The Near-death experience: implications for neuroscience and non-local consciousness

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Overview

Near-death experiences (NDE) raise important questions about the nature of human consciousness, the relationship between brain function and consciousness, the perceptual information that is available to consciousness in moments before death, the role of physical and biological mechanisms associated with altered states of consciousness, and relationships between consciousness, space-time and phenomenal reality. Challenges posed by efforts to define the NDE, claims of anomalous experiences associated with NDEs, the problem of "timing" of NDEs with respect to brain function, recent findings from neuroscience are reviewed, along with emerging evidence for quantum models of consciousness that may help elucidate the nature of NDEs.

I propose that the diversity, complexity and quality of imagery retrospectively interpreted as NDEs reflect a *multiplicity of potential neural pathways* and the degree to which a heritable NDE *predisposition* is present in each unique individual. Certain NDE features are probably explainable by neuroscience and *take place* in 4-dimensional space-time while other NDE features such as confirmed cases of veridical perception and other so-called "anomalous" experiences may be consistent with postulated non-local characteristics of consciousness mediated by quantum-like processes or other non-classical processes (Kafatos et al., 2015) or may reflect relationships between consciousness and the environment that *take place* in higher order space-times. I propose an integral model that reconciles conventional neural explanations and postulated non-classical models of consciousness. The article concludes with suggestions for animal and human studies aimed at further elucidating neurophysiological mechanisms and postulated quantum-like or other non-classical mechanisms in NDEs and other kinds of transpersonal or so-called "anomalous" experiences. Well-funded cooperative research initiatives in functional brain imaging are leading to rapid advances that will make it possible in the near future to empirically test the integral model put forward in this chapter yielding more complete understandings of consciousness including NDEs and other kinds of transpersonal or anomalous experiences.

Challenges posed by defining the NDE

Near-death experiences (NDE) can be characterized as "unusual, often vivid and realistic, sometimes profound life-changing experiences reported by people who have been either physiologically close to death, as in cardiac arrest or other life-threatening medical conditions or emergencies, or by people who believed that death was imminent (Greyson 1999; Holden 2009)." The fact that NDEs are reported both by persons who are confirmed to have been *near death* and persons who had phenomenologically similar experiences in the context of intense fear, dreams or altered states, is consistent with a multi-factorial model in which disparate kinds of physiological and psychological factors precipitate such experiences (Roberts & Owen 1988). Near-death experiencers frequently report significant changes in values and beliefs, including increased spirituality, greater concern for others, a heightened sense of purpose and appreciation of life, and decreased fear of death (Noyes 1980; Ring 1980; van Lommel 2001). In addition to their social and psychological effects, an adequate explanatory model of NDEs must take into account their paranormal aspects including reported "encounters" with persons who were not known to be deceased at the time of the NDE, and verified claims of veridical perception described as out-of-body experiences (Greyson 2001). While the majority of writers on NDEs support neuroscience-based models (Mobbs & Watt 2011) such conventional models cannot explain documented cases of veridical perception and other so-called anomalous experiences that take place in the context of NDEs that may be consistent with postulated non-local aspects of consciousness (Kohr 1983; Ring & Lawrence 1993). Along these lines Kelly and Kelly have argued that contemporary science grounded in physicalism *cannot* provide an adequate model of complex relationships between brain function and consciousness (Kelly & Kelly 2007).

The debate over an adequate model of NDEs and other kinds of transpersonal experiences is related to the fact that disparate models of consciousness are based on conflicting world-views and non-commensurate assumptions about the nature of reality and the characteristics and functions of consciousness. Functionalism, the dominant contemporary scientific model of consciousness, describes "mind" in terms of functions of the brain involved in perception, cognition and memory. Functionalism provides a framework for investigating correlations between brain function and different states or functions of consciousness but it does not delineate or explain the processes that *cause* consciousness or how consciousness *causes* physical or mental processes. Functionalism and other contemporary scientific theories of consciousness argue that NDEs—like all *mental experiences*—are *explainable* by neuroscience and will eventually be *fully explained* by future research findings.

In contrast to science-based explanations grounded in physicalism, transpersonal or Psi models not only *do not assume* the primacy of scientific explanation but posit a different "order" of reality all together in which human consciousness may *take place* and function independently of the brain or—at least in some cases—outside of so-called *ordinary* space-time. Important advances in understanding the nature of consciousness will take place when neuroscience examines relationships between brain function and postulated quantum mechanical mechanisms and other non-classical phenomena. Future more integral neuroscience models that take into account quantum mechanics and emerging concepts in physics will yield research methodologies capable of testing relationships between established neurophysiological mechanisms and postulated non-classical mechanisms at multiple hierarchic levels of organization in

body-brain-environment. Future studies will help elucidate the role of quantum-like processes in both "ordinary" conscious functioning and so-called "anomalous" experiences such as documented claims of veridical perception associated with NDEs. Efforts to develop a *more complete* theory of consciousness will ideally invite dialog from disparate epistemological perspectives including those of anthropology, psychology, neuroscience, psychiatry, transpersonal psychology, and physics (Facco, Agrillo & Greyson 2015). By embracing a multi-disciplinary framework, future theory-building in consciousness research will help reconcile the formalisms of current science with profound insights of the world's great spiritual teachings (Kelly, Crabtree and Marshall 2015).

Validating reports of "anomalous" experiences associated with NDEs

Scientific models of the NDE are based on the analysis of information obtained from retrospective medical chart reviews or in-person interviews of persons who report having these experiences. Rating scales and analytic methods have been developed to assist in identifying relevant descriptive material and compare the characteristics of NDEs in different study populations (Ring 1980; Greyson 1983; Lange, Greyson & Houran 2004). Investigations of accounts of NDE-survivors using different rating scales support that NDEs "take place" or "unfold" as a probabilistic hierarchy of cognitive, affective, transcendental and paranormal components (Greyson 2010). This finding was confirmed by applying a technique in computational linguistics called latent semantic analysis to a large data set of previously examined NDE reports (Lange, Greyson & Houran 2015).

