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Heightened States of Attention: From Mental Performance to Altered States of Consciousness and Contemplative Practices

Mathieu Landry, Amir Raz

Résumé
Alerte mentale : de la performance aux états modifiés de conscience et pratiques contemplatives. Pour certains chercheurs en science cognitive, la notion de vigilance renvoie au concept d'alerte mentale, c'est-à-dire, la capacité d'atteindre et de maintenir un niveau élevé d'attention pour compléter une tâche. Dans cet essai, nous explorons l'influence qu'exerce la vigilance sur la performance, et démontrons comment ces états mentaux d'attention élevée influencent plusieurs processus cérébraux perceptifs, cognitifs et idéomoteurs. Nous montrons également comment certaines conceptions actuelles sur la notion d'alerte mentale instruisent les domaines de recherche portant sur les états altérés de conscience et les pratiques contemplatives. Notre approche repose principalement sur un modèle théorique qui conçoit l'alerte mentale comme un élément central de l'attention. Nous expliquons comment ce cadre de référence fait la distinction entre les habilités mentales permettant d'atteindre un niveau élevé d'attention, et celles permettant de le maintenir. Alors que les premières correspondent principalement à une augmentation transitoire de l'activation nerveuse et de préparation à répondre, nommé l'alerte phasique ; les secondes représentent un profil tonique de l'alerte mentale notamment impliqué dans la régulation et la réactivation endogène des schémas mentaux. Nous détaillons également certaines des caractéristiques comportementales et neurobiologiques associées à ces deux profils, et mettons l'accent sur les recoupements entre le système d'alerte mentale, les processus de l'hypnose et la pratique méditative. Cette synthèse générale de la vigilance humaine ouvre la porte vers de nouvelles pistes de recherche dans ces domaines.

Abstract
Cognitive scientists often view vigilance as a form of alertness – i. e., the ability to attain and maintained attentional focus while accomplishment a task. Here, we explore the ubiquitous influence of alertness on task performance, and demonstrate how these heightened states of attention are core modulators for a widerange of perceptual, cognitive and ideomotor brain processes. Moreover, we will show how current views on alertness may inform the fields of altered states of consciousness and contemplative practices. In this effort, our approach will draw from a prevailing theory that construes alertness as a main component of attention. We will explain how this framework differentiates the abilities required to attain heightened levels of attention from those needed to regulate and maintain that state of alertness. While the former corresponds to the phasic profile of alertness, mainly reflecting transient arousal and response preparation, the latter denotes a tonic profile characterized by the necessity to regulate and reactivate mental sets. We will describe some of the behavioural and neural patterns related to both profiles, and emphasize points of intersections between the alerting system, the process of hypnosis and the practice of meditation. Our essay shall therefore highlight how this overarching synthesis of human vigilance opens novel research avenues for these domains of research.

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Mathieu LANDRY* & Amir RAZ#

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Keywords: Vigilance, attention, alertness, consciousness, hypnosis, meditation.

Résumé. **Alerte mentale : de la performance aux états modifiés de conscience et pratiques contemplatives**. Pour certains chercheurs en science cognitive, la notion de vigilance renvoie au concept d'alerte mentale, c'est-à-dire, la capacité d'atteindre et de maintenir un niveau élevé d'attention pour compléter une tâche. Dans cet essai, nous explorons l'influence qu'exerce la vigilance sur la performance, et démontrons comment ces états mentaux d'attention élevée influencent plusieurs processus cérébraux perceptifs, cognitifs et idéomoteurs. Nous montrons également comment certaines conceptions actuelles sur la notion d'alerte mentale instruisent les domaines de recherche portant sur les états altérés de conscience et les pratiques contemplatives. Notre approche repose principalement sur un modèle théorique qui conçoit l'alerte mentale comme un élément central de l'attention. Nous expliquons comment ce cadre de référence fait la distinction entre les habilités mentales permettant d'atteindre un niveau élevé d'attention, et celles permettant de le maintenir. Alors que les premières correspondent principalement à une augmentation transitoire de l'activation nerveuse et de préparation à répondre, nommé l'alerte phasique ; les secondes représentent un

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profil tonique de l'alerte mentale notamment impliqué dans la régulation et la réactivation endogène des schémas mentaux. Nous détaillons également certaines des caractéristiques comportementales et neurobiologiques associées à ces deux profils, et mettons l'accent sur les recoupements entre le système d'alerte mentale, les processus de l'hypnose et la pratique méditative. Cette synthèse générale de la vigilance humaine ouvre la porte vers de nouvelles pistes de recherche dans ces domaines.

