The Neuropsychology of Dreaming: Studies and Observations
Robert J Hoss, MS

Abstract:

The unique state of the brain in REM sleep, when our more vivid dreams occur, appears to be involved in emotional processing and connecting new material with old material in memory systems, revealing these connections in the form of often personally "meaningful" picture-metaphors. The complex of active centers in the frontal regions may also provide the cognitive capability for not only managing emotion but also psychological restoral, conflict resolution and adaptive learning. Dreams can be observed to incorporate many of the waking state functions of these active centers, including initiating and mediating a resolution by creating and testing imagined scenarios, providing compensating cues to influence the action, and emotionally reinforcing scenarios which meet the anticipated outcome.

Dreaming and Sleep States

Dreaming occurs in many stages of sleep: at sleep onset (stage 1) where hypnagogic images appear; during lighter REM (for rapid eye movement) or paradoxical sleep; and even during deeper sleep (stages 2 and 3) or NREM sleep. Dreams differ in REM from those of NREM. REM stages begin at roughly 90 minute intervals of short duration at the beginning of sleep, becoming more frequent and lengthy before waking and occupying about 20 to 25% of our sleep time. When subjects are woken from REM sleep in laboratory studies, dreams are reported from 80% to near 100% of the time. These tend to be the more vivid, highly visual, story-like dreams that we think of as "dreams". During NREM periods dreams have been found to be less frequent, often more thought-like and more like a replay or practice of prior day events. Although the function of each state is not fully understood, studies have suggested the REM stage is involved in brain development and psychological restoral and adaption as well as consolidation of procedural memories by linking distant but related emotional memories and consolidating them into a smooth narrative. The NREM state is thought to be more involved in physiological restoral and consolidation of episodic and declarative memory. In discussing the neuropsychology of dreaming I will focus on the REM dreams state since most dream content research concentrates on this state and it is likely that most spontaneously recalled dreams arise from this state.

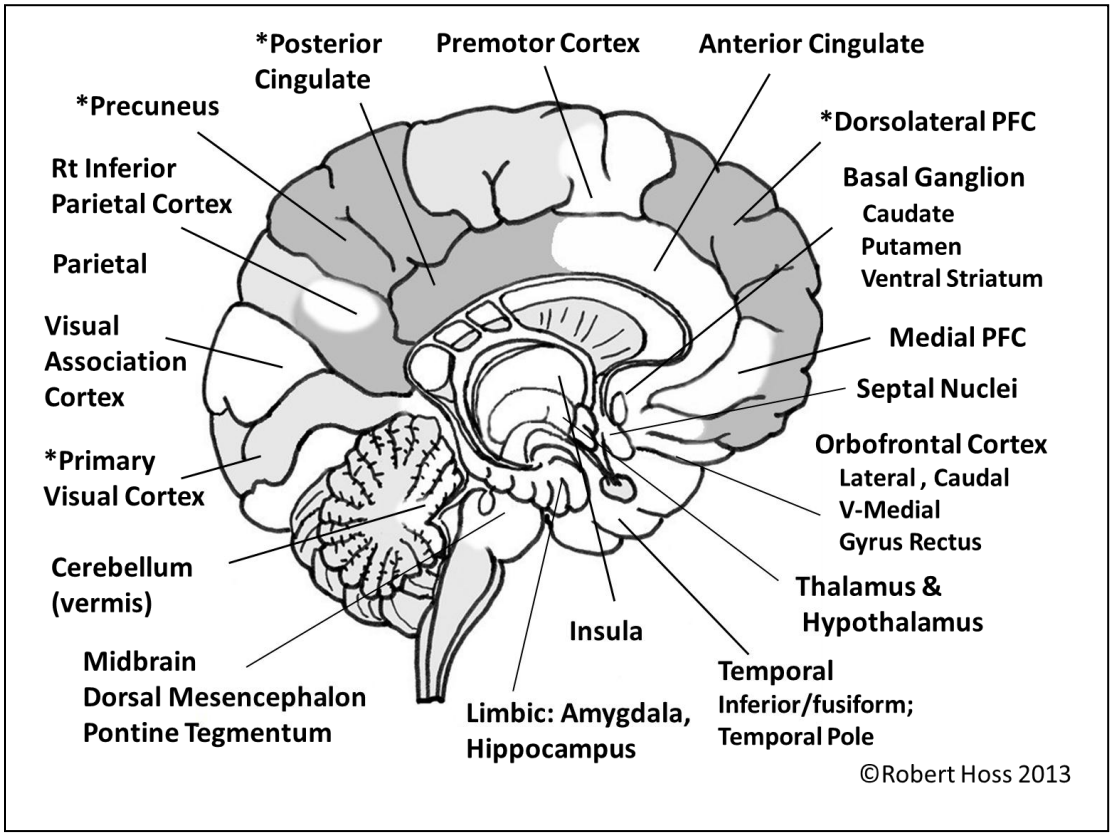
Neurobiology of Dreaming

The unique combination of active and inactive brain centers during REM is shown in figure 1. The figure was derived from a neuro-imaging tabulation by researcher Alan Hobson (2003) of various PET studies (Maquet, Peters et al. 1996; Braun, et al. 1997; Nofzinger, Mintun et al. 1997; Maquet 2000 & 2005). Activity was relative to waking states and/or NREM depending on the test. It shows that, while a great deal of our brain is active in REM, the executive functions that remain relatively inactive or "asleep," including functions such as rational thought, linear logic, and episodic memory, as well as primary sensory and motor functions. As Braun puts it, dreaming is a "state of generalized brain activity with the specific exclusion of executive systems" (Hobson, 2003). In that same article Alan Hobson relates the unique state of the brain to the content of dreams which occur during REM. Hobson (2009) further states that dreaming is a parallel state of consciousness, which is continually running but normally suppressed during waking. To that end he and other researchers have related the nature or content of REM state dreams to the known waking state functions of those centers which are active and inactive (Dang-Vu et.al. 2007; Desseilles et.al. 2010; Maquet 2000 & 2005; among others). This paper will therefore follow a

similar hypothetical approach, that of projecting known waking state function on centers which remain active and passive during REM, and testing whether such function has been or can be observed in dreams. Each center found to be active in the above referenced PET studies is addressed with respect to recent waking state neurological studies, which identify specific mental functions that center has been found to be involved in (alone or in combination with other centers found to be active during REM). A brief review of the active and inactive centers illustrated in figure 1 is provided below, followed by a more in-depth discussion in the remainder of this paper.