In response to claims of paranormal experiences, skeptics argue that the majority of NDE case reports are poorly documented long after their alleged time of occurrence, and are explainable on the basis of normal sensory channels (Ring & Cooper 1997; Holden 2009; Mobbs & Watt 2011). However, confirmed case reports of "veridical perceptions" in the context of NDEs pose difficult research challenges and have been variously interpreted as evidence for both extrasensory dimensions of NDEs or human "survival" of bodily death. Reports of veridical perceptions by congenitally blind near-death experiencers make this phenomenon even more puzzling, as such cases exclude all plausible neuroscientific explanations (i.e. explanations *within* the domain of contemporary science) and provide compelling evidence that consciousness has non-local properties, at least in the context of *some* NDEs (Kohr 1983; Ring & Lawrence 1993). Accumulating evidence that veridical perceptions take place in out-of-body experiences (OBE) *unrelated* to NDEs, and robust findings from rigorously conducted investigations of remote viewing confirm that veridical perception is a widely shared human perceptual ability that occurs both spontaneously—including in some NDEs and OBEs—and during other altered states of consciousness, and in gifted individuals under controlled laboratory conditions (Holden 2009; Ring & Cooper 1997; Paquette 2012). While confirmed cases of veridical perceptions in minimally conscious states or at moments near death are admittedly rare, a complete explanatory model of consciousness must address *extra-sensory* or *non-local* aspects of consciousness reported to take place in NDEs, OBEs and other so-called transpersonal experiences.

The question of "timing" of NDEs with respect to brain function has not been satisfactorily answered

The single most important question raised by NDE research concerns the relationship between consciousness and brain function. Answering this question will require solving the problem of timing of the occurrence of subjective experiences that reportedly take place at near death and are interpreted as NDEs. A satisfactory answer to this question has eluded researchers because of the absence of a strong empirical methodology for ascertaining the actual "timing" of experiences retrospectively interpreted as NDEs.

Most scientific NDE models rest on the assumption that subjective experiences subsequently described as NDEs take place in the moments coinciding with a life-threatening event or psychological trauma, and that this event somehow precipitates or *causes* a NDE. However in the majority of NDE case reports, an exact correspondence between subjective experiences retrospectively interpreted as NDEs it is impossible to ascertain the actual "timing" of occurrence of a traumatic experience in response to physiological or psychological factors. Carefully documented NDEs, including verified reports of veridical perceptions during a period of complete loss of consciousness (e.g. cases of cardiopulmonary arrest with "flat lining"), demonstrate that at least *some* NDEs "take place" exactly when near-death experiencers believe they do (Kelly & Kelly, 2007, p. 419). Such "time anchors" permit verification of claims that a specific objectively verifiable external event actually "took place" at the same time an individual claims to have had a NDE. While such cases provide evidence for a close temporal relationship between brain function associated with some NDEs and extrasensory perception, the majority of NDEs do not include claims of veridical perception and thus do not provide "time anchors" to objectively verifiable external events. Thus, in the majority of cases, the "timing" of NDEs with respect to particular physiological or psychological precipitants cannot be satisfactorily determined.

Because of the paucity of evidence that NDEs take place in the actual moments of trauma or *anticipated* trauma, some writers have argued that at least *some* NDE features can be adequately explained on the basis of "retrospective imaginative reconstruction" of: perceptions that take place when the brain is unconscious; memories of objects or events that may have been perceived just before losing consciousness or just after regaining consciousness; or on the basis of expectations about what was "likely to have occurred" following return of "normal" waking consciousness (Woerlee 2004). Kelly & Kelly object to the memory "reconstruction" hypothesis, citing studies demonstrating that memory of events that take place just before or following loss of consciousness as typically experienced during general anesthesia are "usually confused or completely absent" – in contrast to the lucid states of consciousness and highly detailed recall typical of NDEs (Kelly & Kelly, 2007 p. 387).

Findings of studies showing a "flat line" during a period of temporary loss of consciousness after which a NDE was reported following cardiopulmonary resuscitation are limited by the fact that widely used EEG recording methods may not be able to detect subtle electrical activity in the cortex, and provide no information about electrical activity in sub-cortical brain regions. Recent studies using specialized EEG recording techniques and sophisticated data analysis methods support the notion that a surge of highly coherent brain electrical activity takes place in humans and rodents in the moments immediately before

death. Preliminary findings of a small case series (N=7) of critically ill but neurologically intact patients hospitalized following cardiac arrest, show that a transient "spike" in high frequency (gamma wave) EEG activity takes place in the moments immediately before cessation of cardiac function when there is no discernible blood pressure (Chawla, Akst, Junker, Jacobs, & Seneff, 2009). In this small series, the researchers observed transient spikes in brain electrical activity in roughly one half of individuals who succumbed in the I.C.U. following cardiac arrest. They speculated that end of life electrical surges (ELES) were triggered by a critical level of hypoxia that causes a loss in Na-K ion potentials in large numbers of neurons resulting in a cascade of electrical activity observed as a high frequency EEG current that rapidly dissipates as neurons lose their resting potential. The authors speculated that patients who are successfully resuscitated following cardiac arrest may have vivid recall of images and memories triggered by this cascade of neuronal activity.

Two recent animal studies also reported findings of transiently increased brain activity at near death (Borjigin et al., 2013; Li et al., 2015). Li et al. (2015) found consistent heart rate changes in rats undergoing experimental asphyxia, including four distinct stages starting with onset of asphyxia and ending in ventricular tachycardia and asystole. Continuous electrocorticographic recordings made using electrodes implanted in left and right frontal, parietal, and occipital lobes revealed increased coherence in the gamma band (65 to 115 Hz) and the theta band (5 to 10 Hz) between all cortical sites. Increased functional connectivity was found between frontal, parietal, and occipital cortices in multiple frequency bands. The degree of connectivity between neural networks, feedback, and feed-forward directions in which network connectivity between brain regions increased, and the frequency band in which connectivity was principally observed, varied in a consistent way in relationship to the stage of asphyxia. Further, the same pattern of dynamic variation in connectivity over time was found in all subjects. Increased cortical coherence and connectivity paralleled changes in cardiac rhythms (i.e., cortico-cardiac coherence) during asphyxia but not in healthy, awake animals prior to onset of asphyxia. A surge in cortico-cardiac connectivity took place in both feed-forward (from the heart to each cortical region) and feedback (from each cortical region to the heart) directions, and the degree of connectivity varied with respect to EEG frequency and stage-dependent changes in cardiac rhythm during asphyxia. In all subjects cortical coherence declined precipitously at the onset of ventricular fibrillation which occurred in the moments immediately before asystole. Dramatic surges in the levels of multiple neurotransmitters were reported including norepinephrine, serotonin, dopamine, GABA, and acetylcholine in both frontal and occipital cortex and levels remained elevated as long as 20 minutes following onset of experimental asphyxia. The authors conjectured that surges in neurotransmitters in the first minute of asphyxia may help explain widely reported features of NDE phenomenology. They postulated that the observed 30-fold increase in central norepinephrine may be consistent with transiently increased alertness, attention, and arousal; a 12 fold increase in central dopamine may be consistent with increases in arousal, attention cognition, and affective emotions; and a 20 fold increase in central serotonin may help explain visual hallucinations and mystical experiences. The authors inferred that the observed surge in synchronized cortical gamma activity stimulated by asphyxia signifies an internally aroused brain and supports that the mammalian brain is capable of high levels of complex information processing at near death.

