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Conscious States of Dreaming

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The purpose of this paper is to draw analogies between dreaming and quantum states of the mind and also to make inferences about the relationship between dreaming states, waking states, and memory. That dreaming is intrinsically associated with memory has been an opinion asserted by many researchers including Nielsen and Stenstrom (2005), Fosse, Fosse, Hobson, and Stickgold (2003), and Lee (2010). However, if dreaming is consciously recollected it must be that memory is also active at the time of dreaming, and if this is so, then the use of memory from dreaming must be associated with consciousness in the waking state. If a concept of consciousness is conceived as following from a layering of human perception, cognition, and physiological experience, then the brain may be understood as having the potential to produce quantum states — indeed the complexity of such brain states may make the experience of consciousness possible. The qualia of thoughts and consciousness, such as those experienced when dreams are recalled, can be likened to fluctuations in quantum states of the mind. Dreaming seems ephemeral yet may have a survival function.

Keywords: dreaming, quantum physics, memory

People are not simply conscious (awake) or not conscious (unconscious or asleep) [although they may be] but rather there are differing qualities and degrees of consciousness — such as dreaming — implicit in the cognitive frameworks with which people negotiate the experience of their worlds. So-called “lucid” dreamers, for example, are able to think clearly, to act or reflect whilst experiencing dreaming (LaBerge, 1990). The complexity of conscious and unconscious experience makes the consideration of quantum states a useful metaphor for understanding the interaction of sleeping, dreaming, and memory. Although dreams are likely to be the product of schema assimilation (and remembered dreams as if of recollected events

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experienced in consciousness) during sleep, the purpose of human dreams remains as elusive as the dream episodes themselves. Recognition of dreaming states involves the semi-conscious recollection of memory trace during the sleep consolidation-based stabilisation phase, as such dreaming might be considered a by-product of schema assimilation. Sleep is thus necessary for the consolidation-based enhancement of motor sequence learning (Doyon, Carrier, Simard, Tahar, Morin, Benali, and Ungerleider, 2005, p. 68).

Early research from Jenkins and Dallenbach (1924) indicated that the strength of a memory representation or "trace" could be more preserved by periods of sleep compared with time awake. This is because sensory processing during sleep is diminished compared to in an awakened state, whereas activity of memory processes may not be so, so more consolidation of memory can take place. Moruzzi and Magoun argued in 1949 that the function of sleep was to reinstate the activity of synapses, or to regulate brain processing. If so then memory of dreams involves both anterograde (future orientated) and retrograde (past-orientated) memory, as a remembered dream sequence involves recollection in the present of a future-orientated past physiological experience.

There are two main states of activity during sleep which are both natural cycles — REM sleep (rapid eye-movement sleep) and NREM sleep (non rapid-eye movement sleep). Typically NREM sleep is followed by a short period of REM sleep and dreaming occurs during the REM stage. Learning through habitual actions during consciousness are REM independent but as Greenberg and Pearlman (1974) put it, ". . . activities involving assimilation of unusual information require REM sleep for optimal consolidation" (p. 516). REM sleep is also that which is inductive to memory of dreams upon awakening. As Siegeal (2005) observes, although dreams contain emotions and events that don't correspond to previous days, dreams are not recalled unless they are immediately rehearsed in post-dream waking (p. 82). A person who awakes after the REM sleep cycle is more likely to remember her dreams than one who wakes after a NREM stage of sleep.