A number of active regions appear to be involved in the perception of the dream. Although the primary visual cortex and much of the parietal cortex remains inactive, activity is heightened in the visual association cortex, which processes imagery associations, and the right inferior parietal region, which organizes the imagery into a visual space. Other fictive sensory dream experiences may be due to internally stimulated activity in the vermis cerebellum and other motor and sensory regions as well as activity in the temporal areas involved in facial recognition, auditory processing and episodic recall. Activity in the association regions of the cortex give rise to the picture-metaphor nature of dream imagery, i.e. picturing the emotional, memory and conceptual associations and connections being made within.

Figure 1 – relatively active (white) and *inactive (dark gray) centers of the brain in REM sleep. Derived from neuroimaging studies (Maquet, Braun, Nofzinger et. al. in Hobson 2003)



As expected, areas that regulate sleep, consciousness, alertness and metabolic function, are activated (i.e., pons and midbrain, hypothalamus, and the thalamus, which also provides a central relay function). High activity is seen in the limbic regions involved in emotional processing (amygdala and hypothalamus) and short- to long-term memory consolidation (hippocampal regions). This high activity in the limbic system or "emotional brain" has led researchers to believe that dreams "selectively process emotionally relevant memories via interplay between the cortex and the limbic system" (Seligman & Yellen 1987). Interaction of the hippocampus and amygdala supports Ernest Hartmann's contention that dreams weave new material into established memory guided by emotion, organizing that memory based on what is emotionally important to us (Hartmann 2011).

Activity in adjacent regions involved in emotional control, fear extinction and reward-based adaptive action planning and learning functions (basal ganglia, medial prefrontal, anterior cingulate, lateral, medial and caudal orbital, and infralimbic) suggests that the dreaming brain may be capable of mediating emotional encoding, mental restoration, problem resolution and learning. These theoretical functions will be discussed below.

In NREM (stage 3 & 4 sleep) these same studies indicate that activity diminishes in the dorsolateral prefrontal cortex and the parietal regions (except B40), much as in REM sleep. As differing from REM, however, there is a decrease in activity in the midbrain, thalamus and cerebellum as well as areas that have been found to be involved in emotional processing, analogical decision making and learning (amygdala, hypothalamus, basal ganglia, anterior insula, medial prefrontal cortex, orbitofrontal regions, right temporal lobe and pole B38 and basal forebrain). While activity in NREM decreases in one area of imagery formation (the right inferior parietal cortex), it increases in the visual association and primary visual cortices (B17, 18). Brain activity also increases in the left parietal region and left temporal lobe (B21, 22); areas involved in waking state activities such as contemplating distance, recognition of known faces and accessing word meaning.

During a hybrid state known as Lucid Dreaming (where we become conscious that we are dreaming) regions of the prefrontal cortex, which control logical reasoning and executive decision-making, normally inactive during REM sleep, appear to be activated and EEG tracings become similar to the waking state. PET scans indicated a greater sense of control over the dream (lucidity) when the medial frontal cortex (involved in consciousness) was active, and a greater sense of the dream being out of control when the amygdala (involved in emotional processing) was more active. Conscious control is real as shown by Stephen LaBerge (1981) who discovered ways that lucid dreamers could communicate with researchers from the lucid state, by moving their eyes or flexing their muscles in predetermined patterns. Using an fMRI with a sleeping subject in the lucid state, Michael Czisch (2011) of the Max Planck Institute of Psychiatry in Munich revealed increased activity in a brain region important for movement called the sensorimotor cortex as the participant squeezed his hands in a predetermined manner in the dream.

Theories of Dream Activation

J. Allan Hobson and Robert McCarley (1977) proposed the activation synthesis theory, that the sensory experiences are fabricated by the cortex as a means of interpreting chaotic signals from the brain stem, the pons. They propose that during REM sleep, ascending cholinergic PGO (ponto-geniculo-occipital) waves stimulate higher midbrain and forebrain cortical structures, producing rapid eye movements. The activated forebrain then synthesizes the dream out of this internally generated information. They assume that the same structures that induce REM sleep also generate sensory information. They also argued that dreams are nonsense created when the forebrain makes "the best of a bad job in producing even partially coherent dream imagery from the relatively noisy signals" sent up to it from the brain stem at the onset of REM.

However, researcher Mark Solms (2000) suggests that dreams are generated in the forebrain, and that REM sleep and dreaming are not necessarily directly related. While in the neurosurgery department at hospitals in Johannesburg and London, working with patients having various brain injuries he found that five patients that had damage to the pons region of the brain did not have loss of dreaming. This observation forced him to question the brain stem as the source of the signals interpreted as dreams.

