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The Role of Dreams in the Evolution of the Human Mind

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Abstract: This paper presents an evolutionary argument for the role of dreams in the development of human cognitive processes. While a theory by Revonsuo (2000) proposes that dreams allow for threat rehearsal and therefore provide an evolutionary advantage, the goal of this paper is to extend this argument by commenting on other fitness-enhancing aspects of dreams. Rather than a simple threat rehearsal mechanism, it is argued that dreams reflect a more general virtual rehearsal mechanism that is likely to play an important role in the development of human cognitive capacities. This paper draws on current work in cognitive neuroscience and philosophy of mind in developing the argument.

Keywords: Dreams, sleep, REM sleep, evolution, philosophy of mind, cognitive neuroscience.

Introduction

Although Freud (1900) proposed that dreaming and, specifically, the meaningful content of dreams are related to mental functioning, the tenuous and misunderstood nature of dreams has made the proposition of empirically providing support for, or falsifying, this claim very problematic. The inability to study the effects of dreams on mental functioning has forced many researchers to view dreams as the result of random neural activity (e.g., the activation-synthesis hypothesis; Hobson and McCarley, 1977). If postulations regarding the random nature of dreams are indeed true, then it becomes challenging to construct a theory of how the phenomenology of the dream state could serve a functional role and be better understood through an evolutionary analysis. However, recent research, to be discussed in this paper, which takes into account the physiological mechanisms underlying sleep and dreams, the content of dreams, and the environmental conditions

of selection, points toward the natural selection of dreaming as a state of consciousness which has persisted across the development of the human species. This tends to suggest that the dream state was selected for as an adaptation which increases overall fitness. The leading theory addressing the adaptive qualities of dreaming uses the concept of virtual threat, defined as a dream-state wherein a threatening situation is constructed virtually, and explains that through the rehearsal of various threatening scenarios we may be better equipped to handle real-world threats (Revonsuo, 2000). While this theory offers a plausible evolutionary account of dreaming, the goal of the current paper is to extend the theoretical underpinnings of this hypothesis by commenting on other fitness-enhancing aspects of dreams and the broader influence of dreaming in the evolution of higher mental functioning.

The Subjective Nature of Dreams

The nature of the dream-state is highly subjective and a truly personal experience making the scientific analysis of dreaming somewhat prohibitive. Dreams often contain material that is nonsensical and challenging to interpret rationally, making the characterization of dreams from an objective point of view a perplexing task. While we all dream (though see Solms, 1997, for an example of neuropsychological patients who do not dream), there is incredible variability in the subjective dream experience (Hall and Van de Castle, 1966; Spadafora and Hunt, 1990). Some people rarely remember their dreams and erroneously conclude that they do not dream at all (a condition discussed by Freud, 1900), while others experience vivid dreams with rich visual imagery and emotional content. Sometimes, the story-lines that make up people's dreams follow a tight narrative and have a relatively smooth transition from scene to scene, while at other times dreams appear as illogical and haphazard associations lacking a coherent sense of flow. Some people have full control of their dreams, exerting conscious control over the supposedly random events which typify dreaming (Laberge, Levitan, Dement, 1986), while others are mere bystanders watching the events unfold without any sense of agency approximating waking volition. With the multiplicity of dream dynamics, it is no surprise that there are differing views on the nature of dreams, as a researcher's views on dreaming may directly relate to their own subjective experience of dreaming (Potter, 1996).

Despite this subjective nature of dreams, an evolutionary analysis of dreams should not be disregarded and considered outside the realm of scientific inquiry (although for a competing view see Thompson, 2000). Since the cognitive revolution, psychology and other disciplines have made significant progress in developing and implementing methodologies meant to reveal truths about the mental processes underlying our subjective experiences (Miller, 2003). For example, the tools of cognitive neuroscience have allowed neuroimaging data to inform our theories of cognition (Kandell and Squire, 2000). It is not unreasonable to think that these methods will one day allow for a correlation to be established between certain

patterns of brain activity and corresponding dream content, not unlike how current technology now allows accurate prediction of information from subjective experiences.

As an example, neuroimaging evidence can provide information to distinguish between lower-level sensory experiences (e.g., the experience of visual vs. auditory stimuli) as well as higher-level perceptual experiences (e.g., visual processing of a face stimulus vs. a house stimulus; O'Craven and Kanwisher, 2000). In this vein, it is important to approach the study of dreams in a scientific fashion, not biased by our own subjective dream experiences, but rather by letting our theories rest on scientifically collected data. Towards this aim of objective and scrutinizing scientific inquiry, below we present data concerning the function of dreaming.

