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Brain patterns of Self-awareness

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What is the nature of self awareness? The Oxford English Dictionary (OED) indicates that there are two modes of self-awareness: awareness with and awareness without content. The distinction is evident among the list of six definitions of self-awareness. The first five involve the process of experience: (1) interpersonal cognitive relations, (2) remembering on a first-hand basis one's past actions or experiences, (3) awareness of any object; (4) immediate awareness of one's mental processes, and (5) the totality of mental experiences that constitute our conscious being. Consistent with most chapters in this book, self-awareness thus refers to the content of conscious experience. The sixth definition in the OED offers a broader sense of self-awareness: (6) the general mode of awareness that is distinct from the content that makes up the stream of consciousness.

We suggest that this last definition of self-awareness—as awareness distinct from the content that makes up the stream of consciousness—may be the 'ground' of all experiences of self-awareness. As the ground of experience, we suggest that this putative foundational level of self-awareness needs to be appreciated to fully understand both so-called normal as well as dysfunctional modes of self-awareness, as presented in other chapters in this book. Thus, this chapter serves to introduce the concept of a foundational state of self-awareness, which is both independent of and the source of conscious experiences. This chapter also explores brain states that may differentiate the foundational state of self-awareness from its derivative, diverse modes represented by the major states of consciousness—waking, dreaming and sleeping—as well as the various types of waking self-reflective awareness related to body and environmental awareness.

The prevailing Western view is that an individual cannot be conscious without particular contents in consciousness (Natsoulas, 1997), that one cannot be aware without being aware of *something*. In this paradigm, no subjective state can be its own *object* of experience (James 1902/1961). In contrast, the subjective traditions of the East—the Vedic tradition of India (Maharishi, 1967), and the Buddhist traditions of China (Chung-Yuan, 1969) and Japan (Reps, 1955)—include formalized meditation techniques intended to lead to the direct experience of a state of "pure self-awareness" or "pure consciousness"—a foundational state of consciousness devoid of mental content. For instance, the *Maitri Upanishad* (Maitri Upanishad 6:19, in Upanishads, 1953) states:

> When a wise man has withdrawn his mind from all things without, and when his spirit of life has peacefully left inner sensations, let him rest in peace, free from the movements of will and desire…. Let the spirit of life surrender itself into what is called *turya*, the fourth condition of consciousness. For it has been said: There is

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> something beyond our mind which abides in silence within our mind. It is the supreme mystery beyond thought. Let one's mind…rest upon that and not rest on anything else.

Maharishi Mahesh Yogi (1967), responsible for bringing the Transcendental Meditation technique to the West from the Vedic tradition of India, explains:

> When consciousness is flowing out into the field of thoughts and activity it identifies itself with many things, and this is how experience takes place. Consciousness coming back onto itself gains an integrated state.... This is pure consciousness.

Pure consciousness is "pure" in the sense that it is free from the processes and contents of knowing. It is a state of "consciousness" in that the individual or knower is fully aware or conscious, and can afterwards describe the experience. The "content" of pure consciousness is awareness itself. In contrast, the content of normal waking experiences is awareness of outer objects, inner thoughts and feelings along with a sense of self-awareness.

Pure consciousness can be a direct experience during some systematic meditation practices (Maharishi 1967). This chapter places pure consciousness, experienced during TM practice, in the context of the three ordinary states of consciousness—waking, sleeping and dreaming. These four states are differentiated in terms of the presence/absence of the two key modes of experience: experience of self and experience of objects.

States of consciousness categorized by experience of self and/or of objects are presented in Table 1. For instance, during deep sleep, neither self nor objects exist. During a good night's sleep, there is no experience from falling asleep to waking up. During dreaming, illusory dream images fill awareness. However, the conscious experience of the self who is having the experience is largely absent. During waking experiences, both self-awareness and objects exist and interact to give rise to ongoing experiences. Lastly, meditation practices are reported to produce the state of the self alone, without the cognitive activity of thoughts, perceptions, and feelings. When self-awareness no longer occurs in relation to the boundaries of experience, it is reported as complete silence, as being unbounded. This level of experience is often written with a capital "S"—"Self"— to differentiate it from the experience of self-awareness identified with ongoing experiences, thoughts and actions. As the predominance of self-awareness and/or objects so vary, so brain activation patterns underlying these modes of self-awareness also change. This chapter reviews the literature on each of these four major states of consciousness and identifies brain areas activated and de-activated during each state.

