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Preserved Consciousness in the Absence of a Cerebral Cortex, the Legal and Ethical Implications of Redefining Consciousness and Its Neural Correlates: A Case for a Subcortical System Generating Affective Consciousness

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Preserved Consciousness in the Absence of a Cerebral Cortex, the Legal and Ethical Implications
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Generating Affective Consciousness

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Abstract

Historically, the scientific and medical communities have taken a corticocentric view on consciousness, emphasizing the need for a cortex in producing the conscious experience. The preserved consciousness observed in hydranencephalic children and decorticated rats suggests that some form of consciousness may be produced by a subcortical network. The brainstem, a phylogenetically ancient and conserved brain structure, could serve as the major integrative machinery to produce this form of consciousness, which is called affective consciousness—the evolutionary antecedent to the reflective consciousness that allows humans to reflect on their experiences. The functional convergence of the brainstem with the amygdala, motor system, and other subcortical structures provides the necessary architecture to support an affective state of consciousness by which instinctual-emotional goal-directed behavior is produced. This subcortical system operates by what Merker (2007) calls the selection triangle—an interface between bodily actions (action selection), the world (target selection), and personal motivation—to produce action through integration. By this model, it is possible that consciousness may persist in the absence of a cortex, such as in the persistent vegetative state. Because of this, it is necessary to establish that multiple forms of consciousness exist and to distinguish between affective and reflective consciousness, because such a distinction would have tremendous ethical implications in the conventional medical treatment of those with disorders of consciousness.

Keywords: consciousness, subcortical, affective

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Jahi McMath was just 13 years old when she became the subject of a national debate regarding the nation's legal definition of death. McMath underwent a routine adenotonsillectomy, uvulopalatopharyngioplasty, and submucous resection of the bilateral inferior turbinates on December 9, 2013 for the treatment of her obstructive sleep apnea (Luce, 2015). While recovering in the pediatric ICU, McMath began bleeding from her nose and mouth then suffered cardiopulmonary arrest before circulation was restored via cardiopulmonary resuscitation and subsequent placement on a mechanical ventilator and IV fluids (Luce, 2015). McMath never regained consciousness and on December 12, 2013, she was declared brain dead by the physicians at Oakland Children's Hospital and Research Center (Luce, 2015).

By California state law and under the Uniform Determination of Death Act (UDDA), McMath was, by all accounts, considered dead, and on December 15, 2013, her family was notified that she would be removed from the ventilator, which would ultimately culminate in somatic death (Luce, 2015). McMath's family adamantly rejected a determination of death by neurologic criteria refusing to believe that Jahi was truly dead, but under California state law, they had no legal precedence or grounds for keeping Jahi on life support (Luce, 2015). The family filed a motion in which they argued that California Health and Safety Code Section 7180 (the state's UDDA, which defines death as permanent whole brain death) allowing death to be determined by neurologic criteria, violated their religious freedom to believe that Jahi was still alive (Luce, 2015). The court ruled that Jahi's determination of death was legitimate and on January 5, 2014, the county coroner issued a death certificate with time of death dated December

12, 2013 – when she was initially declared dead (Luce, 2015). The family was able to transfer Jahi to a private care facility until she could be transferred to a hospital in New Jersey, one of only two states in the country that allows a family to reject a determination of death by neurologic criteria on the basis of their religious freedom (Luce, 2015).

On September 30, 2014, the family's lawyer requested a hearing to present new evidence in support of the family's claim that Jahi was still alive (Luce, 2015). The evidence presented included videos of Jahi moving her hands and feet, seemingly in response to her mother's commands, as well as MRI and EEG scans demonstrating continual brain activity (Luce, 2015). The imaging studies were regarded as irrelevant by the physician on the case, Dr. Fisher, and her movements, he said, were reflexive only (Luce, 2015). Those videos were also publicly released. Although he has not examined Jahi in person, after reviewing her case and the video evidence, Dr. Alan Shewmon, a pediatric neurologist noteworthy for his extensive research into consciousness, believes that she is still alive (Lupkin, 2014). Another neurologist, Dr. Wei Xiong at University Hospitals in Cleveland, Ohio, states that the hand movement executed by Jahi in these videos is less consistent with posturing (a reflexive movement exhibited in brain death) and more consistent with a complex motion, which would be unusual for someone who is brain dead (Lupkin, 2014). Jahi has been out of a long-term care facility since August of 2014 and was relocated to her mother's home in New Jersey where she receives 24 hour nursing care (Lupkin, 2014). Now, Jahi has gone through puberty and has reportedly had menstrual cycles, a developmental process that should not be possible in a brain dead patient (Lupkin, 2014). Since Jahi is still considered dead in California, her mother's next step will be getting Jahi's death certificate reversed so she and her daughter can relocate back to their home in California (Lupkin, 2014).

In such a case as Jahi's, we are forced to call into question the legitimacy of determining death by neurologic criteria, along with the ethical and legal consequences of using this standard. The subject of brain death cannot be tackled without first discussing consciousness and its neural correlates, an issue that is yet to be settled by the scientific community. The traditional view of consciousness is a corticocentric one, which asserts that no aspect of consciousness can exist in the absence of a functional cortex. While evidence points to a critical role of the cortex in establishing sophisticated thought and cognition as well as complex reflective consciousness, there is no compelling evidence that a primary form of affective consciousness cannot exist without the cortex. This form of consciousness could be generated by a network of subcortical structures integrating and converging on the brainstem where primary consciousness ultimately arises. In this paper, I will discuss the prevailing theories on consciousness and its suspected neural correlates, as well as the legal implications of its definition, before delving into what I believe are the neural correlates. I will also discuss the importance of establishing a universal definition of consciousness in which we distinguish between affective (primary) and reflective (secondary) consciousness, which are supported by different neural networks and structures. This will be accomplished by investigating disorders of consciousness, the evolutionary origin of consciousness, and challenging the corticocentric view of conscious awareness.

Defining and Differentiating Types of Consciousness

Until recently, the topic of consciousness was delegated to the field of philosophy. The scientific community has only recently adopted this issue with the pursuit of identifying its neural correlates. Historically, neuroscience has taken a corticocentric view of consciousness, insisting that the conscious experience is solely a property of the cortex. In this section, I will

review the evidence that points to this conclusion, but in subsequent sections I will also discuss subcortical structures' ability to produce unreflective, affective states of consciousness.

Before we begin our discussion, we must define consciousness. Consciousness is typically regarded as an inherently sophisticated process and there is little consideration to the various levels of consciousness which exist. The assumption that the cortex is necessary in producing consciousness may be the result of a tendency to conflate consciousness with cognition. The functional evolutionary view of consciousness considers that multiple levels of consciousness exist, however (Panksepp, Fuchs, Garcia, & Lesiak, 2007). Several argue that without the cortex, individuals continue to possess a more robust primary form of consciousness called affective consciousness or pre-reflective self awareness (Izard, 2007; Northoff, 2007; Panksepp et al., 2007). This unreflective state is characterized by basic, core emotions, from which reflective consciousness arose and which are evolutionarily advantageous in the way they drive our instinctual behavior (Denton, McKinley, Farrell, & Egan, 2009; Izard, 2007; Panksepp et al., 2007). The scientific community's tendency to disregard the multifaceted nature of consciousness may be partially responsible for the predominantly corticocentric view of consciousness. It is my belief that the empirical evidence for a corticocentric view is lacking, unable to completely account for the conscious experience with its insufficient generalizability and its failure to consider subcortical structures.

For the purposes of this article, let us establish operational definitions of reflective (secondary) consciousness and primary (affective) consciousness. Izard (2007) defines the two:

Reflective consciousness is characterized by symbolic processes, memory, and ultimately, the capacity for awareness of self and others and for monitoring one's own behavior...primary consciousness is characterized by sensory processes that generate

subjective feelings (cf. James 1890/1950; Izard 1990), especially emotion feelings, and also includes awareness of and responsiveness to objects in the environment. (p. 97)

Though this paper is mainly concerned with affective consciousness and the neural correlates that allow for its generation, reflective consciousness is more widely recognized. Affective consciousness is generally overlooked (or rather, not recognized) in diagnosing disorders of consciousness. The foundational logic upon which the UDDA is built presumably rests on either the absence or presence of reflective consciousness, and does not include any discussion of basic affective consciousness; the assumption is that absolutely no aspect of consciousness survives functional or radical decortication. The traditional definition of consciousness assumes that only one form exists. In the sections that follow, I stress the importance of distinguishing this definition, which is consistent with reflective consciousness, from affective consciousness. The traditional view holds that consciousness is a state of being which is characterized by three elements: awareness, attention, and sense of self (Garrett, 2015).

Awareness refers to knowledge that a situation is happening (Awareness, 2018). In discussing this abstract concept, we must note that there is a threshold of detection which, when surpassed, brings information to the forefront of conscious awareness. Conscious awareness is frequently measured by assessing visual consciousness, where awareness of some external visual stimuli can be measured via neuroimaging techniques in which a series of words are rapidly flashed on a screen before a subject (Garrett, 2015). The words are flashed at rates either at or below the threshold of detection, so when a word is not consciously perceived, only the visual cortex is stimulated, but both the parietal and prefrontal cortex are activated in conjunction with the visual cortex when the subject becomes aware of having seen the word (Garrett, 2015). The results of such studies demonstrate the involvement of a prefrontal-parietal network in creating

conscious awareness of a particular stimulus or present situation. Awareness is not, however, contingent upon prefrontal-parietal activity, but on the connectivity between this network and the thalamus – a dearth of the latter is demonstrated by patients in the vegetative state (Laureys, 2005). Without awareness, these patients also cannot demonstrate attention.