REM Sleep and Dreaming

One of the first and most important findings in the history of research on dreams and dreaming is that which relates the phenomenon of dreaming and the physiological occurrence of rapid eye movement (REM) sleep (Dement and Kleitman, 1957). While dreaming refers to "the subjective conscious experiences that we have during sleep" (Revonsuo, 2000, p.878), REM sleep is a physiologically-defined stage of sleep. It has been established that dreaming does occur during REM sleep through the collection of dream reports from subjects awoken from REM sleep, though the same is true for non-REM sleep (NREM; Hobson, 1988). Rather than being a static process, sleep contains a number of discrete states defined by various physiological measures (Rechtschaffen and Kales, 1968).

The use of electroencephalography (EEG), electro-oculography (EOG), and electromyography (EMG) has proven useful in distinguishing between arousal states during sleep, by measuring brain activity, eye movements, and muscle activity, respectively. As we sleep, our brain passes through various stages in a cyclical manner. Some of these stages are characterized by slow brain activity and other stages occur in which the electrical activity of the brain mimics the waking brain, and can even be considered hyperactivated. This specific, hyperactive stage of sleep is known as REM sleep and has three characteristics that define it: 1) The brain is more active than while in other stages and the EEG consists of alpha and beta activity, similar to waking, 2) Muscle activity is actively inhibited within the central nervous system in order to promote paralysis, and 3) Eye-movements occur during REM sleep because the muscle paralysis does not extend to the eye muscles.

A link between REM sleep and dreaming has been established through various experimental studies (Hobson, 1988). First, it is known that people awakened from REM sleep as opposed to NREM sleep are significantly more likely to produce dream reports and these reports are likely to be more detailed and vivid than NREM dream reports. Also, evidence implicating REM sleep with dreams appears when REM sleep mechanisms malfunction. Normally during REM sleep, signals that elicit all motor output (except for eye movements) are actively inhibited. Disorders that

naturally occur in humans and lesions in other species that damage the inhibitory response can result in physically acting out dreams while asleep (Sforza, Krieger, Petiau, 1997). Further, humans can give a verbal report to substantiate the correspondence of dream actions to waking actions (Ferini-Strambi and Zucconi, 2000).

Other species cannot provide information about mental processes during sleep, so controversy surrounds the question of whether or not animals are dreaming during REM sleep. One perspective is that animals such as cats, which display threat-induced posturing and appear startled by invisible objects while in REM sleep, have a reason to produce such behavior. The reason is linked to their perception of information relevant to these displays without actual corresponding sensory information. In fact, studies using electrophysiological measures to record activity in hippocampal place cells indicate that rats which have spent a considerable amount of time during the day running through a maze show activation of the same place cells during REM sleep which were active during maze running (Louie and Wilson, 2001; Wilson and McNaughton, 1994). These data point towards the possibility that dreaming serves some type of rehearsal function, allowing animals to practice the activities performed while awake, namely running through the maze.

However, we will never know if the subjective experience of dreaming is the same for these animals as it is for humans, as we will also never truly know if another person's subjective dream experience is similar to our own. Just as behaviorists concluded the human mind was a 'black box' incapable of scientific study (Watson, 1913), there is a tendency to assume that we will never be able to gain an understanding of animals' mental states and that any attempt is simply anthropomorphism. However, the neurophysiological evidence mentioned above makes plausible the claim that during REM sleep these animals are experiencing something similar to what people call dreaming, with the caveat that the dream experience will be specific to the perceptual and cognitive abilities of the animal.

While there is a strong correlation between REM sleep and dreaming, it is also clear that dreaming can occur outside of REM sleep, and similarly, instances of REM sleep without dreaming are also feasible (Hobson, 1988; Solms, 1997). An analysis of dream content suggests that there are systematic differences between REM and NREM dream reports (Hobson, Pace-Schott, Stickgold, 2000). This data indicates that just as sleep is not a static unitary process, but rather made of discrete stages, the cognitive processes that take place throughout the sleep cycle, and that are normally uniformly called dreams, differ and can result in different classes of dreams (Fosse, Stickgold, Hobson, 2004). Dreams that occur during NREM sleep lack vivid imagery and, while they may contain themes similar to REM dreams, they often consist of a simple recurring theme.

