.

Moreover, Ben-Soussan et al. [170] also found improved spatial cognition and reflectivity in groups who underwent a single session of QMT, in comparison to two control groups that underwent either simple motor or verbal training. The improvements were thought to stem from changes in functional connectivity, as evidenced by changes in intra- and interhemispheric coherence in theta and alpha bands [170].

Until recently, there has been a paucity of studies that investigated neural modulation during meditative movement. In a recent pilot study, De Fano et al. [163] examined five volunteers performing a single session of QMT characterized by three “blocks” which are rounds of the QMT routine. Since QMT requires executive control, which involves frontal theta activity, higher frontal theta power toward the last of the three QMT blocks, compared to the starting one, is expected. Indeed, a trend of increased theta activity was observed toward the last two blocks compared to the first one, which may reflect not only the cognitive control required by QMT performance but also the increase in cognitive effort that occurs overtime [163].

Going back to the theme of navigation and its connection to attention and salience dorsal and ventral streams discussed above, which are further related to the superior and inferior longitudinal fasciculi [177], 6 weeks of daily QMT was further found to increase white matter integrity as indicated by increased fractional anisotropy in the superior and inferior longitudinal fasciculi, as well as in additional tracts related to sensorimotor and cognitive functions [165].

### **3.3 Tai chi and qigong**

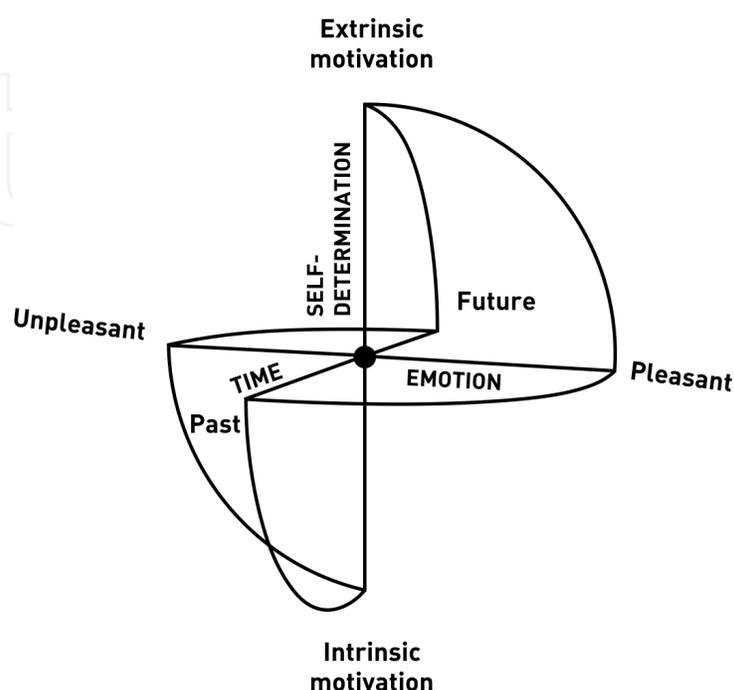
Another meditative movement paradigm, tai chi, has been more heavily studied. Several electroencephalography EEG studies have reported that tai chi can produce

changes in mental state or electroencephalogram patterns associated with other alterations of cognitive or physical indices. An early study by Pan et al. [178] examined the difference in EEG theta between concentrative and non-concentrative qigong states, demonstrating that the frontal midline theta rhythm was related to the concentrative qigong state. As the theta rhythm has been suggested as one of the normal EEG patterns occurring in mental concentration, the authors concluded that the theta rhythm is an indicator of mental concentration during qigong. Notably, Field et al. [179] observed that performance on math computations significantly improved after a 20-min tai chi/yoga training course and was associated with increased frontal theta activity. Field et al. [179] further found a trend of increased theta activity and decreased self-reported anxiety, and the authors attributed this to the relaxation effects of tai chi. This increased frontal theta activity was replicated in a study of skilled female tai chi practitioners, showing a pattern typically occurring during states of relaxation and attention [180].

Additional support for the importance of external movement, in parallel to inner movement and their possible connection, related to theta activity, comes from the fact that frequent movement is preferable to one's health over sedentary behavior, making movement therapies, when applied correctly, beneficial to chronic pain conditions, by ameliorating pain and related symptoms [181]. Moreover, the reported benefits are not only strictly related to musculoskeletal or vascular function but also with the mental dimension of well-being. For example, mindful movement practices, such as tai chi, have been found to significantly help in chronic pain management, for conditions such as osteoarthritis, low back pain, and fibromyalgia (for review, see [182]).

#### 4. The Sphere Model of Consciousness and the position within the sphere

The Sphere Model of Consciousness [15] aims to symbolize the phenomenology of consciousness utilizing the geometrical properties of spatial coordinates within a spherical framework (see **Figure 1**).



**Figure 1.**  
*The Sphere Model of Consciousness (adapted from [11, 13, 15]).*

Each axis of the SMC represents the deployment and polarity of an aspect of experience, with an equilibrium point in the center of the sphere and a graduated scale indicating distance from the center. The center of the sphere represents an equilibrium point, with respect to three spatial coordinates, namely: (1) a horizontal *emotion axis* (e.g., representing the emotional polarities of unpleasant and pleasant), (2) a vertical *self-determination axis* representing the dimensions of value and aspiration [15], and (3) a *time axis* (e.g., representing the temporal deployment of past to future). The center can be considered a state of “Overcoming the Self,” that is, a state of neutrality and detachment from the usual experiences of the Narrative and Minimal selves [15], which is crucial to hypnosis and different meditative practices [183]. Berkovich-Ohana and Glicksohn [28] suggested that experiences related to the Narrative Self are perceived as further away from the body, more abstract, and related to the future and the past. Narrative Self, Minimal Self, and Overcoming of the Self are represented in the SMC as concentric circles around the center of the sphere, with greater distance from the center signifying a more abstract experience of oneself. We shall now merge the electrophysiological and neuroanatomical findings in order to see how one can voluntarily move toward the center of the sphere.

## **5. The importance of attention and intentionally moving toward the center of the sphere**

Movement, volition, and cognition are deeply related [188, 189] and, as seen above, are all related to theta activity. In fact, it has been suggested that the nervous system has evolved to allow active movement and provide a goal-oriented plan; as such, motivation and emotion represent facets of a common phenomenon. That commonality is the motivational-emotional system, which interacts with learning and higher-order cognition [184, 185]. In contrast to meditation practices, which are thought to involve and cultivate mindfulness (being aware of one’s current mental state; about the problems in defining mindfulness, see [186, 187]), different theories of hypnosis posit that the hypnotic response is a form of strategic self-deception in regard to one’s mental state [188]. Thus, it has been suggested that hypnotic response implies a lack of mindfulness, at least regarding particular mental states about which one is strategically deceived [188].

However, we suggest that it is also the combination of attention and intentionality (and not self-deception), which should be addressed in regard to hypnosis and other states of mind [13–15]. People often engage in meditation training because they believe it will result in a specific positive outcome, having received suggestions regarding its potential benefits [56]. Such suggestions—here in the form of self-suggestions, also known as outcome expectancies—are in-line with social cognitive views of hypnosis [10, 189] that posit that hypnosis can be viewed as a use of suggestions for creating changes in thoughts, feelings, or behaviors [56]. As such, self-suggestion implies both attention and intentionality.