A third theory, the continual-activation theory by Zhang (2005), combines the activation synthesis hypothesis with Solms' findings. Zang introducing a temporary memory stage into the memory process to bridge the gap between short-term memory and the long-term memory, and proposes that during our waking time, the memory formed from the working memory is not saved directly into the long-term memory; instead it is saved into a temporary memory. The function of sleep is to process, encode and transfer the data from the temporary memory to the long-term memory. The theory assumes that during REM sleep the unconscious part of the brain processes procedural memory. Meanwhile, the level of activation in the conscious part of the brain is very low as the sensory inputs are basically disconnected. This triggers the "continual-activation" mechanism to generate a "pulse" of information from memory which flows through the conscious part of the brain, inducing each dream. By involving the brain's "associative thinking system" the dream is self-maintained with the dreamer's own thinking until the next pulse of memory insertion. This might be why dream can be observed to have some continuity (within a dream) and then exhibit sudden scene changes (between two dream segments).

The Influence of Brain State on Dream Content

Hobson (2003) states that the combined activity of these brain centers (figure 1) appears to account for not only the unusual characteristics of dreams, but also some of the functions that psychologists and theorists have attributed to dreaming. In this section some of the brain state influence on the dream imagery itself will be discussed. This will be followed by a discussion in the next section on Dream Function how this unique state might provide observable functions that psychologists and theorists have attributed to dreaming.

Dreams as an Expression of the Unconscious

Note in figure 1 that the majority of the centers which are active during REM dreaming are those which process mental material either unconsciously or prior to their actions becoming conscious. Dreams therefore provide us with valuable access to the unconscious. Sigmund Freud (1900) and Carl Jung (1971 p.283) clamed, respectively, that dreams are the "royal road to the unconscious" and "the most readily accessible expression of the unconscious." Robert Stickgold (2009) believes that our dreams are constructed within networks of associated memories that we do not normally access directly, and which therefore might reflect feelings, moods, and attitudes that we don't normally have direct conscious access to - thus "unconscious". He gives an example of a study with amnesiacs who would report dreams about pre-sleep activities that that they had no conscious memory of. He thinks that dreaming is looking for new ways to connect these associative networks, whether these explorations end up being useful or not, thus the action contemplated or carried out in a dream is not necessarily one that actually fits with your conscious beliefs. If true, what we see in dreams is indeed how our mind pictures our world from an "unconscious" perspective – and as such is a valuable source of information about our inner concerns that is not easily accessible otherwise.

Jung observed the language of the unconscious to be symbolic or an "emotionally charged pictorial language" where a conscious event can express its unconscious meaning (Jung, 1973, p30). This non-

rational, figurative nature of dream imagery is due in part to lack of a rational reference in REM (a deactivated dorsolateral prefrontal cortex) and the visual activity taking place in the visual association cortex and right inferior parietal cortex. These regions form picture associations with the emotions, memories and conceptualizations processed within, and organize them into a dream space (Hobson, 2003, p32; Jung-Beeman, 2005; Bottini et al., 1994). Although almost 100% of REM dreams are visual in nature, 40-60% contain auditory sensations, 15-30% contain the sense of movement and less than 1% containing tactile and other sensory experiences (Dang-Vu 2007). Other areas of the brain such as the temporal lobe along with parts of the cerebellum and certain pre-motor and sensory areas can become internally activated in REM, supplying the dream fictive sensory associations (moving, hearing, touch, and sometimes other senses). These too are internally generated figurative representations of whatever mental association stimulated them.

As Jung states, the dream tends to reflect the unconscious emotional impact that a conscious event had on us, however, even though the dream may have been triggered by a waking event, a replay of that event is generally excluded from the dream (Fosse, 2003). This is likely due to inactivity in regions which are involved in episodic and working memory and conscious reflection (for example the precuneus and posterior cingulate cortex). While this inactivity prevents the explicit recall of the triggering waking life episode, the high activity in the limbic regions and hippocampus provide total access to the memory of the emotional aspects of that event. A simple and somewhat humorous example can be seen in the following dream. The conscious event was that the dreamer had just celebrated his 45th birthday, a happy event in most all respects. That night however he dreamed the following: *"I dreamed of a car with a license plate that read…HIDE 45!"* Here we see the dream revealing the "unconscious aspect" as Jung would call it. The dream pictures the emotional conflict triggered his turning 45 – a concern about getting older and a desire to find a means (a "license") to hide the fact. The event itself, the party, was not pictured, only the unconscious emotional impact.

Allan Hobson (2009) proposes a "theory of protoconsciousness" whereby dreams might reflect an unconscious model we maintain which influences our conscious evolution. In other words REM sleep may provide a virtual reality model of the world that is of functional use to the development and maintenance of waking consciousness. This is in some ways similar to Jung's model of the collective unconscious and the "Self" from which the whole building up of ego consciousness is directed. (Jung, 1973, p.169)

Dreams Picture "Connections"

In dreams we find ourselves in a "dream space" which is very much like our waking reality. As noted above, dream imagery may be structured in the association cortex as representations of mental information connected by association, and the dream space may be organized by activity in the right inferior parietal cortex, which creates a meaningful perception of our visual space in the waking-state. These processes, therefore, may play a role in creating dream imagery as representations of memory fragments, then presenting the ions between those memory fragments as combinations of imagery fragments – combining them into a single dream image. Freud called this process "condensation". This relationship tends to take on the form of picture-metaphor, picturing the way our minds makes connections, a language that directly associates and connects seemingly unrelated information, describing a first entity as resembling a second entity in some way, a way of noting and picturing similarity (Hartmann 2011). Parts of the parietal and temporal regions are known to play a role in metaphor processing (Ramachandran 2006; Rapp 2004) so their activity in the dream state may account for this.

The dream language of picture-metaphor becomes more obvious when we tell the dream; it tends to translate into common waking life speech metaphors. An illustration of this is the dream of a man who

had become frustrated and miserable at work but was not sure why: *"I had a frightening dream where I was being chased away by a big buffalo with a little buffalo following it."* I asked him what a big buffalo does. He said: *"he is huge and powerful, when he wants you to go, you go,"* which he recognized as describing his boss. I asked him about the little buffalo. He said, *"He is a little pipsqueak that follows the big one around -- just like that little pipsqueak at work!"* The dream revealed that the source of his discontent was not only the actions of his boss but the relationship that this little pipsqueak of a co-worker had with his boss. Here the metaphors aptly pictured the emotional similarities between the big buffalo and his boss, and the little buffalo and the 'little pipsqueak' at work.

