Sleep is a facilitator of information processing

The human body and mind are constantly subjected to stressors and new stimuli during the course of a day. Sleeping is crucial for coping with such as it nourishes the bodies need for physiological rest and repair after such stress, and also simultaneously facilitates crucial information processing in the mind. In fact, sleep is one of the most essential functions of the human body. The unconscious information processing that takes place during sleep plays a significant role in cognitive information processes such as memory and learning. Essentially, during sleep the mind integrates new information acquired during the previous day into memory and processes it by making necessary connections.

The culmination point of these unconscious information processes seems to be in rapid eye movement sleep (REM-sleep) as brain activity is at its height during this phase of sleep. The activation during REM-sleep resembles that of a conscious state. Also, sleep research has shown that the majority of complex dreaming occurs during REM-sleep (Revonsuo, 1996, 277). However, the exact function of dreams is unknown. Even so, dreams are often a repetition of influential experiences and feelings from the previous day and therefore seem to be linked to information processing that takes place (Partinen, 2007, 18). Consequently, it would seem safe to conclude that REM-sleep has some role in unconscious information processing. Yet, there is a great amount of controversy within the scientific and psychological community regarding the role of REM-sleep in cognitive information processing. One view suggests that REM-sleep is merely a mechanism used by the brain to assist in recovery from sleep by retaining necessary activation levels in the central nervous system (Vertes, 2000, 876), whereas others find that REM-sleep is clearly connected to information processes such as learning, threat-response and problem solving. Hence, the focus of this essay is to investigate the relationship between REM-sleep and cognitive information processes. The research question of this essay is: To what extent does REM-sleep entail cognitive information processing?

1. 1 Phases of sleep

Sleep can be divided into REM-sleep and four phases of non-REM sleep (NREM). The first and second phases of NREM are the closest to a fully awake state, and the third and the fourth phases are the least conscious phases of deep sleep. It is hypothesised that NREM-sleep is in fact the restoring phase of sleep as metabolism is comparatively low in NREM-sleep in comparison to a conscious state (Revonsuo, 1996, 277).

Interestingly, there is relatively little brain activation in NREM-sleep, actually sleep research has shown that there are often only simple dreamlike experiences in NREM-sleep and sometimes more complicated dream experiences. In fact, over half of the participants in dream researches, awoken in the deepest phases of NREM-sleep do not recall any dreams. Moreover, in between these phases of NREM-sleep there are several phases of REM-sleep. Brain activation in these phases resembles that of a conscious state i. e. high frequency beta and gamma waves similar to those found in a conscious state of mind are visible in EEG scans of sleep research participants during REM-phase sleep. Furthermore, participants woken from REM-sleep almost always recall event rich dreams (Revonsuo, 1996, 277). However, sleep research can only reach so far in terms of understanding the processing that takes place in sleep. Data is usually obtained through either physiological measurements or dream journals (Hobson, 2002, 7). This significantly affects the depth of the scientific understanding that can be gained. As physiological measurements tend to be quite superficial, whereas journals are often either incomplete or lacking in objectivity.

In any case, there seems to be a large amount of information processing that takes place unconsciously. The difference between NREM-sleep and REM-sleep can be attributed to the type of information processing that takes place. It is thought that NREM-sleep involves relatively passive encoding of memories from the hippocampus to long-term memory. On the contrary, REM-sleep is thought to involve processing of procedural and emotional memory, which shows in dream content and vibrancy (Partinen, 2007, 40). It might be the case that dreams are not present at all in deeper NREM-sleep as the brain activity is relatively low.

Information processing

Cognitive psychology focuses on understanding the how the mind processes information. Behaviourism Cognitive psychology is concerned with information processes in the mind such as memory, learning, problem solving, and perception (Bourne, 1986, 30). Even so, cognitive psychologists have only recently have come to accept the importance of unconscious processes, namely the importance of sleep time unconscious processes for cognitive information processing (Shevrin, 1996, 2).