When we discuss attention, we make it sound transactional: we ‘pay’ attention when we take notice of a particular stimulus or situation, allocating neural resources towards focusing on some neural input while excluding others (Garrett, 2015). Every day, we are flooded with multitudes of sensory stimuli competing with one another for our attention. It is important for a neurological mechanism to be in place to determine which of these stimuli we attend to. The thalamus, or specifically the reticular nucleus of the thalamus, may play a large role in choosing between competing stimuli (Crick & Koch, 2003). The winning stimulus will be the one to which an individual consciously attends. There are two networks involved in attention, and they work in conjunction with one another: a dorsal network, which focuses attention towards a particular stimulus with the intention of satisfying a specific goal, and a ventral network, which responds to the attentional demands of the stimulus (Garrett, 2015). The anterior cingulate cortex is thought to play an executive role in allocating attentional resources by modifying its firing rate to meet the demands of a particular stimulus or task (i.e. it will increase its firing rate in response to a cognitively demanding task and decrease its firing rate when the task does not call for much attention) (Garrett, 2015). Both attention and awareness of the fact that one is attending to a particular stimulus/situation are essential, but not independently sufficient, to determine reflective consciousness. In order to be considered conscious, by its traditional definition, one must also possess a sense of self.

This sense of self is a central component to identity and is an important element of reflective consciousness. “‘Self-awareness’ refers to the capacity to become the object of one’s own attention” (Morin, 2006, p. 359). An animal possesses self-awareness when it can distinguish itself from its environment, is cognizant of its own experience as a separate entity expressing volitional behavior, and has awareness of itself as an entity which continues to remain that same entity for the duration of its existence (Morin, 2006). It becomes a “reflective observer” (Morin, 2006, p. 359) processing information as it pertains to the self in relation to the external environment. Numerous studies have investigated the neural correlates of self-awareness. For example, with use of the rubber hand illusion and positron emission tomography, Tsakiris, Hess, Boy, Haggard, and Fink (2007) demonstrated the importance of the right posterior insula and right frontal operculum in generating a sense of body ownership. When participants of the study did not perceive the rubber hand to be their own, the somatosensory cortex and parietal cortex were active instead (Tsakiris et al., 2007). This evidence suggests that important to self-consciousness/self-awareness is a network formed by the parietal cortex, somatosensory cortex, posterior insula, and frontal operculum, which operate to connect a conscious percept with one’s own body (Tsakiris et al., 2007). What, then, happens when one or more of these elements of consciousness are not present in an individual?

The Persistent Vegetative State

For the purposes of this section, we will operate under the established diagnostic criteria for disorders of consciousness, under the assumption that there is only one form of consciousness and it is full, reflective consciousness. Disorders of consciousness are classified into five major categories: coma, persistent vegetative state (PVS), akinetic mutism, hyperkinetic mutism, and delirium (Panksepp et al., 2007). I will discuss only the first two categories and will give most

attention to the PVS. Coma and PVS are both characterized by a complete loss of consciousness, and are distinguished by the duration of this altered state of consciousness (Panksepp et al., 2007). Coma is a temporary loss that is eventually recovered, whereas PVS is considered permanent and unlikely to ever resolve, once a period of 12 months or more has elapsed (Panksepp et al., 2007). In PVS, individuals continue to undergo normal sleep-wake cycles and have variable cranial nerve and spinal reflexes, but they have a complete unawareness of self and the environment, incontinence, no language comprehension, and no evidence of sustained, reproducible, purposeful, or voluntary behavioral responses – they are in a state of “wakefulness without awareness” (Garrett, 2015; Laureys, 2005, p. 556). The Multi-Society Task Force (1994) on PVS was assembled to provide guidelines for the diagnosis and treatment of PVS and set forth the following seven diagnostic criteria:

- 1) No evidence of awareness of self or environment and an inability to interact with others;
- 2) no evidence of sustained, reproducible, purposeful, or voluntary behavioral responses to visual, auditory, tactile, or noxious stimuli;
- 3) no evidence of language comprehension or expression;
- 4) intermittent wakefulness manifested by the presence of sleep-wake cycles;
- 5) sufficiently preserved hypothalamic and brain-stem autonomic functions to permit survival with medical and nursing care;
- 6) bowel and bladder incontinence; and
- 7) variably preserved cranial-nerve reflexes (pupillary, oculocephalic, corneal, vestibulo-ocular, and gag) and spinal reflexes. (p. 1500)

Now that we have established the medical standard paradigm for defining PVS, let us establish a new definition which considers the multifaceted nature of consciousness. I would like to suggest that PVS and coma be characterized by a complete loss of *reflective consciousness* with preserved *affective consciousness*; that a minimally conscious state (MCS) be characterized

by partial loss of *reflective consciousness* and preserved *affective consciousness*. Then, it may also be more accurate to define disorders of consciousness by level of awareness, rather than level of consciousness.

The vegetative state can be assessed using neuroimaging techniques as well as the patient's clinical presentation. The neuropathology of the PVS is typically reflected by a state of functional decortication (Panksepp et al., 2007), which can be seen with imaging. Without the assistance of neuroimaging, one cannot accurately determine an individual's level of awareness for they may be minimally or entirely aware, remaining cognitively intact but unable to verbally communicate or behaviorally respond, as in locked-in syndrome (Garrett, 2015). With the use of fMRI during mental imagery tasks, a physician can assess a patient's level of awareness by giving commands and correlating the regions of the brain that correspond to a particular command with the activity visualized on the fMRI scan. Theoretically, those who possess some level of reflective consciousness should be able to volitionally modify their brain activity while undergoing a mental imagery task. The absence of volitionally modified brain activity should not, however, be used to confidently assert a complete lack of consciousness until it can be verified that those in the PVS do not, in fact, possess affective consciousness.

In a study conducted by Monti et al. (2010), brain activity was monitored via fMRI as patients were asked to imagine playing tennis. In one case, a patient was believed to be in a permanent vegetative state for five years before fMRI revealed she was minimally conscious (Monti et al., 2010). Unfortunately, most physicians rely on the patient's clinical presentation at the bedside rather than exhausting medical resources to assess the patient with imaging. Because of the reliance on neurobehavioral testing, it is not unlikely that numerous others have been

misdiagnosed with regard to their state of consciousness. For this reason, it is important to assist neurobehavioral testing with imaging studies.

We must note that assessment via mental imagery tasks should only be used to assert the presence of reflective consciousness, and consider that even in the absence of cortical activity, affective consciousness may persist (reflected by intact subcortical function). Consciousness is an abstract concept and its generation is not only dependent upon the presence or absence of certain structures, but on the integration of processes carried out by those structures. Because the popular view of consciousness as necessarily reflective may be incorrect, understanding the neural correlates of consciousness as they pertain to diagnosing PVS and other disorders of consciousness will effect significant changes in the way we treat such disorders.

Prevailing Theories to Explain the Conscious Experience

While discussing consciousness, we must be careful not to fall victim to the notion of some sentient homunculus within the brain, acting as a discrete center for conscious control, making executive decisions and controlling our actions and thoughts. The prevailing theory of consciousness is that it is the product of distributed modular outputs integrating together. Tononi (2008) equates consciousness with integrated information. He states that the quantity and quality of consciousness is dependent upon the degree to which information generated by a distributed neuronal network is integrated, as well as the extent of the relationships between components of that network, or complex (Tononi, 2008). This is referred to as the integrated information theory (IIT) (Tononi, 2008). Integrated information (f) is the sum of information produced by the neuronal network converging together (Tononi, 2008). “Qualia space (Q) is a space where each axis represents a possible state of the complex, each point is a probability distribution of its states, and arrows between points represent the informational relationships among its elements

generated by causal mechanisms (connections)” (Tononi, 2008, p. 216). A specific experience is perceived, or brought into conscious awareness, by the integration of these informational relationships which, when connecting various points in the Q, generate a specific shape within the Q, creating a distinct conscious experience (Tononi, 2008). This framework is largely consistent with the theory proposed by Crick and Koch (2003) which falls somewhere between proposing a distributed network theory of consciousness and a localized one.

According to Crick and Koch (2003), the cortex functions via a highly interconnected network of coalitions between neurons which compete with and support one another, where the winning coalition determines which external stimuli we attend to and are conscious of. A coalition is composed of a network of interconnected nodes, each responsible for generating an output for a particular feature of a percept; one node on its own cannot reach the necessary threshold for generating consciousness, but a network of nodes, or a coalition, can (Crick & Koch, 2003). This is evidenced by numerous studies of minimally conscious patients who show a conservation of widespread cerebral networks, while their completely unconscious counterparts do not (Schiff et al., 2007). Again, this assumes only one form of consciousness - reflective consciousness - exists. A stimulus is brought into consciousness when the features of that stimulus or object are bound together. Binding refers to the process in which the various features of an object or situation are integrated with one another to form a particular percept (Crick & Koch, 2003).

Crick and Koch (2003) believe that the specific neural correlates of consciousness may be localized to a small set of neurons in the posterior region of the cortex, but that the events leading up to a percept being brought into conscious awareness are widely distributed. As such,

consciousness cannot be produced without the widespread distribution of nodes within a coalition binding together their outputs and yielding a particular conscious experience.

Briefly setting aside theoretical frameworks for consciousness, there is also the question of the biochemistry behind producing consciousness. At an increasingly reductionist level, Crick and Koch (2013) propose that consciousness can be reached via a particular pattern of neuronal firing by a coalition, such as sustained neural activity above the threshold for consciousness or synchronization of neural activity. Activity may be sustained above threshold via a positive feedback loop which pushes neuronal activity above the threshold for access to conscious awareness (Crick & Koch, 2003). The literature points to synchronized firing as the potential mechanism for binding, but Crick & Koch (2003) believe that synchronization rather helps newly formed coalitions to outcompete one another.