The manner, in which the dream connects associated imagery fragments into a composite dream image or story, is often much like the way we connect word symbols to create a sentence in the waking state. Each pictorial element of a concept combines to create the total "meaning" of the concept being presented. This was illustrated in the dream of a young engineer who was worried about the value of his engineering degree at a time when engineers were being laid off (Hoss 2005). The two concepts that made up the word "engineering degree" appeared in the dream pictorially as a slide rule (engineer) with a thermometer (degree) on it! The dream could not speak the words so it spelled them out in picture language.

Dreams Picture Emotion

Dreams are highly influenced by emotion. The limbic areas, in particularly the amygdala, is highly active during the REM dream state leading some researchers believe that emotion does not simply arise from the dream, but rather emotion orchestrates the dream activity (Dang-Vu 2007) integrating dream emotion with dream imagery and action. Emotion plays a major role in organization memory based on what is important to us (Hartmann 2011) and thus likely plays a role in selectivity of which emotional events and memories to process and how new information is woven into exiting memory.

Hartmann (2011) states that the dream, especially the central image (CI), pictures the emotion of the dreamer and that the intensity of the image is a measure of the strength of the emotion. The picture-metaphor simplifies by putting the "feeling-state" of the dreamer or idea directly into an image. The dream presents those feelings in the context of the dreamer's inner and outer life (it "contextualizes" them). The following example illustrates this. A woman, who typically felt in control the events in her life, suddenly learned from the doctor that her husband was terminally ill and she could do nothing about it. That night she dreamed, *"I was locked in a car with no steering wheel and no door handles or window controls. I was rolling backward down a steep hill, and there was no way of stopping it, or getting out of it. I woke up in a panic."* Here the feeling of being totally unable to control the situation was pictured with all of its emotional intensity. Note that the dream presented the event in the context of the emotional impact (the traumatic feeling of a total lack of control) and omitted the explicit event (the meeting in the doctor's office).

Even the color in dreams might be a direct reflection of emotion. It is known that color evokes a somewhat common subliminal physiological (autonomic) and emotional response in humans, and that it differs for different colors. Hoss (2010) has concluded that this waking emotional response to, or association with color, is the same emotional response our brain associates with color in dreams. That is color is likely created within our dreams as representations of emotions and feelings associated with whatever the dream is processing. Color adds an additional feeling modifier to whatever the dream imagery represents. Color has been found to be processed principally in the visual association area V4 as well as fusiform gyrus (Sakai 1995) both of which have been found to be active in REM (Hobson 2003).

The "meaning" that the dream may hold for the dreamer, therefore lies in the meaningful personal associations which each visual construction represents. Fritz Perls (1969), a founder of Gestalt Therapy,

understood this well and asked clients to role-play or "become" the images in their dreams, urging them to experience that "thing" in the dream and express the emotions it contains.

Do Dreams Have a Function?

Dreams have long been understood to be a valuable tool in therapy. External intervention using dreams begins with dream recall and then applies what was discovered within the dream in some manner. This might include exploring deep emotional issues the dreamer is dealing with. Alternatively it might involve applying the raw dream content in some form of therapeutic exercise (imagery rehearsal treatment or art therapy for example). So dreams, once recalled, are found to consistently have a personal "meaning" for the dreamer, but has dreaming evolved to serve an important internal function?

In 1900 Sigmund Freud stated that the function of dreams was to disguise disturbing and harmful unconscious urges and impulses (the substance of the dream) in order to preserve sleep and prevent the dreamer from waking up and being shocked at the images. But this was contradicted by more recent understanding and with the discovery of the REM cycle in 1953, by the fact that dreams happen at regular intervals at least five or six times per night, not just as we are about to wake up as Freud thought.

REM or "rapid eye movement" sleep (where most of our vivid dreams take place) has been linked to various mental and physiological functions, many of them discussed in the paragraphs which follow. Determining the specific function of the dream itself, however, has been somewhat difficult partly because it has not been possible to isolate the role of the dream from the role of the sleep state in which it occurs. Is the dream simply the projection or our brain's interpretation of unconscious processes taking place, or does the dream experience itself play and active role in bringing about some restoral or adaptive learning function? Might the dream be the meaningful internal communications of information within the unconscious regions of our brain, taking place in its natural visual form picturing connections and associations?

What is becoming more apparent is that the dream is not meaningless random neural firings. As we become more knowledgeable of the processing capabilities of those centers, which are active during REM sleep, we can observe evidence of these processes influencing the content of the dreams. Whatever the case may be, it is fairly clear that the recall of the dream is not necessary for the process to take place since we recall such a small percentage of our dreams. While recall is helpful for using dreams in therapy, whatever processes take place in our dreams happen whether we remember the dream or not.