Importantly, as noted earlier, frontal theta EEG activity correlates negatively with default mode network activity [43]. Recalling that high theta activity facilitates response to suggestions (e.g., [56]) and plays an important role in attention [80] and intention, such as intentional learning, and intentional movement [190, 191], we suggest that the combination of attention and intention may help to explain the known variability in hypnotic responding between individuals. This, in turn, suggests that the level of hypnotizability can be related to the participant’s baseline position within the sphere [14, 15]. Together, these may have significant implications for the success of treatments.

Numerous studies have highlighted the importance of hypnosis in various clinical conditions, such as chronic pain [192]. Pain is a conscious experience, which can be considered an interpretation of the nociceptive input and potentially influenced by many factors, such as memories, emotions, and cognitions [16]. Decreased temporal-parietal theta (as well as alpha) activity during pain is consistent with a pain-related activation of the insula [193], which is known to be involved in pain processes [16]. Decreased theta connectivity was also found between the insula and the DMN in fibromyalgia, which may reflect persistent pain encoding associated with the chronic pain state in the disorder [194]. Maladaptive rumination and the re-experience of symptoms, which occur in many chronic pain conditions [195], and are known to be related to the DMN [196–198], were further found to be related to decreased theta band networks in post trauma [199]. Thus, finding ways to voluntarily move from the maladaptive and automatic narrative, which is predominant in these conditions, may aid in ameliorating symptoms.

In fact, studies found decreased DMN activation following hypnosis [138]. Decreased DMN activation, following different therapeutic approaches, is further linked to improvements in pain-related catastrophizing, which is generally self-referential, negative, and automatic [200]. In addition, there is growing evidence that mindfulness, as a volitionally initiated cognitive act, can significantly attenuate the subjective experience of pain [201]. Thus, cultivating experiential openness and acceptance, anchored in the embodied minimal self, and not in the narrative/default self, can reduce pain unpleasantness and lead to a reduction of symptoms in chronic pain patients [202, 203].

Emphasizing the importance of intentionality and its electrophysiological markers can further aid in differentiating hypnosis from “animal hypnosis” or “tonic immobility.” “Animal hypnosis” has been found to effect electrophysiological state, such as altering beta, gamma, and alpha activities, depending on the method of induction, duration, and number of sessions [108, 109]. Nevertheless, one should keep in mind that while “animal hypnosis” can be induced in different ways, ranging from restraint to visual fixation, they are all involuntary [204], while the degrees of freedom in human hypnosis, although debatable, are greater. In fact, “tonic immobility” is physiologically quite different in physiological terms (i.e., defense and anti-predation reactions) [8, 205] and is controlled by a motor inhibitory system [204]. Thus, it is not surprising that in contrast to hypnosis, tonic immobility is more related to decreased theta activity and increased delta activity [108, 109], which are both inversely related to intentionality and volition [206]. Together these emphasize the importance of the intentionality aspect in human hypnosis. Nevertheless, it has been argued that hypnotic ability in humans may have evolved at least in part to allow for the control of pain and anxiety after injury, thereby reducing the likelihood of attack by predators [207].

In conclusion, although not a systematic review of this topic, this chapter offers three primary ideas for further consideration: (1) hypnosis and other “internal movement” paradigms may be regarded as mental navigation, (2) they can be compared to external movement and navigation in space, and (3) they are electrophysiologically mediated primarily by theta activity and require greater intentionality and attention. Based on the SMC, this may be related to an intentional shift away from DMN activity, which is anticorrelated with theta activity, and toward clear goal direction, represented by the center of the sphere. Thus, combined multidisciplinary examination of the connection between consciousness and hypnosis, encompassing cognitive psychology and motor and contemplative neuroscience, would produce greater theoretical understanding and implications on consciousness and hypnosis practice. First, in order to reach our personal and social aims, one can and should train to internally move intentionally from an automatic Narrative to the Minimal self, and eventually reach the state of Overcoming the Self, in order to know and

better master one's own perceptions and mental processing. This idea is also related to the works of Charles Tart [208], who describes our ordinary everyday experience as being in a state similar to hypnotic trance, where we are not sleeping but neither are we truly awake. The solution to this state of affairs, similarly to current contemplative neuroscience results presented here, necessitates waking up to our true selves through a process of self-observation and self-remembrance [11, 12, 14, 208].

Second, the parallels between these two lines of research, namely, the similar electrophysiological modulation present in hypnosis, real movement, and motor imagery and the findings related to diagonal movement, can have a useful impact on the field; it can do so by helping to validate reliable electrophysiological effects of hypnosis and increase our understanding of the related biological mechanisms and connections to internal and external movement. If confirmed in future research, these ideas may have important implications for enhancing the response to hypnosis treatments and for customized, combined therapeutic modalities. In turn, emphasizing the importance of intentional inner and outer navigation and their electrophysiological signature can also aid in differentiating between the different techniques and their possible synergetic effects.

In summary, as we know, hypnosis has many benefits, including the relief of chronic pain. These benefits are possible due to knowledge gained related to how the mind works and thus the possibility of leading it into specific mental and neural states, as is the case with hypnosis. The investigation of the connections between hypnosis and theta activity, among others, further demonstrates an affinity between meditative practices and hypnosis, and that intentionality can play an important role in leading oneself into desired states. In these states we are able to know ourselves better and master our perceptions and the interpretation we give of them. Training ourselves in this direction can, therefore, improve our well-being and quality of life. Future studies should combine behavioral, neuroanatomical, and electrophysiological measures to help in distinguishing different types of hypnotic states and practices, as well as to examine the role of the person's detached and attentive intentionality in reaching them.

## **Author details**

Patrizio Paoletti<sup>1</sup>, Tal Dotan Ben-Soussan<sup>1\*</sup> and Joseph Glicksohn<sup>2,3</sup>

<sup>1</sup> Research Institute for Neuroscience, Education and Didactics, Fondazione Patrizio Paoletti, Assisi, Italy

<sup>2</sup> Department of Criminology, Bar-Ilan University, Israel

<sup>3</sup> The Leslie and Susan Gonda (Goldschmied) Multidisciplinary Brain Research Center, Bar-Ilan University, Israel

\*Address all correspondence to: [research@fondazionepatriziopaoletti.org](mailto:research@fondazionepatriziopaoletti.org)