Investigation into the more reductionist components of consciousness are beyond the scope of this paper, so we will now return our focus to its neural correlates. The notion that consciousness can exist without the cortex is a not a novel one. In 1954 and in the midst of an increasingly corticocentric view of consciousness, Penfield and Jasper put forth a radical proposal, centered around their observations of epileptic patients (as cited in Merker, 2007). They (Penfield and Jasper) suggested that the highest level of integration is not accomplished by the cortex, but by the upper brainstem onto which neural activity converges to produce the conscious experience - they called this system the centrencephalic system (as cited in Merker, 2007). Their theory lays the foundation for Merker's (2007) mesodiencephalic system, which is composed of primary integrative machinery housed at the level of the midbrain and basal diencephalon, and supplied by the telencephalon, which provides it with the contents of the conscious experience.

Penfield and Jasper's Epileptic Studies Lay The Foundation For a Subcortical Model

Penfield and Jasper constructed their centrencephalic system from their observations of epileptic patients. As discussed previously, the PVS is characterized by a state of wakefulness in the absence of awareness. A similar dissociation between wakefulness and awareness is demonstrated by patients experiencing absence seizure – a disorder characterized by a period of unresponsiveness while awake (Laureys, 2005). Interestingly enough, when Penfield and Jasper stimulated the cortex of their subjects, they were able to produce all varieties of seizure except absence seizure (as cited in Merker, 2007). fMRI scans taken while a patient experiences an absence seizure (during which an absence of conscious awareness is demonstrated) reveal a loss of function in the bilateral frontoparietal cortices (Laureys, 2005). While treating epileptic patients, Penfield and Jasper, then, were surprised to see a preservation of consciousness despite the surgical extrication of relatively large portions of the cortex – considered the region of highest integrative function (as cited in Merker, 2007). Moreover, Penfield and Jasper observed that there was no disruption in the consciousness of a patient who was kept under conscious sedation while regions of the cortex were actively being removed (as cited in Merker, 2007).

The groundbreaking work of these scientists has demonstrated that damage to the cortex does not always result in a diminished state of consciousness. Meanwhile, lesioning of the brainstem (Moruzzi & Magoun, 1949) and suppression of subcortical arousal systems (involving the upper brainstem reticular formation and the intralaminar thalamus) during limbic seizure (Blumenfeld, 2012; Kundishora et al., 2017) result in states resembling coma, the persistent vegetative state, or pathological somnolence. Though deficits in higher order cognitive processes are ultimately observed with cortical lesioning and removal, consciousness of self and

environment remains intact, challenging the assertion that the highest level of integrative functioning takes place in the cortex.

Subcortical Model of Consciousness

While the higher order cortices are necessary for the execution of more sophisticated cognition and thought, as well as the ability to self-reflect on one's own thought processes, they are not intrinsic to conscious. The overemphasis on the cortex limits our understanding of consciousness by prematurely cutting off debate around its neural correlates and the extent of cortical activity needed for consciousness to persist. Merker (2007) proposes a mesodiencephalic system [a system involving the midbrain and diencephalon] in which the highest level of integrative function takes place in the brainstem. We must not assume that the primitive nature of the brainstem and other subcortical structures excludes them from consideration.

Though the cortex is likely necessary for reflective consciousness to arise, the immediate unreflective experience of consciousness—also called primary or affective consciousness—only requires the subcortical regions of the brain (Merker, 2007). Northoff (2007) calls this form of consciousness, which allows us to “immediately and unreflectively experience our self,” (p. 101) pre-reflective self-awareness, and proposes a subcortical mediation of this type of consciousness by self-related processing. Self-related processing refers to our ability to discriminate between the self and environment by examining interoceptive stimuli in relation to exteroceptive stimuli (Northoff, 2007). The ventral striatum/N.accumbens, as well as the “tectum, periaqueductal gray, dorsal medial thalamus, and colliculi have been [identified] by Schneider et al. (submitted)” (Northoff, 2007, p. 101) as subcortical structures involved in self-related processing. The circuitry of afferent and efferent sensorimotor projections to and from these structures lead Northoff (2007) to conclude that they may be critical in relating the sensorimotor

with the self, thus giving rise to an immediate experience of the self through self-relatedness to one's immediate environment. This type of consciousness reflects that what one is experiencing is not simply an external stimulus, but oneself as related to that stimulus. This, and other numerous factors, are involved in producing consciousness.

Consciousness is brought into existence by both enabling factors and specific factors (Denton et al., 2009). 'Enabling factors' refers to the particular regions and circuits of the brain that give rise to any degree of consciousness, and 'specific factors' refers to those elements that are responsible for creating a specific conscious percept (Denton et al., 2009). A cluster of nuclei in the brainstem, basal diencephalon, and the thalamus regulate the cortex and give humans the ability to experience consciousness (Denton et al., 2009). Together, "the ascending fibers [of these nuclei] create the essential conditions for any consciousness to occur" (Denton et al., 2009, p. 506) – namely, wakefulness, arousal, and sleep, which are regulated by acetylcholine released by the axons extending from these nuclei. These essential conditions, thus, are generated by a forebrain-brainstem system innervated by a distributed cortical network whose simultaneous activities converge on the brainstem, where, according to Merker (2007), the information is integrated for action. In this system, conscious awareness is predicated upon a functioning brainstem receiving input from other regions of the brain. Cortical functioning contributes to the brainstem's supply of information regarding the external environment, but is not necessary for consciousness to exist.

Though an important source of input to the upper brainstem is supplied by the cortex, it is necessary to identify the presence of both efferent and afferent projections and note that the manner in which the cortex interacts and integrates with the mesodiencephalic network is really suggestive of the superior brainstem's role in generating consciousness (Merker, 2007). The first

attempts at identifying the neural correlates of consciousness lead to the discovery that nearly 80% of PVS patients have abnormalities in the thalamus and that a combination of lesions in both the corpus callosum and dorsolateral brainstem were a frequent occurrence in the PVS as well (Panksepp et al., 2007). Giacino and Whyte identified two major patterns of brain damage in the PVS: 1) diffuse axonal Injury, which is typically related to thalamic malfunction resulting in ischemia and 2) focal brainstem lesioning (as cited in Panksepp et al., 2007). These results would suggest that the disruption in consciousness observed in the PVS is more likely the result of damage to the mesodiencephalic system.

In discussions of consciousness, the literature repeatedly points to the posterior parietal cortex, the prefrontal cortex, and the anterior cingulate cortex in mediating the three central components of consciousness: attention, awareness, and the sense of self. These three regions of the cortex are intersected by the thalamus. They all have a “mutual interface in the nuclei of the dorsal thalamus. The latter [the nuclei] can be divided into first-order (largely sensory relay) and higher-order (“association”) thalamic nuclei (Sherman & Guillery, 2001), and it is with the latter, higher-order nuclei, that the mesodiencephalic system maintains an intimate and complex relationship” (Merker, 2007, p. 74). The thalamus is an important mediator in regulating states of arousal (Schiff et al., 2007). During periods of wakefulness, the thalamus, mediated by the brainstem, maintains the brain’s metabolic rate at the threshold for access to conscious awareness (Schiff et al., 2007). In disorders of consciousness, there is typically a reduction of global metabolic activity to approximately 50% of normal levels (Schiff et al., 2007; Laureys, 2005). However, in some cases of PVS, there is not a significant reduction of global metabolic activity, but in these cases, patients did eventually recover consciousness (Laureys, 2005). Diminished states of arousal exhibited during focal limbic seizure follow from suppression of the upper

brainstem activating system (to which the reticular formation is essential) and the intralaminar thalamus (Blumenfeld, 2012; Kundishora et al., 2017). In a study by Kundishora et al. (2017), some consciousness was restored during limbic seizure with the use of deep brain stimulation of the thalamus. The results of these studies further support a consciousness system comprising the diencephalon and the midbrain with the functional convergence of the thalamus and reticular activating system of the brainstem playing an integral role in states of arousal. The thalamus is also innervated by projections from the basal ganglia.

At the base of the forebrain are the basal ganglia. The basal ganglia are associated with emotion and other motivational circuits (Herrero, Barcia, & Navarro, 2002). Their importance is highlighted by studies of the neuropathology of diseases which disrupt consciousness. Parkinson's, a disease marked by motor tremors, rigidity, loss of balance and coordination, difficulty initiating and sustaining movement, and, in its progressive phase, altered loss of consciousness, is intimately associated with the basal ganglia. The disease is caused by a deteriorating substantia nigra, which results in insufficient dopamine production; subsequently diminishing levels of dopamine lead to basal ganglia dysfunction, which results in the symptomatology of the disease. "Pathology in this system does lead to eye-blink abnormalities (Basso et al. 1996) and, consistent with Merker's hypothesis, visual hallucinations (a disorder of the content of consciousness)" (Collerton & Perry, 2007, p. 89). While Merker does discuss the basal ganglia's role in the mesodiencephalic system, he fails to give quite enough recognition to the basal forebrain for its role in mediating consciousness.