A definition from the second wave of sleep research, provided by Wamsley and Stickgold (2010), holds that, "[d]uring sleep, when attention to sensory input is at a minimum, the mind continues to process information, using memory fragments to create images, thoughts, and narratives that we commonly call 'dreaming'" (R1010). As such, dreams may be "spandrels of sleep" (Flanagan, 1995). The spandral, while an epiphenomenal term, also instantiates a complex neurological interaction. As Hahn, McFarland, Berberich, Sakmann, and Mehta (2012) suggested, the entorhinal cortex layer III is a mediator for memory consolidation during slow-wave sleep and it "inputs to the hippocampus in temporal association memory" (Suh, Rivest, Nakashiba, Tominaga, and Tonegawa, 2011, p. 1415). Furthermore, Nieuwenhuys, Voogt, and van Huijzen (2008) showed that the parahippocampal cortex, which receives diverse sensory-specific and multimodal cortical information (a highly complex area of synaptic functioning) is also useful for REM sleep (see also Markowitsch and Staniloiu, 2013, p. 35). Such alteration of brain-wave functioning in various areas of the brain during sleep is consistent with fluctuations in the quanta of memory consolidation. If sleep reverses the deterioration in performance brought about from prolonged wakefulness, then REM sleep is modulated by the circadian rhythm (Groeger and Dijk, 2005, p. 73). Hobson (2005; Hobson, McCarley, and Wyzinsky, 1975) suggests that neurons which mediate non-REM and REM sleep are motor pattern generators coterminous with norepinephrine serotonin which is non-gating, allowing for conscious brain activity. Sleep, dreaming, and consciousness are thus states on a continuum of brainwave quantum functioning.

There are at least three possible ways in which dreaming and imagination are evident in the quantum physics analogies of the mind. The first begins with the fundamental understanding that quantum physics offers proof that the world we are part of, the world we observe, and our position as observers, brings the world into being. Dreams, which are figments of the imagination produced during sleep, may influence our waking states through either altered experiences of memory, mood, or perception of time and place. The second way dreaming and imagination emerges in quantum theory is as a product of the holism of the many minds theory (which might posit that a dreaming state is one of a near infinite number of possible states that a mind could assume at any one time), and the third is evident in the theoretical speculation that dreaming can be quantified in the "white noise" effect of the modified Schrödinger equation (the fundamental equation of wave mechanics which relates wave formation to the allowed energies of wave function).

At the quantum level, the world and ourselves are made of the same quanta. We are constituted in, and part creators of, the world we live in. While in quantum science it is clear that the world observed is in part created by the observer, it is not clear to what degree the observed world is dependent on the unique biological identity of the observer, or rather, dependent on the person's classical position as an observer. Peter Jackson (2002, p. 7) offers a useful synopsis of the role of consciousness in quantum theory:

> In the transition from the probabilistic quantum realm to the classical realm, a fundamental change occurs, and that appears to be brought about by the experience of the observer. This change takes the technical name of decoherence, in which the probabilities described by the wave function collapse to certainty (100% prob). In their unmeasured superimposed state, there are only probabilities, no actualities. But, as soon as we make a measurement, we create a certainty.

Decoherence is then also a property of a conscious mind, and possibly of the consolidation of memory processing during dreaming states. The question then becomes: is it consciousness that brings about the collapse of the wave function in quantum physics? Wigner claims that the content of consciousness is the fundamental reality and it cannot be escaped but it may be altered in dreaming states (Esfeld, 1999). Quantum states may be realised as the product of chemical and electrical exchanges in synapses of the brain — experienced as the qualia that result from complex interactions of the enzymes, hormones, oxygen, polarization and depolarization which take place in neural cells and pathways. The reality of physical objects is, however, relative to the object's constitution in consciousness. This accords with Heidegger's view of *Dasein*, but not with the arguments of internalism or direct realism (a theory of perception, which argues that we have direct awareness of the external world through our senses). This is in contrast with indirect realism and representationalism, which posit that we are directly aware of only our internal representations of the external world. Dreaming is consistent with both internalism and direct realism, it mediates between our conscious awareness of the two views. The experience of dreaming may be brought about by the experience of docoherence in the REM sleep stage. As LaBerge (1990) states, "[i]n REM sleep, a spinal paralysis causes the muscles of locomotion and vocalization to fail to completely execute the action orders programmed by the brain. Thus, in REM, unlike the waking state, nothing impedes the brain from issuing sequences of motor commands at normal levels of activation, and this probably contributes to the experienced reality of dreamed action" (p. 123). Areas of the brain involved in network dreaming activity include medial temporal, medial prefrontal, midline, and parietal regions (Wamsley and Stickgold, 2010, R1012). Wigner's argument is that the existence of physical objects is useful to make sense of the content of consciousness. The content of consciousness is only accessible to the individual; therefore, other individuals are constitutionally equivalent to physical objects. Our embodied cognitions are independent yet have emergent physical and symbolic qualities and such symbolic qualities can be represented in dream episode memories which are sometimes available to conscious recollection.

