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Are we just dreaming?

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Abstract

In this perspectives piece we examine the role of dreaming in memory consolidation, the underlying neurobiological mechanisms of nightmares and the therapeutic potential of lucid dreaming for treating nightmares. Growing evidence suggests that dream content is shaped by both recent and remote memory sources, with non-rapid eye movement (NREM) sleep favoring the incorporation of recent declarative memories and REM sleep reflecting more remote experiences. When these dreams become pathological, we examine nightmares through the lens of the neurocognitive model, and focus on how nightmares affect mental health. We then explore lucid dreaming as a promising intervention to combat nightmares. Our conclusions claim that definitional ambiguity in dream research limits clinical progress, and we propose action to develop standardized definitions for dreaming and nightmares to guide cohesive research designs and enhance interstudy comparability.

Introduction

Dreaming does not have a unanimous definition among psychologists and sleep researchers. Some argue that dreams are *mental experiences* during sleep that include our thoughts and feelings (Tsunematsu, 2023), while others proport them as a mix of visual, motor, verbal, emotional and cognitive processes that occur during sleep (Scarpelli *et al.*, 2022). Dreaming has also been termed as *sleep mentation* (Scarpelli *et al.*, 2021) or *oneiric production* (Scarpelli *et al.*, 2022), which occurs during rapid eye movement (REM) sleep or non-REM (NREM) sleep (Tsunematsu, 2023). While the definition of dreaming is debatable, perhaps more contentious among scholars are the sources of dream production and how we come to experience them in our sleep. A central focus of this debate is the role of neurocognitive mechanisms in dreaming. Some theories propose that dreams are created by manifestations of our unconscious desires, random neural activity, an attempt to process daily experiences and emotions or memory consolidation (Nir and Tononi, 2010). While other theories suggests dreams prepare humans for real life dangers or represent a form of imagination (Nir and Tononi, 2010). Although there are many theories of dream production, here we focus on the theory of memory consolidation. In this theory, it is proposed that dreams may reflect the processing of information from our waking experiences (Graveline and Wamsley, 2015). Thus, our waking experience creates the foundation for the imagery, perceptions and other sensations emoted during dreams (Graveline and Wamsley, 2015; Wamsley, 2014). However, it is still unclear whether dream production that relies on waking cognitive function, such as learning and memory, utilizes the same neurobiological pathways that are required for these functions while awake (Tononi *et al.*, 2024). If these pathways turn out to be the same, a better understanding of the neurobiological mechanisms behind the creation of dreams will provide insight into areas of the brain that are involved in memory encoding (Tononi *et al.*, 2024).

When dreaming processes are imbued with negative content, we experience a phenomenon known as nightmares. Like dreams, nightmares do not have a unified definition that spans research and clinical settings. For example, in one study, researchers defined the occurrence of a nightmare as when the participant wakes up due to the unpleasantness of what they saw or felt while asleep (Blagrove *et al.*, 2004). Elsewhere, nightmares are described as *intense negative dreams with a clear recall afterward*, regardless of whether the participant had awakened at that time (Lancee and Schrijnemaekers, 2013). Clinically, the Diagnostic and Statistical Manual of Mental Disorders defines nightmares as dreams that induce *dysphoric emotions* and are remembered upon awakening (American Psychiatric Association, 2022). Albeit subjective, the ability to recall nightmares is key to defining them and allows for empirical inquiry of dream content and categorization. Differences in when or if a nightmare induces arousal make it difficult to approximate their prevalence, but it is estimated that 4–10% of the population experiences nightmares (Levin and Nielsen, 2007). While this number may not be large, nightmares can have a profound impact on mental health, particularly depression and suicidal ideation (Lancee and Schrijnemaekers, 2013; Youngren *et al.*, 2024; Bernert *et al.*, 2005; Hedström *et al.*, 2021; Harris *et al.*, 2020). Therefore, studies of nightmares are of great importance to better understand the mechanisms behind the phenomenon, as well as to examine strategies to prevent their negative effects.