## **IntechOpen**

© 2020 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

## References

- [1] De Benedittis G. Hypnosis and biofeedback for the control of chronic pain. In: Mocavero G, Gullo A, Paladini VA, Romano E, editors. *Recent Advances in Anaesthesia Pain Intensive Care and Emergency*. Trieste: A.P.I.C.E. Ed; 1989. pp. 119-131
- [2] Lioffi C, Popi H. Clinical hypnosis versus cognitive behavioral training for pain management with pediatric cancer patients undergoing bone marrow aspirations. *The International Journal of Clinical and Experimental Hypnosis*. 1999;47(2):104-116
- [3] Erickson M. Hypnosis in painful terminal illness. *The American Journal of Clinical Hypnosis*. 1958;56:67-71
- [4] Malrewicz JA, Godin J, Milton H. *Erickson: de l'Hypnose Clinique à la Psychothérapie Stratégique*. Paris: ESF Ed.; 1986. p. 156
- [5] Rimbart S et al. Hypnotic state modulates sensorimotor beta rhythms during real movement and motor imagery. *Frontiers in Psychology*. 2019;10:2341
- [6] Spiegel H, Spiegel D. *Trance and Treatment: Clinical Uses of Hypnosis*. 2nd rev. Washington DC: American Psychiatric Pub; 2008. p. 576
- [7] Rainville P, Hofbauer RK, Bushnell MC, Duncan GH, Price DD. Hypnosis modulates activity in brain structures involved in the regulation of consciousness. *Cognitive Neuroscience*. 2002;14(6):887-901
- [8] Oakley DA, Halligan PW. Hypnotic suggestion: Opportunities for cognitive neuroscience. *Nature Reviews Neuroscience*. 2013;14(8):565-576
- [9] Lynn S et al. Mindfulness, acceptance, and hypnosis: Cognitive and clinical perspectives. *The International Journal of Clinical and Experimental Hypnosis*. 2006;54(2):143-166
- [10] Lynn S, Kirsch IR, Hallquist MN. Social cognitive theories of hypnosis. In: Nash JA, Barnier A, editors. *The Oxford Handbook of Hypnosis: Theory, Research, and Practice*. Oxford, UK: Oxford University Press; 2008. pp. 111-139
- [11] Paoletti P. *Flussi, Territori, Luogo [Flows, Territories, Place]*. Madeira, Portugal: M.E.D. Publishing; 2002
- [12] Paoletti P. *Flussi, Territori, Luogo II [Flows, Territories, Place II]*. Madeira, Portugal: M.E.D. Publishing; 2002
- [13] Paoletti P. *Crescere nell'eccellenza*. Rome, Italy: Armando Publishing; 2008. p. 176
- [14] Paoletti P, Selvaggio A. *Osservazione*. Perugia, Italy: Edizioni 3P; 2011. p. 120
- [15] Paoletti P, Ben-Soussan TD. The Sphere Model of Consciousness: From geometrical to neuro-psycho-educational perspectives. *Logica Universalis*. 2019;13(3):395-415
- [16] Mordeniz C. Pain perception within consciousness. *NeuroQuantology*. 2016;14(2):439-446
- [17] Godot D. Formulating hypnotic suggestions. In: *Handbook of Medical and Psychological Hypnosis: Foundations, Applications, and Professional Issues*. New York: Springer Publishing Company; 2016. p. 57
- [18] Spanos NP. Hypnotic behavior: A social-psychological interpretation of amnesia, analgesia and "trance logic". *Behavioral and Brain Sciences*. 1986;9(3):449-467. DOI: 10.1017/S0140525X00046537
- [19] Kirsch I. Response expectancy as a determinant of experience and

- behavior. *The American Psychologist*. 1985;**40**(11):1189
- [20] Kirsch I. Response expectancy theory and application: A decennial review. *Applied and Preventive Psychology*. 1997;**6**(2):69-79
- [21] Benham G et al. Expect the unexpected: Ability, attitude, and responsiveness to hypnosis. *Journal of Personality and Social Psychology*. 2006;**91**(2):342
- [22] Shor RE et al. Relation of predicted to actual hypnotic responsiveness, with special reference to posthypnotic amnesia. *The International Journal of Clinical and Experimental Hypnosis*. 1984;**32**(4):376-387
- [23] Glisky ML, Tataryn DJ, Tobias BA, Kihlstrom JF, McConkey KM. Absorption, openness to experience, and hypnotizability. *Journal of Personality and Social Psychology*. 1991;**60**(2):263-272. DOI: 10.1037/0022-3514.1060.1032.1263
- [24] Tellegen A, Atkinson G. Openness to absorbing and self-altering experiences ("absorption"), a trait related to hypnotic susceptibility. *Journal of Abnormal Psychology*. 1974;**83**(3):268-277. DOI: 10.1037/h0036681
- [25] Hollander HE, Bender SS. ECEM (eye closure eye movements): Integrating aspects of EMDR with hypnosis for treatment of trauma. *The American Journal of Clinical Hypnosis*. 2001;**43**(3-4):187-202
- [26] Beere DB, Simon MJ, Welch K. Recommendations and illustrations for combining hypnosis and EMDR in the treatment of psychological trauma. *The American Journal of Clinical Hypnosis*. 2001;**43**(3-4):217-231
- [27] Fine CG, Berkowitz AS. The wreathing protocol: The imbrication of hypnosis and EMDR in the treatment of dissociative identity disorder and other dissociative responses. *The American Journal of Clinical Hypnosis*. 2001;**43**(3-4):275-290
- [28] Berkovich-Ohana A, Glicksohn J. The consciousness state space (CSS)—A unifying model for consciousness and self. *Frontiers in Psychology*. 2014;**5**:341
- [29] Hinterberger T et al. Decreased electrophysiological activity represents the conscious state of emptiness in meditation. *Frontiers in Psychology*. 2014;**5**:99
- [30] Winter U et al. Content-free awareness: EEG-fcMRI correlates of consciousness as such in an expert meditator. *Frontiers in Psychology*. 2019;**10**:3.064-3.074
- [31] Josipovic Z. Neural correlates of nondual awareness in meditation. *Annals of the New York Academy of Sciences*. 2014;**1307**(1):9-18
- [32] Vieten C et al. Future directions in meditation research: Recommendations for expanding the field of contemplative science. *PLoS One*. 2018;**13**(11):1-30
- [33] Başar-Eroğlu C, Başar E, Demiralp T, Schürmann M. P300-response: Possible psychophysiological correlates in delta and theta frequency channels. A review. *International Journal of Psychophysiology*. 1992;**13**:161-179
- [34] Başar E, Başar-Eroğlu C, Karakaş S, Schürmann M. Are cognitive processes manifested in event-related gamma, alpha, theta and delta oscillations in the EEG? *Neuroscience Letters*. 1999;**259**:165-168
- [35] Başar E, Başar-Eroğlu C, Karakaş S, Schürmann M. Gamma, alpha, delta, and theta oscillations govern cognitive processes. *International Journal of Psychophysiology*. 2001;**39**:241-248

- [36] Sabourin ME, Cutcomb SD, Crawford HJ, Pribram K. EEG correlates of hypnotic susceptibility and hypnotic trance: Spectral analysis and coherence. *International Journal of Psychophysiology*. 1990;**10**(2):125-142. DOI: 10.1016/0167-8760(1090)90027-B
- [37] Oohashi T, Kawai N, Honda M, Nakamura S, Morimoto M, Nishina E, et al. Electroencephalographic measurement of possession trance in the field. *Clinical Neurophysiology*. 2002;**113**(3):435-445
- [38] Cahn BR, Delorme A, Polich J. Occipital gamma activation during Vipassana meditation. *Cognitive Processing*. 2010;**11**(1):39-56. DOI: 10.1007/s10339-10009-10352-10331
- [39] Cahn BR, Polich J. Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychological Bulletin*. 2006;**132**(2):180-211. DOI: 10.1037/0033-2909.1132.1032.1180
- [40] DeLosAngeles D, Williams G, Burston J, Fitzgibbon SP, Lewis TW, Grummett TS, et al. Electroencephalographic correlates of states of concentrative meditation. *International Journal of Psychophysiology*. 2016;**110**:27-39
- [41] Ray WJ. EEG concomitants of hypnotic susceptibility. *International Journal of Clinical and Experimental Hypnosis*. 1997;**45**(3):301-313. DOI: 10.1080/00207149708416131
- [42] Stevens L, Haga Z, Queen B, Brady B, Adams D, Gilbert J, et al. Binaural beat induced theta EEG activity and hypnotic susceptibility: Contradictory results and technical considerations. *The American Journal of Clinical Hypnosis*. 2003;**45**(4):295-309
- [43] Scheeringa R, Bastiaansen MC, Petersson KM, Oostenveld R, Norris DG, Hagoort P. Frontal theta EEG activity correlates negatively with the default mode network in resting state. *International Journal of Psychophysiology*. 2008;**67**(3):242-251
- [44] Buckner RL, Andrews-Hanna JR, Schacter DL. The brain's default network: Anatomy, function, and relevance to disease. In: Kingstone A, Miller MB, editors. *The Year in Cognitive Neuroscience*. Malden, MA: Blackwell; 2008. pp. 1-38
- [45] Raichle ME, MacLeod AM, Snyder AZ, Powers WJ, Gusnard DA, Shulman GL. A default mode of brain function. *Proceedings of the National Academy of Sciences of the United States of America*. 2001;**98**:676-682. DOI: 10.1073/pnas.98.2.676
- [46] Schütz-Bosbach S, Prinz W. Prospective coding in event representation. *Cognitive Processing*. 2007;**8**(2):93-102
- [47] Friston K, Kiebel S. Predictive coding under the free-energy principle. *Philosophical Transactions of the Royal Society, B: Biological Sciences*. 2009;**364**(1521):1211-1221
- [48] Llewellyn S. Dream to predict? REM dreaming as prospective coding. *Frontiers in Psychology*. 2016;**6**:1961
- [49] Mehta MR. Neuronal dynamics of predictive coding. *The Neuroscientist*. 2001;**7**(6):490-495. DOI: 10.1177/107385840100700605
- [50] Friston K, Mattout J, Kilner J. Action understanding and active inference. *Biological Cybernetics*. 2011;**104**(1-2):137-160. DOI: 10.1007/s00422-011-0424-z
- [51] Batty MJ, Bonnington S, Tang BK, Hawken MB, Gruzelier JH. Relaxation strategies and enhancement of hypnotic susceptibility: EEG neurofeedback, progressive muscle relaxation and self-hypnosis. *Brain Research Bulletin*. 2006;**71**(1-3):83-90