Mots-clés : Vigilance, attention, alerte, conscience, hypnose, méditation.

1 – INTRODUCTION

Many everyday tasks require the constant monitoring of events, such as when one is driving a vehicle and scanning the environment for obstructions (Borghini, Astolfi, Vecchiato, Mattia & Babiloni, 2014). In these mundane contexts, staying focused is often critical for the proper completion of the task, thereby highlighting the pervasive nature of vigilance in task performance (Mackie, 2013). For the past 50 years, researchers interested in uncovering the mechanisms of these heightened states of attention have accordingly turned their focus to the exploration of human performance – a flourishing research program that has improve our global understanding on a broad range of related notions such as arousal, alertness and sustained attention (Oken, Salinsky & Elsas, 2006). In the current essay, we propose to extend this research trajectory and present a general framework that explores how alertness, defined as the ability to achieve and maintain mental states of heightened attention, regulates mental processes involved in altered states of consciousness and contemplative practices. Our proposition draws from a prevailing theory of attention that construes vigilance as a main component of attentional processing (Petersen & Posner, 2012; Posner & Petersen, 1990). We aim to highlight points of intersection between this prevailing view of attention and the (re)emerging sciences of hypnosis and meditation. We will therefore outline some of the attentional intricacies pertaining to altered states of consciousness.

Definitions of vigilance often cluster along two dimensions: A cognitive dimension denoting the ability to remain attentive while performing a task (Parasuraman & Warm, 1998; Posner & Boies, 1971; Robertson & Garavan, 2004; Robertson & O'Connell, 2010), and a clinical dimension mainly referring to a form of aroused and wakeful state at the center of consciousness (Laureys, Owen, & Schiff, 2004; Zeman, 2006). While our framework focuses on the former definition, some crosstalk between these designations is however inevitable. Our overall presentation anchors onto the tripartite theory of attention (Petersen & Posner, 2012; Posner & Petersen, 1990; Raz & Buhle, 2006). At its core, this proposal submits that attention comprises three discrete components: the alerting system, which correspond to the attainment and the maintenance of mental arousal and response preparation; the orienting system, mainly reflecting the attentional ability to prioritize sensory inputs across different modalities; and the executive system, which refers to the supervision and monitoring of attention. This theoretical proposal therefore equates vigilance to alertness and divides it into subcomponents, each reflecting a distinct mode of operation (Posner, 2008). Phasic alertness describes the attainment of an elevated state of mental arousal and response preparation, while tonic alertness refers to the endogenous regulation and reactivation of heightened states of attention. Both of these profiles therefore refer to separate, albeit complementary, roles of the alerting network. Evidence shows that, while the phasic component rests on widespread brainstem-thalamo-cortical networks that thrive on norepinephrine projections radiating from the locus-coeruleus (Aston-Jones & Cohen, 2005; Aston-Jones, Rajkowski & Cohen, 1999; Aston-Jones & Waterhouse, 2016), tonic alertness mainly follows from increased cholinergic activity that enhances global activity in the frontal brain (Hasselmo & Sarter, 2011; Kozak, Bruno & Sarter, 2006; Sarter, Givens & Bruno, 2001; Sarter, Hasselmo, Bruno & Givens, 2005). Phasic and tonic alertness are therefore differentiated at the functional and neuronal levels, thus refining our general appraisal of alertness. Distinguishing these profiles of alertness accordingly provides a compelling framework to explore phenomena pertaining to human vigilance in a more fine-grained manner. We shall broaden the scope of this framework to incorporate the contribution of the alerting system to include altered states of consciousness and contemplative practices (Markovic & Thompson, 2016).