The finding of surges in coherent electrical activity at near death in both the rodent brain and the human brain suggests the involvement of common neural mechanisms in both species, and perhaps more broadly

in the mammalian brain. It can be inferred from these findings that the mammalian brain is highly activated at near death as evidenced by the ordered release of neurotransmitters in multiple brain regions, and a surge in previously unreported neurophysiological coherence between the cortex and heart at multiple frequency bands in the final moments of life. The finding of increased feedback and feedforward coherence between the cortex and the heart at moments near death suggests that modulatory influences take place in both directions at near death, which may affect both brain activity and cardiac function.

Making inferences about neurophysiological mechanisms involving changes in brain or heart-brain connectivity at near death related to the phenomenology of near-death experiences must await findings of prospective controlled studies on humans employing advanced research methods similar to those used in the above animal studies. Formal studies using 24-lead EEG recordings and advanced data analysis algorithms in patients who are dying are needed to confirm these preliminary findings and rule out artifacts as a possible cause of EEG spikes. Pending confirmation of coherent spikes in EEG activity at near-death, advanced functional brain imaging studies using positron emission tomography (PET) or functional magnetic resonance imaging (fMRI) may further elucidate dynamic neural processes in both cortical and sub-cortical brain regions that take place at near-death. If future studies using more advanced brain imaging and data analysis methods support that extrasensory perception takes place in the context of highly coherent EEG activity at near death, such a finding would open important new directions in the scientific investigation of mechanisms associated with postulated non-local characteristics of consciousness.

Although the findings of Chawla et al., Borjigin et al., and Li et al. (Chawla, Akst, Junker, Jacobs, & Seneff, 2009; Borjigin et al., 2013; Li et al., 2015) may help explain reports of vivid imagery at near death associated with critically low brain oxygen levels, these findings do not bear on NDEs that take place in the context of intense fear, lucid dreams or altered states, especially given that individuals who report such experiences generally have not undergone acute physiological insults to brain function and were never actually at risk of dying. The broad range of contexts in which NDEs are reported to take place suggests that a multiplicity of physiological and psychological factors are associated with NDEs; and that disparate initial factors and circumstances may lead to the "activation" of different psychological, physiological, neurophysiological and potentially—in some cases—quantum mechanical or other non-classical mechanisms. This diversity of factors, circumstances and mechanisms results, it would seem, in a variety of NDE-like experiences that "take place" at different times including: the moments when consciousness is "altered" but before loss of consciousness is complete; the moments following loss of consciousness when the brain continues to function normally; following more prolonged periods when cortical brain function as measured by EEG electrodes is absent; during dreams or so-called "altered" states of consciousness related to trance; in response to psychedelics and after "ordinary" waking consciousness returns following cardio-pulmonary resuscitation; during resolution of an "altered" state; or, waking from sleep. In a separate paper the author proposes a multi-factorial model in which a variety of neurophysiological or psychological factors result in activation of dynamically inter-connected brain networks resulting in phenomenal content retrospectively interpreted as NDEs (Lake 2017a).

White crows: the debate over the relationship between brain function and consciousness

Only a single confirmed case of a NDE that "takes place" in the complete absence of brain function is needed to support the hypothesis that consciousness *is possible* in the absence of a functioning brain, and, by the same token, to confirm that an intact fully functioning brain is *not always* a *necessary or sufficient* prerequisite for at least *some kinds* of conscious experiences including encounters with "bodies of light" and other kinds of complex mental imagery typical of NDEs. In fact, the neural prerequisites for NDEs may have more to do with a capacity for complex mental imagery than an intact visual system. Bokkon has found that transient surges of bioluminescence from regions of the visual cortex and retina take place in individuals engaged in intense visual imagery and has argued that such experiences may help explain "encounters" with "bodies of light" frequently reported during NDEs (Dotta 2012; Bokkon 2013). Biophoton emissions during vivid mental imagery were found to be highly correlated with EEG spectral power. These experimental observations are consistent with other research findings of coherent photon emissions in biological systems suggestive of large-scale quantum coherence (Popp 2002). Cases of cortical blindness in which the capacity for visual imagery is preserved provide further evidence that complex visual imagery does *not always* require an intact visual cortex (Ring & Cooper 1997; Ganis 2003). On the basis of these findings Ring and Cooper have argued that visual imagery not only *does not depend on* intact visual cortex, but would be *expected to take place* even in cases of acute cerebral hypoxia impairing "normal" functioning in neocortex (Ring & Cooper 1997).

Isolated cases of complex visual imagery in persons with cortical blindness are not a basis for inferring general relationships between specific characteristics of brain function and NDE phenomenology, much less between brain function and consciousness per se. Nor do dramatic case reports of veridical perception say anything about the incidence of anomalous experiences associated with NDEs. Confirming that a single "white crow" actually exists does not provide enough information to determine how common or rare white crows are, nor can confirmation of the existence of a single white crow explain how white crows came into existence in the first place, when and where one can expect to find them, or in what ways neural or quantum-like mechanisms associated with such "anomalous" experiences may differ from mechanisms associated with black crows (i.e. so-called "ordinary" states of consciousness).

In summary, in view of the small number of documented case reports in which a NDE is confirmed to take place contemporaneously with complete absence of brain function, and in view of carefully documented cases in which complex NDEs take place in unconscious but physiologically and neurologically intact persons or in awake fully conscious persons, it seems not only possible but *plausible* that humans have the capacity to experience NDEs and NDE-like experiences mediated by disparate physiological, psychological and possibly also quantum-like or other non-classical mechanisms. In other words while some NDEs are probably "constructed" from fragmentary perceptions, memories or mental imagery generated in the context of an acute physiological insult to the brain, it seems plausible that other NDEs—more accurately, altered states of consciousness or dreams in which NDEs take place—may be associated with quantum-like or other non-classical processes that manifest as extra-sensory perception or other kinds of "anomalous" experiences.

