The Brainstem as a Conserved System for Consciousness: Integrating Phylogeny, Neurology, and Psychology

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Cover Page Footnote
Kevin P. Kaut (kpk@uakron.edu) is the corresponding author for this paper. The work was completed by Shadia Kawkabani as part of a senior honors thesis.

This article is available in Journal of Neuropsychology and Behavioral Processes: https://ideaexchange.uakron.edu/jnbp/vol1/iss1/3
The Brainstem as a Conserved System for Consciousness: Integrating Phylogeny, Neurology, and Psychology

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Abstract

Our understanding of consciousness is quite possibly in need of further discussion, elaboration, and updating. What was once principally the domain of philosophical inquiry has entered the era of advanced research methods and biomedical ethics – both of which have influenced the need to reconsider this most challenging of topics. The challenge for those interested in consciousness is at least twofold: 1) to further operationally define what is meant by consciousness, with a greater understanding of how consciousness can be manifest, and 2) to better identify the neural mechanisms subserving the diverse presentations/manifestations of consciousness, and reconcile the developing literatures addressing human clinical, experimental, and animal behavioral research. Advances in medical technology allows modern medicine to keep people alive despite a paucity of evidence to suggest they are sentient according to the traditional use of the word. And yet, prolonging and sustaining life has provided an opportunity to further study the human brain during these states of ostensible non-consciousness, thus offering additional insights into the functional consequences of severe neural trauma. And, it is here that researchers have discovered issues of concern with respect to how we make determinations of conscious awareness and evaluations of “life worth living”. Indeed, it is at this juncture of biology, phylogeny (i.e., trans-species perspective), neurology, and cognitive/affective psychology that researchers are most likely to find answers to questions – or at least more questions that demand answers.

In our previous review (Kawkabani & Kaut, 2023, this volume) we described the rationale for a phylogenetically conserved system supporting consciousness. The corticocentric perspective quite naturally assumes the dominant position in theories of consciousness, with particular emphasis on cognitive processes as foundational to understanding and assessing consciousness. However, it has become clearer in recent years that consciousness as a construct itself might benefit from added breadth in its definition, thereby raising awareness that other species (i.e., ‘less’ phylogenetically complex) possess varying levels of conscious behavior. Naturally, from an evolutionary perspective it would make sense that neural mechanisms with adaptive behavioral significance would be maintained across biologically related species. Accordingly, it is tenable that divisions of consciousness might exist – preserved within our central nervous system anatomy and only differentiated under unique conditions where certain anatomical influences are damaged.
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 of 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 (pain, fear, anger, etc.) are felt, possibly free of cognitive awareness and without any apparent awareness of having these feelings. That pure emotions continue to be experienced/demonstrated in the absence of cortical activity calls for attention to 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 currently recognized perspective of consciousness requires the presence of global cortical function, but the acceptance of this theory must be called into question in instances of conscious-like behavior in decorticate animals and hydranencephalic children. A diagnosis of hydranencephaly (see Figure 1) 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, et al. (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

Figure 1. Hydranencephaly. Image showing cranium filled with cerebrospinal fluid in the absence of cortical development. Portions of the midbrain, pons, medulla, and cerebellum are evident.

From: https://radiopaedia.org/articles/hydranencephaly
environments, engage in social interaction, and had “functional vision, orienting, musical preferences, [toy preferences], appropriate affective responses, and associative learning” (Shewmon et al., 1999, p. 364). Though apparent conscious function is rare in hydranencephalic persons, they 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 et al., 1999). If a diagnosing physician bases his or her 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 and colleagues (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. They believe that in hydranencephalic children, consciousness is a consequence of the brainstem’s ‘vertical’ plasticity (Shewmon et al., 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.

As noted by Shewmon and colleagues (1999) none of these children were entirely anencephalic – each 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 et al., 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 et al., 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

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1 In some respects, this may serve as a developmental analogue to the adult patient in a permanent vegetative state (PVS), wherein isolated regions of cortex may still be intact yet consciousness is deemed lost.
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 produce emotions like fear and arousal through its activation of the reticular activating system (for arousal) as well as the motor system (for movement). This might enable the state of behavior (i.e., ‘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 et al., (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 and colleagues (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 et al., 1999). This type of plasticity is vertical, meaning subcortical plasticity for evidently cortical functions (Shewmon et al. 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 colleagues (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 et al., 1999). These researchers 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). It is tenable that both Shewmon et al., (1999) and Merker’s (2007) mesodiencephalic perspectives may be supported.

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. We 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

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.

Medical technology allows for the life of an individual to be artificially maintained through artificial life support advances – although 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 maintains physical homeostasis. The EEGs of patients diagnosed with PVS can substantially differ from one individual to the next, suggesting that the EEG should not be used as a measure of one’s conscious state—although it could be used to correlate brain activity with level of consciousness (Panksepp et al., 2007). Several “whole brain dead” patients continue to exhibit EEG activity (e.g., 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).

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). We 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 consider 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 can 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. We suggest that they might, 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). 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

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20 This is of particular significance with respect to the work of Adrian Owen (see previous article this volume, Kawkabani & Kaut, 2023) who underscores the need for improved behavioral and technical approaches to obtaining responses from patients who otherwise cannot behaviorally or overtly respond.
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 Shiavo 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, Shiavo 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) (see Figure 2). 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, Zambreanu, 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 we surmise here 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

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**Figure 2.** Conceptual model of reflective and pre/non-reflective consciousness and behavior.
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. Alarmingly 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.
References


Journal of Neuropsychology and Behavioral Processes, 1, 27-40


