The Physiology and Application of Lucid Dreaming

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Abstract: Lucid dreaming provides an opportunity for people to learn more about dreams and sleep, and the study on lucid dreaming is a growing field of research in psychology. The physiology of lucid dreaming contributed to understanding areas like brain connectivity and provided opportunities to reveal mechanisms under cognitive functions such as Metacognition. Lucid dreaming therapy (LTD) might provide an alternative solution to mental disorders such as posttraumatic stress disorders (PTSD). Lucid dreaming also opens more windows in sleep studies where researchers might receive real-time feedback from participants. While there are still debates around lucid dreaming, this is a growing field of research that would contribute to many areas in psychology.

1. Introduction

Lucid dreaming is a phenomenon during sleep when knowing that one is dreaming [1]. While the concept of the lucid dream has been prevalent in many religions over thousands of years with links to soul and prophecies, the term “Lucid Dreaming” was first described in 1913 by Van Eeden and later was defined as “dreaming while being conscious that one is dreaming” by LaBerge et al. in 1986 [2]. Even though the phenomenon has been described for a long time, the research into this particular state is still a growing field in psychology. Is looking to contribute to studies related to sleep and other areas such as the study of consciousness. This paper will briefly discuss the physiology of lucid dreaming, its application as a treatment for disorders, its application in sleep research, and some future research directions.

2. Physiology

During the random-eye movement (REM) period, people experience dreams that are often bizarre and delusional, and it is proposed that there is a lack of higher-order consciousness which enables people to be conscious of being conscious [3]. During lucid dreaming, which can also occur during REM, people are having reflective thoughts where they are aware that they are dreaming and have access to their memory, which are associated with higher-order consciousness [4]. While there had been many personal descriptions of lucid dreaming, there were no objective recording methods to verify the existence of such different states of dreaming. The first validation of lucid dreaming happened in the late 1970s and early 1980s when researchers designed studies where participants were asked to move their eyes in a predetermined sequence as soon as they started experiencing lucid dreaming, and showed that the participants were aware of themselves being dreaming when they were lucid dreaming which happened during random-eye movement (REM) period [1]. Since then, this volitional eye-signaling technique has become a valuable tool for studies on lucid dreaming and can contribute to new methods of studying REM sleep.

2.1 Relationship of Lucidity to Rem Sleep

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While lucid dreaming happens during REM, it has been debated whether lucidity is a phenomenon in REM instead of a separate sleep state [5]. The study by Voss et al. measured differences in brain activity during lucid-REM, non-lucid REM, and wakefulness with EEG [5]. It was shown that during lucid dreaming, the power in frequency bands δ and θ resemble that during REM, while power in the γ band resembles that during wakefulness [5]. These showed that lucidity is a hybrid state that has the feature of both non-lucid REM and wakefulness [5].

Researchers found that there is a significant increase in power in the 40Hz frequency band, especially in the frontal regions that differentiate brain activity during lucid dreaming compared to that during non-lucid REM sleep, which they speculate to be critical in the self-consciousness that characterizes lucid dreaming [5].

2.2 Neural Correlates of Dream Lucidity

In the study by Dresler et al. in 2012, the researchers investigated the differences in neural activities in lucid REM sleep and non-lucid REM sleep and suggested that the reflective thoughts that are present in lucid dreaming that is absent in non-lucid REM are caused by the differences in reactivation patterns between lucid REM and non-lucid REM sleep. The participants recruited were able to reach the state of lucid dreaming, and were instructed to give eye-signaling when they are lucid dreaming [4]. EEG and fMRI were used to measure and compare the neural activity between lucid REM and non-lucid REM sleep [4].

It is shown in this study that non-lucid REM sleep characterized an activation pattern that is similar to that of visual hallucination, with activation in brain areas including the thalamus, amygdala, and brain stem, and deactivation in the dorsolateral prefrontal cortex and the precuneus, which are important for Metacognition, self-evaluation and self-referential processing [4]. In contrast, the brain activity during lucid REM sleep is more similar to that during wakefulness, with increased activity in the dorsolateral prefrontal cortex, bilateral frontopolar areas, precuneus, bilateral cuneus, and occipitotemporal cortices, which are crucial for visual processing [4].

These differences in neural activity might contribute to the mechanisms of lucid dreaming and might explain the presence of reflective thoughts in lucid dreaming.

2.3 Functional Connectivity

With the variance in frequency of lucid dreaming in different individuals, Baird et al. conducted a study to investigate the differences in brain structure and functional connectivity between individuals who have lucid dreams frequently and those who do not [3]. The study used structural and functional MRI to measure the differences in brain structure and functional connectivity between the two groups during wakefulness.