For the purpose of this paper we will concentrate on the types of dreams that are normally reported when subjects are awakened from REM sleep. From this perspective, it is possible to make a stronger inference that certain physiological mechanisms of REM sleep influence dreaming. Specifically, activation can be

examined in forebrain areas that are more likely to be informative for a cognitive theory of dreaming, and are claimed to selectively influence dreaming without affecting REM sleep (Solms, 2000). This is not to say that we are unconscious outside of REM while sleeping and that NREM dreams are not also of potential interest, rather, it is argued that the type of consciousness that mostly occurs during REM sleep is of special interest and represents a prototypical dream. Since we currently lack the technology to achieve a highly detailed understanding of the physiological correlates of dreaming, a logical starting point is to use existing technologies to acquire data during REM sleep, in order to see how they can inform a theory of dreaming.

Theories of Dreaming

The theory of dreaming most generally accepted, which offers an explanation of dreaming based on the physiology of REM sleep, is Hobson and McCarly's (1977) activation-synthesis hypothesis. According to this hypothesis, dreams are the result of the forebrain responding to random activity initiated at the brainstem. This is demonstrated by the PGO waves that occur during REM sleep. Specifically, PGO refers to the *pons*, where the activity originates; the lateral *geniculate* nucleus of the thalamus, which is the area through which sensory information passes; and *occipital* areas, where visual information is processed. According to Hobson and McCarly (1977), this random activity, or noise, emanating from the pons, passes through similar sensory-relay stations as information from the environment, and is interpreted in a way that leads to the phenomenology of dreaming. Overall, this theory has received general support for some time because it fits well with physiological data and its explanation of dreaming appeals to a majority of peoples' dream experiences, again, being somewhat haphazard and random. This theory posits that the bizarre nature of dreams is attributed to certain parts of the brain attempting to piece together a story out of what is essentially random information.

The activation-synthesis theory does make intuitive sense, based not only on how we generally remember and report information from dreams, but also on how difficult it is to piece together memories of a dream upon waking. Neuropsychological evidence points towards our tendency to confabulate stories that we believe to be true in order to fit together disparate pieces of information (Gazzaniga, 1985). If true, however, the supposedly random information that leads to dreaming would weaken the evolutionary analysis presented here. If there is no bias towards a particular type of information processed during REM sleep, then it becomes hard to imagine how dreaming could be selected for in an evolutionary context. Specifically if there is no rhyme or reason with regards to the content that makes up dreams, it becomes difficult to understand the advantage of experiencing such a haphazardly concocted virtual dream environment.

A more detailed analysis of dream content and the relation between REM sleep and dreaming, however, demonstrates that the activation-synthesis theory is

incomplete (Domhoff, 2000b). Although dreams tend to be rather bizarre, they are certainly not as disjointed as would be the case if this hypothesis were unilaterally true. In fact, large samples of dream reports from numerous studies point toward the fact that individuals see the majority of dreams as realistic and containing a connected storyline (Foulkes, 1985; Snyder, 1970; Domhoff, 2000a). This is something which should not occur if the information processed in dreams is truly random. Likewise, to be discussed below, certain information is differentially represented in dreams (Hall and Van de Castle, 1966).

Additional neuropsychological evidence reveals that the brainstem mechanism, which is a key ingredient in activation-synthesis theory, is not necessary for dreams to occur. Rather, work by Solms (1997, 2000) points towards the forebrain region as being crucial in the generation of dreams. If there is reason to believe that dreaming is not just the random processing of information, but instead there is some pattern to the types of themes present in dreams and the possibility that dreams can consist of cohesive story-lines, then it seems logical to investigate why these patterns exists and what purpose they serve. Before delving into these details on the functional aspects of dreaming, it is necessary to briefly describe more about the phenomenology of dreaming and how this could be reflected in the brain.

Mental Rehearsal

It can be assumed that the brain is optimally designed for the processing of "real- world" sensory information, so that we can react in appropriate manner when confronted with environmental stimuli. Despite this fact, a large portion of mental life consists not of the processing of actual information, but rather the rehearsal of what to do when we encounter stimuli from the environment (Klinger, 1978). This rehearsal and the cognitive skills involved are likely to have a strong adaptive value.

Present neuroimaging data suggests that this "non-real" information, or information not tied to any current environmental stimuli, is treated in a similar fashion as information processed in a real physical environment. Data from a neuroimaging study, specifically using positron emission topography (PET), supports the notion that when we imagine something of a visual nature and manipulate that image, our visual cortex is activated (Kastner et al., 1999). Likewise, in studies that control for actual movement, it has been shown that by simply imagining the actions involved in a repetitive motor task, the physical representation of the associated pattern of activity in the motor cortex increases (Pascual-Leone et al., 1995).