In the next two sections some of the theories on the function of dreaming will be discussed along with various neurological studies and dream observations that might provide support for those theories

Memory Consolidation

Zhang (2005), who developed the continual-activation theory discussed previously, considers the function of dreaming the processing, encoding and transfer the data from temporary memory to the long-term memory. Hartmann (2011) states that "the most basic function of dreaming consists of connecting new material with old material in memory systems; reorganizing the memory systems, guided by emotion". He does not necessarily consider this "consolidation", but rather a weaving-in, an integration of memory systems, improving creativity. Eugen Tarnow (2003) suggests that dreams are ever-present excitations of long-term memory, which occurs even during waking life. He considers the strangeness of dreams to be due to the format of long-term memory. During waking life an executive function interprets long-term

memory consistent with reality checking, which is not the case during dreaming. One study (Stickgold 2001) showed evidence that, with the flow of information between the neocortex and hippocampus being reduced, illogical locations, characters, and dream flow may help the brain strengthen the linking and consolidation of semantic memories (meaning of information). Payne and Nadal (2004) further hypothesize that dreams strengthen sematic memories which are then consolidated into a smooth narrative, similar to a process that happens when memories are created under stress. In a study by Fosse et. al. (2003), only 1 to 2% of the dream reports contained any replay of waking episodes, leading to the conclusion that dream sleep has no role in episodic memory consolidation. In another study (Horton et. al. 2009) it was determined that autobiographical experiences, which are characterised by some degree of construction as opposed to precise replay of events, are incorporated into dreams. Dream studies have demonstrated the incorporation of emotional memories into sleep mentation (Schredl & Doll, 1998). While these studies primarily focused on REM sleep, Tucker et. al. (2006) observed from daytime nap studies that contained solely non-REM sleep, declarative but not procedural memory was enhanced.

Emotional Processing

High activity in the amygdala and associated limbic system has lead researchers to conclude that dreams selectively process emotionally relevant memories via and interplay between the cortex and the limbic system (Seligman and Yellin,1987); that the amygdale actually "orchestrates" the dream activity (Dang-Vu et. al. 2007) integrating dream emotion with dream action. The effect of dreams on regulating emotion has been long suspected. Even Freud suggested that bad dreams let the brain learn to gain control over emotions resulting from distressing experiences (Cartwright 1993). Kramer (1993) agrees that dreams regulate mood. Stewart and Koulack (1993) state that one function of dreams is adaption to stress over time. Researching twelve years of dream lab data, Griffin (1997) proposed that dreaming metaphorically completes patterns of emotional expectation in the autonomic nervous system and lowers stress levels in mammals. This emotional regulation may result from two important events take place in REM, described by Els Van der Helm (2011): 1) emotional memories are re-activated in the amygdala to hippocampal network during REM and 2) reactivity of the amygdala is down-regulated (due to a massive reduction in stress producing neurotransmitters norepinephrine in forebrain centers including the amygdala).

Robert Stickgold (2009) supports both a waking and sleeping role in emotional processing. He states that the act of remembering dreams in the morning, and then trying to understand the emotional issues that seem connected to them, can help you understand emotional conflicts better. You are using the dream to help identify emotional conflicts that you might not have been totally aware of consciously. From a cognitive neuroscience perspective he considers emotional conflicts to be one of the realms of memories that are processed while we sleep and dream, largely outside of conscious intent or awareness. He considers sleep as permitting a time when the brain can search for and identify useful associations between recently formed emotional memories and older ones, helping to place them in a more useful context, from which their resolution may become more readily apparent. This is much like Hartmann's theories that dreams weave new material into established memory guided by emotion, organizing that memory based on what is emotionally important to us (Hartmann 2011).

Nightmares are perhaps an extreme form of this emotional processing. Although negative emotion appears somewhat more frequently in dream reports than does positive, we do not usually report the dream as a nightmare unless it is extremely upsetting, containing overwhelming anxiety, apprehension and fear. Nightmares can have a number of causes including: heavy emotional stress; severe threat to self or self-image; unresolved or extreme trauma (PTSD); psychological problems; the influence of certain drugs; emerging medical problem requiring attention; or sleep disorders affecting REM/NREM balance. Nightmares are different from night terrors, which may be accompanied by screaming before awakening

with extended disorientation afterwards. Night terrors typically occur (if at all) during the first two hours of sleep in deep sleep (sleep state 4) and the dream itself is generally not recalled. Stanley Krippner, Professor of Psychology at Saybrook University in San Francisco, states that PTSD related nightmares are not characterized by metaphor or symbol but are life-like replays of the event and therefore are not treated by interpretation of the narrative or imagery (Krippner, 2011). Therapy involves "modifying the nightmare (imagery rehearsal therapy) and resolving the issues it presents." Alan Siegel (2012) indicates that recovery (mastery) can be seen as the nightmares begin to incorporate images and references from the present and from the pre-trauma past and become more symbolic and include more illogical dreamlike imagery and metaphors. Long-avoided conflicts will often surface in dreams after a trauma (issues such as unresolved grief, survivor guilt, rage, and terrifying anxieties) that must be acknowledged and worked through for healing to occur.

Creative Problem Solving

Note that there are a number of cognitive centers in the frontal regions of the brain are highly active in REM. This suggests that the dreaming brain may be capable of problem resolution and creative insight.

Problem Solving:

Carl Jung, Monte Ullman (1959) and Greenberg and Pearlman (1975) observed that dreams solve problems related to important unfinished business of the day. Stickgold (2009) also contends that dreams seem to be more about what the brain calculates as most important, even if it is just an unexpected but very emotional event that occurred shortly before you went to sleep. Foulkes (1982) also supports dreaming as "active imagining," creatively combining memories and knowledge. Hatmann (1995) states that the "broad, loose connections of dreaming can provide a different perspective and can help us make important decisions and discoveries." The creative problem solving history of dreams is well documented by Barrett (2001, 2007) who researched the many inventions and artistic creations arising from dreams. She describes dreaming as "thinking in different biochemical state." Her research finds that anything may get solved during dreaming, particularly if the problem involves visualization or where the solution lies in "thinking outside the box"

Making New Connections:

Researcher Robert Stickgold (in Greene 2012) states that dreams "are where we bring things together in fresh, often startling ways, drawing on stores of knowledge from the past, the present, the possible future, in order to find new associations". Harmann (2011) considered this to be a hyper-connected process which, creating new connections more broadly than in waking life allowing us to arrive at new insights. Much like Hartmann, Stickgold believes that dreams are creative and may help us find new patterns and create combinations which break through well-worn ruts.