2 – A Neurocognitive Framework for Phasic and Tonic Alertness

2.1 - Phasic Alertness

In the lab, scientists often operationalize phasic alertness by gauging the effects of warning signals preceding the presentation of target-events. These effects typically include transient increases in mental arousal and response preparation, which in turn benefit task performance (see *Figure 1*; Posner & Boies, 1971; Posner & Snyder, 1975; Thomaschke, Wagener, Kiesel & Hoffmann, 2011; Weinbach & Henik, 2012b). Studies have outlined the underlying components to this psychological effect: A bottom-up reaction reflecting a boost in mental arousal following the presentation of a salient and novel sensory event, and a top-down response corresponding to the orientation of attentional resources along the temporal dimension as a function of the information conveyed by the signal (Weinbach & Henik, 2012b). Phasic alertness therefore mainly results from translating the onset of a signal into rapid arousal and momentous stimulus-response preparation. However, teasing apart these components has challenged researchers, as both yield similar patterns of response at the behavioral and neural levels (Bockler, Alpay & Sturmer, 2011; Correa, Lupiáñez, Madrid & Tudela, 2006; Correa, Lupiáñez & Tudela, 2005; Correa, Sanabria, Spence, Tudela & Lupiáñez, 2006; Coull, Nobre & Frith, 2001; Kusnir, Chica, Mitsumasu & Bartolomeo, 2011; Lange, Krämer & Röder, 2006; Matthias *et al*., 2010; Rolke, 2008; Rolke & Hofmann, 2007; Seibold, Bausenhart, Rolke, Ulrich, 2011; Weinbach & Henik, 2011). Bottom-up and top-down alerting modulate several mental processes across the perceptual, cognitive and ideomotor domains, thus featuring the influence of the alerting system beyond late motoric response systems and into early stages of sensory processing (Correa, Lupiáñez *et al*., 2006; Hackley & Valle-Inclán, 1998). One methodological approach impedes top-down control by rendering the warning cue genuinely unpredictable of the target onset, thereby isolating the effects of bottom-up alertness in the absence of top-down confounds (Correa, Lupiáñez, *et al*., 2006; Hackley & Valle-Inclán, 1998). This research strategy therefore unveils the effects of bottom-up processes on task performance and further corroborates the involvement of early stages of processing during the phasic response (Thomaschke *et al*., 2011). Other reports have revealed interactions between bottom-up and top-down alerting processes (*e.g.*, Lawrence & Klein, 2013), thereby featuring some form of combined benefits on sensory processing and showing how both types of process contribute to the overall effect of phasic alertness.

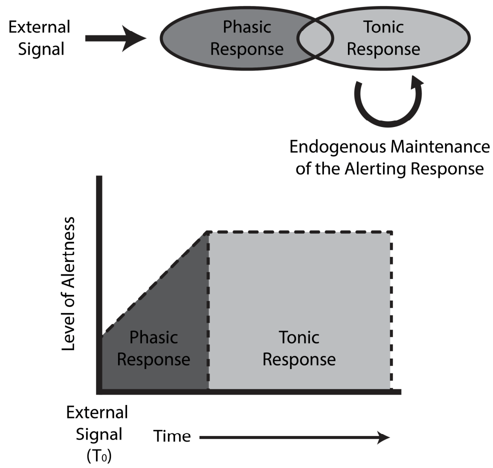

Figure 1
External signal triggers a phasic response of alertness, translating into a tonic response when the alerting response is maintained across time

Evidence also highlights how phasic alertness modulates higher-order cognition, thereby exposing its wide-ranging influence beyond low-level processes (Callejas, Lupianez, Funes & Tudela, 2005; Chica, Bayle, Botta, Bartolomeo & Paz-Alonso, 2016; Chica *et al*., 2012; Costa, Hernández & Sebastián-Gallés, 2008; Dye, Baril & Bavelier, 2007; Fan *et al*., 2009; Fan, McCandliss, Sommer, Raz & Posner, 2002; Fischer, Plessow, Kiesel, 2010; Ishigami & Klein, 2009, 2010; Kusnir *et al*., 2011; MacLeod *et al*., 2010; McConnell & Shore, 2011; Redick & Engle, 2006; Roberts, Summerfield & Hall, 2006; Weinbach & Henik, 2011, 2012a, 2013; Weinbach, Kalanthroff, Avnit & Henik, 2015). This body of findings notably feature interactions between the alerting and executive networks, wherein transient mental arousal and response preparation modulate the selection of relevant sensorimotor information and the inhibition of irrelevant ones (Finke *et al*., 2012; Matthias *et al*., 2010; Nieuwenhuis & de Kleijn, 2013; Thiel, Zilles & Fink, 2004; Weinbach & Henik, 2012a). Evidence suggests that these effects follow from the enhancement of salient and relevant sensory information (Weinbach *et al*., 2015). Because executive functions are central to regulation processes and cognitive control (Hofmann, Schmeichel & Baddeley, 2012), and top-down regulation plays a key role in sustaining the alerting response (Shallice, Stuss, Alexander, Picton & Derkzen, 2008), interactions between the alerting and executive networks submit the possibility that the former may exert some form of indirect influence over top-down regulatory processes via the latter, thus bolstering the maintenance of heightened states of attention. This perspective thereby indexes the transition from phasic to tonic alertness. Additional investigations shall explore this hypothesis.

