What is the Brain Basis of Dissociation?

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“The state of a system at a given instant is the set of numerical values which its variables have at that instant.”[1]

“But from a scientific point of view, we can make no distinction between the man who eats little and see heaven and the man who drinks much and sees snakes.” – Bertrand Russell [2]

Background
Dissociation can take many forms, one of which may result in psychogenic dissociative states. Such states may be explained in the context of dissociation of wake/sleep states and aberrations of consciousness.

The clinical concept of states of being has changed dramatically over the past few decades. It was formerly thought that human existence encompassed only two states: wakefulness and sleep, with sleep being considered simply the passive absence of wakefulness. With the discovery of rapid-eye-movement (REM) sleep in 1953, it became apparent that sleep is not a unitary phenomenon, but rather consists of two completely different states, and each state is an active, rather than a quiescent, process [3]. Each state consists of a number of physiologic variables, which, under normal circumstances, tend to occur in concert, resulting in the appearance of one of the three conventional states of being: wakefulness, REM sleep, and non-rapid-eye-movement (NREM) [4, 5]. Animal experiments and evaluation of humans in the sleep laboratory indicate that the "three states of being" concept must be further expanded to include the observations that the physiologic event markers of one state may intrude into other states, and that the states may oscillate rapidly, resulting in the appearance of bizarre, previously difficult-to-explain and occasionally extraordinary animal and human behaviors, which can occur in diverse naturalistic and clinical settings - with important treatment implications [6-8]. Recent animal experiments support the concept of state dissociation as a normal manifestation of state transition, suggesting the staggered appearance of state-determining physiologic variables: one found suppression of the cortical auditory evoked response shortly before the onset of REM sleep [9], another demonstrated that sleep develops asynchronously in different cortical areas [10]

State Dissociation in Animals
The recurrent recruitment of state-determining parameters is amazingly consistent. However numerous examples of state component dissociation exist. Lesion/stimulation studies, pharmacologic manipulation, and sleep deprivation studies clearly indicate that state dissociation can be induced in animals. In addition to experimental dissociations, there exist naturalistic examples of clinically wakeful behaviors occurring during physiologic sleep such as swimming
or flight during sleep in birds and the phenomenon of unihemispheric sleep in some aquatic mammals (for review, see: [11]).

**State Dissociation in Humans**

Over the centuries, the interpretation of and attitudes toward dissociated or automatic behaviors in humans have changed dramatically - ranging from demon possession, witchcraft, shamanism, hysteria, alien abductions, various psychiatric conditions, and frank malingering, to the current notion of psychobiologic phenomena. Both experimentally-induced and naturally occurring state dissociations in animals serve to predict spontaneously occurring "experiments of nature" and drug-induced state dissociation in humans, which clearly exist on a broad spectrum of expression. Such state dissociations are the consequence of timing or switching errors in the normal process of the dynamic reorganization of the brain as it moves from one state of being to another. Elements of one state persist, or are recruited erroneously, into another state, often with fascinating and dramatic consequences.

Paramount to understanding state dissociation is the concept that sleep is not an “all-or-none global” or “whole brain” phenomenon, but rather, portions of our brains may be awake, while others are asleep – resulting in dramatic clinical experiences and phenomena. Sleep begins with state changes occurring within small groups of highly interconnected neurons and is driven in part by the local production of sleep regulating substances. Portions of the brain used most extensively during prior wakefulness are those which demonstrate increased deep sleep during sleep [12]. Sleep is a local and use-dependent phenomenon subserving synaptic homeostasis [13-15].

**Sleep and Consciousness**

If wakefulness and sleep are not global phenomena, but depend upon the integration and recruitment of various parts of the nervous system, then wakefulness and sleep are analogous to consciousness, which likewise depends upon integration and recruitment of various parts of the nervous system. This concept is termed the “information integration theory” of consciousness, which proposes that consciousness depends not so much on firing rates, synchronization at specific frequency bands, or sensory input per se, but rather on the brain’s ability to integrate information – which is contingent on the effective connectivity among functionally specialized regions of the thalamocortical system [16, 17]. This notion that integration plays an important role in consciousness is supported by findings that during sleep there is loss of integration [18, 19]. Consciousness may be explained by “cognitive binding”: the anatomic substrate of cognitive processing is functionally and discrete neuronal subpopulations. The brain subdivides perceptual processing into modality and submodality, but the perceptions are unified. Cognitive binding is the proposed mechanism mediating the unity of our experiences [20]. Gamma (30-60 Hz) coherent neural activity has been postulated to underlie binding of independent neural assemblies and thus integrate processing across distributed neuronal networks to achieve a unified conscious experience: when gamma activity activates both the specific and non-specific (intralaminar) thalamus simultaneously, different cortical areas are temporally joined and thus bound into a single cognitive experience [21-23]. Conscious perception is related to coordinated dynamical states of the cortical network, rather than to activation of specific brain regions [24,
Consciousness, like sleep and wakefulness, may not be an “all or none” property, but increases in proportion to a system’s ability to integrate information [18].

There is good evidence that cognitive unbinding (uncoupling) plays a role in the unconsciousness occurring during sleep and in drug-induced anesthetic states [16, 26-28]. Various terms have been applied to aberrant consciousness including: state dissociation, dysjunctive states, uncoupling, functional dysconnectivity, cognitive unbinding, temporal decoherence, and synaptic desynchrony.