Collerton & Perry (2007) give consideration to the cholinergic system of the basal forebrain, noting its contribution to the pathology of other diseases that involve disturbances in consciousness, such as dementia. The cholinergic system of the basal ganglia have numerous

projections from the brainstem to the thalamus and substantia nigra (Collerton & Perry, 2007). Fluctuations in the cholinergic system have implications for wakefulness and dreaming. Perry and Piggott (2000) found that the alterations in dream intensity and brain activity observed throughout the duration of sleep cycles (reflective of dreaming – a normal state of altered consciousness) correlate with decreasing brainstem 5-HT as well as the dopaminergic system of the midbrain and the cholinergic system of the basal forebrain. Furthermore, Collerton and Perry (2007) note that a discrepancy between top-down and bottom-up processing resulting from dysfunction in the subcortical cholinergic system can result in hallucinations – another disturbance in consciousness. This evidence suggests that in generating consciousness, the basal forebrain may play an equally important role as the brainstem.

From the results of their 1954 study on absence seizures, Penfield and Jasper conclude that it is the brainstem and not the cortex that plays the highest role in integrating the outputs of a distributed network which converge at the brainstem to carry out purposeful action (as cited in Merker, 2007). The importance of the brainstem in generating consciousness is demonstrated by the restorative ability of DBS treatment in anesthetized animals. Increased activity of the EEG from synchronized discharge to low voltage fast activity and improved behavior (generating an arousal response) were resultant of stimulation of the reticular formation of the brainstem (Moruzzi & Magoun, 1949). “The distribution of the excitable area...includes the central core of the brain stem, extending from the bulbar reticular formation forward through the pontile and mesencephalic tegmentum into the caudal diencephalon” (Moruzzi & Magoun, 1949, p. 252). Their experiment demonstrates the necessary role of this subcortical network in generating consciousness, especially wakefulness and arousal of a subject to alertness.

According to Merker (2007), the centrencephalic system indicated by Penfield and Jasper seemingly involves the reticular formation extending into the midline, intralaminar, and reticular thalamic nuclei. The brainstem, innervated by higher order cortices, ultimately integrates incoming cortical input together to yield consciousness (Merker, 2007). Also exhibiting integrative function – integrating multiple sensory modalities important for spatial orientation -- is the superior colliculus at the roof the midbrain, which receives its input from the substantia nigra of the basal ganglia and projects its integrated output through a multitude of efferents to the thalamus and brainstem (Merker, 2007). Beneath the superior colliculus is the reticular formation, thalamus, periaqueductal gray, and substantia nigra, and at the bottom of the midbrain lies the hypothalamus, which integrates multiple categories of goal oriented behavior (Merker, 2007). Merker (2007) proposes that the synencephalon (a region of the brainstem between the diencephalon and midbrain) is perfectly situated to create a bottleneck in which distributed cortical outputs project through the integrative machinery of the midbrain and converge at the brainstem where the “massively parallel and distributed information capacity of the cerebral hemispheres [is further integrated] into the limited-capacity, sequential mode of operation” (p. 63) necessary for the execution of volitional behavior. The system operates by what Merker (2007) calls a *selection triangle* by which the brainstem carries out integration for action by connecting three components of behavior: motivation, target selection, and action selection.

There are three main contributions to behavior indicated by the selection triangle. It considers that a conscious organism has a particular motivation (the motivational) for carrying out a specific action (action selection) based upon the assessment of its environment (target selection); action selection is mediated by the resources and environmental states available to that organism (the target states of the external environment) as well as consideration into the

amount of energy that would be expended in each of its possible choices of action (the action states of the body) (Merker, 2007). In order for the organism to select an optimal action state based upon the available target states of its external environment and in accordance with its motivation for producing an action, it must have a sense of the world around it, and this is accomplished through sensory inputs and/or via the action of the superior colliculus executing self-related processing (Merker, 2007; Northoff, 2007). This necessitates that the organism have an awareness of its own physical existence, as well as emotionally and motivationally guided behavior to accomplish a particular goal within an external environment with which it is capable of interacting (Merker, 2007). The interaction between bodily action (the body/self), target selection (the world), and motivation (the motivational) described by the selection triangle is consistent with Northoff's (2007) pre-reflective self awareness through self-related processing, which emphasizes one's ability to discriminate between the self and the environment and subsequently relate oneself to one's surroundings for the immediate, unreflective experience of consciousness to arise.

The acquisition of information about the environment is obtained through use of the senses. While the sensory organs do enrich our conscious experience, it should be noted that consciousness is not contingent upon one's ability to perceive the various sensory modalities. Someone with impaired sensory function (e.g., someone blind or deaf) still possesses consciousness. For simplicity's sake, however, we will trace the neural circuitry of conscious perception first starting at the level of the cortex. The various sense organs transduce the respective sensory modalities. The transduced signals project to the corresponding primary and secondary sensory cortices and then towards the midbrain and forebrain in a parallel fashion, to produce bodily action through movement. In the absence of cortical input and/or the senses,

however, a primary form of consciousness would still be supported by the mesodiencephalic system proposed by Merker (2007) in combination with that proposed by Izard (2007) and in accordance with Tononi's (2008) IIT in which he equates consciousness with integrated information. We will call this the subcortical model of consciousness.

Traditionally, the appraisal of consciousness through integrating information considers the integrated information to be supplied in a parallel manner by a widely distributed network of coalitions (Tononi, 2008; Crick & Koch, 2003). This is typically referring to a network within the cortex. Though, in producing an unreflective state of awareness, it may be that cholinergic projections of the basal ganglia from the thalamus and substantia nigra to the brainstem (Izard, 2007) constitute a distributed subcortical network by which information integration takes place within each structure of the network and, as Merker suggests (2007), ultimately converges on the brainstem where it is integrated further, giving rise to consciousness. The basal ganglia project to the ventral anterior and ventral lateral nuclei of the thalamus as well as the superior colliculus. When there is intact cortical function, the thalamus relays information back to the cortex and this would allow for reflective consciousness to arise. With or without the cortex, however, the substantia nigra of the basal ganglia also projects its output towards the superior colliculus, which integrates various sources of information and provides a sense of spatial orientation of the body in relation to its environment as well as a necessary distinction between the self and the environment, providing us the neural substrate possibly responsible for target selection and pre-reflective self awareness (Merker, 2007; Northoff, 2007). Also projecting its output to the superior colliculus (via direct innervation and indirect projections through the periaqueductal gray) is the hypothalamus, which plays an integral role in "regulating and integrating motivational states related to goal-directed behaviors" (Merker, 2007, p. 71).

It is here then, between the hypothalamus and periaqueductal gray, that the superior colliculus provides the necessary machinery to “implement a three-way interface” between motivation, target selection, and action selection (Merker, 2007, p. 71). Once information is integrated by the superior colliculus, the output is projected to the thalamus which works in conjunction with the reticular activating system of the brainstem in mediating arousal states (Schiff et al., 2007; Morruzi & Magoun, 1949). The integrated information by the superior colliculus also projects to the brainstem via collicular efferents where it is combined with the distributed and parallel outputs of the cortex (if present) as well as the outputs of the integrative machinery of the mesodiencephalon with the functional convergence of the limbic system and amygdala all converging on the brainstem to generate affective consciousness (Merker, 2007; Denton et al., 2007). If this subcortical model of consciousness holds true, it will be absolutely necessary to emphasize whole brain loss of functioning in diagnosing brain death, for any amount of brain activity – namely in the subcortical regions of the brain - could indicate that some form of consciousness may still exist. The subcortical model is further supported by theories on the evolutionary origin of consciousness.

Evolutionary Origin of Consciousness

The emergence of consciousness is likely due to its adaptive advantage. In support of this evolutionary advantage, Merker’s (2007) selection triangle posits that with the advent of consciousness, animals could select the most optimal choice for action (action selection) based upon their evaluation of the present environment (target selection) to fulfill a particular goal or desire (motivation), such as remaining hydrated for survival. When confronted with an environmental threat (e.g., lack of food/water availability, presence of a predator, etc.), an animal’s behavior is mediated by the primordial emotions (e.g., thirst, hunger, fear, etc.) in order

to alleviate that threat. The primordial emotions are defined by Denton et al. (2009) as “the subjective element of the instincts which are the genetically programmed behaviour patterns which contrive homeostasis,” (p. 500) generated by subcortical regions and from which consciousness may have originated. The neural correlates of consciousness can be studied with respect to the primordial emotions by examining the immediate gratification that is achieved by satiating the particular primordial emotion causing an animal distress (Denton et al., 2009). Satiating the primordial emotion subsequently increases an organism’s odds of survival by restoring homeostasis, thus giving organisms in possession of consciousness an important adaptive advantage.

The functional evolutionary view of consciousness echoes Merker’s view of consciousness as an immediate and unreflective experience. It posits that an ancient form of primary, affective consciousness gave rise to the more sophisticated self-reflective consciousness, which enables higher order cognitive processes, such as the ability to consciously reflect on one’s own experience and possess awareness of one’s own awareness (Panksepp et al., 2007). Abundant research in animal models supports the theory that there is an affective consciousness which preceded the secondary (reflective) form of consciousness that gives humans the presumably unique ability to conceptualize and discuss our own conscious experiences. Mammals possess epicenters for affective experiences within the medial and ventral regions of the brain, which endow them with the ability to experience primordial emotions such as thirst, hunger, and suffocation in instances of a disturbed homeostatic state (Denton et al., 2009; Panksepp et al., 2007). Primordial emotions hold functional relevance for driving goal-oriented behavior that aims to restore homeostasis.