Emerging theories in physics may help explain anomalous aspects of NDEs and other transpersonal experiences

Insights into so-called anomalous aspects of NDEs will come from a deeper understanding of the relationship between the physical brain and space-time. Neural and non-classical mechanisms associated with anomalous aspects of NDEs may help explain transpersonal experiences broadly. Along these lines the work of Lange & Houran (Lange & Houran 1996; Houran 2000) suggests that the content of perceived apparitions cannot be adequately explained on the basis of postulated electromagnetic or neurochemical brain processes alone, but is mediated by disparate contextual variables related to both the type of transcendental experience and the state or arousal preceding the experience. From the perspective of parapsychology the debate over the significance and ontological status of NDEs invokes two competing theories: the so-called "super-psi" hypothesis and the survival hypothesis. Based on a review of criteria denoting relative scientific merit of the respective models Rousseau has argued that the survival hypothesis may be a more plausible explanation than the "super-psi" hypothesis (Rousseau 2012). Many models discussed in the parapsychology literature rest on assumptions of non-local quantum mechanical effects in living systems, are inherently indeterminate and are not *potentially* falsifiable using available technologies and current research methods (Vannini 2008). Thaheld has contributed important theoretical work in the area of "biological non-locality" postulated to take place when quantum-like processes manifest as entanglement between living systems (Thaheld 2003; 2005). Findings of EEG and fMRI studies suggest that non-local correlations between electromagnetically isolated brains may be consistent with quantum-like entanglement between complex living systems (Standish et al., 2003, 2004; Richards et al., 2002; Walach 2001; Wackerman 2003; Achterberg et al., 2005). Reviews of psychological, neurobiological, quantum-like, and parapsychological models of "anomalous cognition" are available in Cardeña, Lynn & Krippner (Cardeña, Lynn & Krippner 2000), Leder (Leder 2005), Kelly & Kelly (Kelly & Kelly 2007) and Krippner & Friedman (Krippner & Friedman 2010).

It is widely accepted that all living and non-living systems are reducible to quantum-level processes, however the fact that a complex system can be described using the formalisms of quantum mechanics does *not necessarily imply* that quantum-level processes are associated with particular properties or functions of the system in ways that are *non-trivial*. Some researchers have expressed doubt about the validity of quantum models of consciousness in general asserting that quantum-like models may constitute popular metaphors that add little to the rigorous scientific work of theory building (Jahn & Dunne 2011). In contrast to such *quantum skeptics*, leading theorists including Stapp, Hameroff and Penrose argue that microscopic QM-level processes not only play important roles in consciousness but that such non-classical processes constitute fundamental mechanisms of brain function that make conscious experience possible (Stapp 2014; Hameroff & Penrose 2014). Other theorists have argued that even if future studies confirm quantum entanglement at the level of correlations in simple two-particle systems involving sub-atomic particles, this finding *cannot adequately explain* the information density and rich phenomenology associated with "ordinary" conscious experience or so-called transpersonal experiences such as NDEs and out-of-body experiences (Vitiello, 2001, esp pp. 17-20). Vitiello and Freeman have argued that, in contrast to quantum mechanics, quantum field theory provides more complete and more robust descriptions of the dynamics of complex non-linear dynamics in living systems, and may thus provide a more adequate framework for modeling consciousness (Vitiello 2001,

esp pp 17-20; Freeman & Vitiello 2011). For example highly coherent EEG activity that takes place during "ordinary" conscious states such as in short-term memory formation may be consistent with predictions of quantum brain dynamics.

Quantum field theory is the basis of Quantum Brain Dynamics (QBD), which may help elucidate biomagnetic field changes in brain activity associated with both "ordinary" and anomalous conscious states. QBD posits that symmetry-breaking in the brain's electromagnetic field caused by ionic fluxes in axonal membranes, results in the formation of Nambu-Goldstone quanta (sub-atomic particles classified as Bosons), which, on transitioning to a stable ground state, form meta-stable "condensates (Jibu 1995). Boson-condensates subsequently merge into highly ordered macroscopic states that manifest as tightly coupled correlations of microscopic *non-local* brain states (i.e., states that take place *independently* from synaptic connectivity). Correlated non-local states are massively in phase fulfilling the classical QM definition of "coherence." The net result is that the entire brain, particular networks, or networks of networks, behave as a *coherent macroscopic quantum system*. In this model the properties or "qualia" of consciousness are manifestations of coherent macroscopic quantum states created during symmetry-breaking when electromagnetic fields interact in the brain. QBD provides a new synthesis of complex systems, neuroscience and quantum field theory however, like other quantum models of brain function, the predictions of QBD are not *currently* falsifiable using existing technologies and research methods.

Starting from the theoretical work of Linde and others, Smythies has argued that consciousness, matter and space-time "are equal ontological partners"; in other words, all three exist as fundamental kinds of "things" in the universe (Smythies 2003; Linde 1990). In the same vein Paj proposed a cosmological model based on the premise that space-time *can exist* only in relationship to a primary kind of *universal consciousness* which he characterizes as a *primordial quantum field* (Paj 2013). By postulating that consciousness is a fundamental kind of "thing," both models avoid some of the problems of agency—namely, how the "worlds" of the physical and the mental can conceivably interact and influence one another—that arise in monism and dualism.

Some theoretical physicists have argued that the 3 dimensions used to describe space in Newtonian mechanics may be an arbitrary and incomplete description of the universe and that "reality" is *hyperdimensional*. Superstring theory, for example, postulates that the universe consists of at least 10 spatial dimensions and gravity "extends" into a kind of higher dimensional space. In this vein Hawking has proposed that physical objects and processes take place in 4-dimensional space-time structures called *branes* that are *embedded* in higher-dimensional space-time manifolds that reflect the actual structure of the universe (Hawking 2001). Assuming that *brains* or other complex systems capable of manifesting consciousness are "embedded in" 4-dimensional *branes* which are in some sense *related to* or "projected on" a higher-dimensional space-time *background* in which they have existence, the properties of a higher-dimensional space-time would be expected to constrain the nature and functions of consciousness. Along similar lines starting from Plato's allegory of the cave Sirag has proposed a hyperspace model of the universe according to which our 3-dimensional bodies are "shadows" of a higher dimensional world in which consciousness plays a primary role (Sirag 1997).