One technique that may be a solution for circumventing the effects of nightmares is known as *lucid dreaming* (de Macêdo *et al.*, 2019). Lucid dreaming is when an individual becomes consciously aware throughout a dreaming episode (Tononi *et al.*, 2024). This conscious awareness allows the person to interact with their dreams as if they were awake and even allows them to control the dreaming narrative (Tononi *et al.*, 2024). A meta-analysis reported that 55% of 24,282 individuals had experienced lucid dreaming at least once in their lifetime (Saunders *et al.*, 2016). Interestingly, it is possible to learn how to induce lucid dreams through different training methods (Tan and Fan, 2023). The successful control of dream content raises the possibility that tapping underlying neurobiological and psychological resources could be used as a therapy for nightmare relief (de Macêdo *et al.*, 2019). Beyond the treatment of nightmares, lucid dreaming could also be a potential means to enhance our learning (Bonamino *et al.*, 2023). In support of this notion, a meta-analysis that reviewed lucid dreaming germane to motor tasks concluded that motor tasks practiced during lucid dreaming showed significant performance improvements during waking (Bonamino *et al.*, 2023). Thus, lucid dreaming represents not only a promising avenue for combating distressing dream content, it may also provide a key to strengthening neuroplasticity (de Macêdo *et al.*, 2019; Bonamino *et al.*, 2023).

Herein we present findings pertaining to queries that were posed by Palagini *et al.* including the "relationship between dreaming and memory, pathological dreaming (e.g., nightmares) their neurobiological processes and how they affect mental health and psychological functioning, and the mechanisms of lucid dreaming and the role of lucid dreaming in psychological functioning." We do not cover the emotional processing and conscious aspects of memory as it relates to dreaming, nor do we cover other mental health impacts of nightmares aside from depression and suicide. We also do not cover other therapeutic interventions for nightmares aside from lucid dreaming. Addressing these questions is important because doing so clarifies how dreaming contributes to memory consolidation through stage-specific neural activity, elucidates the neurological mechanisms underlying pathological dreaming, including dysfunction in limbic and prefrontal circuits, and identifies clinically relevant interventions such as lucid dreaming that may mitigate nightmare-related distress and enhance psychological functioning.

Dreaming and cognition: memory sources of dreaming

Although dreaming is often associated with REM sleep, it is also present during NREM sleep and dream content may be influenced by both stages (Tsunematsu, 2023). Typically, dreams that occur during REM sleep are more vivid, emotionally intense and bizarre, whereas dreams that take place during NREM sleep are more likely to reflect recent episodic memories (Wamsley, 2014; Malinowski and Horton, 2021; Hudachek and Wamsley, 2023). Episodic and semantic memories are both classified under declarative memory, a type of memory involved in accessing past information (Dickerson and Eichenbaum, 2010). When such memories are recalled years later, they are referred to as remote memories (Dickerson and Eichenbaum, 2010; Kreutzer *et al.*, 2011). Episodic memory refers to the capability of storing, processing and retrieving lived personal experiences (Dickerson and Eichenbaum, 2010). This type of memory is what is involved in remembering attending sports events or participating in childhood activities. In contrast, semantic memory refers to the ability to recall specific learned facts, such as the color of bees or the shape of a stop sign (Dickerson and Eichenbaum, 2010). Several studies have explored the idea of episodic memory as a foundation for dreams (Graveline and Wamsley, 2015). In one study, participants watched a film in a laboratory and, upon dreaming were more likely to incorporate elements of the laboratory such as wearing electrodes, than elements of the film into their dreams (Graveline and Wamsley, 2015). This suggests that recent lived experiences contribute more to dream production than the passive intake of information (Graveline and Wamsley, 2015). Such contextual integration likely stems from NREM sleep-associated consolidation of episodic memories (Malinowski and Horton, 2021). Notably, the episodic memories that surface in dreams are not usually exact replays of remembered events (Wamsley, 2014). Furthermore, not all dreams are constructed from episodic memories; most dreams rely on prior experiences and can therefore also include other remote and semantic memories (Wamsley, 2014). For example, when dreaming of unfamiliar people, their faces are structurally represented with prior knowledge of facial features (Wamsley, 2014).

The incorporation of episodic memory fragments into our dreams can help us process emotions and strengthen learning (Malinowski and Horton, 2021; Picard-Deland *et al.*, 2021). One hypothesis posits that memory reactivation during sleep recapitulates these elements into our dreams (Wamsley, 2014). In support of this hypothesis, a noninvasive technique known as targeted memory reactivation (TMR) has been shown to aid in reactivating certain memories during sleep via sensory cues (Carbone and Diekelmann, 2024). For example, an odor can be presented during a learning task to associate the odor with that specific cue. When that same odor is presented during sleep, it can aid the sleeper in recalling the learned cue while dreaming (Carbone and Diekelmann, 2024). TMR has also been suggested to be beneficial for declarative and procedural memories, with an undetermined impact on the processing of emotional memories (Carbone and Diekelmann, 2024). Therefore, TMR may be a promising avenue for the integration of episodic memories into dreams (Carbone and Diekelmann, 2024).