Baars (2005) suggests that consciousness itself is “biologically fundamental and phylogenetically ancient” (p. 7) and was likely present at least as far back as the earliest mammals—for alertness, sensory perception, memory, and motor function are all necessary components in producing goal-oriented behavior. Because of the highly conserved and phylogenetically ancient nature of the brainstem, it is probable that the origin of consciousness is tied to the brainstem as well as other subcortical regions of the brain. Goal-oriented behavior is ultimately driven by the core primordial emotions, which are produced by diencephalic, mesencephalic, and medullary mechanisms (Denton et al., 2009). Therefore, the theory proposed by Denton et al. (2009) is consistent with Merker’s (2007) theory that consciousness preceded the development of the cortex and is implemented by the primitive lower regions of the brain.

Interestingly, as increasingly lower regions of the brain (such as the periaqueductal gray) are electrically stimulated, there is a corresponding increase in affective intensity (Panksepp, 1998). Panksepp (1998) envisions a system of emotional circuits coded by value, converging and interacting with:

coherent brainstem representations of the body and nearby attentional/waking systems of the brain. Affective feelings may be caused by the neurodynamics of basic emotional circuits interacting with neural schema of bodily action plans. One key brain area where such interactions occur is found within centromedial diencephalic midbrain areas such as the periventricular and periaqueductal gray (PAG) and nearby tectal and tegmental zones. Here [...] a Simple Ego-type Life Form (a primitive SELF structure) is instantiated in those circuits. The ability of this ‘primal SELF’ to resonate with primitive emotional values may help yield the raw subjectively experienced feelings of pleasure, lust, anger, hunger, desire, fear, loneliness and so forth. (p. 566)

The system he has conceptualized provides us with a neural dynamic process by which the primal subcortical circuitry may produce the primordial emotions and primary affective consciousness.

In discussing the primitive regions of the brain versus the neocortex, it is necessary to distinguish between higher-level processes as they pertain to degree of sophistication versus degree of control. It seems that there is a tendency to conflate consciousness with cognition. The two are distinct. Consciousness is not inherently sophisticated or complex. While less sophisticated and more primitive than the cortex, the brainstem executes a higher level of control over behavior than the cortex. Merker (2007) provides an example of this: in instances in which an individual is experiencing fear, hunger, or pain, subcortical regions of the brain can supersede the executive control of the cortex to direct volitional behavior, essentially outcompeting the cortex for control over action. For example, when blood gas levels fall out of their normal range, automatic respiratory function (controlled by the brainstem) falls out of unconscious automaticity and into consciousness awareness as one is filled with an overwhelming sense that they are suffocating and subsequently must make a behavioral choice (action selection) about their circumstances (target state) to alleviate their state of respiratory distress (motivation) (Merker, 2007). This example demonstrates how a primal function such as respiration can be consciously perceived, highlighting the necessary divide between cognitive complexity and consciousness; consciousness does not inherently derive from complex behavior or cognition (Merker, 2007). In its most basic form, consciousness is simply a state of subjective feelings - a state which is seemingly produced by subcortical structures, as further evidenced by studies of decorticated animals and hydranencephalic children.

Consciousness Survives Radical Decortication

It has long been known by neuroscientists that decorticated animals tend to be more interactive, more engaged, and more emotional than their neurologically intact counterparts, a phenomenon which occurs because “decortication releases primary process emotionality” (Panksepp, 2007, p. 103). Uninhibited by the higher order cortical processes for sophisticated thought and cognition, the limbic system and brainstem produce extreme emotionality in decorticated animals, suggesting that core affective consciousness persists without mediation by the cortex.

There is not enough emphasis given to the role that emotion plays in consciousness. Emotion, however, would suitably provide the motivational component of the selection triangle to drive affective consciousness and emotional-instinctual behavior. Joy, sadness, anger, and fear are considered basic emotions, and can be activated by environmental stimuli and without sophisticated cognition; once activated (through subcortical emotion processing), they serve the motivational role in the selection triangle, thus supporting affective consciousness (Izard, 2007; Merker, 2007). Projections between emotion processing systems (such as the limbic system) and the mesodiencephalic system generate these basic primordial emotions (Denton et al., 2009; Izard, 2007; Merker, 2007). “Very medial homeostatic detectors (i.e., for hunger, thirst, etc.) regulate adjacent core emotional systems that generate many distinct instinctual-emotional “intentions in action” - to use Searle’s (1983) felicitous phrase” (Panksepp, 2007, p. 102). Emotion, thus, provides the necessary drive for regulating attention and goal-oriented behavior. Decorticated animals possess the necessary subcortical structures for producing emotionality and affective consciousness.

There is a tendency for neuroscientists to regard consciousness as a concept being uniquely human - to assert that the experience of consciousness hinges on an organism’s

neurological organization being analogous to that of the human. This is an erroneous and anthropocentric assumption, and understanding that animals are in fact sentient beings capable of primary conscious perception is a necessary step in untangling the mysterious web that is consciousness (Panksepp, 2007). We must note the limitations of their conscious experience and distinguish between reflective consciousness and affective consciousness. Again:

Reflective consciousness is characterized by symbolic processes, memory, and ultimately, the capacity for awareness of self and others and for monitoring one's own behavior...primary consciousness is characterized by sensory processes that generate subjective feelings (cf. James 1890/1950; Izard 1990), especially emotion feelings, and also includes awareness of and responsiveness to objects in the environment" (Izard, 2007, p. 97).

It is primary affective consciousness that animals possess and which survives after decortication.

From this, we can suppose that the more ancient subcortical structures of the brain endow decorticated organisms with emotionality and affective consciousness. Analogous studies of decorticated rats suggest that consciousness persists after cortical resection (Moruzzi & Magoun, 1949; Panksepp, Normansell, Cox, & Siviy, 1994). Panksepp et al. (1994) studied the effects of radical neonatal decortication on the social play of juvenile rats and found that 1) the appearance and vigor of social play in decorticates was normal, not differing from that of the controls and 2) motivation to play remained intact after decortication. Taken with their observation of frequent ultrasonic vocalization (USV) during rat play and the discovery that this USV is actually an ancestral form of laughter (Panksepp & Burgdorf, 2010; Panksepp & Burgdorf, 2003), we cannot ignore the increasing evidence that rats are sentient beings in possession of affective consciousness. Such USV patterns could be elicited with tickling, and inhibited or precluded by

fear (elicited through sudden, startling bright lights and rough handling, as well as the smell a predator's urine) (Panksepp & Burgdorf, 2010). Panksepp and Burgdorf (2003) conclude that this evidence points to these USV patterns as an evolutionary antecedent to human joy, reflective of the laughter exhibited by humans during social play in childhood. That this survives decortication provides further evidence for conscious production in subcortical structures, likely the medial and superior aspects of the brainstem.

This is supported further by the observation that decorticated rats continue to spontaneously display coherent, well-organized, and motivated behavior under environmental guidance when the midbrain and diencephalic regions (the mesodiencephalic region) of the brain are electrically stimulated, suggesting that the ability to generate the motivation, orchestration, and spatial guidance required for carrying out these behaviors is supported by the neural substrates that remain following decortication (Merker, 2007). This is likely the case in patients with PVS who, like neonatally decorticated animals and hydranencephalic children possess intact brainstem and subcortical function. As such, they may possess affective consciousness, in which pure emotional feelings (pure pain, pure fear, pure anger, etc.) are felt, possibly free of cognitive awareness and without any apparent awareness of having these feelings. That pure emotions continue to be felt in the absence of cortical activity calls for attention into the ethics of treating patients with disorders of consciousness, such as hydranencephalic children.

Consciousness in Hydranencephaly: An Anomaly or Evidence for Decorticate

Consciousness in Humans?

The presently recognized theory of consciousness requires the presence of global cortical function, but the acceptance of this theory must be called into question in instances of consciousness in decorticate animals and hydranencephalic children. A diagnosis of

hydranencephaly typically means that the label *developmental vegetative state* will be attached to one's prognosis (Shewmon, Holmes, & Byrne, 1999). Anencephaly is a condition in which the cerebral hemispheres do not develop, the pathology of which varies from genetic malformation, to vascular trauma, to hypoxic-ischemia, to toxic trauma sustained during fetal neural development (Merker, 2007). Hydranencephaly occurs when, in the absence of the cerebral hemispheres, cerebrospinal fluid occupies the cranial cavity (Merker, 2007). In their study of four hydranencephalic children (between the ages of 5 and 17) with near or complete lack of a cortex and possession of discriminative awareness, Shewmon, Holmes, and Byrne (1999) take on the issue of how much cortical functioning is necessary for consciousness to persist. These children had essentially zero to minimal cortical function but nevertheless possessed discriminative awareness: they were able to distinguish familiar from unfamiliar people and environments, engage in social interaction, and had "functional vision, orienting, musical preferences, [toy preferences], appropriate affective responses, and associative learning" (Shewmon, Holmes, & Byrne, 1999, p. 364). Though apparent conscious function is rare in hydranencephalic persons, Shewmon, Holmes, and Byrne (1999) suspect this may be a fate superimposed – a "self-fulfilling prophecy," if you will - on these children by the tendency to prematurely label them in a developmental vegetative state.

Typically, children born with hydranencephaly are placed into foster care or institutionalized at the insistence of their physicians who assert that they will never be able to socially interact, possibly stunting them from potential social and cognitive improvement. In three of these cases, the subjects were initially institutionalized/care forfeited by their parents and showed declining functionality until adopted into the care of individuals who provided them with constant affection and stimulation, after which time they began to show improvement

(Shewmon, Holmes, & Byrne, 1999). If a diagnosing physician bases their diagnosis on the clinical presentation of the patient displayed within their limited period of assessment, they are increasingly likely to assume that the patient has no remaining aspect of consciousness. Shewmon, Holmes, and Byrne (1999) warn that the rarity of reported consciousness in hydranencephalic patients can be the result of 1) skepticism by physicians who assume that parental reports of conscious behavior in their children are the product of psychological denial, 2) the intermittent frequency of their behavior, 3) the brief period of time under which the patient is clinically assessed, and/or 4) observation by unfamiliar physicians being perceived as an uncomfortable disruption in their daily routine, thus affecting their behavior. Shewmon, Holmes, and Byrne (1999) believe that in hydranencephalic children, consciousness is a consequence of the brainstem's 'vertical' plasticity (Shewmon, Holmes, & Byrne, 1999). It is possible then that with frequent stimulation and attention, some conscious function can be recovered in children purported to be in a developmental vegetative state, for they possess the necessary subcortical architecture to support consciousness.