State of consciousness	Self	Objects
Sleep	No	No
Dreaming	No	Yes

Waking	Yes	Yes
Pure Consciousness	Yes	No

Table1: Self and Objects in Each State of Consciousness. An heuristic classification for organizing a review of the literature.

Sleep state: Self and Objects Cease to Be

The dance of perceptual and motor systems during waking changes abruptly with the onset of sleep. Sleep progresses through four stages, each marked by distinct EEG patterns. Stage 1 sleep involves the gradual sliding in and out of awareness. Stage 2 sleep, with its characteristic sleep spindles, is the mark of sleep onset. Stage 3 and 4 sleep are marked by high amplitude, slow (1-3 Hz) synchronized EEG. Delta sleep is homeostatically driven (Feinberg 1999; Feinberg 2000) and is reported to be important for restoring frontal executive functions during waking (Anderson and Horne 2003).

EEG patterns that characterize waking and sleeping are generated in the thalamus and the cortex, regions linked by reciprocal projections. The thalamus is the major gateway and integrator for sensory and arousal information to enter the cortex, and thus is the first stage that is blocked with sleep onset (Steriade 2001). Sleep onset, marked by the occurrence of sleep spindles (12-15 Hz), is associated with the absence of perception and self-awareness. During Stage 2 sleep, Sleep spindles are generated within the thalamus (Steriade 2003) as a result of rhythmic and prolonged bursts of the GABAnergic nucleus reticularis thalamic (NRT) neurons (Steriade, McCormick et al. 1993; Steriade 2001). The NRT receives axonal collaterals from both thalamic neurons that project to the cortex and cortical neurons that project to the thalamus. In turn, the NRT projects its axons into the thalamic nuclei, exerting a variety of possible influences over thalamocortical activity. Thus, the NRT is uniquely positioned to influence the flow of information between the cortex and thalamus and exert phasic and tonic control over the mode of thalamic cell activity. The figure below depicts the central position that the NRT plays in guiding traffic in thalamocortical circuits: serving as a fundamental gating mechanism for thalamocortical dynamics and, therefore, subjective experience.

Figure 1 about here

While Stage 2 sleep is nominally the mark of sleep onset and loss of awareness, 45% of individuals report 'being awake' when they are aroused from EEG-defined Stage 2 sleep (Sewitch 1984). Thus, self-awareness is still intact in many individuals during Stage 2 sleep. As sleep deepens into Stage 3 and 4 (slow wave sleep, SWS), less than 3% of individuals report being awake when their sleep is interrupted (Sewitch 1984).

During SWS, both the self and objects appear to be absent. The control of sleep onset appears to be related to hypothalamic and basal forebrain circuits that inhibit thalamocortical activity and as well as brainstem monoaminergic firing (Pace-Schott and Hobson 2002). The balance of activity between sleep-active and waking-active neurons represents a switching mechanism for triggering sleep. As sleep deepens, with the active withdrawal of excitatory systems in the hypothalamus and brainstem, thalamocortical cells become further depolarized giving rise to delta frequency EEG, characteristic of SWS

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(Steriade, Curro Dossi et al. 1991; Steriade 2001). The cortex appears to contribute to the thalamic rhythm generating mechanism during SWS. Layer 6 cortical-thalamic pyramidal cells drive NRT neurons that, by virtue of their inhibitory actions and widespread projections to dorsal thalamus, hyperpolarize thalamocortical neurons and synchronize pools of thalamocortical cells and their projections back to the cortex (Petsche, Pockberger et al. 1984; Steriade 2001; Anderson and Horne 2003). This thalamocortical interaction forms a stable, reinforced, slow rhythmic EEG that is considered to disallow normal information processing and thus precludes both self-awareness and mental content of awareness.