These new connections might provide creative solutions to waking problems or personal insight that is helpful to our psychological well-being. This is illustrated in the dream of a woman who had come to believe that her husband was the source of all their marital problems. She had a dream which compensated for this belief: *"I have a recurrent dream of being terribly angry with my husband, who I am always running away from. These dreams continued until one night I turned around and faced my husband and looked at his face… it was my father's face!"* Here we see a new connection is made between the two leading to a new insight which compensates for the previous perception or norm.

Psychological Resolution, Restoral and Growth

Compensation:

Jung stated that the general function of dreaming was to restore out psychological balance through recognizing misconceptions of the ego, and 'compensating' for these deficiencies in our personality in order to bring our awareness back to reality, and warn of the dangers of our present course (Jung 1973, 34, 127). Others have observed this compensatory inner thinking taking place. Early on, Alfred Adler also suggested that dreams play a problem solving role by diverging from rational logic towards an inner logic driven by emotion which either reinforces or inhibits the contemplated action. A study by Patrick McNamara et. al. (2002) provided evidence that dreaming may involve a process of learning from novel outcomes (particularly negative outcomes) by simulating alternative ways of handling these outcomes by generating counterfactuals to the violation (the compensating function discussed above). In other words, dreams identifying a violation or novel outcome based on what we consider to be the norm, then integrate this new information into memory by generating and testing "if it were true what might happen" scenarios.

This process of self restoral through the compensating action of the dream, is apparent in the following dream of a man who was offered a new teaching position based on his earlier expertise. He was conflicted because he felt his skills were too rusty. He was about to turn down the position when he had the following dream: "*I am walking along in the desert and happen upon an old rusty car with a man inside that looked dead. My unknown companion said he was just asleep and urged me to wake the man.. I argued that it was useless but after much discussion (mediation) reluctantly gave in and shook the man. When I did, both the man and the car came to life and the car transformed into a newer car."* He recognized the metaphor that he still had it within himself, and took the assignment.

Maintenance of the 'Self':

Jung (1971, p.126) spoke of dreams as maintaining the psyche or greater 'Self' (capital S); both the conscious and unconscious parts of the persona. Fiss (1986) also postulated that dreams maintain the 'self' and Jouvet (1998) indicated that they do this by "reprogramming cortical networks to maintain psychological individuality despite adverse waking experiences". Hartmann (2011) also contended that emotions guide the integration of new material into established memory in order to establish our "emotional being - our basic sense of self." Indeed we may establish an internal, unconscious model of 'self' that forms a reference for evaluating our experiences and conscious conception of self (our ego). A. D. Craig (2009) suggests that the anterior cingulate contains a representation of the 'self' in time, comparing feelings related to the past, present and projected future. The orbofrontal also provides a self-referential focus (Gusnard 2001). An example of the unconscious model of 'self' acting to compensate for a diminished view of self, held by the conscious mind, is shown in the following dream. The dreamer began seeing herself prematurely as an old person, unable to recover the talents of her earlier years. The dream appears to re-establish the inner model of the whole 'self'. *"I entered a stone castle. As I went down the stairs, I saw on my left a large stone archway and a room beyond. On the left side of this room was a young woman. As the sunlight streamed in she came forward, and I saw that she was me. She walked toward me and we blended into one person."*

Psychological Growth:

Beyond self-maintenance and problem solving, dreams also may help bring about our psychological growth and maturation. Jung claimed that dreams provide a 'transcendent' function, (1971, pp. 273, 279)

which brings about the emergence of a new awareness and a more integrated personality (a process he called "individuation"). He observed a regulating or directing tendency at work creating a process of psychic growth whereby gradually a wider and more mature personality emerges (Jung 1973, p161). Jung wrote that the dream achieve this through: recognizing the motives of the ego and 'compensating' for these deficiencies by creatively integrating unconscious and conscious material (revealing new connections and viewpoints) in order to arrive at a new attitude whereby the unconscious and the conscious self are more integrally connected and move together. Jung made an important point related to this process in that the dream ego plays a key role in that it must accept the scenario in order for integration to take place. Others agree that dreams help develop the ego (Jones, 1962) and integrate our fragmented personality (Perls, 1976). David Feinstein (1990) observed how dreams mediate conscious and unconscious perceptions in order to achieve the self-maintenance and transcendent functions that Jung describes. He indicated that dreams either: find a way to accommodate the material within our internal model (the 'old myth'); strengthen an unconscious 'counter myth' or creatively develop a 'new myth' (a new inner model) that better accommodates internal and external reality. Ernest Hartmann (2011) also characterizing dreams as a learning process; an adaptive, emotion guided, hyper-connective mental function, which is in part how the brain learns by creating new connections and weaving new material into established memory to arrive at "new insights that might give us a broader view or perhaps make a change in our lives".

Is the Dreaming Brain Capable of Psychological Resolution?

Greene (2010) states that, far from being idle fancies, dreams are enablers of "the most sophisticated human cognitive functions." The capability for dreams to perform the many cognitive functions discussed above, might be supported by the state of the brain during REM sleep. There are many centers active during REM, which in the waking state are known to perform many of these functions attributed to dreams. Although there is no proof that these centers play identical roles during REM their influence can be observed in dreams.