- [52] Jensen MP, Hakimian S, Sherlin LH, Fregni F. New insights into neuromodulatory approaches for the treatment of pain. *The Journal of Pain*. 2008;**9**(3):193-199
- [53] Zeig JK. An Ericksonian approach to hypnosis: The phenomenological model of hypnosis; the nature of hypnotic "states"; multilevel communication and indirection; and why all hypnosis is not self-hypnosis. *Australian Journal of Clinical & Experimental Hypnosis*. 2008;**36**(2):99-114
- [54] Spanos NP, Barber TX. Toward a convergence in hypnosis research. *The American Psychologist*. 1974;**29**(7):500-511
- [55] Brown KW, Leary MR, editors. *The Oxford Handbook of Hypo-egoic Phenomena*. Oxford: Oxford University Press; 2016
- [56] Jensen MP, Adachi T, Hakimian S. Brain oscillations, hypnosis, and hypnotizability. *The American Journal of Clinical Hypnosis*. 2015;**57**(3): 230-253
- [57] Freeman R, Barabasz A, Barabasz M, Warner D. Hypnosis and distraction differ in their effects on cold pressor pain. *The American Journal of Clinical Hypnosis*. 2000;**43**(2):137-148
- [58] Galbraith GC, London P, Leibovitz MP, Cooper LM, Hart JT. EEG and hypnotic susceptibility. *Journal of Comparative and Physiological Psychology*. 1970;**72**(1):125-131
- [59] Kirenskaya AV, Novototsky-Vlasov VY, Zvonikov VM. Waking EEG spectral power and coherence differences between high and low hypnotizable subjects. *The International Journal of Clinical and Experimental Hypnosis*. 2011;**59**(4):441-453
- [60] Montgomery DD, Dwyer KV, Kelly SM. Relationship between QEEG relative power and hypnotic susceptibility. *The American Journal of Clinical Hypnosis*. 2000;**43**(1):71-75
- [61] Tebecis AK, Provins KA, Farnbach RW, Pentony P. Hypnosis and the EEG. A quantitative investigation. *The Journal of Nervous and Mental Disease*. 1975;**161**(1):1-17
- [62] Jensen MP, Sherlin LH, Askew RL, Fregni F, Witkop G, Gianas A, et al. Effects of non-pharmacological pain treatments on brain states. *Clinical Neurophysiology*. 2013;**124**(10):2016-2024
- [63] Williams JD, Gruzelier JH. Differentiation of hypnosis and relaxation by analysis of narrow band theta and alpha frequencies. *The International Journal of Clinical and Experimental Hypnosis*. 2001;**49**(3):185-206
- [64] Corby JC, Roth WT, Zarccone VP Jr, Kopell BS. Psychophysiological correlates of the practice of tantric yoga meditation. *Archives of General Psychiatry*. 1978;**35**(5):571-577
- [65] Perlini AH, Spanos NP. EEG alpha methodologies and hypnotizability: A critical review. *Psychophysiology*. 1991;**28**(5):511-530. DOI: 10.1111/j.1469-8986.1991.tb01989.x
- [66] Pagano RR, Rose RM, Stivers RM, Warrenburg S. Sleep during transcendental meditation. *Science*. 1976;**191**:308-310
- [67] Glicksohn J. The structure of subjective experience: Interdependencies along the sleep-wakefulness continuum. *Journal of Mental Imagery*. 1989;**13**:99-106
- [68] Hebert R, Lehmann D. Theta bursts: An EEG pattern in normal subjects practicing the transcendental meditation technique. *Electroencephalography and*

Clinical Neurophysiology.  
1977;**42**(3):397-405. DOI:  
10.1016/0013-4694(1077)90176-90176

[69] Pagano RR, Warrenburg S. Meditation: In search of a unique effect. In: Davidson RJ, Schwartz GE, Shapiro D, editors. *Consciousness and Self-Regulation: Advances in Research and Theory*. Vol. 3. New York: Plenum; 1983. pp. 153-210

[70] Glicksohn J, Berkovich-Ohana A. Absorption, immersion, and consciousness. In: Gackenbach J, editor. *Video Game Play and Consciousness*. New York: Nova Science Publishers Inc.; 2012. pp. 83-99

[71] Holroyd J. The science of meditation and the state of hypnosis. *The American Journal of Clinical Hypnosis*. 2003;**46**(2):109-128

[72] Mitchell DJ, McNaughton N, Flanagan D, Kirk IJ. Frontal-midline theta from the perspective of hippocampal "theta". *Progress in Neurobiology*. 2008;**86**(3):156-185

[73] Berkovich-Ohana A, Glicksohn J, Goldstein A. Mindfulness-induced changes in gamma band activity—Implications for the default mode network, self-reference and attention. *Clinical Neurophysiology*. 2012;**123**:700-710. DOI: 10.1016/j.clinph.2011.07.048

[74] Canolty RT, Edwards E, Dalal SS, Soltani M, Nagarajan SS, Kirsch HE, et al. High gamma power is phase-locked to theta oscillations in human neocortex. *Science*. 2006;**313**(5793):1626-1628

[75] Montgomery SM, Sirota A, Buzsáki G. Theta and gamma coordination of hippocampal networks during waking and rapid eye movement sleep. *The Journal of Neuroscience*. 2008;**28**(26):6731-6741

[76] Garcia-Rill E, Kezunovic N, Hyde J, Simon C, Beck P, Urbano FJ. Coherence

and frequency in the reticular activating system (RAS). *Sleep Medicine Reviews*. 2013;**17**(3):227-238

[77] Jung-Beeman M, Bowden EM, Haberman J, Frymiare JL, Arambel-Liu S, Greenblatt R, et al. Neural activity when people solve verbal problems with insight. *PLoS Biology*. 2004;**2**(4):1-15