SWS seems to reflect nearly complete sensory disengagement, suggesting a more profound resting state of cortex in general, and the prefrontal cortex (PFC) in particular. Highly synchronous delta EEG is associated with decreased global blood flow as well as significant regional decreases, especially in PFC (Marquet 2000; Balkin, Braun et al. 2002). These SWS thalamocortical dynamics may serve a greater purpose, helping to reorganize cortical circuits highly active during waking experiences, in part by homeostatically regulating ionic currents, as well as energy and enzyme regulation (Steriade, McCormick et al. 1993; Anderson and Horne 2003). By virtue of the dramatic shift in the style of neural activity provided by SWS, the PFC may recover its crucial functional role in guiding executive processes during waking (Desteshe and Sejnowski 2001; Muzur, Pace-Schott et al. 2002), as supported, for example, by positive correlations between performance on neuropsychological tests of executive functioning and delta EEG during sleep (Anderson and Horne 2003).

This significant reduction in PFC activity, which continues in dreaming states, may thus correspond to the loss of many aspects of executive function, including a sense-of-self during sleep. In terms of our table, the near complete absence of self-awareness and awareness of objects in SWS is characterized by the generation of strongly synchronized delta EEG. This contributes to the disconnection of the brain from the outside world, cessation of mentation, and suspension of self-awareness (Llinas and Ribary 1998).

Dreaming: Illusory dream images

The transition between waking and SWS may be characterized by global reduction in brain activity levels. The transition between SWS and dreaming, however, is marked by a general reactivation of some brain areas, such that the early morning dreaming or rapid-eye-movement (REM) sleep periods can be metabolically more active than the subsequent waking periods. During REM, selective reactivation of the medial portions of the PFC are observed, including medial PFC and the cingulate cortex, in the presence of continued deactivation of anterior and dorsolateral PFC (Balkin, Braun et al. 2002; Muzur, Pace-Schott et al. 2002).

Our current understanding of the neuronal basis of dreaming is centered on the activation of cholinergic nuclei in the mesopontine tegmental area (pedunculopontine and lateral dorsal tegmental nuclei). These so-called “REM-on” cells are nearby monoaminergic nuclei that are simultaneously turned off, hence referred to as REM-off cells. REM-off cells include the locus coeruleus, the source of cortical norepinephrine, and selected raphe nuclei, the source of cortical serotonin. The REM-on cells gained their name from their relative silence during waking and sleep, and sudden rapid firing at the onset of dreaming, exerting acetylcholine (ACh)-mediated effects on thalamocortical circuits. These ACh cells alter the firing patterns of thalamocortical cells by depolarizing them and thus, inhibiting the burst firing mode necessary for slow wave oscillatory behavior associated with sleep onset and deep sleep. In particular, these cells activate the thalamic nuclei responsible for visual dream images (lateral geniculate body) and motor sequences in dreams plans (ventral anterior and ventral lateral nuclei) (Hobson 1995). We seldom act out our dramatic dream scenarios. This is because during dreaming the mesopontine tegmental nuclei generate a global state of bodily atonia (lack of muscle tone) by organizing a powerful brainstem inhibitory influence on spinal motor neurons.

In dreaming, individuals report experiences of bizarre, fragmented and improbable mentation. With the onset of dreaming, portions of the ventromedial and medial areas of the PFC are activated, sometimes to levels that exceed those seen during waking (Nofzinger 1997). As earlier noted, the dorsolateral PFC remains deactivated in REM sleep, probably because it is inhibited by acetylcholine, and because monoaminergic tone has been lost (Muzur, Pace-Schott et al. 2002). Ventromedial PFC is closely tied to limbic areas and emotions, whereas dorsolateral PFC subserves executive processing functions like self-awareness, working memory, planning, and decision-making (Fuster 2000). Thus, dreaming appears to constitute a generalized state of perceptual and emotional activation—objects of experiences—without the normal participation of executive systems which work on higher order processing like support of self-regulatory processes, reality checking and monitoring functions of working memory including experiences of self.

