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CONNECTION BETWEEN SLEEP AND THE FORMATION OF NEW MEMORIES

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Connection Between Sleep and the Formation of New Memories

Sleep is crucial. Sleep is necessary for all living things to grow, whether it is physically or psychologically. To fully understand how sleep impacts cognitive behaviors and processes in people, it is necessary to understand why sleep is an important factor for the brain to change and create new memories, as well as the role that neuroplasticity plays. The following paper details a rationale and study for research dedicated to neuroscience while highlighting the relevance and importance of the emphasis on sleep in all living things in order to stimulate memory functions. In addition, the following paper offers the author's reflections on the learning and a proposal for future health benefits.

Sleep and Brain Plasticity

The National Library of Medicine defines *neuroplasticity* as,

> "also known as neural plasticity or brain plasticity, is a process that involves adaptive structural and functional changes to the brain. It is defined as the ability of the nervous system to change its activity in response to intrinsic or extrinsic stimuli by reorganizing

its structure, functions, or connections after injuries, such as a stroke or traumatic brain injury (TBI)" (Puderbaugh & Emmady, 2022).

Brain plasticity refers to the brain's ability to adapt and restructure itself over the course of a person's lifespan in response to novel experiences and environmental cues. This process entails the development and strengthening of new brain connections as well as the removal of unneeded or superfluous connections. Studies show that the brain adapts to what it uses. For example, the more you use a map or a machine, the more likely your brain adapts to its functions and usage. Even animals, such as house pets, are able to remember and be conditioned by knowing what time it is for them to eat and be fed. When these processes occur within the brain, more neural connections strengthen. Neuropsychologist Donal Hebb (1949) said, "Neurons that blast collectively string collectively" (p. 209). Minds are not just moving neurochemically but anatomically, from their neuroplasticity. Current pathways make different cellular connections which aren't used as often and diminish over time. These neural connections strengthening within the brain rely on one key factor, sleep. When humans learn and attain new information or are able to acquire new skills, the brain forms new or strengthens existing connections. This process is known as synaptic plasticity, "SHY proposes that the fundamental function of sleep is the restoration of synaptic homeostasis" (Tononi & Cirelli, 2014, p.12).

Sleep and Memory Formation

Additionally, memory consolidation is a process in which memories are established and strengthened, involving the transfer of newly acquired information from short-term to long-term memories. This process is essential and crucial for the formation in which a living subject forms new memories, and "research suggests that memory consolidation takes place during sleep through the strengthening of the neural connections that form our memories." (Stickgold, 2007,

p.412). Numerous studies indicate that sleep plays an essential role in memory consolidation. A study published and consulted by *Nature Neuroscience* discovered that sleeping and resting after learning a new concept enhances one's memory, resulting in better retention of newly learned information. Furthermore, the researchers in the study discovered that sleep helps to enhance and transfer memory from the hippocampus, a lower area within the brain known to store memory. In addition to enhancing memory consolidation, further studies have shown that sleep also benefits one's ability to create and form new ideas, known as creativity, and skills like problem-solving. For example, Friedrich Kekulé, a chemist, "discovered the chemical structure of benzene, realized the molecule was circular rather than acyclic based on a vision he had in a dream." Similarly, Otto Loewi, who won the 1936 Nobel Prize for work on Chemical Transmission, was also inspired by a dream (Lewis et al., 2018). These famous discoveries and possibilities are amongst the many in the world and would not have been possible without the ability to be creative and problem-solve. As "dreams mimic a critical stage of creativity: brainstorming the range of possibilities, or what psychoanalysts call free association," says Robert Stickgold (2003p. 411) from Harvard University. Furthermore, scientist Stuart Quan discovered that the brain's ability to process and consolidate new information is likely during the time that we sleep (Quan, 2022). That disturbance or deprivation of sleep can result in impairments of this process. "Sleep deprivation seems to impair the ability to retain new information and disrupt memory consolidation to a great extent" (Zagaar et al., 2013, p.751).