[78] Jensen MP, Adachi T, Tomé-Pires C, Lee J, Osman ZJ, Miró J. Mechanisms of hypnosis: Toward the development of a biopsychosocial model. *The International Journal of Clinical and Experimental Hypnosis*. 2015;**63**(1):34-75

[79] Zahedi A, Stuermer B, Hatami J, Rostami R, Sommer W. Eliminating stroop effects with post-hypnotic instructions: Brain mechanisms inferred from EEG. *Neuropsychologia*. 2017;**96**:70-77

[80] Aftanas LI, Golocheikine SA. Human anterior and frontal midline theta and lower alpha reflect emotionally positive state and internalized attention: High-resolution EEG investigation of meditation. *Neuroscience Letters*. 2001;**310**(1):57-60

[81] Srinivasan R, Winter WR, Nunez PL. Source analysis of EEG oscillations using high-resolution EEG and MEG. *Progress in Brain Research*. 2006;**159**:29-42

[82] Whitham EM, Pope KJ, Fitzgibbon SP, Lewis T, Clark CR, Loveless S, et al. Scalp electrical recording during paralysis: Quantitative evidence that EEG frequencies above 20 Hz are contaminated by EMG. *Clinical Neurophysiology*. 2007;**118**(8):1877-1888

[83] Yuval-Greenberg S, Deouell LY. The broadband-transient induced gamma-band response in scalp EEG reflects the execution of saccades. *Brain Topography*. 2009;**22**(1):3-6

- [84] Kahana MJ, Sekuler R, Caplan JB, Kirschen M, Madsen JR. Human theta oscillations exhibit task dependence during virtual maze navigation. *Nature*. 1999;**399**(6738):781-784
- [85] Buzsáki G. Theta rhythm of navigation: Link between path integration and landmark navigation, episodic and semantic memory. *Hippocampus*. 2005;**15**(7):827-840
- [86] Buzsáki G, Moser EI. Memory, navigation and theta rhythm in the hippocampal-entorhinal system. *Nature Neuroscience*. 2013;**16**(2):130
- [87] Glicksohn J. Cutting the “Gordonian knot” using absorption and dream recall. *Journal of Mental Imagery*. 1991;**15**(3 & 4):49-54
- [88] Glicksohn J. Absorption, hallucinations, and the continuum hypothesis. *The Behavioral and Brain Sciences*. 2004;**27**(6):793-794
- [89] Glicksohn J. Patterns of occurrence of four states of consciousness as a function of trait absorption. *Journal for Person-Oriented Research*. 2019;**5**(1):27-36
- [90] Pekala RJ, Wenger CF, Levine RL. Individual differences in phenomenological experience: States of consciousness as a function of absorption. *Journal of Personality and Social Psychology*. 1985;**48**(1):125-132. DOI: 10.1037/0022-3514.1048.1031.1125
- [91] Qualls PJ, Sheehan PW. Role of the feedback signal in electromyograph biofeedback: The relevance of attention. *Journal of Experimental Psychology. General*. 1981;**110**(2):204-216. DOI: 10.1037/0096-3445.1110.1032.1204
- [92] Tops M, Boksem MAS. Absorbed in the task: Personality measures predict engagement during task performance as tracked by error negativity and asymmetrical frontal activity. *Cognitive, Affective, & Behavioral Neuroscience*. 2010;**10**(4):441-453
- [93] Crawford HJ, Brown AM, Moon CE. Sustained attentional and disattentional abilities: Differences between low and highly hypnotizable persons. *Journal of Abnormal Psychology*. 1993;**102**(4):534-543. DOI: 10.1037/0021-1843X.1102.1034.1534
- [94] Kumar VK, Pekala RJ. Hypnotizability, absorption, and individual differences in phenomenological experience. *The International Journal of Clinical and Experimental Hypnosis*. 1988;**36**(2):80-88. DOI: 10.1080/00207148808409332
- [95] Berkovich-Ohana A, Glicksohn J. Meditation, absorption, transcendent experience and affect: Tying it all together by the consciousness state space (CSS) model. *Mindfulness*. 2017;**8**:68-77. DOI: 10.1007/s12671-015-0481-9
- [96] Silva CE, Kirsch I. Interpretive sets, expectancy, fantasy proneness, and dissociation as predictors of hypnotic response. *Journal of Personality and Social Psychology*. 1992;**63**(5):847-856. DOI: 10.1037/0022-3514.1063.1035.1847
- [97] Council JR, Kirsch I, Hafner LP. Expectancy versus absorption in the prediction of hypnotic responding. *Journal of Personality and Social Psychology*. 1986;**50**(1):182-189. DOI: 10.1037/0022-3514.1050.1031.1182
- [98] Nadon R, Kihlstrom JF, Hoyt IP, Register PA. Absorption and hypnotizability: Context effects reexamined. *Journal of Personality and Social Psychology*. 1991;**60**(1):144-153. DOI: 10.1037/0022-3514.1060.1031.1144
- [99] Mohr C. Are there varying depths in flow? Altered states of consciousness, absorption, and the brain. *Journal of Consciousness Studies*. 2018;**25**(11-12):115-130

- [100] Glicksohn J. Hypnotic behavior revisited: A trait-context interaction. *The Behavioral and Brain Sciences*. 1987;**10**(4):774-775. DOI: 10.1017/S0140525X00055771
- [101] Kihlstrom JF. Neuro-hypnotism: Prospects for hypnosis and neuroscience. *Cortex*. 2013;**49**(2):365-374
- [102] Gruzelier JH. Redefining hypnosis: Theory, methods and integration. *Contemporary Hypnosis*. 2000;**17**(2):51-70
- [103] Graffin NF, Ray WJ, Lundy R. EEG concomitants of hypnosis and hypnotic susceptibility. *Journal of Abnormal Psychology*. 1995;**104**(1):123-131. DOI: 10.1037/0021-1843X.1104.1031.1123
- [104] Schacter DL. EEG theta waves and psychological phenomena: A review and analysis. *Biological Psychology*. 1977;**5**(1):47-82. DOI: 10.1016/0301-0511(1077)90028-X
- [105] White D, Ciorciari J, Carbis C, Liley D. EEG correlates of virtual reality hypnosis. *The International Journal of Clinical and Experimental Hypnosis*. 2008;**57**(1):94-116
- [106] Cardeña E, Jönsson P, Terhune DB, Marcusson-Clavertz D. The neurophenomenology of neutral hypnosis. *Cortex*. 2013;**49**(2):375-385
- [107] van Wijk BC, Daffertshofer A, Roach N, Praamstra P. A role of beta oscillatory synchrony in biasing response competition? *Cerebral Cortex*. 2009;**19**(6):1294-1302
- [108] Roshchina GIA, Koroleva VI, Davydov VI. Changes in the high-frequency electrical brain activity in the animal hypnosis state in rabbits. *Zhurnal vyshei nervnoi deiatelnosti imeni I P Pavlova*. 2010;**60**(3):352-363
- [109] Rusinova EV, Davydov VI. Dynamics of changes in electrical activity in the rabbit cerebral cortex during sequential sessions of “animal hypnosis”. *Neuroscience and Behavioral Physiology*. 2010;**40**(5):471-478
- [110] Davidson RJ, Schwartz GE. The psychobiology of relaxation and related states: A multi-process theory. In: *Behavior Control and Modification of Physiological Activity*. New Jersey: Prentice Hall; 1976. pp. 399-442
- [111] Chiesa A, Serretti A. A systematic review of neurobiological and clinical features of mindfulness meditations. *Psychological Medicine*. 2010;**40**(8):1239-1252
- [112] Thomas J, Jamieson G, Cohen M. Low and then high frequency oscillations of distinct right cortical networks are progressively enhanced by medium and long term Satyananda yoga meditation practice. *Frontiers in Human Neuroscience*. 2014;**8**:197
- [113] Lehmann D, Faber P, Achermann P, Jeanmonod D, Gianotti L, Pizzagalli D. Brain sources of EEG gamma frequency during volitionally meditation-induced, altered states of consciousness, and experience of the self. *Psychiatry Research*. 2001;**108**:111-121. DOI: 10.1016/S0925-4927(01)00116-0
- [114] Lutz A, Greischar LL, Rawlings NB, Ricard M, Davidson RJ. Long-term meditators self-induce high-amplitude gamma synchrony during mental practice. *Proceedings of the National Academy of Sciences of the United States of America*. 2004;**101**:16369-16373. DOI: 10.1073/pnas.0407401101
- [115] Ivanovski B, Malhi GS. The psychological and neurophysiological concomitants of mindfulness forms of meditation. *Acta Neuropsychiatrica*. 2007;**19**(2):76-91
- [116] Berman AE, Stevens L. EEG manifestations of nondual experiences