Thus, we would suggest that the self is largely absent during dreaming,[1] due primarily to de-activation of the dorsolateral PFC and consequent 'off-line' status. In terms of our chart, ventral medial and medial PFC, as well as medial parietal areas, appear important in some aspect of the experience of objects, while dorsolateral PFC appears to be important for the experience of self-awareness. But perhaps there is more here. Raichle and colleagues (Raichle, MacLeod et al. 2001) reviewed data from many sensory tasks and concluded that medial PFC (and other midline) regions are preferentially activated in eyes-closed waking states during comparatively more self-referral conditions (passive, undirected flow of attention), than during object-referral, eyes-closed task conditions (demanding directed sensory/motor attention) (Fiset, Paus et al. 1999; Paus 2000). We may tentatively interpret dream neuroimaging patterns in this context: the medial PFC may be related to the identity and emotional value of the 'agent' in the dreams, but without the self-monitoring, reality-checking functions of working memory performed by the dorsolateral PFC. A form of experience is thereby available in sleeping dreams that is fundamentally different from waking. In dreams, clear self-awareness is lacking and the suppression of environmental sensory information (Llinas and Ribary 1998) inhibits the

[1] During lucid dreaming, individuals report they are aware that they are dreaming and can manipulate the dream state scenario. We suggest that this is a special case of dream, which is characterized by EEG patterns that differ from those accompanying normal dreaming. As brainstate mechanisms of lucid dreaming are not understood, we focus in our review on normal dreaming Travis, F. T. (1994). "The junction point model: A field model of waking, sleeping, and dreaming relating dream witnessing, the waking/sleeping transition, and Transcendental Meditation in terms of a common psychophysiologic state." Dreaming **4**(2): 91-104.

organizing influence of ordinary objects of experience; hence, the often bizarre, fragmented, unremembered quality of dreams.

Waking State: The integration of the self and objects

Waking is characterized by the experience of the outer world and the awareness that you are having the experience, that you are conscious. Both a sense-of-self and outer objects or inner mentation are available to awareness in waking experience.

Neuroimaging studies suggest that wakening, the initial return to self-awareness that accompanies regaining conscious awareness, is predominantly a function of the activation and return of integrated thalamic activity, while the subsequent values of alertness, executive functions, and a more complete range of self-awareness appear (5-20 minutes after initial waking) dependent upon dorsolateral PFC activation (Balkin, Braun et al. 2002). Thus, whereas a fundamental awareness of self would depend upon the thalamic activation (with minimal cortical assistance) supported by midbrain reticular activation, a fuller sense of the self in the world relies on the integrated functioning of the PFC. The PFC would presumably coordinate via the NRT and general thalamic and midbrain activity fully intact experiences of self-awareness supporting normal mental content and executive functions. This coming online of PFC creates a full complement of integrated self-regulatory thalamocortical executive function.

A variety of waking experiences characterized as more self-referential or self-referral and less driven by environment stimuli are associated with activation of both medial frontal and parietal association areas. Experiences of objects during waking, operationalized as bodily processes contributing to one's point of view, are reported to activate medial parietal cortices, including the precuneus and angular gyrus (Taylor 2001). Experiences of self-awareness during waking predominately activate a midline frontal-parietal network. For instance, stories containing either 1st or 3rd person pronouns were found to activate the precuneus in a PET study (Ruby, Sirigu et al. 2002), and the anterior cingulate in a fMRI study (Vogeley, Bussfeld et al. 2001). The level of abstractness of 1st person reflection (personality traits versus physical traits) activated precuneus and angular gyrus, respectively (Kjaer, Nowak et al. 2001). Action planning also activates these structures (Ruby, Sirigu et al. 2002). Other studies have reported medial frontal activation during self-referential judgments of pictures (Gusnard, Akbudak et al. 2001), and in self-referential judgments of trait adjectives (Kelley, Macrae et al. 2002). Thus, a distributed system of midline structures appear to be important for predominantly self-referential or self-referral waking experience.

A Meditative State: The experience of pure consciousness without time, space, and body sense.