A question, then, is why would mental imagery of a physical activity activate the same brain regions as the activity itself? This double-activation would make sense if mental imagery reflects exercise/practice for the brain (or if imagining a thing and "really" doing a thing are not as distinct as many assume they are). By being able to practice a response, or exercise a part of the brain without having to physically experience a behavior-eliciting stimulus (especially one that is potentially dangerous), we can optimize mental functioning and, ultimately, our response to an actual

situation (Cumming and Hall, 2003). It is well known that mental imagery techniques greatly facilitate multiple aspects of performance from sports to music (e.g., Feltz and Landers, 1983). Further, the most successful individuals at creative endeavors are usually those that have the best imagery skills (Intons-Peterson, 1993). Thus, it appears advantageous to be able to create vivid representations in the mind's eye of various scenarios, which in fact, is what dreaming entails.

Threat Rehearsal

When awoken abruptly from a terrifying nightmare, it is easy to understand the strength dream imagery has in generating both physiological and cognitive responses. In the case of a nightmare, heart rate is accelerated, sweating occurs, and a general feeling of fear and anxiety can extend for some time after the dream has finished (Mellman et al., 1985). Even though dreams are a form of mental representation, in the sense that perception is not tied to stimuli in the environment, they are generally experienced as real and the content is perceptually indistinguishable from waking perception (Freud, 1900).

If merely imagining an event has the power to better prepare us for an actual event by physically activating comparable brain regions, then it should follow that the more realistic the simulation of events, the more the brain treats the information as real. Also, if this capacity to simulate an environment allows us to be optimally prepared to deal with challenges in a real environment, it should affect fitness and be naturally selected for across generations (Darwin, 1995). The threat-simulation hypothesis of dreaming argues that this is the purpose of dreams and the reason why dreaming has evolved (Revonsuo, 2000). It is suggested by this theory that dreams serve the purpose of allowing for the rehearsal of threatening scenarios in order to better prepare an individual for real-life threats. This is supported by evidence from dream reports to be discussed below.

An Evolutionary Perspective

In order to evaluate the threat simulation theory of dreaming (of the kind found in REM sleep), it is useful to discuss it in an evolutionary context, and consider whether dreaming meets the necessary requirements of evolution by natural selection; namely, genetic variation, inheritance, and differential fitness. As for the first condition, there is evidence that REM sleep is genetically varied between and within species. REM sleep seems to be exclusive to placental and marsupial mammals (Winson, 1993). This suggests a particular phylogeny of dreaming, and that there was some point in time in which this characteristic was acquired and further spread to evolving species. Also, the amount of REM sleep placental and marsupial animals tend to require varies in a shared manner throughout their life cycle (Siegel, 1995), pointing towards an underlying genetic control over dreaming.

Likewise, different physiological processes occurring during REM must have

undergone processes of natural selection. Consider disorders in which people physically act out their dreams, and the potential dire consequences that could result from such disorders. Those who acted out their dreams may have put themselves at great risk. As the trait of physical inhibition during dreaming varies in humans, those individuals with the trait which inhibits paralysis during REM sleep seem to have been predominately removed from the current dreaming population, indicating also that the second condition of inheritance is satisfied.

When considering the third proposition of the differential fitness of dreaming in modern humans, it is important to understand the environment in which selection was occurring. Our human ancestors faced a number of challenges posed by interactions with conspecifics within and between groups (Foley, 1989), as well as in procuring food and protecting themselves from predators (Kaplan and Hill, 1985). In this environment, the ability to most efficiently react when a real threat is apparent would obviously confer a survival advantage. Evidence from mental imagery and dream studies suggest that rehearsal in the dream is treated as a real threat and, therefore, those individuals with these imagery skills to rehearse threatening scenarios should have an improved ability to deal with threat, making them more likely to be the progenitors of offspring. Through the survival and procreation of their offspring, this ability of, and propensity towards, imagery would be differentially passed on to future generations.

If dreaming was selected for because of its adaptive function, the general content of dreams should certainly reflect this, and consist of situations that allow the rehearsal of scenarios that ultimately lead toward increased fitness. This is exactly what is seen, with studies indicating that dream content is biased toward negative elements reflecting threat, as opposed to positive elements. Data collected from over 500 dream reports by Hall and Van de Castle (1966) indicate that about 80% contained negative emotions, while only about 20% contained positive emotions. These negative dreams are also disproportionably likely to contain threatening elements such as animals and male strangers in threatening encounters. The evidence points towards the overrepresentation of threatening events in dreams, which should not occur if dream content is random. Through appropriating and learning to deal with these threats in dreams, it is proposed here that an animal could increase its overall evolutionary fitness.