Many writers have postulated that so-called "anomalous" effects are explainable as non-local or supra-luminal phenomena associated with quantum entanglement or quantum tunneling according to classical quantum mechanics, and especially quantum electrodynamics (QED) theory (See MacGregor 2008 and Millar 2015 for reviews). Rauscher and Targ have argued that anomalous phenomena are explainable and even *expected* in the context of an 8-dimensional space-time metric, a *hyperspace* model of the universe that is more consistent with contemporary interpretations of quantum mechanics than the conventional Newtonian model of space and time from which current medical models of consciousness are constructed (Rauscher and Targ 2001). In the same vein Greene and Krippner proposed a hyperspace model for "separation experiences" including out-of-body experience commonly reported in the context of NDEs (Greene 1999; Greene and Krippner 1990). Starting from six scientific and metaphysical propositions Audain's extraneuronal hyperspace theory builds on the work of Greene and Krippner arguing that information contained in signals (sic "cognons") that the brain transduces into a form of energy and space exists outside of 4-dimensional space-time in a hyperneuronal matrix (Audain 1999).

Toward an integral model of consciousness

An *integral* model that combines and *reconciles* the perspectives of conventional neuroscience models, quantum-like models, and hyperspace theories will provide a more robust conceptual framework in which to investigate the diverse experiences and characteristics of consciousness. A future *integral* framework for theory-building may yield more adequate explanations of both "ordinary" cognitive and perceptual functions and experiential states, disorders of consciousness, and so-called "anomalous" phenomena taking into account the range of factors and processes that influence and constrain consciousness at multiple hierarchic levels in the complex body-brain-environment system. I am proposing an integral model that encompasses both classically described neural mechanisms and postulated non-classical mechanisms. In the model some—probably the majority—of *states* or *functions of consciousness* are associated with established neurophysiological mechanisms, while certain states or functions are associated with transient, highly coherent macroscopic quantum fields or other kinds of non-classical phenomena. In the former case, conventional theories in psychology and neuroscience provide adequate descriptions and explanations of perception, cognition and memory, which take place in the domain of "ordinary" space-time. In contrast, in the latter case, I am proposing that certain states or functions of consciousness *are possible* and may in fact take place *only* in the context of quantum-like phenomena or *higher-dimensional space-times* and such states or functions of consciousness are often construed as "transpersonal," "paranormal" or "anomalous." I believe the proposed model provides a more robust framework for conceptualizing inter-relationships between established physical and physiological mechanisms underlying brain function on the one hand, and postulated quantum-like processes and higher dimensional space-times on the other hand.

States or functions of consciousness that take place with respect to quantum-like processes or higher dimensional space-times probably involve discrete neurons, neural networks or groups of functionally interconnected networks that "resonate with" other (non-living or living) systems situated in other space-time domains including the special case of *space-time domains enfolded by other brains or machines*. In other words, certain *states* or *state changes* that take place in the brain are associated with coherent

macroscopic quantum fields or other kinds of non-classical processes (e.g. scalar fields) that "condition" space-time resulting in entanglement between systems that exist in "ordinary" space-time and systems that exist in higher dimensional space-times. This phenomenon can be described as a kind of *resonance* between state spaces that are non-local with respect to each other in 4-dimensional space-time but may *over-lap* in higher dimensional space-times with the result that "information" in the entangled state spaces is co-extensive in two or more networks within one brain, in two or more brains, or between one or more brains and other complex living or non-living systems. Like other models of consciousness that invoke quantum mechanics or other kinds of postulated non-classical phenomena, the proposed model cannot be tested at present using available empirical methods. In spite of the impossibility of verifying the proposed model at this time, I offer the model to invite discussion and debate that may lead to studies that will further elucidate the nature of transpersonal and "anomalous" experiences currently described as *extra-sensory perception,* telepathy, clairvoyance, remote viewing, and veridical perception during NDEs or OBEs.

Discussion

The structural and functional properties of brains can be described using formalisms borrowed from disparate paradigms including neuroscience, molecular biology, information theory, complex systems theory and quantum mechanics. Each paradigm offers a different perspective about the nature of consciousness that invites formal empirical investigation (MacGregor 2008). Different conceptual lenses used by disparate paradigms have yielded different descriptions and understandings of brain function, and different hypotheses about the relationship between brain function and consciousness. Tononi has argued that an adequate theory of consciousness must take into account the nature of the physical universe and complex living systems in which consciousness takes place or can *potentially* take place (Tononi 1998). The body-brain can be viewed as a dynamic complex system comprised of biological, informational and energetic processes that interact reciprocally with the environment. Contemporary scientific models of perception rely on established theories in psychology, neuroscience and biophysics to explain the range of reported perceptual states including claims of so-called "anomalous" experiences. In contrast, more recent models of consciousness postulate the existence of novel kinds of energy or information based on quantum mechanics or other non-classical processes such as scalar waves and pilot waves (Kafatos et al 2015). Thaheld provides a framework for investigating putative biological entanglement in simple in vivo systems of cultured neurons and in intact brains (Thaheld 2006).

I have argued that all states and functions of consciousness cannot be described or explained on the basis of a single psychological, physiological or other mechanism. It follows that the phenomenology of NDEs and other kinds of transpersonal experiences cannot be adequately explained on the basis of a single mechanism. This paper puts forward an integral model that addresses NDEs from the perspectives of neuroscience and theoretical physics. The model is based on the assumption from evolutionary-developmental theory that neurobiological mechanisms underlying NDEs are *inherited predispositions* that are *released* in response to a multiplicity of endogenous or exogenous factors that *precipitate* shifts in neural dynamics which *correspond to* "unfolding" of a unique NDE (Lake 2017b). Carefully documented cases of "time anchors" have confirmed that at least some NDEs probably "take place"

coinciding with periods of complete loss of consciousness; however, questions pertaining to the timing and duration of NDEs remain unanswered. While some NDE features are probably generated *de novo* as recurrent mental imagery and may originate in older mammalian brain regions, others may be constructed from fragments of remembered sensory experiences encoded in neocortex. Other features of NDEs including confirmed reports of veridical perception during a period of complete loss of consciousness and other so-called *anomalous* experiences cannot be adequately explained by current science and may be consistent with quantum-like processes or other non-classical processes reviewed in this paper. A small in-vitro study found indirect evidence of macroscopic quantum entanglement between cultured nerve cells that were electromagnetically isolated (Pizzi 2004). The recent discovery of quantum-scale vibrations in neuronal microtubules in the living brain provides additional indirect evidence for macroscopic quantum effects and possibly quantum entanglement in brain tissue (Satyajit 2013). It is significant that the findings of Satyajit et al (Satyajit 2013) support the hypothesis that EEG rhythms may derive from quantum-level microtubule vibrations. Hameroff and Penrose have interpreted this finding as consistent with predictions of their ORCH-OR model of quantum consciousness (See Hameroff & Penrose 2014 esp section 4.5). As reviewed in this paper, surges in coherent brain electrical activity take place in both animals and humans at near death (Chawla, Akst, Junker, Jacobs, & Seneff, 2009; Borjigin et al., 2013; Li et al., 2015). Stapp has argued that the recent finding of surges of highly organized oscillatory EEG activity in the pre-motor cortex of monkeys provides evidence that macroscopic quantum-like fields take place in the mammalian brain (Rubino 2013; Stapp 2014).