These children engaged in play and exhibited discriminatory awareness about which toys, individuals, and situations would yield a positive experience. They seemingly possessed an understanding of how they could manipulate their bodies in order to engage in a meaningful interaction with their environment (the toys, individuals, and situations) as well as an understanding of the feelings that this interaction would elicit. These subjects demonstrated the selection triangle in action: they exhibited situationally appropriate behavior while engaging with individuals and the environment, suggesting that a connection was consciously made between the environment (target selection), motivational-emotional circuitry (the motivational), and the body (action selection) (Merker, 2007). So, by all appearances, the behavior of these children is

intentional and sentient, contradicting their purported developmental persistent vegetative state and pointing to the conclusion that they possess at least some degree of consciousness, however unreflective that may be.

Noted by Shewmon, Holmes, and Byrne (1999) is that none of these children were entirely anencephalic – every one of them did have some residual cortical tissue. This may be grounds to dispute the assertion that consciousness can exist without a cortex. However, they retort that despite the cortical remnants of these children, there was not sufficient cortical remains in any individual to support the necessary framework for consciousness, again pointing to subcortical regions of the brain as the center for their conscious awareness (Shewmon, Holmes, & Byrne, 1999). In any case, the classic case of hydranencephaly is one in which the patient has remnants of temporo-occipital cortex and despite this, diagnostic clinicians have no hesitation in labeling them decorticate and necessarily vegetative (Shewmon, Holmes, & Byrne, 1999). The near absence of a cortex has been sufficient criteria for most physicians to predict with essentially absolute certainty that the patient will be vegetative. The cases discussed above should be grounds enough to carefully reconsider our assumptions about the neural correlates of consciousness and the degree of cortical activity necessary for consciousness to arise.

Panksepp (2007) defines consciousness as “the experience of body and world, without necessarily understanding what one is experiencing” (p. 102). This is the primary form of consciousness that these children likely possess. There is a level of awareness about what one is experiencing, but there is not necessarily a comprehension of that awareness. Denton et al. (2009) suggests that a hydranencephalic individual expressing agitation under circumstances of thirst, for example, may not be a reflection of their conscious awareness of their thirst, but the result of an active anterior wall of the third ventricle exciting the reticular activating system and

generating an arousal and agitation response. However, the immediate gratification of awareness to one's thirst disputes this possibility on the grounds that the absorption of a sufficient amount of the water ingested to resolve the sensation of thirst would not be achieved for at least 10 minutes after drinking it (Denton et al., 2009). This suggests a conscious appraisal of quenching thirst, not a physiological one. Neuroimaging supports this, and, thus, the theory that the primitive brainstem and telencephalon are vital in producing the primordial emotions, along with the idea that these emotions are likely the origin of conscious awareness (Denton et al., 2009). Denton et al. (2009) propose that the functional convergence of the limbic system with the brainstem and reticular activating system gave rise to affective conscious awareness, which is augmented by activation of the amygdala to produces emotions like fear and arousal through its activation of the reticular activating system (for arousal) as well as the motor system (for movement). This would enable the state of consciousness observed in these hydranencephalic children.

These patients, as Northoff (2007) notes, exhibit social salience achieved via a subcortically mediated system of self-relatedness in which they are able to discriminate between internal and external stimuli with regard to their own self, thus allowing them to navigate and interact with the world around them. The upper regions of the brainstem hold the key to sensation of our bodily demands, and they provide the individual with a sense of conscious ownership over their own bodily experiences (Denton et al., 2009; Panksepp, 2007). Panksepp (2007) posits that the "more ancient, medially concentrated interoceptive motivational-emotional urges of the brainstem" (p. 102) provide the foundation for the lateral aspects of the brainstem that allow an organism to extract information about its environment and produce goal-directed behavior. The emotional limbic systems providing the basis for instinctually and emotionally

motivated action are adjacent to the brainstem and are regulated by homeostatic detectors within the medial aspect of the brainstem (Panksepp, 2007). There are two medial emotional-instinctual brainstem layers interacting with one another to produce affective consciousness and such production may exist without self-awareness (Panksepp, 2007). This is likely the case with hydranencephalic children, who, Shewmon, Holmes, and Byrne (1999) report, exhibit greater levels of agitation and emotionality than their normocephalic counterparts, again demonstrating that primary process emotionality is released without modulation by higher cortices (Panksepp, 2007).

Given that the subcortical mediation of consciousness in humans has really only been verifiably observed in cases of congenital brain malformation where consciousness is present, it is possible, as Shewmon, Holmes, and Byrne (1999) postulate, that any degree of consciousness observed in hydranencephalic patients is actually a result of the developmental plasticity of the brainstem and other subcortical structures. They suggest that consciousness may be inherently a cortical function, but when malformation makes it impossible for the cortex to support consciousness, the plastic nature of the subcortical regions allow them to take on that cortical function to produce robust consciousness (Shewmon, Holmes, & Byrne, 1999). This type of plasticity is vertical, meaning subcortical plasticity for evidently cortical functions (Shewmon, Holmes, & Byrne, 1999). Horizontal plasticity (cortical plasticity for cortical functions and subcortical plasticity for subcortical functions) has long been established, but thus far no vertical plasticity has been reported in the literature except by Shewmon and his colleagues (Shewmon, Holmes, & Byrne, 1999).

Two of the hydranencephalic children possessed greater visual capacity despite a complete lack of occipital lobe, when compared with the other two who had diminished visual

capacity despite having occipital remnants (Shewmon, Holmes, & Byrne (1999). Shewmon, Holmes, & Brynes (1999) suspect that this reflects brainstem vertical plasticity because the brain malformations arose earlier in the development of those two with vision, at a time of greater developmental plasticity in each of them. Or, as Merker (2007) suggests, it may be that “no special explanations such as neural reorganization based on plasticity are needed to account for” (p. 79) their observed consciousness and visual capacity, because “the pattern is easily accounted for by the intactness of the brainstem auditory system in these children (Lott et al. 1986; Yuge & Kaga 1998), crowned by a projection from inferior to superior colliculus” (pp. 79-80). I suspect that both Shewmon, Holmes, & Byrne’s (1999) theory of vertical plasticity as well as Merker’s (2007) mesodiencephalic theory are correct.

Vertical plasticity can account for consciousness in cases of congenital brain malformation (since these malformations arise during gestation and neural development, providing sufficient time for compensatory reorganization by subcortical structures to support functional consciousness), but cannot explain consciousness in the PVS or continuation of consciousness after loss of cortical function later in life. I contend that in patients with PVS, a robust form of consciousness—*affective consciousness*—is supported by the mesodiencephalic system. It may be that the mesodiencephalic system provides the neural substrates required for consciousness to exist in hydranencephalic children, and that their experience of consciousness is enhanced by vertical plasticity.

The diminished capacity for conscious awareness in these children has been taken to support the claim that the cortex is necessary for consciousness to arise and that it can only be vertical plasticity that produces their consciousness. The impaired consciousness, however, cannot exclusively be correlated with their degree of cortical activity. Merker (2007) explains

this as it relates to the Sprague effect, in which visual hemineglect is produced by cortical damage, which subsequently impairs the brainstem visual system as well. “This means that the functional deficit following damage limited to the cortex cannot, as a matter of course, be taken to reflect an exclusively cortical contribution to functional capacity, because the deficit may reflect “remote” effects on brainstem systems, as well” (Merker, 2007, p. 67). Additionally, the purportedly-complete loss of consciousness in the PVS cannot necessarily be equated with the absence of cortical activity because in instances of PVS, there is an inherent disruption in the connectivity between cortices and the brainstem, and ultimately a lack of cortical inputs converging on the brainstem for integration (Merker, 2007). We cannot, therefore, accurately determine the scope of the deficit of consciousness produced by damage made solely to the cortex, nor by assessing the corresponding reduction or cessation of cortical activity. Because of this, we must consider the ethical and legal implications of assuming that a lack of cortical activity necessarily means an absolute lack of consciousness.

Legal and Ethical Implications of Redefining Consciousness With Regard to Disorders of Consciousness

In 1776, the founding fathers of the United States declared, “we hold these truths to be self-evident, that all men are created equal, that they are endowed by their Creator with certain unalienable Rights, that among these are Life, Liberty and the pursuit of Happiness” (The Declaration of Independence, U.S. 1776, para. 2). “The International Covenant on Civil and Political Rights [passed by the United Nations General Assembly on March 23, 1976] provides that ‘every human being has the inherent right to life. This right shall be protected by law. No one shall be arbitrarily deprived of his life’ (Art. 6)” (Guceac & Boaghi, 2013, p. 1). At what point is the right to life forfeited for those declared brain dead, and what about those in a PVS

whose lives are sustained through life support and whose lives are in the hands of their medical power of attorney? In the case of Jahi McMath, her right to life was terminated when her physicians declared her brain dead and when the state of California subsequently issued her death certificate.