Two well-known concepts of quantum mechanics that also provide insight about dreaming states are Heisenberg's uncertainty principle and (the analogy of) Schrödinger's cat. Heisenberg's (1927) uncertainty principle, in which it is impossible to say accurately both the location and velocity of matter on account of matter's simultaneous wave- and particle-like behaviour, finds parallel in the seeming impossibility of "locating a thought" in conscious experience within the brain — "thought" being a product of synaptic inter-relations distributed across a given area. Similarly, notions of entanglement and superposition (which inspire the analogy of Schrödinger's [1935/1983] Gedankenexperiment in which the cat in the box may be both alive and dead, or in any state in-between), also lend themselves to variations in the process of gating and non-gating of synaptic activity and, consequently, disconnections between form and substance, consciousness and unconsciousness in dreaming and waking states.

As Esfeld (1999) points out, when conducting quantum physics experiments concerning the collapse of the wave function as a result of the interaction between the object and the measuring instrument, there is entanglement between the object and the instrument. Consequently, the object is not in an eigenstate (a quantum state that is left unchanged after observation corresponding to a particular operator) of the measured observable. The measuring instrument does not indicate a definite numerical value of the observable. This is known as the measurement problem as it precludes the possibility of a reduction to an eigenstate of the observable.

Von Neumann (1963) extends this chain up to an observer. The observer's body and brain are entangled with the object and instrument. But if we take an observer into consideration, we end up with a description according to which the body of the observer, including her brain, is entangled with the instrument and object. The measurement problem can be formulated as the question of how a state reduction to one of the eigenstates of the measured observable can occur in this chain. Is there a way of explaining this link between classical and quantum worlds? The many worlds view argues that there is a wave function for the whole universe and no measurement problem as the position of each observer causes a branching into another world. The many minds view postulates a decoherence in which one quantum state is revealed in one of many possible minds and the universal wave function carries on evolving (Jackson, 2002). Such docoherence could also describe the experience of dreaming during the REM phase of sleep and the myriad states of consciousness and brain-wave functioning in waking states.

According to Esfeld (1999), using the Schrödinger equation, a possible solution to the measurement problem is that a state reduction is supposed to occur as an objective event in the physical realm before the von Neumann chain reaches the consciousness of the observer (a pre-measurement of quantum entanglement established between the system and observer achieving decoherence by interaction with the environment). However, the existence and entanglement of the observer changes the observation. It is not considered useful to assume that consciousness causes state reductions, yet the quantum state applies to all physical systems — the quantum mechanical physical reality needs to be reconciled with Newtonian physics. However, it may be possible to describe decoherence as coterminous with gating and non-gating synaptic functioning in the form of changes in distributed intelligence across brain functioning. Such decoherence might be a by-product of the ability to manipulate abstract symbols in the human mind in awakened states — as Markowitsch (2013) states, "[l]ong term storage of information has most likely a survival value" (p. 1). Such ability has evolutionary relevance.

People are prone to comprehend scale in terms of state reductions, as the classical realm with no entanglement may be the only way nature can appear to human observers (Esfeld, 1999, p. 151). Yet from the theory of orchestrated objective reduction (Orch–OR) [Penrose and Hameroff, 2011], we know that this view doesn't capture how appearances come into being. The many minds theory offers a way out of this impasse that also accounts for phenomenon such as dreaming and memory. Quantum mechanics without state reductions describes the whole of physical reality by assuming that an observer has many minds, in which she abstracts from an entanglement what is objectively present (Jackson, 2002). If what is objectively present is filtered from a composite view by an awakened mind (or a mind in an awakened state of consciousness) a dreaming mind might process memories from a composite of recollections from a number of possible minds. As brain-wave functioning alters during REM sleep, memory recollection is reorganised as the result of the quantum state of such possible minds.

Von Neumann (1963) has suggested it requires consciousness at the point of measurement to collapse the wave function, given that the experimenter and that which is measured are all made of quanta. In the many minds theory, the process of decoherence, the collapsing of the wave function to produce one result, does not quantify at that measurement point alone, given that there is no necessary intervention by the consciousness of the observer. In this view there is no problem of measurement, because the experience of the observer does not contradict the quantum states. In one or an infinity of possible minds, the wave function predicts a yes and no, and all the probabilities in between (Jackson, 2002). Fluctuations in the wave function during dreaming states may result in the entangled recollections of dreaming.