The model I have proposed argues that alterations in the *normal level of consciousness* associated with physiological trauma, psychological stress, dreaming, or altered states activate releaser mechanisms in the form of neural networks or groups of inter-connected networks (i.e., *connectomes*) that determine the relative complexity or depth and features of NDEs as well as their actual or "apparent" duration. Widely used electroencephalographic (EEG) recording techniques suggest that some persons who report NDEs may have these experiences in the absence of brain activity (i.e. when they are "flat lined") however such techniques do not have the sensitivity to reliably measure complex neural dynamics that take place at moments near death. In contrast to early studies purporting to show that NDEs take place when the brain is "flat lined" recent animal and human studies using advanced EEG recording and data analysis methods support that highly coherent brain activity consistent with complex consciousness takes place at near death (Li et al 2015; Borjigin et al., 2013; Chawla et al., 2009; Lake 2017).

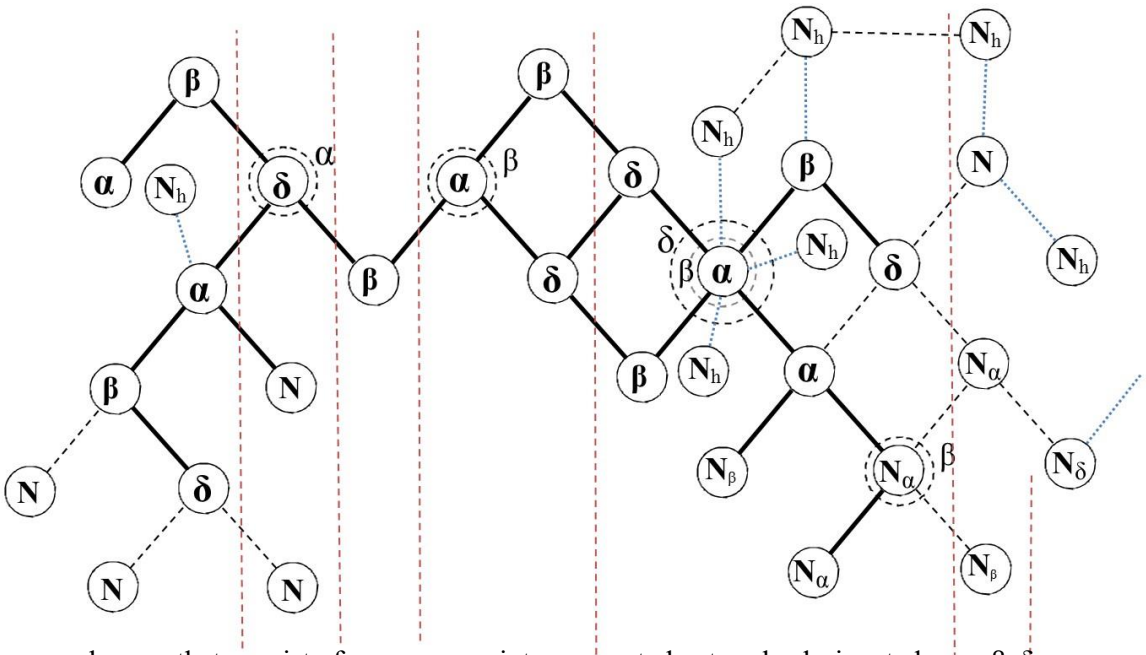
The attributes of a particular NDE (or other transpersonal experiences) are related to dynamic neural patterns that are activated or *released* by unique precipitating factors and constrained by the extent to which a heritable NDE *predisposition* is present in each person and is shaped during development (Lake 2017a). Some NDEs precipitated by psychological trauma may "unfold" almost instantaneously in contrast to NDEs reported in the context of cardio-pulmonary resuscitation following a near-fatal illness or injury, which may require *more real time* to "unfold." Cases of apparently instantaneous or "timeless" NDEs do not support simple linear correlations between the relative *depth*, complexity and *apparent duration* of NDEs, and the actual duration of a period of loss of consciousness or alteration in the level of consciousness during which they are *reported* to take place (Sabom 1982, p 59-60; Ring 1980, p. 129).

Relationships between dynamically interconnected networks that act as releaser mechanisms at the levels of neuronal function, network dynamics and postulated quantum-like processes may be *linear* or *non-linear* in relationship to initial conditions and modulatory processes that take place on different temporal and spatial scales. In some cases, activity in a particular neural network or group of inter-connected networks may comprise the dominant "mode" underlying a unique NDE. In other cases the phenomenology of a particular NDE (or other transpersonal experience) may be the result of dynamic activity in multiple networks that interact sequentially or in parallel. An unlimited and indeterminate number of permutations of dynamically interconnected networks or groups of functionally inter-connected networks may operate as a releaser mechanism corresponding to a potentially *unlimited* and *indeterminate number of permutations* of NDE features, patterns and subjective experiences. The phenomenal content of a particular NDE (or other transpersonal experience) is constrained by multiple exogenous and endogenous factors that drive "transitions" between "modes" in the moments before, during or after a period of alteration in "normal" waking consciousness.

Neural processes and other biological mechanisms associated with NDEs and other transpersonal experiences probably take place in "ordinary" 4-dimensional space and time as described in Newtonian mechanics. In contrast, confirmed reports of veridical perception or other "anomalous" experiences may be associated with postulated quantum-like processes that *take place* in higher order space-times. In the latter case it is conceivable that particular "states" of dynamic brain activity *affect* the properties of space-time in which neural networks or the brain-body as a whole is situated or *enfolded*, resulting in quantum *entanglement at the level of molecules, interconnected groups of neurons or complex webs of neural networks. Depending on the scale at which quantum entanglement* takes place, it is conceivable that *highly coherent states* occur in disparate neural networks in the brain-body-environment context in which a unique person (or animal) is situated and, under some conditions, in other body-brain-environment systems comprised of two or more persons, animals or other living or non-living systems. Applying fractal theory to brain network theory may add an important new dimension to models of brain function (Bieberich 2012). It is conceivable that the neural dynamics associated with complex consciousness such as NDEs—and possibly transpersonal experiences in general—will be found to behave in ways that are analogous to infinitely recursive fractals that may operate in 4-dimensional space-time or higher-order space-times depending on factors that operate in each unique case.