With the advent of organ transplantation, a new era began in which an increasing demand for vital organs of the deceased brought on the proposal by Henry Beecher and the Harvard Ad Hoc Committee that the irrevocable loss of function of the entire brain qualifies as death (Sade, 2011). This state of being is widely known as brain death, and with the adoption of the Uniform Determination of Death Act (UDDA), a legal redefinition of death has been adopted, such that “an individual who has sustained either (1) irreversible cessation of circulatory and respiratory functions, or (2) irreversible cessation of all functions of the entire brain, including the brain stem, is dead. A determination of death must be made in accordance with accepted medical standards” (Sade, 2011, pp. 1-2). The resounding acceptance of this legislation stems from the knowledge that a total lack of brain functioning means a total lack of consciousness. Despite its overwhelming acceptance by the medical community, the passing of this legislation has sparked enormous controversy and, in some instances, for good reason.

Advances in medical technology allow for the life of an individual to be artificially maintained with life support machinery – the right to such life saving procedures is forfeited when a patient is declared brain dead. With this legislation, an individual whose heart continues to beat and whose lungs continue to ventilate but who displays no brain functioning is legally equated with a somatically dead individual. And in accordance with the Dead Donor Rule (DDR), which requires that an organ donor be necessarily dead for the legal removal of their vital organs, the UDDA effectively allows for vital organs to be harvested from someone

pronounced brain dead (Sade, 2011). This legal definition of death should be reconsidered on several bases.

Despite the legal obligation to define brain death as the “irreversible cessation of all functions of the entire brain, including the brain stem,” (Sade, 2011, pp. 1-2) many patients diagnosed with brain death continue to exhibit some brainstem functioning that keeps the body in homeostasis. The EEGs of patients diagnosed with PVS can substantially differ from one individual to the next, indicating that EEG is not being used as a measure of one’s conscious state—though it should be used to correlate brain activity with level of consciousness (Panksepp et al., 2007). Several “whole brain dead” patients continue to exhibit EEG activity (sometimes preserved hypothalamic functioning), which Potts (2001) notes is quickly dismissed as “residual isolated cellular activity with no relevance to the declaration of brain death.” (p. 482). When this is the case, there is clearly a deviation from the UDDA and subsequently the DDR. Bernat resolves this issue by redefining death “as the permanent cessation of the critical functions [he considers these to be awareness, breathing, and circulatory control] of the organism as a whole,” whereby ‘critical’ refers to “the extent to which a given function of the organism as a whole is necessary for the continued health of the organism” (as cited in Potts, 2001, p. 482). This definition hinges on the fallacy that an “organism as a whole” is not a whole integrative functioning unit without the assistance of the brain.

Sade (2011) argues that in instances of ceasing life support for those pronounced brain dead or in a PVS, the DCD is not strictly adhered to, since the physician suspending life support is technically a necessary agent in bringing about the death of the patient. This is in accordance with Shewmon’s (2001) critique of the whole brain death paradigm, in which he deconstructs

and criticizes the logic upon which the foundation of the UDDA is built, wherein the brain is thought to endow the body with integrative unity. He reflects on this logic and concludes:

Most integrative functions of the brain are actually not somatically integrating, and conversely, most integrative functions of the body are not brain-mediated. With respect to organism-level vitality, the brain's role is more modulatory than constitutive, enhancing the quality and survival potential of a presupposedly living organism. (Shewmon, 2001, p. 457)

An organism remains an integrative functioning unit despite a lack of brain function. At least two of the critical functions outlined by Bernat persist in the absence of a functioning brain. A ventilator working to expand the diaphragm assists continuous breathing by bringing oxygenated air into the lungs, but with regard to gas exchange between oxygen and carbon dioxide, respiration persists (Potts, 2001). The heart continues to pump blood throughout the body, and, in that sense, circulatory control persists (Potts, 2001). These system functions can persist for long periods of time, as evidenced by the work of Yoshioka and associates who used ADH and epinephrine to sustain life in whole brain dead patients for an average of 24.1 days and as long as 54 days (as cited in Potts, 2001). The continued functioning of these systems is dependent upon life support, and the physician, by removing life support, becomes a necessary agent in bringing about the somatic death of the patient (Sade, 2011). The semantics of this argument are admittedly murky, but semantics have always played an essential role in law.

A higher brain standard of death has been proposed in which an individual is considered dead when they “permanently” cease all consciousness (per the currently accepted convention of consciousness), though the brainstem remains intact (Sade, 2011). Those who support this standard argue that for one to be considered brain dead, they need not lose function of the entire

brain, but just those regions of the brain necessary for consciousness. This suggests that some physicians may be subjectively defining brain death, and thus not abiding by the guidelines set forth by the DDR or UDDA (Sade, 2011). I will also note here that those in support of this standard believe that consciousness necessitates cortical functioning, and do not distinguish between affective consciousness and reflective consciousness. For this reason, it is imperative that we recognize the ability of the subcortical structures to produce affective unconsciousness. Regardless, by definition of the UDDA, an individual exhibiting brainstem function would not be considered brain dead. They would be in a PVS instead. There is a necessary divide between brain death versus PVS, as well as PVS versus minimal consciousness. Brain dead patients are neither awake nor aware; PVS patients are awake without awareness of the self or environment; and minimally conscious patients are awake and at least somewhat aware. Medical treatment and care differs substantially between each of these diagnoses, and a failure to rigorously follow diagnostic procedure can mean terminating life when there is no legal, medical, or ethical precedence for doing so. This illegal, subjective interpretation of the UDDA therefore demonstrates the need for further examination into the subcortical mediation of consciousness.

Though it is typical, not all patients diagnosed with PVS have a total absence of cortical activity. Increasingly, we see anomalies that dispute a corticocentric view and, despite a growing body of evidence against it, these cases are typically regarded as anomalies: exceptions to an already “established” corticocentric model of consciousness (Panksepp et al., 2007). As more so-called anomalies arise, it seems that the diagnostic criteria for PVS becomes increasingly flexible. For a PVS diagnosis, some now emphasize not a total absence of cortical functioning, but an absence of the global cortical functioning purported to enable the production of

consciousness. However, in some instances, global frontoparietal activation, as well as subcortical and lower functioning cortices, can be seen in the PVS, demonstrating the lack of consistency in these diagnostic criteria for state of consciousness (Laureys, 2005). In their examination of 33 PVS patients, Kotchoubey et al. (2006) show that an elementary cortical learning process can persist in the VS. They observed habituation of the cortical component N1 of auditory evoked potentials (the sources of which are in the superior temporal gyrus and the frontal lobe), suggesting that with repeated stimulation, the cortex eventually learns to selectively dismiss the immaterial stimulus (Kotchoubey et al., 2006). Learning is a sophisticated cortical cognitive function. By ignoring such evidence, any attempt by medical professionals to insist absolutely that no aspect of consciousness remains when informing the medical decisions of patients' families should be considered negligent.

Declaring that someone is in a PVS, despite the presence of such global cortical activity, can play a critical role in end-of-life decisions—and in the presence of cortical activity, the diagnosis should be reconsidered. In diagnostic medicine, the issue of cortical activity in PVS is most commonly resolved by looking at the consistency with which unconscious patients seemingly appear to be aware, but the intrinsic difficulty of distinguishing between those who are minimally conscious and those without any consciousness commonly results in misdiagnoses. Disorders of consciousness are misdiagnosed at an alarming rate of 40%, and the patient's inability to produce behavioral signs of their awareness makes it particularly important for physicians to partake in imaging studies when assessing a patient's level of consciousness (Monti et al., 2010). In the event that an individual is granted the legal authority to make medical decisions on behalf of a PVS patient, life support can be withdrawn, after which time the patient will eventually die and, with permission, their organs will be harvested for donation (Sade,

2011). This can become an ethical issue when the line between PVS and minimally conscious state (MCS) is blurred. This is also with the assumption that those in a PVS possess no consciousness at all. I assert that they do, in fact, possess affective consciousness, which can be supported by a subcortical network mediating core emotions.

What the scientific community holds to be true about consciousness can only be confidently asserted with regard to the apparently conscious individual who is able to articulate a response. Panksepp et al. (2007) raise concern over recent scientific evidence that challenges the assertion that all aspects of consciousness are absent from those in a PVS. In the PVS, primary somatosensory evoked potentials, as well as activity in the brainstem and thalamus, can be produced in response to pain, and with no activity seen in higher order processing areas (Laureys, 2005; Panksepp et al., 2007). So an external stimulus can elicit activation of the primary sensory cortex, but fails to reach higher order association areas of the cortex, which are considered necessary for conscious perception of the stimulus. Such studies provide a necessary dissociation between wakefulness and awareness (regions of the cortex may be activated without actually giving rise to conscious awareness) (Laureys, 2005). Possession of wakefulness, but not awareness, characterizes the PVS (Laureys, 2005).

The current understanding of pain processing holds that activity in the secondary somatosensory cortex and frontoparietal network (neither of which are activated in the PVS patient after administration of a painful stimulus) are considered necessary for the conscious perception of pain (Laureys, 2005). However, despite an apparent lack of cognitive awareness of one's surroundings and situation, and even without the capacity to comprehend such states, the PVS patient may continue to possess bodily and emotional feelings. According to Panksepp et al. (2007), emotions may still exist without cognitive awareness of those feelings, and the emotional

reactions and pain reflexes exhibited by those in the PVS may actually be a reflection of the primary affective consciousness that arises from our body's ability to monitor its homeostatic state and drive behavior aimed at restoring homeostasis when it senses a discrepancy.