The meditative state may be unfamiliar to many readers. The prevailing Western view of self-awareness is that an individual cannot be conscious without being conscious of something. However, the last several decades have seen a few authors discussing a state of consciousness that may underlie perceptual and mental experiences. O'Shaughnessy (1986) suggested that consciousness itself is "...distinct from particular consciousnesses or awareness." He proposed that this level of consciousness may be like an "empty canvas" that can not be viewed representationally, but makes possible and is physically necessary to view a painted picture" (O'Shaughnessy, 1986). Woodruff-

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Smith (1986) defined a level of consciousness that is "the inner awareness that makes an experience conscious....a constituent and constitutive feature of the experience itself." Baar offers a theater metaphor which includes an attention director or deep self whose function seems similar to what other writers have described, providing a context (framework) to connect one conscious event with another (Baars 1997).

Ancient traditions of meditation are distinguished from prevailing modern concepts in presenting both theoretical and experiential aspects of the experience of pure consciousness or "consciousness itself". This state of Self-awareness is clearly distinct from normal waking experiences. Recently, we conducted a content analysis of descriptions of deep experiences during practice of the TM technique (Travis and Pearson 2000). Three themes characterized the meditation experience during practice of the TM technique: silence, unboundedness, and the loss of time, space and body sense. "Time, space, and body sense" are the essential framework for understanding waking experience. Specific qualities (color, shape, size, movement, etc.) are the content of waking experiences. During the experience of consciousness itself, both the fundamental framework and the content of waking experience were reported to be absent. This suggests that pure consciousness is not an "altered" state of waking. This state of self-awareness is not described as a distorted waking experience. Rather, it is described by the absence of the customary qualities and characteristics of waking experience. Subjects report being awake during this state, and can subsequently describe the absence of time, space, and body sense. Thus, the subjective descriptions of consciousness itself portray a state of Self-awareness without waking processing and contents (Travis and Pearson 2000). It is the "empty canvas" aware of its status as an empty canvas. Pure consciousness is not itself a bounded object or experience, but enables and is necessary to any experience.

The experience of pure consciousness during meditation is marked by unique patterns of activity in the dorsolateral PFC and parietal areas. During practice of visualization form of Tibetan Buddhism for example, intensely focused attention and experiences reported as "loss of the usual sense of space and time" were associated with increased frontal and decreased parietal cerebral blood flow (Newberg, Alavi et al. 2001). Similar findings were noted in cerebral blood flow during "verbal" based meditation by Franciscan nuns involving the internal repetition of a particular phrase (Newberg, Pourdehnad et al. 2003). In contrast, practitioners of Transcendental Meditation (TM) practice[2] report that the absence of any concentration or effort unfolds experiences of "unboundedness" and the "loss of time, space and body sense." These experiences of Self-awareness were associated with profound bodily relaxation, marked by spontaneous breath quiescence (10-40 sec periods of essentially no respiratory activity) and global, high amplitude, slow frequency (alpha) EEG patterns which are general highly coherent across frontal leads (for review, see (Travis and Pearson 2000); (Farrow and Hebert 1982; Badawi, Wallace et al. 1984; Mason, Alexander et al. 1997; Travis and Wallace 1999).

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Thus, the activity of the prefrontal cortex, which became active in the transition from dreaming to waking, also appears to be important for the experience of pure consciousness. The experience of pure consciousness is marked by high levels of frontal EEG coherence. EEG coherence is a measure of the stability of phase relationship between scalp leads. Many researchers consider that higher levels of coherence indicate cerebral areas are linked for transitory periods to connect together or 'bind' the diverse processing modes in service of the larger cognitive event. While early research on TM practice investigated coherence in narrow EEG bands (theta and alpha), more recent research suggests that reliable markers of TM effects can also be seen with broadband (8-45 Hz) EEG (Levine 1976; Travis, Tecce et al. 2002). Broadband coherence is theorized to represent large-scale cortical integration necessary for the unity of subjective experience (Varela, Lachaux et al. 2001). Thus, broadband frontal coherence may characterize the large-scale neural integration necessary to unite thalamocortical circuits to support the experience of pure self-awareness? awareness itself.