Let's take an example of a dream where psychological restoral, new insight and perhaps learning appears to take place. It is the dream from the corporate executive whose company was restructuring and eliminating top executives. He was holding out for the possibility that some position would open internally because he feared that if he looked elsewhere he would never find an equivalent job at his age and would also lose his retirement package. The positions open to him internally, however, were uncertain and not well suited to his career, but he considered it too risky to look outside. He had the following dream: *"I am a passenger in a boat on a dark underground river trying to find a way out and a 'position' in the windows where I can see daylight* **(conflict detected and figuratively presented).** *A tour guide appears behind me* **(action initiated and scenario planned)** *and points out an opening in the front of the boat that I had not seen before and says,"you can walk out that door* **(compensating or counterfactual cue introduced)**." *I didn't understand what he was saying at first and was reluctant since it didn't make sense, but finally at his constant urging* **(mediation)** *I walked out the door* **(scenario tested)** *and found myself out in front. At that point the boat emerged from the cave and into a bright beautiful sunlit setting of calm water* **(emotional reinforcement).**" Possible evidence of learning, and dampening of his fear reaction, comes from the action of the executive subsequent to the dream. He made some calls and put his resume out which resulted in an offer of a superior position in another company, and his literally "walking out the door".

Let's take a look at whether the brain state in REM might contain the cognitive capacity for an emotional processing function capable of resolving emotional conflicts in this manner. The hypothesis here is that the dreaming brain (during REM) has the capacity (based on the centers which are activated) to perform the following functions: a) detecting when something is wrong (a norm violation) and figuratively

presenting the situation; then b) initiating action by introducing (planning?) and testing a scenario; and c) introducing cues (which compensate or inject counterfactuals) that guide the action of the dream ego; then d) emotionally reinforce the scenario depending on the outcome; which e) might result in learning (emotional memory consolidation) and perhaps even dampening or extinction of the prior emotional reaction.

Do Dreams Detect and Present Norm Violations?

As discussed above, McNamara (2002) hypothesize that the cognitive operations in dreams function to identify a norm violation or novel outcome (recorded in episodic memory) and then integrates this new content into memory by generating counterfactuals to the violation ("what-if" scenarios which in effect compensate for the violation). Jung (1973, p 34) likewise stated that dreams "produces dream material that re-establishes equilibrium" through a process of "compensation". A norm violation might be something that does not agree with expectation based on the inner model (the norm) we have established for reality and our role in it. It can be anything from an event that triggered an unresolved emotional conflict, to an emotionally significant surprise or threat of some kind. In the example above it appears there may have been a violation of the executive's perception of high self-worth (the norm). This is brought on by a sense of feeling out of control, being at a loss in finding a satisfying position within the company and a conflicting fear of venturing outside into the unknown. The dream represented the emotional state figuratively as being stuck in a situation with no control (passenger in a boat in a dark tunnel) looking for a satisfactory position (position in the window where he could see the light).

The cognitive areas of the brain that are active during dreaming appears equipped for detecting when something is wrong and initiating action. The basal ganglion, anterior cingulate and parts of the orbofrontal cortex are active during REM sleep. In the waking state these centers are known to play important roles in error detection, as well as the monitoring of conflict and anomalies (Falkenstein 2001; Bush 2000; Allman 2001; Botvinick,1999; Posner 1998; Carter1998). The orbofrontal inspects events that deviate from expectation (Petrides 2007). The anterior cingulate acts as part of a general performance monitoring system that detects conditions under which errors in reasoning have occurred or might occur (Carter 1998) and goes into action when there is a violation in expectancy (Oliveira 2007).

Do Dreams Initiate Action (Test Compensating Scenarios)?

Some researchers consider dreams to be adaptive in that they rehearse and test various scenarios to better prepare us for waking life. Antti Revonsuo (2000) theorizes that dreams evolved to permit us to rehearse threatening scenarios in order to better prepare for real-life threats. Coutts (2008) describes dreams improves the mind's ability to meet human needs during wakefulness by testing scenarios - those that appear to adapt are retained, while those that appear maladaptive are discarded. Humphrey broadened the role of dreams beyond threat rehearsal to that of practicing of different physical, intellectual and social skills (in Blackmore 2004).

If the dream does have the capacity for adaptive learning, perhaps the anterior cingulate, the medial prefrontal cortex and the basal ganglia lend a degree of organization to this process. The anterior cingulate is known to imagine or observe and select a scenario and mediating action aimed at choosing between conflicting perceptions (Allman 2001). It does this in conjunction with the basal ganglia which are thought to be the brain locus for reward-based planning and learning (Yamada 2007) particularly decisions related to novel, unexpected situations (Balleine 2007). The anterior cingulate also generates performance expectations, observes the outcome, and monitors the consequences (Apps 2009; Hayden 2009, Oliveira 2007). It receives information about a stimulus, selects an appropriate response, monitors the action, and adapts behavior if the outcome is not as expected (Luu 2004). The medial prefrontal

cortex is also involved in: plan generation (Partiot 1995); goal directed behavior and reward processing (Kringelbach 2005; Vertes 2002); and self-referential behavioral stimulation and rehearsal (Gusnard 2001).

In the case of the executive's dream, we have a conflicting perception between the high sense of self-worth which should provide him a good position anywhere, and the blow to that perception based on the unexpected situation which what happening in the company where he felt he was no longer considered important. So the dream introduces a compensating scenario or "what if" counterfactual that is goal directed, and tests it on the dream ego. The subsequent actions of the dream ego are monitored and mediation takes place when the dream ego becomes confused or resists following the scenario. When the dream ego does follow the cues however a rewarding outcome is created.

In the above dream example, a single scenario it presented and tested. In many dreams (probably the majority) it takes many attempts at bringing forth associations to evolve and test successful scenarios. This is perhaps why we commonly observe dreams to organize into segments delineated with abrupt scene changes. Each segment appears to evolve toward a resolution or goal by introducing new connections and associations and viewing the problem from a different perspective. Jung (1945) observed that these dream series (within a nigh or over a longer period) seem to be subordinated to a common goal, resembling the successive steps in a planned and orderly process of development. The dreaming brain may indeed be planning and testing scenarios, observing and altering them in an attempt to reach a desired outcome. The following series is an example.