2.1 - From Phasic to Tonic Alertness

Once achieved, maintaining this heightened state of attention often proves challenging whenever one is completing a dull and unengaging task (Robertson & Garavan, 2004; Robertson & O'Connell, 2010). Ample evidence stresses the difficulty of upholding attention for an extended period of time while battling mental boredom (Kahneman, 1973; Mackworth, 1968; Mackworth, 1950; Robertson & O'Connell, 2010; Warm, 1984). Reasons explaining attentional failures over time remain however unclear. Whereas some researchers claim that reduction in tonic alertness mainly follows from the depletion of attentional resources (*e.g*., Warm, Dember & Hancock, 1996), others advocate that this phenomenon results from the tediousness nature of certain tasks which prompts the disengagement and displacement of attentional resources from external events towards internal ones (Robertson, Manly, Andrade, Baddeley & Yiend, 1997; Smallwood & Schooler, 2006, 2015). In this fashion, the former view postulates that intense mental workload causes drops in task performance, thereby promoting the idea that tonic alertness possesses limited resources. According to this framework, the constant monitoring of task-related attentional requirements is quite demanding and involves substantial mental efforts during vigilance tasks (Caggiano & Parasuraman, 2004; Helton & Russell, 2011a, 2011b, 2013; Smit, Eling & Coenen, 2004; Warm, Parasuraman & Matthews, 2008). Supporting this construal, individuals often report greater mental fatigue after completing these sorts of assignments (Grier *et al*., 2003; Szalma *et al*., 2004). Conversely, other researchers have challenged the resource depletion account by stressing the importance of factors other than resource availability, such as task engagement (Cheyne, Solman, Carriere & Smilek, 2009; Pattyn, Neyt, Henderickx & Soetens, 2008; Scerbo, 1998; Smallwood *et a*l., 2004). This alternative view focuses instead on the notion of under-stimulation. This divergent perspective therefore submit the idea that, as time passes, rising monotony increases tendencies to disengage from the task, wherein individuals simply start performing the task in a "mindless" or "absentmindedness" manner (Smallwood & Schooler, 2006). Instead of investing their mental resources into task performance, individuals therefore engage into mind-wandering, a form of automatic self-referential mode of thinking (Smallwood & Schooler, 2006). In these situations, attention resources are veered from the task-at-hand towards this latter form of mental activity. As predicted by this model, battling under-arousal with greater task engagement reduces attentional withdrawal and overall performance decrement (Pop, Stearman, Kazi & Durso, 2012). Beyond these theoretical quarrels, both accounts emphasize the importance of tonic alertness to monitor and regulate attention processes in order to maintain the attentional focus on the task (Shallice *et al*., 2008; Stuss, Shallice, Alexander & Picton, 1995). This common ground between these opposing views underlines the centrality of regulatory processes and attentional resources to maintain task-relevant mental processes active while keeping task-irrelevant thoughts at bay (Thomson, Besner & Smilek, 2015).

Brain lesions and neuroimaging findings intimate that tonic alertness relates to an extensive right-lateralized network comprising the frontal, insular, cingulate and parietal cortices (for review, see Langner & Eickhoff, 2013). Consistent with the idea that upholding heightened levels of attention relies on control and regulation processes, previous findings link these cortical regions to higher-order cognitive functions such as executive (Dosenbach, Fair, Cohen, Schlaggar & Petersen, 2008; Dosenbach *et al*., 2006; Tolomeo *et al*., 2016), orienting (Chica, Bartolomeo & Lupiáñez, 2013; Corbetta, Patel & Shulman, 2008), and monitoring systems (Menon & Uddin, 2010; Shenhav, Botvinick & Cohen, 2013). This extended network likely encompasses neurocognitive systems implicated in the supervision and maintenance of mental sets for facilitating the processing of task-contingent events (Langner & Eickhoff, 2013). Following earlier models of vigilance (Stuss *et al*., 1995), this proposal liken tonic alertness to a top-down supervisory-attention system involved in the allocation of cognitive resources. In particular, this model emphasizes the role of two critical neurocognitive systems: The anterior mid-cingulate and mid-lateral prefrontal cortices involved in conveying information about task-relevancy, maintaining task schemas and monitoring outcomes; and the anterior insula involved in task-sets activation and efforts signalling (see *Figure 2*). While proponents of this model call upon various findings to support these claims, their proposal remains debatable in some respects. Namely, the functional roles of certain neural regions featured in their model remain disputed and difficult to ascertain. For example, the role of cingulate area remains highly debated amongst neuroscientists (*e.g*., Kolling, Behrens, Wittmann & Rushworth, 2016). Hence, while this neurocognitive model provides a testable framework, future empirical investigations are needed to elucidate the functional components of tonic alertness. Nevertheless, converging evidence exhibit the importance of top-down regulation and monitoring processes for maintaining mental sets active and inhibiting extraneous mental events while keeping attention on task. We shall underline the importance of these mental processes in hypnosis and meditation.