The rich phenomenology associated with NDEs and other kinds of transpersonal experiences suggests that an adequate explanatory model of consciousness will include both established neurophysiological mechanisms and quantum-like or other postulated *non-classical* processes. I propose that the dynamic interconnectivity between networks is in a state of continuous flux in response to modulatory inputs at a classical (neurophysiological) and non-classical (e.g. QM, QFT) level resulting in multiple overlapping deterministic and stochastic patterns of brain activity on multiple temporal and spatial scales.

Figure 1 illustrates disparate psychological, neurophysiological and postulated non-classical mechanisms associated with NDEs and possibly other kinds of transpersonal experiences that affect or are affected by brain activity. Note that different kinds of classical and non-classical processes take place on different temporal and spatial scales in "ordinary" space-time or higher order n-dimensional space-times (i.e. "hyperspace").



- ρ_N are releasers that consist of one or more interconnected networks designated as α, β, δ

- In the simplest case a releaser consists of only one network however releasers may consist of 2, 3 or an indeterminate number of interconnected networks

- A particular network or group of functionally related networks may "overlap" with one or more other networks (dashed circles) resulting in two or more *functionally overlapping* and *inter-connected* releasers (e.g., a particular network may function as $\mathbf{N_\alpha}$ in one releaser, $\mathbf{N_\beta}$ in another releaser, or as a complex $\mathbf{N_\alpha::N_\beta}$ releaser corresponding to one or more *functionally overlapping and interconnected* releasers, etc.)

- Vertical dashed lines represent "boundaries" between discrete networks or groups of functionally related networks

- N depict networks or groups of networks that are interconnected with other networks in "ordinary" 4-dimensional space-time

- Solid black lines are in the plane of the illustration and depict connections between discrete networks in 4-dimensional (i.e. "Newtonian") space-time

- Blue lines extend out of the plane of the illustration and depict postulated interconnections between networks (and releasers) that may take place in higher order n-dimensional space-times (i.e. "hyperspace") mediated by intra-brain quantum-level processes (see above)

- N_h depict networks or groups of networks that are interconnected with other networks across higher order n-dimensional space-times.

Research recommendations

A prospective longitudinal study should be conducted on persons at near-death in order to further clarify the roles of disparate neurophysiological mechanisms and putative non-classical mechanisms in NDEs. Van Lommel has pointed out that there are many circumstances in which NDEs are reported including cardiac arrest (the most studied phenomena), shock following massive blood loss, traumatic brain injury, intra-cerebral hemorrhage, near drowning, asphyxia, serious diseases and coma (van Lommel 2004). Further, experiences similar to NDEs are reported during the terminal phase of illness and are called deathbed visions (Wholihan 2016). The variety of circumstances in which NDE phenomenology takes place provides researchers many choices for designing studies that adapt to the unique timing and more importantly, the duration of medical circumstances in which NDEs may take place. Thaheld has remarked that changes in brain activity associated with cardiac arrest take place so rapidly that little experimental time is available (Thaheld personal communication 8-22-2016) and Van Lommel (Van Lommel 2004) have suggested that clinically induced death due to hypothermia might provide a context for investigating changes in brain function on a controlled basis over a prolonged period of time during which a NDE may take place. A prospective longitudinal study design would ideally employ 24-lead EEG recordings and sophisticated EEG analysis algorithms, and when feasible, fMRI, to test for correspondences between highly coherent brain states measured on EEG and/or fMRI and particular features of NDEs including claims of veridical perception.

Because of ethical considerations that preclude the use of implanted electrodes in humans (with the exception of patients who undergo surgery for refractory seizure disorders), the findings of EEG studies on humans at near death will not be directly comparable to the findings of Li et al. (2015) in which electrocorticographic leads were implanted in sub-cortical brain regions. However, estimates of sub-cortical electrical activity may be made using specialized EEG methods together with recently developed in vivo imaging approaches based on connectomics theory (Grech et al., 2008; Alkemade, Keuken, & Forstmann, 2013).

In addition to human studies functional brain imaging studies should be done on experimental animals already scheduled for humane euthanasia, to determine whether findings of surges in coherent EEG activity reported in rodents (and humans) at near death are a robust phenomenon or merely artifacts of signal collection and analysis techniques. Following Li (2015) et al., future animal and human studies should use simultaneous recordings of brain and cardiac electrical activity to determine whether and in what specific respects feedback and feedforward activity between the brain and heart takes place in different animal species and humans. When ethically feasible, EEG data should be supplemented by assays of neurotransmitter metabolites to ascertain whether surges in neurotransmitter activity at near death are a consistent and a robust effect in different species. If EEG studies confirm a consistent pattern of brain electrical activity at near death, advanced studies using functional brain imaging technologies

including PET and fMRI could be conducted to further investigate this phenomenon. Ideally, future functional brain imaging studies would incorporate important recent advances in fMRI imaging technology including high-field scanners and ultra-fast sampling pulse sequences needed to acquire high resolution images of neural processes that take place on time scales of milliseconds to seconds. This technique will permit analysis of real-time changes in brain neural network connectivity at near death (Boly et al., 2013). Findings of future EEG and functional brain imaging studies should be analyzed using advanced methods of network theoretical analysis, including the ones discussed in this paper, to compare and integrate data obtained across different spatial and temporal scales using different imaging techniques including EEG, fMRI, and magneto-encephalography (MEG) (Stam & Teware, 2014). Using these approaches it is already possible to investigate brain function in minimally conscious states, vegetative states, or in the moments immediately before or after death, yielding valuable insights about changes in micro- or macro-level networks that may be associated with NDEs.

Depending on the findings of prospective human studies, further studies could be undertaken to investigate whether consistent reports of NDEs or other kinds of transpersonal experiences result from stimulating the brain. For example studies using transcranial magnetic stimulation (TMS), EEG biofeedback and state-of-the-art brain-computer interface technologies aimed at inducing dynamic brain activity associated with NDEs (or other transpersonal experiences) could be undertaken to determine whether anomalous experiences reported in NDEs, lucid dreams and altered states can be reliably *induced* under controlled conditions by stimulating the brain in different ways.

For reasons discussed in this paper, a falsifiable theory of consciousness based on quantum mechanics or other postulated non-classical processes is not empirically falsifiable at the present time. However, existing functional brain imaging technologies make it possible to test for correlations between EEG or fMRI measures associated with specific functional "states" in global or regional brain activity and so-called anomalous effects that may be consistent with quantum-like models of consciousness. A finding of apparent above-chance correlations between highly coherent brain activity and reports of anomalous experiences in NDEs, lucid dreams or altered states, would provide indirect evidence for macroscopic highly coherent entangled states between the brain and the environment consistent with the predictions of quantum-like models of consciousness. Random event generators (REG) could be used to test for correspondences between coherent brain states and NDEs—or other kinds of transpersonal experiences—that may be consistent with postulated non-classical mechanisms.