The study showed that the group with frequent lucid dreams had increased resting-state functional connectivity between the left anterior prefrontal cortex (PFC) and the bilateral angular gyrus (AG), bilateral middle temporal gyrus (MTG), and right inferior frontal gyrus (IFG) [3]. While these areas show increased activity during lucid REM sleep, suggested by previous studies, they demonstrate suppressed activity during non-lucid REM sleep. The researchers thus proposed that increased functional connectivity in these areas during wakefulness is associated with higher possibilities of having lucid dreams [3].

The anterior prefrontal cortex is associated with Metacognition, and thus the association of its connectivity with lucid dreaming frequency confirms with previous studies, suggesting its importance in self-evaluations and metacognitive judgments [3]. The researchers also proposed that lucid dreaming might be linked to the frontoparietal control network (FPCN), which involves the default mode network and the dorsal attention network, and suggested that the FPCN might have the role of regulating and integrating information that involves internally and externally directed processes [3].

While the functional connectivity of the PFC-AG-MTF network is associated with lucid dreaming, characterized by higher-order consciousness, it might be speculated that this network might be important in the self-consciousness of one's state [3].

3. Application in Treatment

Lucid dreaming therapy (LDT) has been used in several studies as a treatment for nightmare disorders and showed its effectiveness [6]. Nightmares often occur during REM sleep with themes that are distressing and can impact daytime functioning with enough frequency [6]. In the study by Holzinger et al. in 2020, all the participants were asked to keep a sleep diary, and the participants in the LDT group underwent six weekly lucid dream therapy sessions. In the sessions, the participants share their experiences and dreams and discuss what they can change about the dream with the group, and they also studied theoretical information about LD and learned to apply self-hypnosis [6].

The study found that LDT effectively reduced the anxiety and depression level in posttraumatic stress disorder (PTSD) patients suffering from nightmares [6]. They also suggested that the sessions provide a helpful tool that the participants can utilize even after the study [6]. While many psychological disorders have nightmares as a symptom, LDT might be a helpful intervention worth studying and might be applied to help more people in need.

4. Application in Sleep Studies

While studies on sleep experience and dreams often depend on subjective retrospective reports, a study by Konkoly et al. managed to facilitate real-time two-way communication with lucid dreaming during sleep [7]. The study consisted of different sets of experimental strategies to validate the interaction during lucid dreaming that was carried out independently by four research teams [7].

In the study, the participants were instructed to enter a lucid dreaming state and were asked simple questions such as mathematical questions and yes-or-no questions during sleep [7]. They were instructed before sleep on how to respond, which include volitional eye movements and facial muscle contractions [7]. The results from the different procedures all contributed to validating that real-time two-way communication during sleep is possible and suggested that it is possible for individuals to communicate in meaningful ways during sleep [7]. The study also shows evidence of sleep-learning, where participants form new declarative memories related to the questions asked during sleep and were able to recall when awakening [7]. Moreover, the study shows the perseverance of cognitive abilities, such as the use of working memory when solving mathematical problems [7].

One question raised, however, was whether these two-way communications were entirely carried out during REM when the participants were asleep. As suggested by Voss et al., lucid dreaming has been shown to be a hybrid state [5]. The current study by Konkoly et al. relied on standard criteria from current research, but it might be possible that different regions of the brain might be in different sleep stages, including REM, waking, and stage N1 (the first stage of non-REM)[7]. These might suggest a need for further studies into the categorization of sleep stages and can potentially inspire more possibilities for research.

5. Future Research

While lucid dreams might be a useful way to study sleep and dreams, one issue is that lucid dreaming is a relatively rare phenomenon and can be hard to capture in lab settings [7]. There was a problem of having small sample sizes in most studies on lucid dreaming, which suggests a need for more participants to achieve greater statistical power and generalize to a greater population. One approach, as suggested by Baird et al., is to have more extensive population screening for those who

are frequent lucid dreamers [1]. Alternatively, some studies are focusing on methods of inducing lucid dreams, such as through pharmacological induction and with transcranial electrical brain stimulation, and more research is still needed for these approaches to be applied on a grander scale for sleep studies [1].

While most lucid dreams occur during REM sleep, some studies found that it is also possible for lucid dreams to occur during non-REM (NREM) sleep [1]. However, there is still a lack of objective evidence for NREM lucid dreams, which can be a direction for future research that might contribute to studies in NREM sleep [1].

Some studies have focused on some groups of the population. One example is the study by Dodet et al. on patients with narcolepsy [8], which showed that they have a greater tendency to have lucid dreams when compared to the general population and can also enter the state of lucid dreaming in naps. This might contribute to future research on napping, where lucid dreaming can be incorporated as a tool [8].

6. Conclusion

Lucid dreaming is a phenomenon that can occur during REM sleep and is a hybrid state that characterizes both sleeping and waking where individuals are preserving many cognitive abilities, including Metacognition, and allows real-time two-way communication. These opened more possibilities for research, and lucid dreaming might provide a valuable tool in sleep studies.

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