Beyond Threat Simulation

While Revonsuo (2000) limits his argument to the effectiveness of dreams in preparing for real-world threats, it is our goal now to extend this argument. We propose that the fitness-enhancing benefits of dreaming is not restricted to threat rehearsal, and the evolution of other higher-order cognitive faculties has been strongly influenced by a dreaming mechanism. By commenting on other fitness-enhancing aspects of the phenomenology of dreaming, besides threat, it also becomes possible to integrate our theory with portions of Hobson and McCarley's (1977)

activation-synthesis hypothesis, with particular regards to their view on the random information that leads to dreaming.

While dream content is not completely random, as demonstrated by the fact that there tends to be an over-representation of negative affect (Hall and Van de Castle, 1966; Merrit et al., 1994)) and social interactions (Kahn et al., 2002), there still is a great deal of variability and randomness observed in dream content. We argue that this variability is likely due to activation propagated from the brainstem, and that this noise in the system is beneficial. The advantages of having noise as a crucial factor in a dream-generation mechanism could be likened to the benefits of genotypic variability in the evolution of species (cf., Darwin, 1995). Given an unpredictable and variable environment, variability in traits increases the possibility that a certain trait will randomly confer an advantage under certain circumstances, this being the crux of Darwin's theory of natural selection. In dreams, the potential advantage of noise and variability in the system allows for a broad range of scenarios to be simulated and new scenarios to be created rather than having the same type of dream occur repeatedly. This concept relates to ideas discussed by Kahn, Combs, and Krippner (2002), in terms of stochastic resonance which they contend prevents mental activity from perseverating, which allows for novel situations to be developed through the presence of noise in the system.

Aside from our theory being in a state of consonance with theories of both activation-synthesis and threat-simulation, we also contend that increased fitness is not limited to situations of threat rehearsal and that the information processing occurring in dreams should be similarly represented in the brain as is waking cognition. This is the case because if sleeping and waking cognition are quite different, then rehearsing threatening situations in a dream may not transfer into the ability to better handle similar situations in waking life. However, evidence from lucid dream studies (described below) indicate that tasks such as counting and singing during a dream, which should activate the left and right hemispheres, respectively, do just that. When a person is singing in a dream, their right hemisphere is more active, and conversely when a person counts, the left hemisphere becomes more activated (LaBerge and Dement, 1982). A more recent PET study demonstrated that subjects trained on a serial reaction time task showed task-related increases in brain activity during REM sleep which was correlated with improved performance on the task after sleep (Maquet et al., 2000).

Also, from a neuropsychological perspective, evidence comparing bizarre dream cognition with certain psychopathology indicates another link between brain activity in dreams and waking. For example, people who suffer from damage to frontal and temporal brain areas typically report the misidentification of faces during waking life, a condition known as Fregoli syndrome. Some research has indicated that a decrease of activity in these regions, reported from neuroimaging studies in sleep, correspond to similar reports of misidentification during dreaming (Schwartz and Maquet, 2002). So, the functional architecture of our brains similarly influences both sleep and waking cognition and perception, supporting the idea that

neurophysiological correlates of cognition appear stable across the two forms of consciousness.

Situated Cognition in Dreams

While the above argument points towards the similarity between thoughts while dreaming and in waking life, clearly there is a difference in how the two states are experienced and the type of cognition occurring in each. As discussed earlier, for the majority of time spent dreaming, we accept as real even the most bizarre scenarios, and are able to make rationalizations allowing us to treat the dream as real. Generally speaking, we are fooled into accepting a dream experience as a real experience, until we awake and reflect on the content of the dream. This indicates a general deficit in certain aspects of executive functioning (e.g., deficits in planning, monitoring, attention switching, etc.), including skills relating to critical-thinking and our ability to access specific types of memories.

While dreaming, an effect of the general deficit in executive functioning is that our cognitive machinery becomes fully engrossed in perceptions and goal-states directly relevant to perceptions of the dream. This has a considerable resemblance to the idea of situated cognition, in which cognition is tied to the moment and restricted to satisfying goals pertaining to current concerns (also, perceptual narrowing has been shown in alternate contexts within the rubric of the threat-rigidity effect, proposed by Staw, Sandelands, and Dutton, 1981). It can be argued that all non-human cognition is situated, and that it is the ability to extend thinking beyond the here-and-now of perception and motivation that makes human cognition unique (Bogdan, 1997). It has even been hypothesized that what humans currently experience during REM sleep shares a similarity to waking consciousness in early hominid brain evolution (Panksepp, 1998). Jaynes (1976) takes this idea even further by arguing that there was a time, roughly 3000 years ago, when humans lacked consciousness and acted in a way that parallels the situated nature of dream consciousness.