This does not contradict the role for consciousness in classical experiments where outcomes are thought not to be dependent on the observer. Again, to state a paradox, such outcomes could not be known without the presence of an observer. Perhaps it is better to view this as one form of measurement (classical) working towards the outer limits of the exclusion of consciousness, and the other form of measurement (quantum) to the inner limits of inclusion. Dreams could then be described as spatio-temporally coherent fragments of conscious experience that emerge from memory recollection in REM sleep resulting from (quantum) changes in brain-wave function.

For von Neumann (1963), everything is regarded as being quantum, including the brain of the observer, which corresponds to a mentalistic and positivistic view of reality, a view which may be recollected in dreaming states. Von Neumann found that only consciousness could hold the privileged immaterial position in which consciousness is not part of the physical universe but is res cogitans. Wigner (1964) argued that the consciousness of the observer led to a collapse of wave function, and the reduction of probability into a measurement which Bohm (1990) postulated implied both an implicate and explicate order in the space–time quantum. Changes in brain state might also be coterminous with the collapse of wave function, evidenced for example in the "distorted lucidity" of recalled dreaming states. The conscious perception or experience of a brain state unfolding in consciousness is a substrate for all reality, while the latter (the dreaming state) is a non-conscious but recalled experience of space and time unfolded from implicate order. It is the task of the conscious mind to provide explicate order to the events and perceptions about which it is involved. Acceptance that all is made of quantum stuff does not necessarily entail that consciousness is res cogitans, but that it is a different order of thing.

As Jackson (2002) points out, the orthodox view of the probabilities of quantum physics suggests that the electron's indefiniteness is transferred to the measuring apparatus, but, at the collapse of wave function, the measured state goes into the eigenstate corresponding to the result obtained. The many minds view also assumes that the entire universe has a quantum state. As Jackson (2002) explains, this quantum state is a superposition of states corresponding to many different macro realms, where all realms are actual: "The idea is that the world splits at each measurement, like a tree into branches, with 'daughter' worlds for each result" (p. 14). Consequently as the sleeping mind oscillates between patterns of NREM and REM sleep, dreaming (and conscious recollection of dreams) may occur as a consequence of quantum fluctuations in brain states.

However, the question then becomes, if all of the realms are actual, then why can't we see them? The many worlds theorists argue that after splitting, these realms have no access one to another. However, during REM sleep the mind may temporarily recollect fragments of dream memories of the perceptions which might represent possible quantum shifts. Dreaming states are relevant because each of the many minds representing different probabilities of the eigenstate may not be entirely closed to one another. There will be probabilistic traces of the other in each, and these traces collectively represent a measure of reducible memory trace processed during sleep.

The many minds theory poses a difficulty for the Cartesian in that there is no sharp distinction between subject and object. As Bilodeau (1996) reasons, our analytic habits are more to do with how our minds appear to function to us than any necessarily direct natural correspondence. It may be that our notion of the workings of a physical substrate needs to change as we register the shift in our comprehension of our experiences within classical and quantum worlds. Yet there are as yet no precise experimental coordinates to the end-point of this objective. Bilodeau argues that phenomenal consciousness offers an inconsistency in the way we are capable of perceiving our world (such an inconsistency might be found in the recollection of dreaming states). However, this dividability into properties and spatial relationships may be entering its final phase. This is known as the "hard problem." To transcend the hard problem we need a non-classical ontology, which is neither physicalism (everything which exists is no more than its physical properties), idealism (the only things knowable are the contents of consciousness) or dualism (mental phenomena are non-physical properties of physical substances).

As Bilodeau (1996) points out, we cannot necessarily expect that the qualia of the mind are of the same order as that which produces the mind. There is more to mind's relationship to the quantum world than epiphenomena superimposed on patterns of information processing. Rather, in the many minds theory, each possible eigenstate is correlated with at least one mind. Each mind sees an outcome in the classical world, yet does so containing the possibilities of other minds. Yet as each mind sees an imprint of possibility of the other, distinguishing between minds is not the same as distinguishing between possibilities, as there may be many millions of possibilities for any given mental state. It is possible that dreaming results as the ephemera derived from the complex processing or fluctuations between possible states of the mind during sleep.