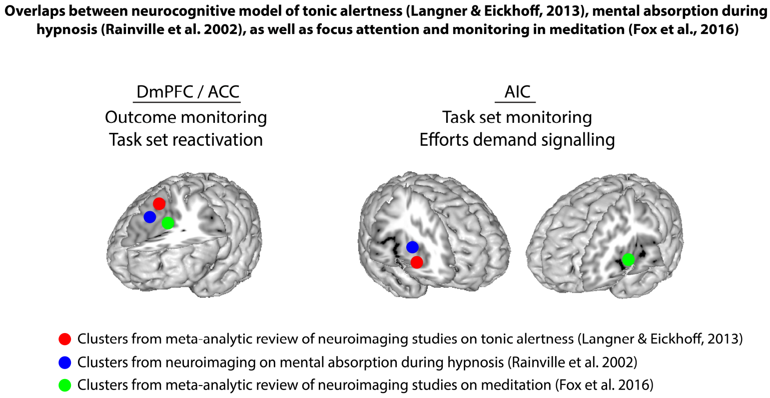

Figure 2
Overlaps of brain regions associated with the neurocognitive model of tonic alertness posited by Langner & Eickhoff (2013), with mental absorption during hypnosis, with focused attention and monitoring in meditation. ACC = Anterior Cingulate Cortex. DmPFC = Dorsomedial Prefrontal Cortex. AIC = Anterior Insular Cortex).

An important neuroimaging discovery concerning the neural mechanisms of tonic alertness associate episodes of mind-wandering (i.e., attentional failures) with activity in the default network of the brain (e.g., Mason et al., 2007): a widespread intrinsic neural system comprising several bilateral neural regions, such as the medial prefrontal, the medial and lateral parietal, and medial temporal cortices (Buckner, Andrews-Anna & Schacter, 2008; Raichle, 2015; Raichle *et al*., 2001; Raichle & Snyder, 2007). Consistent with the idea that mind-wandering follows from perceptual decoupling from the environment, neuroscientists found anti-phasic patterns of activity between the default- and the dorsal attentional networks (see *Figure 3*; Fox *et al*., 2005). Some researchers advance the idea that these binary neural dynamics underlie on- and off-task mental activities, which implies incessant competitions between task-relevant and task-irrelevant neural processes for the control of the “mind’s eye” (Fox *et al*., 2005). Yet, grasping the functional role of these brain dynamics may prove more challenging than this coarse appraisal (Margulies *et al*., 2016). Nonetheless, at the behavioural level, anti-correlated patterns between the default and attention networks may correspond with inherent difficulties for individuals to stay focus and on-task, since circumstances of under-arousal putatively favour default network activity and therefore trigger episodes of mind-wandering. Taking into account the aforementioned findings, this critical piece of evidence purports that neural patterns associated with tonic alertness continually compete in a discrete fashion with a network often linked with off-task mental states, and that this competition may determine the ability to stay focused on the task-at-hand (Barron, Riby, Greer & Smallwood, 2011; Braboszcz & Delorme, 2011).

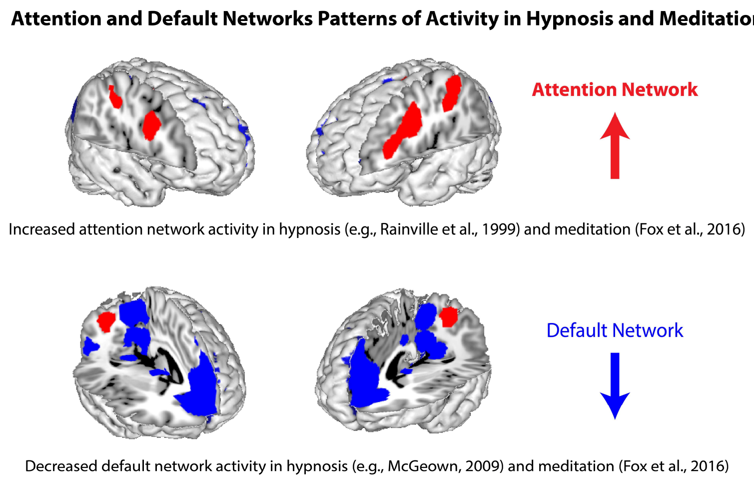

Figure 3
Neuroimaging studies of hypnosis and meditation report increased activity in the attention and decreased activity in the default networks (McGeown *et al*., 2009; Deeley *et al*., 2012; Fox *et al*., 2016)