To further explore the impact of sensory cues on dreams, a systematic review of 51 studies explored the influence of various external sensory stimuli on dream content (Salvesen *et al.*, 2024). The authors concluded that somatosensory stimuli, that is, stimuli responsible for perceiving "touch, pressure, temperature, pain and proprioception," were more likely to influence dream content than auditory stimuli (Salvesen *et al.*, 2024). They also noted that olfactory stimuli influenced the emotional content of dream production, whereas visual stimuli had little impact on dream content (Salvesen *et al.*, 2024). In addition, it seemed to matter whether the stimulus could be rationally incorporated into the dream, with the authors suggesting that if a dreamer was unable to seamlessly incorporate the stimulus, it could act as a cue for them to become aware that they are dreaming and inadvertently induce lucid dreaming (Salvesen *et al.*, 2024). However, when they explored the impact of a stimulus during different stages of dreaming, either REM or NREM, they found inconclusive evidence as to which stage had a greater impact on dream production (Salvesen *et al.*, 2024). In another study examining the influence of somatosensory stimuli on dream content, researchers trained participants on a virtual reality (VR) flight task prior to dreaming while playing a vibraphone melody for successful tasks completed (Picard-Deland *et al.*, 2021). The participants were then randomly assigned to one of five groups: TMR vibraphone stimulation during NREM, TMR vibraphone stimulation during REM, a nap with TMR vibraphone stimulation, staying awake with TMR vibraphone stimulation and staying awake without TMR vibraphone stimulation (Picard-Deland *et al.*, 2021). After this period of sleep/wake, the VR flight task was then performed again by all participants. The researchers found that those who had incorporated elements of the VR flight task into their dreams performed better when they were retested compared to those who did not (Picard-Deland *et al.*, 2021). Interestingly, the type of element that participants incorporated into their dreams also impacted how participants performed, with those who incorporated a kinesthetic element performing better than those who incorporated a visual element (Picard-Deland *et al.*, 2021). The study concluded that dreaming of tasks in REM sleep resulted in more improvement on the second VR flight NREM (Picard-Deland *et al.*, 2021). Overall, these studies confirmed the notion that somatosensory stimuli have a greater impact on dream content than other types of stimuli, and further highlight the idea that task integration into dreams aid in memory consolidation (Picard-Deland *et al.*, 2021; Salvesen *et al.*, 2024).

In a recent meta-analysis on learning and post-dream awakening, the authors suggested that memory consolidation happens during dreaming when one integrates the content of the learned task into the dream, because improved memory performance was observed on tasks post-dreaming (Hudachek and Wamsley, 2023). They also found that NREM sleep was more likely to have a stronger impact on memory post-dreaming (Hudachek and Wamsley, 2023). Based on these findings, the authors believe that NREM dreams are more likely to be sourced from recent declarative memories, and REM dreams are associated with remote memories (Hudachek and Wamsley, 2023). However, these assertions are not uncontested, as some reports suggest that dreams are due to heightened neural connections that create opportunities for the remodeling of waking memories and allow the memories to either be encoded or forgotten (Voss and Klimke, 2018). Yet the interpretability of such findings is complicated by methodological inconsistences that pervade the field of dream research (Hudachek and Wamsley, 2023).

Due to lack of consistency in dream research, methods of dream collection do not follow a standard procedure (Hudachek and Wamsley, 2023). For instance, the number and timing of dream report queries vary considerably across studies, ranging from single morning recalls to up to fourteen nighttime awakenings per participant (Hudachek and Wamsley, 2023). Such inconsistency affects the likelihood of capturing task-related dream content, especially given the known decay of dream recall and its dependence on sleep stage (Hudachek and Wamsley, 2023). Additionally, the approaches used to quantify task incorporation differ substantially, with some studies employing dichotomous classifications of dream content, while others use graded or continuous measures, as raters varied from independent coders to the participants themselves (Hudachek and Wamsley, 2023). These discrepancies in both sampling and scoring introduce methodological inconsistencies that complicates cross-study comparisons. One meta-analysis noted that, due to the extent of this variability, not all methodological design elements could be systematically accounted for in their analysis (Hudachek and Wamsley, 2023). This limits the precision of the observed effects and underscores the urgent need for greater standardization in dream research methodologies. While ultimately studies emphasize the cognitive benefits of dreaming, disruptions in the dreaming process can give rise to maladaptive outcomes, most notably in the form of nightmares.