We know that in the PVS, cranial nerves remain intact and patients continue to intermittently exhibit facial expressions, such as grimacing or crying, akin to conscious emotional responses (Panksepp et al., 2007). It is assumed that such responses are reflexes, not reflective of any underlying emotional affective state, since conscious perception of pain is experienced at the cortical level. However, this assumes that conscious awareness of one's pain is necessary for the body to experience that pain. "Visceral sensory-motor integrative homunculi exist in lower regions of the brain," (Panksepp, 2007, p. 102), so there is no reason to assume that affective consciousness cannot persist in the absence of a cortex while subcortical structures remain intact. This is underscored by the knowledge that those subcortical neural structures which produce raw emotionality are the same ones involved in producing instinctual behaviors, like those exhibited by PVS patients (Panksepp et al., 2007). Perhaps the raw experience of rage and fear are not absent from PVS patients when they display "sham rage," for example (Panksepp et al., 2007). This is an abstract concept of which we cannot be certain, but it is also one we cannot definitively exclude because, as Panksepp et al. (2007) point out, there is not sufficient convincing evidence to conclude that raw emotions are only felt after they have been processed by the higher order cortices purported to produce a conscious awareness of the feelings being produced at the subcortical level.

Panksepp et al. (2007) discuss one case which has drawn much controversy – that of Terry Schiavo – in which a legal battle over whether to continue life support culminated in the legal decision to withdraw life support and allow Ms. Schiavo to die of dehydration. They

question the ethics of this decision when they consider that Shiao likely continued to experience horrible thirst, for example, since the neural mechanisms for thirst remain intact in the PVS (Panksepp et al., 2007). At the very rudimentary level, Shiao may have experienced pre-reflective self-awareness, which may have given her a sense of her own immediate bodily experiences, without higher cognitive reflective awareness to those experiences (Northoff, 2007). If patients in the PVS continue to experience raw affective states, “withdrawal of life-support may violate the principle of nonmaleficence and be tantamount to inflicting inadvertent ‘cruel and unusual punishment’ on patients whose potential distress, during the process of dying, needs to be considered in ethical decision-making about how such individuals should be treated, especially when their lives are ended by termination of life-supports” (Panksepp et al., 2007).

It seems that the primary reasoning for dismissing pain in these patients (and those with cortical malformation/underdevelopment), is the result of neuroscientists' present assumption that the perception of pain is exclusively intertwined with human consciousness; the experience of either is primarily regarded as being dependent on intact cortical function, thus the understanding of pain has come to be based entirely upon self report, to the extent of disregarding the physical experience of suffering (Anand, 2007). Additionally, there is a notable oversight here: experimentation reveals that pain is not, in fact, altered by stimulation of the somatosensory cortex, though it is altered by stimulation of the thalamus (Brooks, Zambreau, Godinez, Craig, & Tracey, 2005; Nandi, Aziz, Carter, & Stein, 2003). There is an emphasis, then, on verbal self-report of pain, and this emphasis is drawn from the verbal response of normocephalic, coherent, cognitively- and consciously-intact individuals, informing this conclusion. Whether suffering can exist without awareness to that suffering is unknown, but I surmise that it can. If it is possible to feel pain without conscious perception of it, then this colors

our traditional approach to inducing end of life in PVS patients in a rather negative light. At the very least, we should give consideration to the possibility that the PVS patient feels visceral pain and suffering and that we should minimize their discomfort at the end of life—and a freedom from cruelty and unusual punishment is a right afforded to all under the United States Constitution.

Furthermore, medical advances in treating patients who have sustained traumatic brain injury have shown promise in restoring some function to those in a PVS or MCS. Those in a MCS express some level of awareness. Considering that most physicians provide a PVS diagnosis by clinical observation at the bedside and without extensive neuroimaging, a medical power of attorney can be terminating the life of a fully or minimally conscious individual who is simply unable to express their state of conscious awareness. Schiff et al. (2007) suspect that this state of consciousness is a consequence of diminished activity in distributed neural networks, and, in their case study of a minimally conscious patient 6 yrs status post traumatic brain injury, they demonstrate some recovered function with use of bilateral deep brain stimulation (DBS) of the central thalamus. When undergoing DBS, the patient showed improvement in arousal, mobility, oral feeding, coherent language, and meaningful interactions with others (Schiff et al., 2007). Their theory is that the underactive neural networks, which produce a diminished state of consciousness, are compensated for by neural activation via DBS treatment (Schiff et al., 2007). The implications of these DBS studies are far-reaching in the field of medicine, because disorders of consciousness are typically judged as irreversible after a period of 12 months has elapsed, and common practice is to discontinue treatment after such time. This study challenges that norm and asserts that arresting treatment or ceasing life support can be premature for some patients.

Presently, with the diagnostic techniques available to us, neuroscientists and clinicians cannot definitively ascertain a patient's state of consciousness without verbal self-report. The future of diagnostic medicine is unknown, and defining death by the criteria set forth by a higher standard of brain death, at this point in our understanding of consciousness, is negligent; it is paramount that we maintain discourse on the subject for its ethical implications.

Conclusion

Principally, the literature takes a corticocentric perspective of consciousness in which integration and conscious perception are achieved by the cortex. However, consciousness demonstrated in decorticated animals and hydranencephalic children challenge this perspective. Merker (2007) instead points to the upper brainstem region—referred to as the mesodiencephalic region—extending from the midbrain to the basal diencephalon, as the primary network responsible for generating conscious perception via integration of a distributed neural network into a goal oriented pathway for the execution of volitional behavior.

The highly conserved nature of the brainstem supports this theory and the theory that the origin of consciousness lies in the primordial emotions, which are a consequence of the medial aspect of the brainstem (Panksepp, 2007). The theory is even further supported by experimental studies on the effect of radical decortication on the continued consciousness, learning and behavior patterns of animal models—their behavior being virtually indistinguishable from their neurologically intact counterparts, at least to the inexperienced observer (Panksepp et al., 1994). Observation of the evidently conscious behavior in hydranencephalic children also points to the brainstem as the primary mediator of consciousness.

It is important for the scientific community to continue its discussion of consciousness, and for the field of neuroscience to become more involved in this discussion. Members of the

scientific and medical community must also adopt a distinction between affective consciousness (which allows us to experience raw basic emotions) and reflective consciousness, the latter being widely acknowledged and the former given little credence, if any, by those who do not stress the functional evolutionary relevance of subcortical structures and their potential role in consciousness.

Sustained discourse and exploration into the neural correlates of consciousness is necessary. It will ultimately affect how we treat patients in the PVS, patients with hydranencephaly, and patients with other disorders of consciousness, for the ethical dynamics of society require that we treat those with consciousness quite a bit differently than those without any semblance of it. This is especially important, because clinical diagnoses inform medical decisions by patients' families, who trust that medical recommendations are made by informed, well-educated, and objective physicians. In its raw form, the UDDA is a reliably justified means of determining death by neurologic criteria. However, with the occurrence of subjective interpretation of its criteria and the increasingly common use of a higher brain standard of death, reliance on the UDDA can ultimately compromise objectivity when making diagnoses of brain death.

What is quite astonishing about the UDDA and the "whole brain death" model is its unabashed approval in the face of an expanding body of anomalies that do not fit that model (Potts, 2001). Here, "whole brain death" is presented in the parenthetical form because in many instances of its diagnosis, the patient continues to exhibit some brain activity, and by definition, not death of their whole brain. Alarming so, when a patient is purported to be brain dead and new evidence arises suggesting continued brain activity in those patients (this was the case for Jahi), that activity is taken to reflect a noncritical function (as with continued hypothalamic

function exhibited in some brain dead patients) or is viewed as residual brain activity (Potts, 2001). Otherwise, those cases are dismissed as anomalies by scholars who uphold the whole brain death model as the golden standard for defining death to ensure that physicians are operating within the bounds of the DDR when harvesting organs. Those who object to the model or are hesitant to accept a brain death diagnosis are branded as uninformed by the very people who purport the issue is settled (Potts, 2001). The assertion that any disagreement on the issue is a consequence of misunderstanding, and that the issue of brain death is settled, abridges discourse on a subject which is decidedly not settled (Potts, 2001).

Given the mounting evidence in support of a subcortical model for consciousness, coupled with the alarmingly high rate of misdiagnosis in disorders of consciousness, it has become ethically imperative to redefine the neural correlates of consciousness and how that relates to diagnosing PVS (developmental and acquired) and brain death. Prematurely assuming that a patient lacks consciousness has dire consequences for their subsequent treatment or lack thereof. In particular, this will affect how families decide whether or not to withdraw life support from those declared PVS. "If affective consciousness can exist without cognitive capacities, removing life supports without providing graceful alternatives opens up the possibility of inflicting too many innocent people with a series of terrible feelings that they are in no position to alleviate" (Panksepp et al., 2007). Additionally, it will seriously affect the quality of life for hydranencephalic children, such as with pain management or in instances of physician advisement that the patient be institutionalized (essentially placing these children in an environment where they will rarely receive affection or cognitive stimulation that may improve the state of their consciousness) (Anand, 2007; Shewmon, Holmes, & Byrne, 1999).

There is much to be learned about consciousness, the neural correlates of which are still being disputed. Panksepp (2007) discusses his frustration with the neoneurobehaviorism which regards animals as simple beings hardly capable of emotion, and stresses that if the neurocognitive community wishes to advance its knowledge of consciousness, it must do two things: 1, look beyond its strictly reductionist mentality and refusal to examine “how mental experience could ever emerge from physiochemical processes of the brain” (p. 102); and 2, recognize that animals are sentient beings with subcortically derived “incredibly robust emotional and perceptual homologies” (p. 103). With this perspective, we open the doors to numerous experimental possibilities with the aim of shedding further light onto our understanding of conscious perception.

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