3 – Alertness Alters Planes of Consciousness

We have highlighted how attaining (*i.e*., phasic response) and maintaining (*i.e*., tonic alertness) heightened states of attention modulate task performance and higher-order cognition, and described some of the neural patterns subserving these effects. We will now turn to the pervasive influence of the alerting system onto altered states of consciousness and contemplative practices. What is the relationship between alertness and these forms of mental practices? Often framed as self-regulation and relaxation practices, hypnosis and medication intersect at various phenomenological, cognitive and neural levels (Raz & Lifshitz, 2016). Paradoxically, despite being considered efficient means for inducing deep states of mental and physical relaxation, we will show how maintaining high levels of alertness is critical for both. In this fashion, phasic and tonic alertness are central to hypnosis and meditation. We will accordingly show how the framework we previously outlined informs current views on altered states of consciousness and contemplative practices. We hope to shed light on some of their attentional components and address some of their theoretical shortcomings. In particular, several theorists of hypnosis and meditation tend to construe attention as a unitary process, when in fact attention draws from multiple brain systems (Fan *et al*., 2002). By sketching a general framework linking alertness to altered states of consciousness, we aim to tackle this limitation and highlight some of the attentional intricacies underlying hypnotic phenomena and meditation practices.

3.1 - Alerting enable mental absorption in hypnosis

Definitions of hypnosis generally refer to a collection of psychological phenomena centered on the production of behavioural and mental responses for modifying perceptions, thoughts, actions and emotions (Nash & Barnier, 2008;

Yapko, 2015). During this process, individuals undergoing hypnosis typically go through an induction phase intended to promote mental absorption and increased susceptibility to hypnotic suggestions, and a suggestion phase where instructions promote the production of specific mental or behavioural responses (Maldonado & Spiegel, 2008). A wide-range of findings foster the idea that top-down cognitive processes represent core vehicles to the experience of hypnosis (Crawford, 1994; Dienes, 2012; Egner & Raz, 2007; Gruzelier, 1998, 2006; Raz, 2011). According to this view, attention, executive functions and monitoring systems putatively afford individuals the cognitive means to focus their mental efforts towards generating a reliable hypnotic response. This process comprises attending to the suggestion, implementing a reliable mental strategy, and regulating their responses. The implication of higher-order cognition is accordingly critical across these various stages.

While hypnosis causes observable changes in behaviour, a broad collection of hypnotic phenomena only surfaces at the subjective level, coercing researchers into adopting a combination of first- and third person approaches to explore hypnotic phenomena (Cardeña, 2014; Cardeña, Jönsson, Terhune & Marcusson-Clavertz, 2013; Lifshitz, Cusumano & Raz, 2013). Adopting this strategy, studies show that highly hypnotic susceptible individuals experience greater phenomenological variations during the hypnotic trance (Pekala & Kumar, 2007; Terhune & Cardeña, 2010). These subjective changes often include deepening feelings of mental absorption, wherein individuals immerse themselves in the hypnotic experience at the expense of extraneous environmental and contextual information (Maldonado & Spiegel, 2008; Tellegen & Atkinson, 1974). This feeling of mental absorption mainly reflects individuals' propensity to increase and maintain their attentional focus on the hypnotic instructions in parallel to their changing subjective experience (Terhune & Cardeña, 2016). Some findings intimate that this sort of immersion facilitates response preparation and increases hypnotic suggestibility (Brown, Antonova, Langley & Oakley, 2001; howeser, see Lynn, Kirsch & Hallquist, 2008).

Individuals undergoing hypnosis therefore become highly focused on complying with the directives of the operator while experiencing a deep feeling of mental absorption. The alerting system enables individuals to sustain this heightened state of attention throughout the process of hypnosis. Drawing from the neurocognitive framework of alertness we previously outlined, we contend that the alerting system represents a cornerstone for fostering these global changes in attention during hypnosis. In particular, the ability to attain and maintain this heightened state of attention is largely consistent with the functional roles of phasic and tonic alertness. Various contextual and operational factors, including the instructions from the operator, likely act as forceful signals for triggering a phasic response, which in turn, bolsters the attentional focus. Supporting this idea, response preparation – a central aspect of phasic alertness – represents a key element in the production of a reliable hypnotic response (Lynn, Kirsch & Hallquist, 2008). According to socio-cognitive theorists of hypnosis, expectancy for change in subjective experience, implemented via situational cues that likely elicit phasic alertness, is a core component to the reliable production of a hypnotic response (Kirsch, 1985, 1997; Kirsch, Wickless & Moffitt, 1999; Silva & Kirsch, 1992; Wickless & Kirsch, 1989). This construal capitalizes on the idea that, once formed, response sets can produce a wide-range of automatic and unconscious responses (Kirsch & Lynn, 1997, 1998). For example, the suggestion for arm levitation may trigger the feeling that the arm rises by itself based on automatic responses and anticipation for this specific kind of subjective experience. In this fashion, expectations are considered essential for yielding a reliable response and generating corresponding subjective feelings.