Squires (1998) has argued that since quantum physical equations do not contain what we observe, they are either wrong, or new equations are needed. If we take Squires as correct at the representational level, then Squires and we need to add non-linear elements to the Schrödinger equation to account for all the effects of wave function collapse. Because stochastic or non-determined processes are involved in quantum physics, a random white noise process may be identified in the modified Schrödinger equation. This random white noise may theoretically register the imprint of dreaming in the quantum mechanical view; it carries the trace of the individual eigenstate of many possible minds. As Jackson (2002) points out, instead of proposing an infinity of worlds, we could ascribe every sentient being with a continuous infinity of simultaneous minds, which differentiate over time. In this understanding, one mind per person is expressed as a kind of multi-mind. In this many minds theory, dreaming is the cumulative effect of the recognition of one mind to the other which may result in the noise that manifests as dreaming states when sleeping — and also potentially the imagination when waking. A dream is an echo of a frame of meaning, which may have many versions of reality, yet upon waking the strongest frame gets selected. When dreaming, people lose the accuracy of the memory recall because they have little sensory visual imagery with which to test reality. For Tulving (1985), autonoetic (self-knowing) and noetic (knowing) consciousness are relevant. Autonoetic consciousness, or the awareness of personal time including the past and the future, is characterised by retrieval from episodic memory (i.e., personally experienced events), while noetic consciousness, or learned knowledge that is accompanied by personal awareness, is retrieved from semantic memory. Or there may be separate retrieval processes of differing strength levels along an undifferentiated dimension which relate to different underlying memory systems (Selmeczy and Dobbins, 2013, p. 66).

Why do people only remember dream episodes versus full narrative experiences? As Lee (2010) remarks, "[l]ack of dream recall [as full narrative memories] suggests the modern emphasis on the significance of waking realities at the expense of oneiric experiences" (p. 288). It is not simply that natural selection has pre-conditioned us to dismiss dreams on waking but that the cognitive states of dreaming are suppressed on waking experience; as Lee (2010) also states "dreaming constitutes an unbroken chain of memory to the organisation of everyday life" (p. 288). It is rare that memory can provide unproblematic access to detailed aspects of any particular dream. Dream recall is effected during sleep, and the ability to recall dreams is most active during the REM phase of sleep. But dream recall and memory in both traditional and modern cultures are regarded as continuous with conscious experience in the waking world (Lee, 2010, p. 293). The memory of dreams in a waking state, that Freud termed day "residue" — acknowledges the fact that memories of previous dreaming experience can effect and have a delayed reaction on conscious cognitions. However, Freud's symbolic language of dreams was eclipsed by the activation–synthesis hypothesis of Hobson, McCarley, and Wyzinski (1975) which was a neuroscientific account of dreaming that posits that dreams originate from neural signals in the brainstem generated during REM sleep. For Hobson et al. (1975), dreaming occurs when a sleeping brain attempts to process that chaotic input into its "higher-level cortical circuitry" but it can also occur in non-rapid eye movement sleep (Wamsley and Stickgold, 2010, R1010).

As Nielsen and Stenstrom (2005) observe, remembered dreams only very rarely portray complete episodes — this occurs in only 1.4% of reports, whereas in another study, up to 65% of incomplete episodes of dream elements were linked to waking events (p. 1286). However, in negative dream states such as nightmares, dream imagery is episodic. As they state, a traumatic event may be replayed as a group of "isolated spatio-temporal, perceptual and emotional details which may or may not preserve autonoetic" (self-in-time) awareness (p. 1286). However, it is clear that (like some forms of imagination) dreams simulate reality insomuch as they take place in spatially coherent environments, in which a self-interacts perceptually. There is orientating sensory information, and a sense of self which engages in emotional and intellectual exchanges. Consequently, the spatial and temporal valences that signify dreaming are coterminous with the spatio-temporal binding that characterises consciousness (Nielsen and Stenstrom, 2005, p. 1287).