All living systems, including the human brain, emit photons as a function of metabolic processes that take place at the infra-cellular level. The properties of such "biophotons" or ultraweak photon emissions (UPEs), vary with respect to metabolic processes in the plant or animal emitting them. Analysis of biophoton emissions in various states of consciousness, and – when available—findings from simultaneous EEG recordings may provide a basis for making inferences about correspondences between brain activity and biophoton emissions in cases where NDEs are retrospectively reported following successful resuscitation. A similar research paradigm could be used to investigate correspondences between electrical brain activity and biophoton emissions when phenomenologically similar experiences are reported in the context of hypnosis, lucid dreams or altered states (i.e. states in which NDE-like phenomena are reported but there is no risk of death). Preliminary research findings support that healthy

human subjects in a very dark environment instructed to vividly imagine bright light reliably display significant increases in the normal level of biophoton emissions from the right cerebral hemisphere, as measured by a photomultiplier tube (PMT) (Dotta 2012). Thaheld has suggested that this finding could be adapted to a study on persons who may be undergoing a NDE in the context of an acute medical crisis in which NDEs are likely to be reported. To minimize artifacts from ambient light Thaheld has suggested shielding the photomultiplier tube and placing a mask or opaque goggles over the eyes. The easiest way to reduce ambient light would be to conduct the study in a very dark room. The initial phase of the study would collect baseline data on biophoton emissions from a normal awake subject and a normal sleeping subject (during REM and non-REM sleep) in a very dark room. The second phase of the study would measure biophoton emissions during an acute medical crisis, and in a third and final phase measures of biophoton emissions would be done following cardiopulmonary resuscitation (or resumption of normal waking consciousness). In cases where a patient succumbs, measures of biophoton emissions would be made at the moment of clinical death (i.e. cessation of cardio-pulmonary function) and for several days thereafter until the biophoton count drops down to the normal background level. Finally, Thaheld has suggested that hypothermia induced states of deep coma or clinical death provide a more prolonged time frame in which it would be more practical to monitor ongoing changes in biophoton emissions. When such studies are being conducted it should be kept in mind that biophoton emissions can be influenced by local geomagnetic activity and by cosmic rays on a daily basis and the automatic dark photon count generated by a photomultiplier tube (PMT) has to be taken into consideration (Dotta 2012).

Positive findings from any of the above studies would lead to hypotheses about mechanisms at the interface between classical and non-classical processes associated with NDEs or other transpersonal or so-called anomalous experiences. For example a finding of above chance correspondences between neurophysiological activity and highly coherent biophoton emissions or non-random changes in REG output would constitute *provisional indirect* evidence for non-local correlations (i.e. “entanglement”) between a person’s mental state and an external system that may be consistent with the predictions of quantum-like models of consciousness. Prospective trials could then be conducted to test and further refine any such hypotheses under controlled conditions.

Concluding remarks

Models of consciousness based on quantum mechanics, quantum field theory and other non-classical theories are presently not falsifiable because technologies needed to confirm relationships between brain function (at a microscopic or gross level) and quantum processes do not exist. Further, even were quantum-like or other postulated non-classical mechanisms falsifiable using available technologies, confirmation that such processes take place in the brain or between brain and environment would provide only indirect evidence for the involvement of putative quantum-like processes in consciousness, and would not constitute compelling proof that non-classical mechanisms play a central or essential role in consciousness including the special case of NDEs or other transpersonal or so-called ‘anomalous’ experiences.

I have argued that certain features of NDEs are explainable using current neuroscience while other features may be consistent with the predictions of quantum-like models of consciousness. For example, confirmed reports of "non-local" veridical perception reported to take place during NDEs may reflect entangled states between highly coherent quantum fields enfolding the human brain and the environment (Tressoldi 2011). Since at this time it is not possible to design studies capable of empirically investigating claims of putative quantum mechanical or other non-classical processes in living systems, what remains is to develop research methodologies that may provide indirect evidence for the existence of quantum-like processes in the brain. I have proposed human and animal studies with this goal in mind.

Advances in neuroscience are yielding powerful new research methods that will soon make it possible to answer important fundamental questions about the nature of human consciousness, including the relationship between the brain and different states or experiences of consciousness. In the coming years, well-funded cooperative research efforts will yield valuable insights about brain mechanisms associated with "ordinary" waking consciousness, disorders of consciousness, NDEs and other transpersonal or so-called anomalous experiences. The rate of research progress will accelerate as new brain imaging technologies become more affordable and widely available. These advances will lead to portable inexpensive high fidelity EEG, fMRI and other functional imaging technologies that will—for the first time—make it possible to investigate consciousness in all its respects in naturalistic settings. Emerging fMRI techniques using high-field scanners and ultra-fast sampling pulse sequences will soon permit the acquisition of high resolution information about real-time neural processes that take place on time scales of milliseconds to seconds providing important clues to changes in functional connectivity associated with altered states of consciousness including NDEs as well as transpersonal and anomalous experiences broadly. These approaches will yield valuable insights about changes in brain activity in minimally conscious states and vegetative states, in the moments *before* and *after* clinical death, during lucid dreams and altered states. Combining functional brain imaging techniques with highly sensitive bio-photon detectors and REG machines may yield indirect evidence for quantum-like or other non-classical processes consistent with postulated non-local characteristics of consciousness.

As I conclude this paper I feel that a caveat is in order. Barring a fundamental shift in the philosophical tenets of scientific method that go beyond a strictly reductionist, physicalist paradigm, formal Western-style research studies addressing NDEs and other transpersonal or so-called "anomalous" experiences may continue to be limited by conservative ideological biases entrenched within science. If in the coming decades little progress takes place in the methodology of scientific research, future studies using the most advanced technologies may continue to yield incomplete or biased understandings of physiological and postulated non-classical mechanisms associated with consciousness. Just as mastery of the human genome has failed to provide an *accurate and complete explanation* of human nature including "normal" biological functioning and the complex factors and causes associated with health and illness, in the absence of a Kuhnian revolution in the basic premises and structure of scientific method, achieving the goal of a complete functional map of the human brain *cannot potentially explain* consciousness in all its aspects (Stam 2014; Logothetis 2015)

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