Neurobiology of nightmares and effect on mental health

There are many theories as to the cause of nightmares. For example, psychoanalytic models of nightmare creation, such as the one proposed by Freud, suggest that nightmares reflect the transformation of libidinal urges into anxiety containment to preserve sleep (Nielsen and Levin, 2007). The Threat Simulation Theory states that nightmares maintain a "biologically adaptive function" by rehearsing responses to danger, thus ensuring survival in waking life (Nielsen and Levin, 2007). Moreover, Kramer's mood regulatory theory of dreaming advocates for nightmares arising when nonnightmare dreaming fails to effectively manage emotional surges (Nielsen and Levin, 2007). Another theory that has been put forward is the Affect Network Dysfunction Model, which roots nightmares in dysfunctional neural networks responsible for emotional regulation and fear extinction (Nielsen and Levin, 2007). Such dysfunction fails to prevent the reorganization of fear memories into nonthreatening dreams (Nielsen and Levin, 2007). In summary, prevailing theories converge on the view that nightmares originate from aberrant activity within neural circuits governing affect regulation, fear extinction and the cognitive integration of emotionally salient experiences during dreaming.

Among the many theories that have been proposed, the main theory that we will focus on here is the neurocognitive model proposed by Levin and Nielsen (2007). This model was selected over other theoretical frameworks due to its empirical grounding in neuroimaging evidence and its mechanistic specificity in implicating well-characterized neural circuits. The basis of this theory is that, on a neural level, nightmares originate from the interplay between the amygdala, hippocampus, medial prefrontal cortex and anterior cingulate cortex (Levin and Nielsen, 2007). In support of this model, functional magnetic resonance imaging (fMRI) of nightmare sufferers has demonstrated that anterior cingulate activation is involved in nightmare production (Shen *et al.*, 2016). Furthermore, another fMRI found that increased activity in the medial prefrontal cortex, anterior cingulate cortex and hippocampus is correlated with nightmares (Marquis *et al.*, 2021). When fear is experienced in dream content the insular and midcingulate cortices are activated (Sterpenich *et al.*, 2020), and severe nightmares reduce blood flow in the medial prefrontal and anterior cingulate cortices (Marquis *et al.*, 2019). Together these studies support the neurocognitive model and tout the limbic system as a key locus of nightmare-related brain activity. However, more research is necessary to further understand the interaction of these areas and the molecular mechanisms involved.

Nightmares and psychological functioning

Nightmares can cause a person distress and adversely affect their mental health. In support of this notion, one study found that participants were more likely to experience depression the day after experiencing a nightmare (Lancee and Schrijnemaekers, 2013). Furthermore, it has been shown that a person who experiences a nightmare, regardless of frequency, is more likely to score lower on self-reported well-being than a person who does not have a nightmare (Blagrove *et al.*, 2004). Interestingly, nightmare content is associated with the mental health of the person experiencing the nightmare. The type of nightmare a person experiences is also correlated to suicide risk (Youngren *et al.*, 2024), even after controlling for depression (Bernert *et al.*, 2005). Nightmares that are associated with trauma, also known as post-traumatic nightmares (Youngren *et al.*, 2024), are more likely to be correlated with an increased incidence of suicidal ideation compared to nightmares of an unknown origin, or idiopathic nightmares (Youngren *et al.*, 2024). There are, however, conflicting data on the link between nightmares and the risk of suicide. Some reports refute the idea that nightmares and suicide are linked but rather find that nightmares are associated with an increased risk of depression (Hedström *et al.*, 2021). Indeed, a recent meta-analysis showed that nightmares were only weakly linked to suicide (Harris *et al.*, 2020). Some subjective tools often used in psychological research to assess different aspects of nightmare experiences are the Nightmare Frequency Questionnaire (NFQ) and the Nightmare Distress Questionnaire (NDQ). The NFQ is used in both clinical and nonclinical populations to measure how often individuals experience nightmares over a given time. Participants rate the frequency of their nightmares using a scale (e.g., from "never" to "several times a week") and the metric also examines the association of nightmares with trauma, sleep quality, or mental health symptoms. Alternatively, the NDQ developed by Belicki (1992), assesses the emotional and functional impact of nightmares, rather than just their frequency (Belicki, 1992). Participants answer 13 Likert-scale items targeting: difficulty coping with nightmares, sleep disruption, daytime distress and beliefs about nightmare origin and meaning. Thus, while nightmare frequency is a good outcome measure in research, nightmare distress correlates with psychopathology and impaired functioning. This distinction is crucial in both diagnosis and treatment planning as the intervention efficacy of treatment outcomes for nightmare-related distress can be studied. Regardless of the strength of the link between nightmares and suicide, the overall relationship between nightmares and mental health is an important topic that warrants further study due to the potential for negative health effects, and to completely understand the implications of future health outcomes.