This situated aspect of dreaming also makes sense from an evolutionary perspective and further supports aspects of the threat-simulation theory. While it is advantageous to rehearse situations that are subjectively deemed as threatening, it is equally disadvantageous to come across a threatening scenario in real life and invest the time required to wonder whether or not that situation is real. Therefore, in order for this dream mechanism to be selected for, an important aspect of its initial selection is that the perceived threats encountered during a dream must be experienced as a real. This means that certain higher-order mental processes, which would function to appraise the situation in an intellectual fashion (mostly frontal areas), would likely have to be deactivated, which research indicates is the case (Mazur, Pace-Schott, Hobson, 2002).

In most dreams there are deficits in the ability to solve complex problems. Evidence from fMRI studies during REM sleep, show that there is a decrease in activity of the prefrontal cortex, which would normally be associated with a decrease

in executive functioning (Mazur et al., 2002). Specifically, it has been found that there is a decrease in activity of the dorsolateral prefrontal cortex during REM sleep. This cortical region of the brain is crucial for tasks that require us to switch from our current line of thinking and inhibit a task once initiated. The deactivation of this region during a dream-state makes intuitive sense, in that for most dreams even very bizarre scenarios are normally accepted without question and we generally just go with the flow of the dream. We can visit with people who have passed away or interact with those whom we have not seen in years and yet this normally does not stop the dream from continuing or cause us to come to the conclusion that we are dreaming.

Social Cognition in Dreams

While the dorsolateral prefrontal cortex appears to be inhibited during REM, there is not a uniform deactivation of the frontal regions in the brain during states of dreaming. For example, there is a consistent increase in activity of the anterior cingulate in REM sleep (Braun et al., 1997). The anterior cingulate is a medial frontal region implicated in such functions as decision-making, conflict resolution, social cognition, and social judgment tasks which probe a subject's theory of mind (TOM) and requires subjects to take into account the intentions and mental states of others (Devinsky, Morrell, Vogt, 1995). In fact, recent studies link activation of the anterior cingulate with capacities of a TOM module (Vogeley et al., 2001). These data suggest that aspects of cognition centering on the processing of social information are strongly activated during REM sleep.

This is particularly interesting since it is thought that our complex social interactions and the information processed in the social domain played an integral role in the development of primate's mental capacities (Whiten and Byrne, 1988). If these pathways are active during REM sleep and this type of information is being rehearsed, then it should function to effectively strengthen the effects that processing of social information has on mental development. Further supporting this role is the tendency for a large proportion of dreams to contain other people and represent various social situations (Kahn et al., 2002).

Another example of a skill that has arguably played a pivotal role in other functional aspects of the human intellect and could serve to be shaped by dreaming is that of interpretation. As discussed by Bogdan (1997, p.108), "…key advances in interpretation, such as the recognition of belief, were accelerated by increased opportunities to interact with or manipulate subjects and slowed down by a lack of such opportunities." As such, via teasing, play, mental rehearsal/imagery, or dreaming, the individual is given the opportunity to utilize successful strategies in dealing with these situations and further develop interpretive skills. In fact, studies of children's dream-reports indicate that their dreams more often contain family members and close friends than adults' dreams (Hobson, 1988), possibly due to the fact that it is more important for younger children to be practicing close interpersonal

skills than it is for adults.

It, however, could be argued that the rehearsal of social situations would not play a significant role in increasing one's fitness. In order to address this claim, it is necessary to comment on the potential benefits of being socially sophisticated. First, in terms of pure survival value, those individuals who best interact with those around them, i.e., those who interact without interpersonal conflict and confrontation, will likely have better access to resources in their social group, be it mates or food (Foley, 1989). There is wide variation between cultures in the types of traits that render an individual fit, and what makes humans a successful species is that our ability to deal with the social environment that we are thrust into is not completely pre-wired (Sapir, 1921; Whorf, 1956). Those individuals that could use feedback from the environment to effectively modify their social interactions would be best off, as individual groups often have particular social nuances. Also, clearly in our own species, the traits we have which help us deal with social situations vary greatly and under certain circumstances can be beneficial, while at other times potentially put us at risk. Due to the variable fitness of particular behaviors at particular times, we need to be adept at interpreting cultural standards when interacting with others. For example, one cultures "alpha male" could potentially be ostracized in another culture. This newly ostracized individual would be less likely to obtain mates, and would be less competitive for the resources that would influence his survival. Therefore, something that could tip the scale in allowing someone to best deal with important social interactions would likely be selected for over time.