in meditators. *Consciousness and Cognition*. 2015;**31**:1-11

[117] Berkovich-Ohana A, Dor-Ziderman Y, Glicksohn J, Goldstein A. Alterations in the sense of time, space, and body in the mindfulness-trained brain: A neurophenomenologically-guided MEG study. *Frontiers in Psychology*. 2013;**4**:912

[118] Berkovich-Ohana A, Glicksohn J, Ben-Soussan TD, Goldstein A. Creativity is enhanced by long-term mindfulness training and is negatively correlated with trait default-mode-related low-gamma inter-hemispheric connectivity. *Mindfulness*. 2017;**8**(3):717-727

[119] Knyazev GG. EEG delta oscillations as a correlate of basic homeostatic and motivational processes. *Neuroscience and Biobehavioral Reviews*. 2012;**36**(1):677-695

[120] Ben-Soussan TD, Mauro F, Lasaponara S, Glicksohn J, Marson F, Berkovich-Ohana A. Fully immersed: State absorption and electrophysiological effects of the OVO whole-body perceptual deprivation chamber. *Progress in Brain Research*. 2019;**244**:165-184

[121] Parker S, Bharati SV, Fernandez M. Defining yoga-nidra: Traditional accounts, physiological research, and future directions. *International Journal of Yoga Therapy*. 2013;**23**(1):11-16

[122] Dennison P. The human default consciousness and its disruption: Insights from an EEG study of Buddhist jhāna meditation. *Frontiers in Human Neuroscience*. 2019;**13**:178

[123] Del Felice A, Arcaro C, Storti SF, Fiaschi A, Manganotti P. Electrical source imaging of sleep spindles. *Clinical EEG and Neuroscience*. 2014;**45**:184-192. DOI: 10.1177/1550059413497716

[124] Mason LI, Alexander CN, Travis FT, Marsh G, Orme-Johnson DW, Gackenbach J, et al. Electrophysiological correlates of higher states of consciousness during sleep in long-term: Practitioners of the transcendental meditation program. *Sleep*. 1997;**20**(2):102-110

[125] Travis F. Transcendental experiences during meditation practice. *Annals of the New York Academy of Sciences*. 2014;**1307**(1):1-8

[126] Asada H, Fukuda Y, Tsunoda S, Yamaguchi M, Tonoike M. Frontal midline theta rhythms reflect alternative activation of prefrontal cortex and anterior cingulate cortex in humans. *Neuroscience Letters*. 1999;**274**(1):29-32

[127] Gevins A, Smith ME, McEvoy L, Yu D. High-resolution EEG mapping of cortical activation related to working memory: Effects of task difficulty, type of processing, and practice. *Cerebral Cortex*. 1997;**7**(4):374-385

[128] Ishii R, Shinosaki K, Ukai S, Inouye T, Ishihara T, Yoshimine T, et al. Medial prefrontal cortex generates frontal midline theta rhythm. *Neuroreport*. 1999;**10**(4):675-679

[129] Mizuhara H et al. A long-range cortical network emerging with theta oscillation in a mental task. *Neuroreport*. 2004;**15**(8):1233-1238

[130] Sammer G et al. Relationship between regional hemodynamic activity and simultaneously recorded EEG-theta associated with mental arithmetic-induced workload. *Human Brain Mapping*. 2007;**28**(8):793-803

[131] Onton J, Delorme A, Makeig S. Frontal midline EEG dynamics during working memory. *NeuroImage*. 2005;**27**(2):341-356

[132] Menon V. Salience network. In: Toga W, editor. *Brain Mapping. An Encyclopedic Reference*. Vol. 2.

New York: Academic Press, Elsevier;  
2015. pp. 597-711

[133] Menon V, Uddin LQ. Saliency, switching, attention and control: A network model of insula function. *Brain Structure & Function*. 2010;**214**:655-667. DOI: 10.1007/s00429-010-0262-0

[134] Murayama K, Matsumoto M, Izuma K, Matsumoto K. Neural basis of the undermining effect of monetary reward on intrinsic motivation. *Proceedings of the National Academy of Sciences of the United States of America*. 2010;**107**(49):20911-20916

[135] Brewer JA, Worhunsky PD, Gray JR, Tang YY, Weber J, Kober H. Meditation experience is associated with differences in default mode network activity and connectivity. *Proceedings of the National Academy of Sciences of the United States of America*. 2011;**108**(50):20254-20259

[136] Farb N, Segal Z, Mayberg H, Bean J, McKeon D, Fatima Z, et al. Attending to the present: Mindfulness meditation reveals distinct neural modes of self-reference. *Social Cognitive and Affective Neuroscience*. 2007;**2**:313-322. DOI: 10.1093/scan/nsm030

[137] Hölzel B, Ott U, Hempel H, Hackl A, Wolf K, Stark R, et al. Differential engagement of anterior cingulate and adjacent medial frontal cortex in adept meditators and non-meditators. *Neuroscience Letters*. 2007;**421**:16-21. DOI: 10.1016/j.neulet.2007.04.074

[138] Deeley Q, Oakley DA, Toone B, Giampietro V, Brammer MJ, Williams SCR, et al. Modulating the default mode network using hypnosis. *The International Journal of Clinical and Experimental Hypnosis*. 2012;**60**:206-228. DOI: 10.1080/00207144.2012.648070

[139] Lifshitz M, Cusumano EP, Raz A. Hypnosis as neurophenomenology.