Nightmares and lucid dreaming

One major question that has emerged from studies of nightmares is how can we treat them to improve the quality of life of those who suffer from them? One potential treatment approach for nightmares is lucid dreaming (Bonamino *et al.*, 2023). When we become aware that we are dreaming, it is then possible to interact with and change the content of our dreams, in essence, control dream outcomes (Gieselmann *et al.*, 2019). There are many ways to induce lucid dreaming (Tan and Fan, 2023). Some induction methods include mnemonic induction of lucid dreams (MILD), reality testing (RT) and the senses-initiated lucid dream (SSILD) technique (Tan and Fan, 2023). MILD involves awakening in the middle of the night, remembering what was dreamt about and watching out for those recalled signs of dreaming when sleep is resumed (Tan and Fan, 2023). In the RT induction method, one must question if they are dreaming in addition to being observant of the dream environment (Tan and Fan, 2023). Similar to MILD, SSILD requires the dreamer to wake up after 5 hours of sleep and focus on visual, auditory and somatic perceptions before waiting a predetermined amount of time prior to going back to sleep (Tan and Fan, 2023).

In general, dream research relies on subjective measures, but eye signals are one way to objectively detect whether someone is lucid dreaming (Tan and Fan, 2023). To perform studies using eye signals, prior to falling asleep, lucid dreamers are asked to move their eyes in a predetermined pattern such as looking left and right two times quickly once they realize they are in a dream (Baird *et al.*, 2019). When the subjects are determined to be asleep by polysomnography, these eye signals can then be recorded on an electrooculogram to verify that they are lucid dreaming (Baird *et al.*, 2019). A systematic review showed that MILD was the most effective technique with an induction rate of greater than >40% (Tan and Fan, 2023).

A recent systematic review highlighted the promise of lucid dreaming. Although most studies had small sample sizes, low evidence levels and risk of bias, ten of the 11 studies (4 randomized controlled trials (RCTs), 2 case series, 5 case reports) showed positive effects of lucid dreaming in children and adults, including reduced nightmare frequency (up to 50%) even without full lucidity (Ouchene *et al.*, 2023). Unfortunately, a meta-analysis was not possible due to heterogeneity in the included study designs and protocols. Regardless, the authors call for standardizing protocols for better research and clinical application, as it is paramount for utilizing lucid dreaming as a patient-centered, nonpharmacological approach to address internal conflicts through dream control.

In agreement with this review, another study found that lucid dreaming was an effective therapy to combat nightmares (de Macêdo *et al.*, 2019). Lucid dreaming has also shown to decrease levels of depression in those with chronic nightmares (Holzinger *et al.*, 2020). These outcomes are likely due to the ability to control the nightmare content, thus making them less stressful (Tan and Fan, 2023).

Conclusion

This perspectives piece synthesized current evidence on the role of dreaming in memory consolidation, the neurobiological mechanisms underlying nightmares and the therapeutic potential of lucid dreaming. Findings suggest that NREM and REM sleep contribute differently to memory incorporation into dreams, with somatosensory stimuli enhancing task-related content and post-sleep performance. The neurocognitive model of nightmares, implicating dysfunction in the amygdala, hippocampus, medial prefrontal cortex and anterior cingulate cortex, is supported by emerging neuroimaging data. Lucid dreaming, through targeted induction techniques, demonstrates promise as a nonpharmacological intervention for nightmares and may facilitate motor learning.

One major area for improvement in sleep research is creating a unified, universally agreed upon definition and term for dreaming and nightmares (Tsunematsu, 2023; Scarpelli *et al.*, 2022; Scarpelli *et al.*, 2021; Blagrove *et al.*, 2004; Lancee and Schrijnemaekers, 2013; American Psychiatric Association, 2022). One proposal is that dreaming is defined as a subjective, immersive sensory, emotional and cognitive mental experience that occurs during both REM and NREM stages of sleep. Establishing universal definitions would enable consistent study designs and enhance the comparability of studies, thus strengthening the conclusions of meta-analyses and systematic reviews in the field. Additionally, this standardization would support the development of unbiased measurement tools for assessing dream and nightmare experiences. For example, shared criteria for rating nightmare severity (i.e. emotional intensity) and frequency (i.e. per week) would improve consistency and replicability of clinical and experimental sleep research. Together, these ideas can continue pushing forward sleep medicine.

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