In reality, cognitive information processing takes a relatively long time. Essentially, for any new information to have an effect on the human mind the information needs to first be perceived by the sensory system; eyes, ears, or the skin. Some type of change has to be first registered and only then can any further information processing take place. This further processing can happen immediately, but it is more often than not the case that the stimulus is gone before any conclusions can be drawn (Bourne, 1986, 12). Therefore, memory plays a key role in information processing as we often have to rely on it to draw any conclusions. The multi-store memory model suggested by Atkinson and Shiffrin in 1968 gives a relatively accurate model of cognitive information processing. It suggests that memory can be split into three phases sensory, short-term memory, and long-term-memory. Information moves between the different types of memory through rehearsal and retrieval. However, the model has been subjected to critique over being too simplistic in terms of transfer between the different types of memory. In fact, the model relies solely on rehearsal as a means of transfer ignoring the importance of effort and strategies used by an individual (Hill, 2001, 106).

In particular, the multi-store memory model works on the principal that information is processed as it is given attention to. Naturally, as new stimulus are constantly entering the mind and the sensory organs, while in a conscious state of mind, the mind can only give attention to so many things and is often preoccupied in the processing and storing of new more prominent information. Therefore, it would seem logical that as there is little time during the conscious period to process all the information entering the brain during the day, that is most information processing actually happens during some other time, namely during sleep.

Theories of dream function

Dream research is essential to the study of sleep time unconscious information processes as it provides a view into any processing that takes place during sleep. However, the exact function of dreams is difficult to determine. Some psychologists and the general public alike would like to think that dreams are meaningful in themselves. Conversely, the activation synthesis dream hypothesis suggests that dreams might just be derivatives of the neuron activation during sleep (Hobson, 2002, 71). Either way dreams appear to be of significance in terms of study of REM-sleep information processing, since dream-experiences are most common in REM-sleep (Revonsuo, 1996, 277).

The psychoanalytic level of analysis is largely based around Freud's theory of personality and dream theory. The primary theory on dream function presented by Freud was that of wish fulfilment i. e. dreams are disguised expressions of unconscious desires and impulses (Tulonen, 2008, 56). However, Freud's theory is largely without empirical evidence as it is based on case studies that he conducted himself, in spite of this, his theory seems to suggest that dreams have a meaningful content and therefore there is some type of information processing that occurs during sleep.

However, perhaps the most widely accepted theory is the reprogramming dream theory. The proposal made is that dreams are necessary for the brain to process new information and make necessary connections. The brain also works to remove any excess unnecessary information from memory during dreams (Tulonen, 2008, 55). This theory also supports the idea that there is information processing during sleep and more specifically during the REM-phase of sleep.

Information processing during REM-sleep

Learning processes in REM-sleep

Learning is undoubtedly one of the most important cognitive information processes as it entails a number of other information processes e. g. perception, problem solving, and memory. Learning can take place through a number of pathways and constitute anything from a simple learned motor function to understanding of abstract scientific concepts. Therefore, a distinction should be made between repetitive learned motor function and information that is consciously and deliberately learned, understood, and stored in memory i. e. factual or semantic information. That is, procedural and declarative memory respectively.

More in depth, learning is a compilation of different cognitive processes i. e. perception, memory, and problem solving. There are a number of models that conceptualise the learning process. For instance, David Kolb’s experiential learning model identifies four stages of the learning cycle: concrete experimentation, reflection, abstract conceptualisation, and active experimentation. Concrete- and active experimentation involve learning from experience, whereas reflection and abstract conceptualisation involve inferring based on memory of past experience (Kolb in Sternberg, 2000, 227). The reprogramming theory of sleep suggests that different phases of sleep are of central importance for processing and interconnecting of memories i. e. reflection and abstract conceptualisation, and therefore achieving learning (Tulonen, 2008, 55).

2. 1. 1 Early brain development

REM-sleep information processing is central to learning and development from the very onset of brain activity in a foetus. The human foetus spends around 16 hours a day in rapid-eye movement sleep. This is necessary for brain growth as REM-sleep involves high brain activity and continuous neuron stimulation creating new links in the cortex (Hobson, 2002, 76). Furthermore, a similar phenomenon is also present after birth, that is, the amount of REM sleep for an infant is unusually large; around 8 hours whereas by adulthood this declines to at most 2 hours per night (Partinen, 2007, 43).