There is a consensus forming amongst some theorists that altered hippocampus function during sleep accounts for the episodic dream memory and that hippocampal changes (or activity of the hippocampus, entorhinal cortex and other parahippocampal regions) contribute to the characteristics of dream content (Nielsen and Stenstrom, 2005, p. 1286). Thus, when sleeping but in a dreaming state, the perception of a dream as occurring in the here and now may or may not correspond to the spatio-temporal location of the dream. This in itself might occur in parallel with other functions such as narrative organisation, and could occur on the threshold of consciousness and thus be self-observable by both dreamer and awakening sleeper (Nielsen and Stenstrom, 2005, p. 1287). Such experience at the "threshold of consciousness" could be understood in quantum terms. The hippocampus is responsible for both temporal and spatial patterns (specifically the presubiculum regions). However, the emotional sources of dreaming are regulated by the amygdala which controls encoding and the retrieval of emotional memories and physical expression (Nielsen and Stenstrom, 2005, p. 1288). Amygdala activity raised during REM sleep rather than during wakefulness maintains a reciprocal dependence with hippocampus in storage of memories — amygdala gates sensory information through the entorhinal cortex (Nielsen and Stenstrom, 2005, p. 1288). The cognitive-level replay that is characteristic of dreams corresponds to reduced levels of acetylcholine in NREM sleep or quiet wakefulness and is believed to result in the consolidation phase of episodic memory, producing information flow from the hippocampus to the entorhinal cortex (Wamsley and Stickgold, 2010, R1012).

Although it is apparent that there is a link between memory and dreaming, there is as yet no causal linkage. However, when an integrated episodic memory is experienced during waking, information may flow from the hippocampus to the cortex — such hippocampal outflow is blocked during REM, with neural information flowing from the cortex to hippocampus (Fosse, Fosse, Hobson, and Stickgold, 2003, p. 6). Dreaming during REM sleep results in the suppression of brain chemistry which registers stress, and difficult emotional experiences may be processed which results in the ability to recall difficult memories without trauma (Barnett, 2012, p. 9) Thus dreams may help to emotionally regulate traumatic experiences. As Wamsley and Stickgold (2010) state, dreaming is:

> . . . the product of a mind that is constantly encoding and processing information about the world. When sensory input is at a minimum, newly formed memory traces are stabilized during offline states of quiet wakefulness and sleep, through the repeated reactivation of experience-related activity patterns. During sleep, this reactivation of memory traces contributes to the imagery, thought, and narrative of dreaming. (R1013)

Both REM and NREM sleep are involved in the consolidation of different forms of memory. Consequently, dreaming is "influenced by the retrieval of recent memories in the sleeping brain" (Wamsley and Antrobus, 2009, p. 283). Thus dreaming states may be "quantum, trace, or ghost visions" of the disorganised contents of recent recollected memories, undergoing re-organisation in the brain. However, while the relationship between memory and conditioning is not clear, what is clear is that the hippocampus plays a role in the acquisition and retrieval of fear conditioning in animals; but conditioning itself may be distinct from human cognitive memory as it produces a far stronger physiological and behavioural response. As Wamsley and Antrobus (2009) assert, "hippocampus-dependent learning can be reactivated and expressed during human sleep, effecting the emotional quality of experience" (p. 289). Thus, for Walker (2005), given current understanding of the neurophysiological substrates of memory forming and consolidation, "we are able to move away from the question of whether sleep is the key factor responsible for memory formation, and instead, begin disentangling certain confusions around the argument of exactly what type of sleep is or is not required with regard to discrete stages of memory development" (p. 64). It stands to reason that the plethora of sensory stimuli received in the course of wakefulness will require periods of relative cessation in order to be processed into schema that are memorable and those that are commonplace and can be discounted from conscious recollection. Tononi and Cirelli (2005) argue that the benefits of sleep, including performance enhancement, are associated with synaptic downscaling as a continuation of the homeostatic regulation of slow wave activity (p. 85). Such wave activity may also be analogous to a reduction in quantum fluctuation in the "many minds" theory. If it were possible that dreams are thus recalled fragments of memories at the cusp of changes in quantum states in consciousness during REM sleep, this also may lend credence to the idea that problem-solving as a part of schema processing can be accomplished while asleep. The human brain may itself be a form of quantum-computer.

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