Sleep can be divided into two sections: rapid eye movement (REM) and non-rapid eye movement (NREM). "Within the field of sleep research, there is strong support for the view that REM sleep is associated with brain development" (Shaffery JP, Lopez J, Bissette G, Roffwarg HP, 2006). From this, impairments in the presence of REM are likely to affect many of the

following behaviors, as REM is a period of brain development. NREM sleep can then be divided into three stages: brainwave patterns and physiological changes. NREM sleep follows a chronological order in which a person first falls asleep, and their brain produces theta waves, and where muscle activities slow down. Many researchers have concluded that memories are formed and consolidated before sleep. Sleep spindles are in action when establishing procedural memories, such as specific skills or habits. Sleep spindles are "one of the hallmarks that define brain activity during non-rapid eye movement (NREM) sleep" (Schonauer, 2018, p.1). During the last stages of NREM, delta waves show slow amplitudes and waves, helping and consolidating emotional memories. Each sleep step and stage is unique and critical to one's memory process. At different stages of sleep, memories are consolidated in different ways.

Neural Mechanisms of Sleep and Memory

During sleep, various neurotransmitters, networks, and brain structures exchange signals. Gamma-aminobutyric acid (GABA) is a neurotransmitter that regulates sleep. As the name implies, GABA can inhibit neural activity within the brain, which plays a significant role in regulating sleep. Studies show that GABA is a "main inhibitory neurotransmitter in the mammalian brain" and that "sleep-enhancing effects have been established" (*Effects of Oral Gamma-Aminobutyric Acid (GABA) Administration on Stress and Sleep in Humans: A Systematic Review*, 2020). Following GABA is serotonin. Serotonergic neurons can be found in the raphe nucleus in the brain stem. As it promotes wakefulness during the day, they also regulate sleep-wake cycles at night, typically when we sleep. Various interactions and workings of brain structures result and depend on the sleep-wake cycle. Among these structures are the hypothalamus, the brainstem, and the thalamus. The thalamus is a station for sensory information, while the brainstem controls vital functions such as breathing and actively moving.

The brain undergoes and performs several neurobiological processes while asleep in order to consolidate and form memories. The hippocampus, a brain structure in the temporal lobe, plays a vital role in memory formation and consolidation. During sleeping, the hippocampus reinforces neural connections associated with previously attained information, promoting memory consolidation. Sleep also allows declarative memories to be consolidated. Memories consisting of facts and certain events are declarative memories. Consolidating declarative memories involves the process and transfer of information from the hippocampus to the neocortex region of the brain. Neocortex is known as where long-term memories within our brains are stored. By transferring information and messages from the hippocampus to the neocortex, sleep undermines and promotes the consolidation of declarative memories.

Interestingly enough, "Methods to test declarative memory are key in investigating effects of potential cognition-enhancing substances--medicinal drugs or nutrients" (Riedel & Blokland, 2015, p.1). The ability to keep declarative memories and access them in recalling and processing names, dates, places, facts, and events is essential for declarative memories to be stored and protected. In addition, declarative memory is also specialized for dynamic processing and learning in a short time.

Conclusion

Among the most common sleep-related cognitive disorders, such as insomnia, there is growing evidence that poor sleep can have a lasting impact on a wide range of mental disorders. Johns Hopkins Medicine defines the term as "difficulty initiating or maintaining sleep, is a symptom, not a diagnosis or a disease. It may be due to a lack of sleep or poor quality of sleep." Dementia is a disease that results in injury to the brain; however, a common misconception is that it is significantly characterized by a loss of memory along with difficult thinking,

problem-solving, and language skills, all of which originate and benefit from sleep. It has been concluded by researchers and scientists that "Alzheimer's disease (AD) is a neurodegenerative disorder in which there is a progressive decline in cognitive function. It is the most common cause of dementia" (Miller, 2015, p.1). While sleep can show improvement and health benefits in some areas, the lack of sleep can also greatly impact humans and animals.

Further evidence and research within neuroplasticity and brain development could have led to significant evidence towards the prevention, as well as treatments for these disorders and implications, initially leading towards improving the quality of life of millions of people worldwide. Ultimately, the paper presented aims to illustrate sleep's critical role in brain plasticity and the formation of new or existing memories. In the study of sleep and neurobiology, several neurotransmitters, neural networks, and structures are captivated within the brain to interconnect with one another and through each other to perform certain abilities and functions. Several studies presented in this paper indicate the importance and necessity of adequate sleep for certain cognitive performances, learning, and memory retention skills and habits. By consolidating and retrieving newly profound information, sleep enhances the process of transferring short-term to long-term memories. All in all, inadequate sleep or sleep deprivation can disrupt and impair memory consolidation, resulting in cognitive deficits. In order to understand and unravel the way sleep affects cognitive behaviors, it is necessary to understand how and why sleep affects cognitive behavior, especially if one wishes to change and create new memories in the future or have last memories.

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