The deepening and upholding of mental absorption likely rests on the constant reactivation of mental sets via tonic alertness. The rationale here is straightforward, as the absence of tonic alertness would merely impedes individuals' abilities to maintain attentional focus throughout the hypnotic procedure. Evidence supports this construal. In particular, neuroimaging findings relate feelings of mental absorption to a frontoparietal attention network that overlaps with regions pertaining to tonic alertness (see *Figure 2*; Rainville, Hofbauer, Bushnell, Duncan & Price, 2002). These overlapping regions include the anterior insular and cingulate cortices, two regions we previously associated with the supervision and maintenance of mental sets during high tonic alertness. This result supports our view that hypnosis draws from mental processes that enable the maintenance of attentional focus in the same fashion that tonic alertness benefits task performance. Neurophysiological evidence further emphasizes this point by showing increased oscillatory patterns related to focused attention during the hypnotic procedure (Jensen, Adachi & Hakimian, 2015). Furthermore, a body of neuroimaging findings also link hypnosis to reduced default network activity (see *Figure 3*), thereby providing indirect evidence in support of our claim that hypnosis reflect task engagement, as opposed to mind-wandering (Deeley *et al*., 2012; Demertzi *et al*., 2011; McGeown, Mazzoni, Venneri & Kirsch, 2009). Together, these findings capture some of the critical features of hypnosis, whereby hypnotized individual often report concurrent feelings of relaxation and effortlessness, while remaining intensely focused on producing the hypnotic response. They additionally promote that these mental states of "effortlessness mental absorption" lessens episodes of mind-wandering, wherein the process of hypnosis putatively bolster tonic alertness, which in turn suppresses task-irrelevant spontaneous thinking (Lynn, Laurence & Kirsch, 2015). Altogether, this body of evidence uncover the centrality of phasic and tonic alertness – i.e., the attainment and maintenance of this heightened state of mental absorption – for the process of hypnosis.

3.2 - Meditation and alertness

Contemplative practices refer to a broad family of mental exercises geared towards attentional and emotional regulation in hope of achieving various goals, ranging from relaxation and well-being to spiritual enlightenment (Coleman, 2002; Lutz, Dunne & Davidson, 2007). While governing principles vary across meditative practices, many such practices either invite practitioners to focus their attention on specific mental objects (*e.g*., breath sensations), or promote a form of non-judgmental monitoring of present-moment mental events (Lutz, Slagter, Dunne & Davidson, 2008). These approaches mainly attempt to guide individuals into increasing their awareness of irrelevant spontaneous thoughts, disengage from them, and shift their attention back onto their prime target. In this fashion, with proper teaching and training, meditators become adept at monitoring and suppressing episodes of mind-wandering (Mrazek, Smallwood & Schooler, 2012). This prospective outcome explains why many psychologists consider certain forms of contemplatives practices as valuable means to train individuals into overcoming harmful habitual modes of thinking (Slagter, Davidson & Lutz, 2011; Tang & Posner, 2009). In this regard, mindfulness-based meditation is widely considered a valuable technique in the therapeutic armamentarium (Khoury *et al*., 2013).