Majid Mirmiran conducted an experiment on the functional significance of REM-sleep in relation to infant rat development, which showed how essential REM-sleep is for early development. In the study infant rats were deprived of REM-sleep by interfering with monoamines in the brain from 1 week of age to 3 weeks of age. The rat’s were then tested as adults and compared with normal rats. Unsurprisingly the rats were severely affected and the findings showed that the deprived rats had hyperactivity, hyperanxiety, attentional distractability, reduced sexual performance, and reduced cerebral cortical size in comparison to control rats (Mirmiran, 1986, 283). Without a doubt the findings are limited in how much they can be generalized to human infants and foetuses. However, the same research could not have been carried out on human infants without raising serious ethical issues. In any case, the research clearly exemplifies the importance of REM-sleep for brain development in early life of a mammal.

2. 1. 2 Memory consolidation

Not only is REM-sleep necessary for infant development and learning, but it's also essential in learning new skills regardless of age. For instance, visual recognition of different objects is a process that is learned from very early on in life. The importance of REM-sleep for forming procedural memories necessary for learning a visual recognition task is illustrated by a study conducted by Karni et al. on sleep deprivation. The study showed that performance in a given visual discrimination task improved significantly over a single night of sleep, whereas when participants were selectively deprived REM-sleep there was no significant performance gain. Moreover, when participants were deprived of NREM-sleep the performance gain remained unaffected (Karni, 1994, 679).

The reliability of Karni's study is relatively high as it demonstrates that the given task is unaffected by NREM deprivation and will improve over a single nights sleep, whereas other studies are not as clear and may have been affected by the stressfulness of the sleep deprivation procedure. Furthermore, Stickgold et al. attained similar results in a more recent study on visual discrimination and REM-deprivation (Stickgold, 2000, 1237). In any case, sleep deprivation is a very stressful procedure and has a great impact on the validity of any research. However, REM-sleep seems to be clearly important for developing of procedural memory. The significance of REM-sleep for developing procedural memory and visual recognition skills may be one reason for unusually large amounts of REM-sleep in infancy. It may even be the case that without REM-sleep an infant may be unable to develop a consciousness and perceptual and motor skills. However, currently there is little evidence available for such.

Conversely, there are several researches that refute the role of REM-sleep in procedural memory consolidation. For instance, a recent research conducted by Genzel et al. on REM-sleep and slow-wave NREM-sleep deprivation showed that neither procedural memory nor declarative memory seems to be affected by REM-sleep or deep NREM-sleep awakenings. However, the task used to test procedural memory was a motor task requiring finger tapping, whereas declarative memory was tested by recall of word lists. It may be possible that different types of memory are processed in different phases of sleeps. In fact, the conclusion reached by the researchers is that declarative memory consolidation takes place in stage two NREM-sleep and that simple motor tasks are processed in stage two NREM-sleep or require very little REM-sleep (Genzel, 2009, 302-304). However, the sample size was relatively small in this research (n= 12) so further research is necessary to establish any firm conclusions on declarative memory consolidation.

The role of sleep in declarative memory consolidation was first demonstrated by Jenkins and Dallenbach (1924). The participants of the experiment were asked to learn non-sense syllable lists after which they either went to sleep or continued awake. Recall was then tested at one hour intervals. When the results for the sleeping condition were compared with the waking condition it was found that after eight hours; 6 times more non-sense syllables were remembered in the sleeping condition (Jenkins in Bourne, 1986, 104). However, the sample consisted of only two participants so the findings are very limited in how much they can be generalised. Nevertheless, further research into the area has shown that at least some consolidation of declarative memories takes place in sleep, namely in phase slow wave NREM-sleep (Stickgold, 2005, 1275). However, REM-sleep seems to be of little importance to declarative memory consolidation. Cohen even (1979) went as far as to claim that the dreaming that takes place in REM-sleep interferes with memory consolidation (Cohen in Bourne, 1986, 105).