**Wake/sleep and Consciousness Aberrations in Humans**

The prototypic examples of human state dissociation are narcolepsy and REM sleep behavior disorder (RBD) [11]. For instance, in narcolepsy the symptom of cataplexy (sudden loss of muscle tone triggered by emotionally laden events) simply represents the inappropriate intrusion of one element of REM sleep (muscle paralysis) into wakefulness. In RBD, the ability to “act out one’s dreams” (or “dream out one’s acts”) is due to the abnormal persistence of waking muscle tone during REM sleep. These clinical conditions of admixed wakefulness and sleep provide clear evidence that wakefulness and sleep are not necessarily “whole brain” phenomena.

**The following conditions/phenomena likely represent examples of wake/sleep dissociation:**

- Narcolepsy
- RBD*
- Paroxysmal sleep attacks
- Paradoxical insomnia
- Sleep parasomnia
- Sleep paralysis
- Hypnagogic/hypnopompic hallucinations*
- Out of body experiences
- “Repressed” memories of sexual child abuse*
- Near death experiences
- Status dissociatus
- Agrypnia excitata
- Anesthetic states (conscious sedation)
- *Deonotes forensic implications

**The following non-sleep clinical conditions/phenomena likely result from abnormalities of consciousness:**

- Thalamocortical Dysrhythmia
- Schizophrenia
- Autism
Support for these conditions representing “cognitive uncoupling” include:

1. Magnetoencephalographic study in patients with brain tumors demonstrating loss of functional connectivity not only in the region of the tumor, but remotely – even in the uninvolved hemisphere [29].
2. Corticothalamic dysrhythmia [30].
3. Preserved and evolving changes in brain connectivity in persistent vegetative state and minimally conscious state [31-33].
4. Studies in autism and schizophrenia [34-40].
5. “Paradoxic kinesis in Parkinson’s disease [41].

Therapeutic Implications
There is reason to believe that deep brain stimulation or the administration of medications such as zolpidem may improve conditions resulting from a breakdown in connectivity [42, 43].

Summary
Given the large number of clinical conditions which may be explained by wake/sleep dissociation and/or aberrations of consciousness, there is good reason to believe that psychogenic dissociative states may simply represent dysjunctive states of consciousness.

The concept of state dissociation in humans was made possible only by applying information obtained from basic science animal research studies to the human condition - without which these often dramatic, and treatable conditions would have remained in the mystical, supernatural, or psychiatric arenas, without appropriate or effective treatment options. Sleep or wakefulness occurring asynchronously in bits and pieces of the brain is a most useful concept. From our standpoint, the basic science work in the function and mechanism of sleep is pertinent, not only adding to our knowledge in these important areas for the sake of knowledge, but also in providing clinicians with important information that is of immense clinical importance. The payoff of such research has been great, and demands that it should be ongoing. The field of sleep research and sleep medicine is in a unique position to foster close interactions between basic scientists, clinicians, and behavioral scientists, the result being basic science answers to clinical and behavioral questions, and unanswered clinical and behavioral questions guiding the direction
of and reinforcing the basic science research. The clinical conditions discussed above underscore the value of close cooperation among those working at all levels: molecular, cellular, multi-cellular, clinical, and behavioral. Continued study of state dissociation and consciousness by basic scientists, clinicians, and behavioral scientists will undoubtedly identify and explain even more of these fascinating conditions, with important therapeutic implications. The reciprocal benefits of close collaboration between basic scientists and clinicians will continue to be realized.

Bibliography

20. Mashour GA. Consciousness unbound. Toward a paradigm of general anesthesia.
Anesthesiology. 2004;100:428-433.
22. Meador KJ, Ray PG, Echauz JR, Loring DW, Vachtsevanos GJ. Gamma coherence and
316.
24. Melloni L, Molina C, Pena M, Torres D, Singer W, Rodriguez E. Synchronization of
neural activity across cortical areas correlates with conscious perception. The Journal of
Neuroscience. 2007;27:2858-2865.
26. White NS, Alkire MT. Impaired thalamocortical connectivity in humans during general-
27. Clement EA, Richard A, Thwaites M, Ailon J, Peters S, Dickson CT. Cyclic and sleep-
like spontaneous alternations of brain state under urethane anesthesia. PLOS ONE.
28. Mashour GA. Integrating the science of consciousness and anesthesia. Anesthesia and
Analgesia. 2006;103:975-982.
Dijk BW, de Munck JC, de Jongh A, Cover KS, Stam CJ. How do brain tumors alter functional
30. Llinas RR, Ribary U, Jeannodon D, Kronberg E, Mitra PP. Thalamocortical
dysrhythmia: a neurological and neuropsychiatric syndrome characterized by
magnetoencephalography. Proceedings of the National Academy of Sciences. 1999;96:15222-
15227.
31. Schiff ND, Ribary U, Rodriguez Marino D, Beattie B, Kronberg E, Blasberg R, Giacino
J, McCagg C, Fins JJ, Llinas R, Plum F. Residual cerebral activity and behavioural fragments
32. Fins JJ, Schiff ND, Foley KM. Late recovery from the minimally conscious state. Ethical
33. Di HB, Yu SM, Weng XC, Laureys S, Yu D, Li JQ, Qin PM, Zhu YH, Zhand SZ, Chen
YZ. Cerebral response to patient's own name in the vegetative and minimally conscious states.
34. Andreasen NC, Arndt S, Swayze II V, Cizadlo T, Flaum M, O'Leary D, Ehrhardt JC, Yuh
WTC. Thalamic abnormalities in schizophrenia visualized through magnetic resonance image
35. Andreasen NC. Linking mind and brain in the study of mental illness: a project for a
36. Whittington MA. Can brain rhythms inform on underlying pathology in schizophrenia?