This dreamer was struggling in her attempt to assert herself; to engage her symbolic inner 'masculine'. Her prior life had been filled with tragic masculine role models. As a child her father was emotionally abusive and her mother made it known that she considered assertive behavior in a woman to be "sinister." In later life her ex. husband was alcoholic and would "squash" any attempt she made to assert herself. She had a five segment dream. In the opening segment *"two sinister men killed another man who was blocking traffic".* In the second a man "squashed a beautiful dragon fly." In a third segment the dream makes a failed attempt at integration by placing her in a motel room with another man – which upset her so she left. The next segment appears to demonstrate to the dream ego that the integration of masculine and feminine can be a rewarding experience: *"I went to the office to change rooms, it was in a dark warehouse building and I had to crawl through a dark hole. A man and a woman pulled me 'up from the darkness' into the lighted room."* The final segment again attempts masculine and feminine integration but appears to be derailed by connecting with associations of alcoholism" "*There were two old drunks, male and female, lying in the bed. I was totally disgusted, packed up and left."*

Does the Dreaming Brain Provide Cues to Guide and Influence the Action?

In mediating a scenario, the anterior cingulate is known to providing cues to other areas of the brain (Allman 2001), influencing and monitoring performance and outcome (Carter, 1998) in order to select an appropriate response. That selection is generally based on placing a reward value on anticipated outcomes (Bush, 2002). The anterior cingulate works jointly with the insula (also active in REM) which is known to be involved in our sense of self, subjective feelings, sudden insight and guiding perceptual decision making (Medford 2010; A.D. Craig 2009). The basal ganglia may also contribute cues that motivating us to seek eventual rather than immediate reward (Packard 2002). The medial prefrontal cortex monitors learning and provides a 'sense of knowing' and confidence judgments (Marley, 2009) and as such may give the guiding forces observed in our dreams a sense of authority and wisdom.

In the executive's dream we see these compensating or counterfactual cues delivered with a 'sense of knowing' in the tour guide who announces "you can walk out that door". The cues lead to a solution

which motivates the dreamer to take action representative of eventual rather than immediate reward. Note that there is a mediation that takes place as the dream ego struggles to understand and accept the message – much as he in waking life struggles with his fear of "just walking out the door".

Do Dreams Emotionally Reinforce the Anticipated Outcome?

Finally, it appears that when the dream scenario has led to the anticipated outcome, in particular when the dream ego has accepted the guiding cues and/or followed a successful scenario, the dream emotionally reinforces the scenario. The dream self-rewards, typically creating a rewarding ending. This may be part of the emotionally directed learning process that Ernest Hartmann (2011) spoke of when he stated that dreams integrate new material with old material into memory, guided by emotion, organizing memory based on what is emotionally important to us. This emotional reinforcement can be seen at the end of the 'rusty car' dream when both the man and the car come back to life.

This rewarding action may be a byproduct of the anterior cingulate selecting the appropriate scenario and placing a reward value on that outcome (Bush 2002). The anterior cingulate together with the basal ganglia are highly involved in focused, reward-based decision-making and learning and adapting to changing conditions (Allman 2001,Yamada 2007). The caudal and ventral medial orbitofrontal cortex is also involved in expectation and regulating planning behavior based on reward and punishment, influencing changes in ongoing behavior (Kringelbach 2005; Bechara 1994). With all these centers active during REM it is therefore not surprising that we might observe self-rewarding activity at the completion of a dream scenario that meets expectation.

All emotional reinforcement does not necessarily appear positive. Jung (1973, p.34) stated that sometimes dreams "warn of the dangers of our present course." Perhaps an example best illustrates the concept. The girl in this example had deep fundamental religious beliefs. She frequently tried to suppress a side of herself she considered evil by going through a prayer ritual whenever she had what she considered 'evil thoughts.' After one such episode she dreamed: "*This evil person had come alive again and feared that an "entity" was at work I went through a ritual of exorcism to eliminate the evil person (personal motive), but the more I tried the darker the sky became. Suddenly a voice said, 'stop - you are only making it worse."* Here the dream is figuratively presenting her dysfunctional beliefs about herself and her prayer ritual as an exorcism. The dream then compensates by showing the sky getting darker rather than lighter as she goes through her ritual. Finally it evokes an emotionally intense warning.

Is Learning, Emotional Dampening or Perhaps Extinction Taking Place?

The emotional self-rewarding of successful dream scenarios may also be a means of learning, of "organizing memory based on what is emotionally important" as Hartmann put it. This learning may also involve dampening the emotional response. Many of us have had the experience of falling to sleep with an upsetting situation on our mind, only to waken in the morning less disturbed about it. There are a number of brain regions active in REM that in the waking state play a role in dampening or "extinction" of emotional response. The medial prefrontal cortex has been found to be involved emotion regulation and extinction of conditioned fear (Sotres-Bayon & Quirk 2010). Van der Helm (2011) reported an increase in functional connectivity between the ventral medial prefrontal cortex with the amygdala in REM sleep. The REM active basal ganglia is also considered by some as central to extinction learning (Quirk 2000) and selecting which response to make or inhibit (Lieberman 2000). Within the basal ganglia, the ventral striatum has been shown to activate areas of the prefrontal cortex, the orbitofrontal cortex and the central nucleus of the amygdala which are important the inhibitory control and extinction learning (Romaguera 2012, Quirk 2000).

Reflecting on the dream of the executive, there appeared to be a learning and extinction of the fear response that made itself evident after the dream. Shortly after the dream he made some phone calls and got his resume out; experiencing a new sense of calm through the process. Oddly, prior to the dream, he had turned down a call from a search firm out of fear of the unknown. Fortunately they called back and he took the job (walked out that door) and it became the most rewarding job of his career.

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