However, the sleep phase in which memories are consolidated does not only depend on the type of memory i. e. declarative or procedural, but also it seems to be dependent on emotional content. As mentioned earlier, REM-sleep seems to be related to processing of emotional memories (Partinen, 2007, 40). That is, if a memory has emotional context then it is likely that it is processed in REM-sleep. For example, a study conducted by Wagner et al. gave clear empirical support for processing of emotional declarative memories in REM-sleep. The study showed that retention of emotional texts was significantly improved in comparison neutral texts over a period of late-night sleep. Similar effects were not found in early-night sleep, which consists mainly of NREM-sleep, whereas, in late night-sleep REM is predominant. In fact, earlier studies have shown that REM-sleep shows increased activation of the amygdala, which is associated with processing of emotional memories (Wagner, 2001, 112-113). What’s more, is that the study avoids adverse effects of deprivation and is therefore more reliable than studies conducted using sleep deprivation. In other words, REM-sleep is of some importance in terms of processing of emotional content even though other studies have shown that REM-sleep is not significantly involved in consolidation of non-emotional declarative memories.

Creative problem solving in REM-sleep

Problem solving in relation to REM-sleep, anagram problem solving – Walker MP, Liston C, Hobson JA, Stickgold R. (2002). http://www. sciencedaily. com/releases/2009/06/090608182421. htm – creative problem solving enhanced by REM

Dreams as information processing vessels

Dreams are often considered to be deficient of cognitive activity; however, several studies have shown that this is not necessarily true. The threat simulation dream theory presented by Antti Revonsuo suggests that evolutionary success depends on successful threat response, which is rehearsed in the relative safety of dreams. Revonsuo suggests that the mind actively generates dreams, which are comprised of threatening events in different combinations. These dreams are often repeated over several nights in order to develop and maintain threat response capabilities (Revonsuo, 2000, 482). Empirical support for the threat simulation dream theory comes from dream content analysis studies. For instance, a study conducted by Valli et al. found that threatening events are overrepresented in dreams in comparison to actual number of threatening events experienced when awake. Also, the events experienced in dreams were often very realistic and focused on to the dream self i. e. the self is often actively engaged in combating these threatening events in the dreams (Valli, 2000, 491).

Clearly, if dreams are merely a repercussion of neuron activation during REM-sleep, as suggested by the activation-synthesis hypothesis, then it’s quite likely that dream content would be disorganized and incoherent. Conversely, Valli’s content analysis suggests that the mind actively engages in coherent rehearsal of threat response. However, the study was conducted by a dream journal method, where the participants record their own dreams after a night of sleep. This raises questions of validity and objectivity. Even so, the study not only indicates that there is clear support for Revonsuo's threat simulation theory, but it also indicates that the mind processes information through dreams in REM-sleep.

Furthermore, there is evidence that during dreams the mind engages actively engages in self-reflection i. e. becomes aware of one's own thoughts and actions. Research has shown this to be beneficial to mental health. For example, recently Kontkanen showed that dreaming is helpful in trauma coping for children. Kontkanen conducted a dream content analysis on ' traumatised' Palestinian children aged 5-17 and children, of the same age, living in ' normal' conditions. High levels of self-reflection and self-awareness were found to be beneficial to the mental health of the traumatised Palestinian children. In the control group high levels of self-reflection in dreams were found to be dysfunctional. However, several individual with high levels of self-reflection in the control group, conversely, showed symptoms of poor mental health. Consequently, Kontkanen suggests that self-reflection processing in dreams should increase and diminish according to need in order to maintain good mental health (Kontkanen, 2000, 523-524). Surely, the dream journal method used in the study has its limitations and there is also doubt whether results gathered from children can be generalised to adults as such processing might also be attributed to development. Nevertheless, the study points at the necessity of dreams in cognitive information processing and mental health.

Conclusions

Draw conclusions based on presented evidence, on how necessary is REM-sleep for cognitive information processing.