Neuroimaging confirms the efficacy of such practices at empowering attention to override mind-wandering by revealing decreased default network activity in experienced meditators, as well as greater activity and connectivity patterns for regions implicated in cognitive control and monitoring (Brewer *et al*., 2011; Hasenkamp, Wilson-Mendenhall, Duncan & Barsalou, 2012). A recent meta-analysis of neuroimaging studies further establishes that styles of meditation based on attentional focus and monitoring engages brain regions implicated in attentional control, executive function and cognitive monitoring, such as the dorsolateral prefrontal, premotor and dorsal anterior cingulate cortices, supplementary motor area, as well inferior and rostrolateral frontal gyri (Fox *et al*., 2016) . These findings confirm the involvement of higher-order neurocognitive processes in meditation. Specifically, authors from this meta-analytic essay link these neural patterns to a various higher-order cognitive functions, such as interoceptive awareness and detection of salient events, working memory and mental object manipulation, regulation and monitoring processes. Combined with results showing decreased default network activity, these results show that, just as for hypnosis, brain patterns related to meditation comprise regions likewise related to tonic alertness (see *Figure 2*). The same rationale relating alertness to hypnosis therefore applies for meditation; we argue that maintaining the attentional focus on a mental object during meditative practices rests on the endogenous reactivation of mental sets via tonic alertness. In this regard, many forms of meditation putatively rely on the ability to sustain, control and monitor attentional processes (Malinowski, 2013). Thus, tonic alertness represents a core component of meditative practices, as maintaining a high level of arousal is pivotal for efficient attentional and emotional regulation (Cahn & Polich, 2006; Lutz *et al*., 2007). Both focused attention and monitoring styles of meditation clearly draws from tonic resources, as these forms of meditation rests on attending pre-specified mental objects and monitoring mental events, while staying watchful of mental distractions (Lutz *et al*., 2008). Moreover, mounting evidence shows the enduring impact of meditative training on vigilance and attentional flexibility, as individuals become better at monitoring their own attentional states and avoiding the displacements of attention towards task-irrelevant perceptual or cognitive events (MacLean *et al*., 2010; Mrazek, Franklin, Phillips, Baird & Schooler, 2013; Pagnoni & Cekic, 2007; Slagter *et al*., 2007; Slagter, Lutz, Greischar, Nieuwenhuis & Davidson, 2009; Valentine & Sweet, 1999). This type of mental training therefore promote the idea that tonic alertness resources are flexible (Tang & Posner, 2009). In regards to our previous discussion about the current views on attentional failures, these findings either entails that mental practice increases overall regulation resources, as per the resources depletion account, or that training benefits their flexible monitoring and management, as predicted by the under-arousal view. Regardless of both viewpoints, findings emphasize how improvements primarily emerge at the level of tonic alertness, as showcased by the reduction in episodes of mind-wandering following mindfulness training, thereby revealing the plasticity of this attention system (Mrazek *et al*., 2013). Some gains also transpire for the executive network, reflected by improved selection of relevant sensorimotor information and inhibition of irrelevant one *(Tang et al*., 2007). Overall, this nascent research domain highlights the possibility to improve tonic alertness capacities, leading to psychological benefits that translate into better mundane task performance and overall well-being.

Further evidence also hints to the fact that meditation improves the management of top-down anticipatory resources, a relevant aspect to phasic alertness. One notorious example notably shows how meditative practices improve the flexible allocation of attention in the attentional blink paradigm. In this experimental approach, researchers typically embed two targets in a rapid stream of visual stimuli. Whenever the second target appears within a critical refractory period relative to the first one and participants attend to both target events, their performance and conscious report of the second target greatly decreases (Raymond, Shapiro & Arnell, 1992; Sergent, Baillet, & Dehaene, 2005; Shapiro, Raymond & Arnell, 1997). Some have argued that this decline follows from some type of temporal bottleneck in attentional processing, whereby attending to the first event prevents the deployment of attentional resources to the second one *(e.g*., Chun & Potter, 1995). Using this experimental strategy as a mean to investigate the effects of mindfulness meditation on attention, a research group found that rigorous practice allows practitioners to eventually overcome such limitations by reliably extending their attentional resources across both target events, instead of solely focusing on the first one (Slagter *et al*., 2007; Slagter *et al*., 2009). Thus, individuals become better at planning and managing their attentional focus. Practitioners therefore become more proficient at allocating their attention in an effortless manner (Wallace, 2006).

Overall, these overarching findings demonstrate how contemplative practices rely on the alerting system to monitor and maintain attentional resources active. These mental practices largely draw from the endogenous regulation and reactivation of mental sets. Moreover, they highlight the inherent plasticity of the alerting system.

4 – CONCLUSION

Due to its pervasive nature, vigilance has been the subject of considerable study; researchers have scrutinized the notion of vigilance from different angles across multiple domains of enquiry. Few, however, have attempted to link this body of work into an overarching synthesis. Relying on a prevalent framework pertaining to the cognitive neuroscience of attention, we herein demonstrate how vigilance represents a core modulator of human cognition and consciousness. We explain how phasic and tonic alertness provide the conceptual means to understand the effects of vigilance on human performance, while connecting this research to the sciences of hypnosis and meditation. Critically, we show how the effects of alertness, which largely originate from sub-cortical brain structures concerning arousal, go beyond task performance and extend to the realm of alerted consciousness and contemplative practices. Accordingly, we consider phasic and tonic alertness as core constructs of human performance and experience. We hope that our account fuels future investigations to explore further intersections across the multiple domains of vigilance.

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