Neuroimaging studies in our laboratory (Arenander, Travis, et. al., in progress) and others are anticipated to reveal the unique brain state configuration associated with this ground state of self-awareness. In this unique state, we can imagine that global blood flow is reduced, but that, unlike SWS and REM, regional connectivity analysis will find that dorsolateral PFC remains a 'player' and is not turned off as it is in sleep and dreaming, thus supporting an intact sense-of-self. A generalized PFC-mediated, top-down re-organization of brain and bodily processes is hypothesized. This would involve a controlled, partial reduction of monoaminergic and reticular activation and corresponding stabilization of NRT slow oscillatory drive on thalamocortical circuits to maintain settled states of awareness and disallow sleep (Arenander 1996; Travis and Wallace 1999).

Recent studies (Mason, Alexander et al. 1997; Travis 2002) suggest that repeated alternation of waking, dreaming, and sleeping with twice-daily experience of pure consciousness during meditation practice leads to long term plastic changes in brain function and a remarkable shift in conscious experience. Amongst long term practitioners of the TM technique, EEG alpha rhythms are significantly increased during SWS delta oscillations, and broadband coherent frontal EEG is observed to be increased during waking cognitive tasks. These brainstate modifications are found predominantly in individuals who report the experience of the ground state of self-awareness as coexisting throughout waking, sleeping, and dreaming states of consciousness. These brainwave measures of heightened neural synchrony correlate with a significant transformation of personal experience in which the individual reports the continuous, unbroken experience of Self-awareness—awareness of the self alone—across the entire 24 hours of each day (Alexander, Davies et al. 1990) Travis et. al., 2004, submitted).

This research indicates the possible existence of an additional, fifth major mode of human self-awareness—an integrated state of Self-referral awareness and objects of awareness. This mode of the Self would serve as a stable, nonchanging 'ground' for all changing experiences across waking, sleeping, and dreaming states of consciousness. The systematic development of such an integrated state of awareness appears to have advantageous mind/body consequences. Practitioners of the TM technique are found to have greatly reduced mental and physical problems (Orme-Johnson 1987; Orme-Johnson 1987; Herron, Hillis et al. 1996; Herron, Schneider et al. 1996; Orme-Johnson and Herron

1997; Herron and Hillis 2000) . Research shows the coherent cortical activity characteristic of this state is correlated with higher levels of health of mind and body. For example, there is a high correlation between EEG coherence and increased emotional stability, moral reasoning, self-referral orientation, neuromuscular and cognitive efficiency, and intelligence, and decreased negativity and neuroticism (Dillbeck and Orme-Johnson 1987; Eppley, Abrams et al. 1989; Alexander, Rainforth et al. 1991) Travis et. al., 2004, submitted; (Orme-Johnson and Haynes 1981).

These initial studies suggest that ancient meditative techniques can provide insight into the full potential of mind/body health. Future research on brainstate signatures of conscious experience will yield significant and exciting insights into the neural mechanisms of self-awareness as well. In particular, these findings should help clarify the distinction (Searle 2000) between the neural correlates of consciousness itself (Self-referral NCC) and the neural correlates of consciousness of a particular perception (object-referral NCC).

Conclusion

This chapter has introduced the concept of a foundational state of self-awareness, which is posited to be both independent of and the source of conscious experiences. Research suggests that high levels of broadband frontal EEG coherence are associated with this ground state of self-awareness. This basic awareness may act as an “empty canvas” upon which we organize, direct, and experience the ever-changing circumstances of our lives. Intact, highly synchronous prefrontal circuits appear to be critical to the direct experience of this ground state of awareness, as well as the transition from an episodic, meditation-dependent experience of this condition to its gradual development as a coexisting continuum across waking, dreaming, and sleeping states of consciousness. Our review supports the existence of at least two primary modes of self-awareness, one with and one without content, as well as the possibility of a third, integrated mode, in which knower and known, Self and objects coexist. Future research should continue to characterize both this putative ground of self-awareness and the consequences of its repeated and systematic experience on brain plasticity and function. Once such a research-based foundation is established, then the various, diverse expressions of self-awareness can be better understood as progressive layers of processing and interaction between the knower (Self-awareness) and the known (the inner and outer environment). In turn, we should be in a better position to understand and effectively treat the variety of dysfunctional modes of self-awareness.

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