Flanagan (2000) raises the potential criticism that dreams do not give us an accurate representation of ourselves and conspecifics, positing that there is no advantage conferred in dreams by rehearsing various social interactions. He claims that the development of a TOM module based on dreamed social interactions would be flawed, and that accurate depictions of others and ourselves is the exception rather than the rule while dreaming. While we do not disagree that in dreams ourselves and others often act in a surprising and atypical manner, overall our representation of those we know is quite impressive and accurate. From their visual appearance, to the tone of voice, to the style of speaking, by virtue of the fact that we recognize and interact with those we know in the dream-world, we have an amazing ability to unconsciously recreate dream characters from those people with which we typically interact (above and beyond any verbal description that we could give of that person). While we surely cannot say a dream character's behavior is how that person would act in 'real life,' we also know that there is no way to accurately predict how that person will behave when encountering a new situation in real life. In waking life, the best that we can do is interpret overt cues and then attempt to understand a person's intentions and predict their actions, for which dreams offer such a venue.

Dream Ontogeny

While the social aspects of dreaming offer insight into the socio-

developmental benefits of dreams, so does an examination of the ontogeny of sleep and dreaming. Multiple facets of our mental development are ontogenetically scheduled (Bertenthal, 1996). For example, at about nine months of age it is apparent that infants acquire the new skill of treating others as intentional beings (Trevarthen, 1979). Other mental capacities also begin to develop within a predictable timeline, a universal characteristic of the human species and occurring independent of culture. Likewise, the architecture of sleep cycles follows a specific ontogeny that is consistent to humans as a species (Frank and Heller, 2003).

REM sleep occurs most frequently in newborns, and decreases throughout the lifespan. Newborns can spend about eight hours a day in REM sleep, and REM sleep actually occurs at sleep onset (Winson, 2002). In contrast, as we age, sleep onset is characterized by stages of NREM sleep, followed by REM sleep in less amounts. By the age of three, REM sleep is reduced to about three hours a day and continues to decline throughout the lifespan.

Why is REM sleep such a prominent brain state in the developing brain? One answer to this question follows from the previous argument as to the potential function of dreams, i.e., a virtual rehearsal mechanism. It is well known that children, and even other species, suffer detrimental effects when raised in impoverished environments (Joseph, 1999). The converse is also true. Infants raised in environments with rich amounts of information show increased cognitive skills at an earlier age, and this can even extend throughout the lifespan (Diamond, 1988); an enriched environment during the development of the nervous system optimizes its functionality.

As mentioned above, all evidence points toward the notion that virtual environmental stimuli are treated in essentially the same way as real stimuli from the environment. Therefore, it would make adaptive sense for an organism that is young and still developing to experience the most rich and vivid environment possible. If this is experienced in infant dreams, then this is exactly what has been selected for, as newborns spend a good deal of time in this virtual environment.

Of course, the virtual environment will likely be a reflection of the real environment and how infants interact with their virtual environment is going to be a function of the perceptual and cognitive capacities they have developed. So, the REM mentation of infants, which we are arguing constitutes a type of dreaming, probably consists of recreations with important sensory information that is taken in while awake. It is this information, and these interactions with the physical and social world, which is likely vital in shaping the future mental development of the child.

The brain connections that are thought to be developed during REM sleep are not going to be haphazardly put into place and subsequently strengthened, rather, through dreaming, these connections may be optimized based on experience. If mental rehearsal can induce change and lead to the reorganization of the brain in relatively short periods of time (Pascual-Leone et al., 1995), surely the cumulative time spent dreaming will impact brain development as well. While this argument

may seem contradictory to data indicating that dreaming is a gradual cognitive process that does not take place regularly until around ages 5-9 (Foulkes, 1999), the dream experience is bound to be tightly coupled with the development of general mental abilities including perception, language, and memory. Further, the lack of verbal dream reports should not exclude, a priori, the possibility that a form of a dreaming is taking place.

Hypotheses can be generated based on the notion that infants have a type of dreaming mechanism, and this dreaming mechanism influences the development of certain cognitive abilities. Specifically, we predict that an optimal environment that has a good deal of complexity will interact with a healthy sleep schedule to cause an optimal development of intellectual capacities. Conversely, a disruption in the normal REM cycle of a developing individual could have negative consequences on the development of mental functions. An example of a disorder where this hypothesis could be investigated is autism. Autism has been likened to a TOM deficit and is associated with disrupted sleep patterns (Richdale and Prior, 1995). Based on the theory developed in this paper, it is predicted that a portion of the deficits observed in autistics is due to their lack of REM sleep. We theorize that through an inability to dream, the autistic brain is negatively affected and through this negative effect, so are subsequent behaviors, such as interactions with the world around them.