*Frontiers in Human Neuroscience*. 2013;**7**:469

[140] Crabbe JB, Dishman RK. Brain electrocortical activity during and after exercise: A quantitative synthesis. *Psychophysiology*. 2004;**41**(4):563-574

[141] Gutmann B, Hülsdünker T, Mierau J, Strüder HK, Mierau A. Exercise-induced changes in EEG alpha power depend on frequency band definition mode. *Neuroscience Letters*. 2018;**662**:271-275

[142] Babiloni C, Marzano N, Iacoboni M, Infarinato F, Aschieri P, Buffo P, et al. Resting state cortical rhythms in athletes: A high-resolution EEG study. *Brain Research Bulletin*. 2010;**81**(1):149-156

[143] Dietrich A. Functional neuroanatomy of altered states of consciousness: The transient hypofrontality hypothesis. *Consciousness and Cognition*. 2003;**12**(2):231-256. DOI: 10.1016/S1053-8100(1002)00046-00046

[144] Dietrich A, Audiffren M. The reticular-activating hypofrontality (RAH) model of acute exercise. *Neuroscience and Biobehavioral Reviews*. 2011;**35**(6):1305-1325

[145] Voss DE. Proprioceptive neuromuscular facilitation. *American Journal of Physical Medicine & Rehabilitation*. 1967;**46**(1):838-898

[146] Diamond A. Effects of physical exercise on executive functions: Going beyond simply moving to moving with thought. *Annals of Sports Medicine and Research*. 2015;**2**(1):1011

[147] De Bono E. Information processing and new ideas—Lateral and vertical thinking. *The Journal of Creative Behavior*. 1969;**3**(3):159-171

[148] Shapiro F. Eye movement desensitization: A new treatment for

- post-traumatic stress disorder. *Journal of Behavior Therapy and Experimental Psychiatry*. 1989;20(3):211-217
- [149] Shapiro FE, editor. *EMDR as an Integrative Psychotherapy Approach: Experts of Diverse Orientations Explore the Paradigm Prism*. Washington: American Psychological Association; 2002. pp. 7-444
- [150] Nishida M, Pearsall J, Buckner RL, Walker MP. REM sleep, prefrontal theta, and the consolidation of human emotional memory. *Cerebral Cortex*. 2009;19(5):1158-1166
- [151] Stickgold R. EMDR: A putative neurobiological mechanism of action. *Journal of Clinical Psychology*. 2002;58(1):61-75
- [152] Stickgold R. Sleep-dependent memory processing and EMDR action. *Journal of EMDR Practice and Research*. 2008;2:289-299. DOI: 10.1891/1933-3196.2.4.289
- [153] Pagani M, Amann BL, Landin-Romero R, Carletto S. Eye movement desensitization and reprocessing and slow wave sleep: A putative mechanism of action. *Frontiers in Psychology*. 2017;8:1935
- [154] Brady B, Stevens L. Binaural-beat induced theta EEG activity and hypnotic susceptibility. *The American Journal of Clinical Hypnosis*. 2000;43(1):53-69
- [155] Jirakittayakorn N, Wongsawat Y. Brain responses to a 6-Hz binaural beat: Effects on general theta rhythm and frontal midline theta activity. *Frontiers in Neuroscience*. 2017;11:365
- [156] McConnell PA, Froeliger B, Garland EL, Ives JC, Sforzo GA. Auditory driving of the autonomic nervous system: Listening to theta-frequency binaural beats post-exercise increases parasympathetic activation and sympathetic withdrawal. *Frontiers in Psychology*. 2014;5:1248
- [157] Crawford HJ, Gruzelier JH. A midstream view of the neuropsychology of hypnosis: Recent research and future directions. In: Fromm E, Nash MR, editors. *Contemporary Hypnosis Research*. New York: Guilford Press; 1992. pp. 227-266
- [158] Solca M, Mottaz A, Guggisberg AG. Binaural beats increase interhemispheric alpha-band coherence between auditory cortices. *Hearing Research*. 2016;332:233-237
- [159] Adrian ED. *The Physical Background of Perception*. Oxford: Clarendon Press; 1948. p. 95
- [160] Von Stein A, Sarnthein J. Different frequencies for different scales of cortical integration: From local gamma to long range alpha/theta synchronization. *International Journal of Psychophysiology*. 2000;38(3):301-313
- [161] Marson F, Paoletti P, Lasaponara S, Glicksohn J, De Fano A, Ben-Soussan TD. Cerebral spectral perturbation during upper limbs diagonal movements. In: Ramana V, editor. *Advances in Neural Signal Processing*. [In press]
- [162] Parkes LM, Bastiaansen MC, Norris DG. Combining EEG and fMRI to investigate the post-movement beta rebound. *NeuroImage*. 2006;29(3):685-696
- [163] De Fano A, Leshem R, Ben-Soussan TD. Creating an internal environment of cognitive and psycho-emotional well-being through an external movement-based environment: An overview of quadrato motor training. *International Journal of Environmental Research and Public Health*. 2019;16(12):2160

- [164] Leshem R, De Fano A, Ben-Soussan TD. The implications of motor and cognitive inhibition for hot and cool executive functions: The case of quadrato motor training. *Frontiers in Psychology*. (in press)
- [165] Piervincenzi C, Ben-Soussan TD, Mauro F, Mallio CA, Errante Y, Quattrocchi CC, et al. White matter microstructural changes following quadrato motor training: A longitudinal study. *Frontiers in Human Neuroscience*. 2017;**11**:590
- [166] Pfurtscheller G, Da Silva FL. Event-related EEG/MEG synchronization and desynchronization: Basic principles. *Clinical Neurophysiology*. 1999;**110**(11):1842-1857
- [167] Kilavik BE, Zaepffel M, Brovelli A, MacKay WA, Riehle A. The ups and downs of beta oscillations in sensorimotor cortex. *Experimental Neurology*. 2013;**245**:15-26
- [168] Ben-Soussan TD, Berkovich-Ohana A, Glicksohn J, Goldstein A. A suspended act: Increased reflectivity and gender-dependent electrophysiological change following quadrato motor training. *Frontiers in Psychology*. 2014;**5**:55. DOI: 10.3389/fpsyg.2014.00055
- [169] Lasaponara S, Mauro F, Ben-Soussan TD, Carducci F, Tombini M, Quattrocchi CC, et al. Electrophysiological indexes of eyes open and closed resting states conditions following the quadrato motor training. *International Journal of Bioelectromagnetism*. 2016; **18**:99-108
- [170] Ben-Soussan TD, Avirame K, Glicksohn J, Goldstein A, Harpaz Y, Ben-Schachar M. Changes in cerebellar activity and inter-hemispheric coherence accompany improved reading capacity following quadrato motor training. *Frontiers in Systems Neuroscience*. 2014;**8**:81. DOI: 10.3389/fnsys.2014.00081
- [171] Lasaponara S, Mauro F, Carducci F, Paoletti P, Tombini M, Quattrocchi CC, et al. Increased alpha band functional connectivity following the quadrato motor training: A longitudinal study. *Frontiers in Human Neuroscience*. 2017;**11**:282
- [172] Ben-Soussan T, Glicksohn J, Goldstein A, Berkovich-Ohana A, Donchin O. Into the square and out of the box: The effects of quadrato motor training on creativity and alpha coherence. *PLoS One*. 2013;**8**:e55023
- [173] Ben-Soussan TD, Glicksohn J, Ohana AB, Donchin O, Goldstein A. Step in time: Changes in EEG coherence during a time estimation task following quadrato motor training. In: *Proceedings of the 27th Annual Meeting of the International Society for Psychophysics*; 24-27 October 2011; Herzliya, Israel. Vol. 27. pp. 239-244
- [174] Engel AK, Fries P. Neuronal oscillations, coherence, and consciousness. In: Laureys S, Gosseries O, Tononi G, editors. *The Neurology of Consciousness*. 2nd ed. Amsterdam, The Netherlands: Elsevier; 2016. pp. 49-60
- [175] Sauseng P, Klimesch W, Schabus M, Doppelmayr M. Fronto-parietal EEG coherence in theta and upper alpha reflect central executive functions of working memory. *International Journal of Psychophysiology*. 2005;**57**:97-103
- [176] Travis F, Tecce J, Arenander A, Wallace RK. Patterns of EEG coherence, power, and contingent negative variation characterize the integration of transcendental and waking states. *Biological Psychology*. 2002;**61**:293-319
- [177] Bennett IJ, Motes MA, Rao NK, Rypma B. White matter tract integrity predicts visual search performance in