An Important Exception

Thus far, we have been careful to use qualifiers such as "generally" and "a majority of the time", when referring to the situated nature of dream cognition because it is possible to have waking-like cognition operate while dreaming (Laberge et al., 1981). This phenomenon is known as lucid dreaming and occurs when the dreamer realizes, within the dream, that they are dreaming and that their actual body is asleep in bed. With this knowledge in mind, the dream continues and the dreamer is able to manipulate and interact within the dream world from a waking frame of consciousness. Research has shown that people are able to reach this state in a sleep laboratory and are able to indicate their lucidity to the waking world by giving distinct eye signals that are recorded by EOG (LaBerge et al., 1986). Upon waking, a dream report is given in which the subject describes how many eye movements they made and the duration between these eye movements. These reports are shown to match up with observed physiological data (Laberge et al., 1981).

This is a capacity that we contend has to be unique to humans, and represents a level of awareness that is often not attained in the waking state (although see Hegel for talk of a similar type of waking "self-consciousness"; Hegel, 1979). While lucid dreaming occurs rarely for people in the general population, it is a skill that can be learned through various techniques (Laberge, 1980). These techniques generally have the person become more aware of their state of consciousness and question their reality throughout the day. By forcing the person to step outside the flow of their current perceptions and motivations during waking life, there is an increased chance

that this will occur during dreaming and facilitate a lucid dream. This allows a kind of feedback between the dreaming and waking state to be reached where a more unsituated approach to waking life affects the level of situatedness in the dream and *vice versa*. Thus, a by-product of the dreaming virtual-rehearsal mechanism may be the ability to obtain a higher level of awareness of one's place in regards to one's surroundings.

Since higher mental operations can occur during dreams, this is surely bound to interact and feed into waking cognitive abilities, and while it might not confer an obvious benefit to fitness, dreams are a venue that have been used in a number of cultures to attain higher states of consciousness (e.g., Tibetan dream yoga, and the practices of the Senoi) and increase one's sense of well-being (Wangyal, Rinpoche, and Dahlby, 1998). Since no neuroimaging work has been done with lucid dreaming one can only speculate, but it is possible that people who are frequent lucid dreamers would show a different functional pattern of activation while in REM sleep, with greater activation of frontal regions. This potential difference in activation for lucid dreamers demonstrates the importance of taking into account subjective dream reports when interpreting data on the physiology of sleep in general, and REM sleep in particular.

Conclusion

When you consider the plasticity of the brain — with as little as 10-20 minutes of motor practice a day on a specific task the motor cortex reshapes itself in a matter of a few weeks (Karni et al., 1998) — the time spent in our dreams would surely shape how our brains develop, and influence our future behavioral predispositions. The experiences that we accrue from dreaming across our life span are sure to influence how we interact with the world and are bound to influence our overall fitness, not only as individuals, but as a species. However, this argument does have flaws.

One challenge to our hypothesis that deserves mentioning is the fact that we do not always remember our dreams (Freud, 1900). There is a tendency to think that what we cannot consciously recall does not influence us, but this is surely not the case. Consider the mere exposure effect, where preference decisions are biased by prior exposure to a stimulus, especially if that stimulus is unconsciously perceived (Bornstein and D'Agostino, 1992). These experiments demonstrate that the decisions we make are often based on information that we cannot consciously access. Likewise, it is common to wake up without being able to remember any dreams at all and, later in the day, encounter some cue in the environment that triggers memories of a dream. This should serve as evidence that we cannot always trust our conscious minds to accurately inform us of the contents of the mind and that our actions may be heavily based on information to which we do not always have access.

While it has been proposed that dreaming is a by-product of the way in which the architecture of sleep was designed (Flanagan, 2000), the evidence presented here

suggests that there are clear cognitive and behavioral ramifications due to the fact that while asleep our mind not only continues working, but acts in such a way that we are necessarily thrust into various virtual scenarios. The processing of dream content, which consists of variations in scenarios encountered during daily life in which we interact with the physical and social world, is bound to influence our cognitive capacities and subsequent appraisal of real-world content. As greater technological advances occur in the field of cognitive neuroscience we should be able to directly test some of the fundamental hypotheses generated in this paper. Specifically, we should be able to gather information pertaining to the development of the dreaming mind in humans and others species, as well as information regarding the potential benefits gained by dreaming and the costs incurred in its absence. While only through the empirical validation of the theory proposed in this paper may we be able to better understand the role of dreaming as an evolutionary adaptation, the current work is a start along this road.

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