- young and older adults. *Neurobiology of Aging*. 2012;**33**(2):433-e21
- [178] Pan W, Zhang L, Xia Y. The difference in EEG theta waves between concentrative and non-concentrative qigong states—A power spectrum and topographic mapping study. *Journal of Traditional Chinese Medicine*. 1994;**14**(3):212-218
- [179] Field T, Diego M, Hernandez-Reif M. Tai chi/yoga effects on anxiety, heart rate, EEG and math computations. *Complementary Therapies in Clinical Practice*. 2010;**16**(4):235-238
- [180] Liu Y, Mimura K, Wang L, Ikuda K. Physiological benefits of 24-style Taijiquan exercise in middle-aged women. *Journal of Physiological Anthropology and Applied Human Science*. 2003;**22**:219-225. DOI: 10.2114/jpa.22.219
- [181] Ambrose KR, Yvonne MG. Physical exercise as non-pharmacological treatment of chronic pain: Why and when. *Best Practice & Research. Clinical Rheumatology*. 2015;**29**(1):120-130
- [182] Peng PWH. Tai chi and chronic pain. *Regional Anesthesia and Pain Medicine*. 2012;**37**:372-382
- [183] Farb NA, Desormeau PA, Dinh-Williams LA. The neuroscience of hypo-egoic processes. In: *The Oxford Handbook of Hypo-egoic Phenomena*. 2016. pp. 109-131
- [184] Llinás RR. *I of the Vortex: From Neurons to Self*. Cambridge, Massachusetts, London, England: MIT Press; 2002. p. 320
- [185] Pesce C, Ben-Soussan TD. “Cogito ergo sum” or “ambulo ergo sum”? New perspectives in developmental exercise and cognition research. In: McMorris T, editor. *Exercise-Cognition Interaction: Neuroscience Perspectives*. Elsevier Academic Press; 2016. pp. 251-282. DOI: 10.1016/B978-0-12-800778-5.00012-8
- [186] Chiesa A. The difficulty of defining mindfulness: Current thought and critical issues. *Mindfulness*. 2013;**4**(3):255-268
- [187] Lutz A, Jha AP, Dunne JD, Saron CD. Investigating the phenomenological matrix of mindfulness-related practices from a neurocognitive perspective. *The American Psychologist*. 2015;**70**(7):632
- [188] Dienes Z, Lush P, Semmens-Wheeler R, Parkinson J, Scott R, Naish P. Hypnosis as self-deception; meditation as self-insight. In: *Hypnosis and Meditation: Toward an Integrative Science of Conscious Planes*. Oxford, United Kingdom: Oxford University Press; 2016. pp. 107-128
- [189] Kirsch I. The social learning theory of hypnosis. In: Lynn SJ, Rhue JW, editors. *Theories of Hypnosis: Current Models and Perspectives*. New York: Guildford Press; 1991. pp. 439-466
- [190] Babiloni C, Vecchio F, Bares M, Brazdil M, Nestrasil I, Eusebi F, et al. Functional coupling between anterior prefrontal cortex (BA10) and hand muscle contraction during intentional and imitative motor acts. *NeuroImage*. 2008;**39**(3):1314-1323
- [191] Mölle M, Marshall L, Gais S, Born J. Grouping of spindle activity during slow oscillations in human non-rapid eye movement sleep. *The Journal of Neuroscience*. 2002;**22**(24):10941-10947
- [192] Hilgard ER, Hilgard JR. *Hypnosis in the Relief of Pain*. New York, London: Routledge; 2013. p. 312
- [193] Rissacher D, Dowman R, Schuckers SAC. Identifying frequency-domain features for an EEG-based pain measurement system. In: *Proceedings*

of 2007 IEEE 33rd Annual Northeast Bioengineering Conference. New York: IEEE; 2007. pp. 114-115

[194] Hsiao FJ, Wang SJ, Lin YY, Fuh JL, Ko YC, Wang PN, et al. Altered insula-default mode network connectivity in fibromyalgia: A resting-state magnetoencephalographic study. *The Journal of Headache and Pain*. 2017;**18**(1):89

[195] Sullivan MJ, Sullivan ME, Adams HM. Stage of chronicity and cognitive correlates of pain-related disability. *Cognitive Behaviour Therapy*. 2002;**31**(3):111-118

[196] Hamilton JP, Furman DJ, Chang C, Thomason ME, Dennis E, Gotlib IH. Default-mode and task-positive network activity in major depressive disorder: Implications for adaptive and maladaptive rumination. *Biological Psychiatry*. 2011;**70**(4):327-333

[197] King AP, Block SR, Sripada RK, Rauch S, Giardino N, Favorite T, et al. Altered default mode network (DMN) resting state functional connectivity following a mindfulness-based exposure therapy for posttraumatic stress disorder (PTSD) in combat veterans of Afghanistan and Iraq. *Depression and Anxiety*. 2016;**33**(4):289-299

[198] Kucyi A, Moayed M, Weissman-Fogel I, Goldberg MB, Freeman BV, Tenenbaum HC, et al. Enhanced medial prefrontal-default mode network functional connectivity in chronic pain and its association with pain rumination. *The Journal of Neuroscience*. 2014;**34**(11):3969-3975

[199] Shim M, Im CH, Lee SH. Disrupted cortical brain network in post-traumatic stress disorder patients: A resting-state electroencephalographic study. *Translational Psychiatry*. 2017;**7**(9):e1231-e1231

[200] Cunningham NR, Kashikar-Zuck S, Coghill RC. Brain mechanisms impacted by psychological therapies for pain: Identifying targets for optimization of treatment effects. *Pain Reports*. 2019;**4**:4

[201] Zeidan F, Grant JA, Brown CA, McHaffie JG, Coghill RC. Mindfulness meditation-related pain relief: Evidence for unique brain mechanisms in the regulation of pain. *Neuroscience Letters*. 2012;**520**(2):165-173

[202] Lutz A, McFarlin DR, Perlman DM, Salomons TV, Davidson RJ. Altered anterior insula activation during anticipation and experience of painful stimuli in expert meditators. *NeuroImage*. 2013;**64**:538-546

[203] Sivertsen M, Normann B. Embodiment and self in reorientation to everyday life following severe traumatic brain injury. *Physiotherapy Theory and Practice*. 2015;**31**(3):153-159

[204] Klemm WR. Neurophysiologic studies of the immobility reflex ("animal hypnosis"). In: *Neurosciences Research*. New York, London: Academic Press; 1971. pp. 165-212

[205] Gallup GG Jr. Animal hypnosis: Factual status of a fictional concept. *Psychological Bulletin*. 1974;**81**(11):836

[206] Braboszcz C, Delorme A. Lost in thoughts: Neural markers of low alertness during mind wandering. *NeuroImage*. 2011;**54**(4):3040-3047

[207] Nash MR, Barnier AJ, editors. *The Oxford Handbook of Hypnosis: Theory, Research, and Practice*. Oxford, United Kingdom: Oxford University Press; 2012. p. 802. DOI: 10.1093/oxfordhob/9780198570097.001.0001

[208] Tart C. *Waking up: Overcoming the obstacles to human potential*. Lucidity Letter. Boston: New Science Library; 1986;**5**(2):307