

# The Influence of Infant Sleep Quality on Prefrontal-Amygdala Connectivity and Emotional Regulation



**Figure 1:** Image depicting brain recharging from sleep as it gives it the energy it needs to function. Image taken from <https://newatlas.com/health-wellbeing/pre-sleep-behavior-routine-brain-neuron/>

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## Introduction

Even before an infant can begin to understand its emotions, sleep plays a hidden yet critical role in connecting two of the brain's emotion centers, laying the foundation for emotional regulation and advancement. Countless studies have linked sleep quality to emotion regulation, showing that disruptions in sleep can significantly affect how individuals experience, express, and manage their emotions. Two parts of the brain that play an important role in the emotional development of a person are the prefrontal cortex (PFC) and the amygdala (Killgore et al., 2013). The prefrontal cortex, located directly behind the forehead, is responsible for more advanced functions like emotional regulation, decision-making, and controlling attention. The Amygdala is a small, almond-shaped structure deeper inside the brain and it is responsible for emotional reactivity, threat detection, and emotional memory. These two brain regions work together with the amygdala detecting emotionally significant stimuli while the prefrontal cortex helps with regulating the response to those stimuli. In other words, the amygdala "feels" the situation/emotion, and the prefrontal cortex "reacts" to it (Kong et al., 2013). When a child is born, the amygdala is already almost fully developed and actively functioning, while the prefrontal cortex is still immature and begins to develop and foster its connection with the amygdala. As the infant's brain matures, the connectivity between the prefrontal cortex and the amygdala strengthens. This connection is important for the development of emotional regulation abilities.

While many studies have examined how sleep influences emotional development in adolescents and adults, very limited research has investigated how sleep quality impacts the early formation of the prefrontal-amygdala connection during infancy (Vandekerckhove et al., 2017). This area has been understudied because it is a period where the brain is extremely sensitive to

its environment. Understanding the impact of sleep quality on the brain development of infants is important because this process plays a key role in their emotional development and cognitive development. This proposed research aims to explore the relationship between sleep quality in infancy and the development of the prefrontal-amygdala emotion regulation circuit, with a focus on how this connection supports early emotional regulation. I hypothesize that infants with greater sleep quality will develop stronger prefrontal-amygdala connectivity, and as a result, they will have a more regulated emotional response system.

### **Background**

Studies have been conducted to analyze the relationship between the quality of sleep and the regulation of emotions in adolescents and adults. Previous studies propose that both biological brain development and environmental factors like sleep quality play important roles in influencing emotional development throughout early childhood. According to one study conducted by Zhang et al. (2024), it was found that the complexity of certain regions of the prefrontal cortex in 3-month-old infants predicted levels of both positive and negative emotionality. The more complex microstructure there was in some of these subregions of the PFC, the more negative emotions were felt by the infant. The infants were exhibiting higher negative emotionality meaning they displayed increasing emotional reactivity, fussiness, or distress. The increased complexity of the subregions was connected with a fast-paced maturity of the PFC so it was able to detect emotional cues more intensely however, it still lacked the regulatory capacity to manage them. As a result, infants may become overly sensitive to emotional experiences before they have developed the ability to control or understand their reactions. The cause of the structural complexity and its development is unclear; however, it is important to note that both nature and nurture play key roles in shaping the development of the

child. When the child is born it already has the prefrontal cortex structure. However, the development of the child in its mother's womb is impacted by the outside conditions like the health and socioeconomic conditions of the mother as any mental or physical exertion can impact the development of the child potentially resulting in complications in their biological development (Zhang et al., 2024).

Another journal article, by Vandekerckhove et al. (2017) explores the deep interconnectedness of sleep and emotional regulation. Sleep and emotional development go hand-in-hand because emotional experiences during the day can influence sleep quality at night, and poor sleep can impair the brain's ability to regulate emotions the next day. For example, sleep deprivation can heighten emotional reactivity and reduce one's ability to cope with stress, leading to a toxic cycle that affects overall physical and mental health. This relationship is especially critical during infancy, a period when sleep supports both rapid brain growth and emotional development (Vandekerckhove et al., 2017). In support of this connection, a study conducted by Hysing et al. (2015), found that children who suffer from sleep problems early in their childhood are at a higher risk of developing both social and emotional issues from mental health problems to problems related to expression like aggression or hyperactivity. These effects were more evident in children who experienced chronic or persistent sleep disturbances, including short sleep duration and frequent nighttime awakenings (Hysing et al., 2015). Overall, these studies looked at the connection between sleep disturbances early in life and how they may disrupt emotional development and increase the risk of mental health issues in the future. However, most existing research has focused on older children and adults, leaving a critical gap in understanding how sleep quality affects the emotional brain during infancy.

While most existing studies have focused on older children, adolescents, and adults, they all support the idea that sleep plays an important role in emotional regulation. However, research is lacking on how the quality of sleep affects the earliest stages of brain connectivity, specifically the connectivity of the prefrontal cortex and amygdala. These are the two subregions of the brain that are central to emotion regulation. Since infancy is a period of rapid brain development, this study aims to investigate whether sleep quality during infancy influences the development of the prefrontal-amygdala connection, specifically the impact on emotional performance.

### Methods

Flachsmeyer, M., Sterkenburg, P., Barrett, B., Zaal, S., Vonk, J., Morisse, F., Gaese, F., Heinrich, M., & Sappok, T. (2023). Scale of Emotional Development – Short: reliability and validity in adults with intellectual disability. *Journal of Intellectual Disability Research*, 67(10), 1046–1060. <https://doi-org.ccny-proxy1.libr.ccny.cuny.edu/10.1111/jir.13080>

This journal article dives into the study analyzing the connection between intellectual disorders (ID) and emotional development (ED) using the Scale of Emotional Development (SED-S). Intellectual disorder refers to a person who has limited cognitive functioning which further hinders other skills like communication and self-care. To SED-S's effectiveness, the study focused on a diverse group of adults with intellectual disabilities where n=724. Using tools like factor structure, internal consistency, and reliability across subgroups, they were able to measure the individual's emotional development while also taking note of previous psychiatric diagnoses. After the study was completed, the researchers found that those who showed strong or high levels across all studied factors also had stronger SED-S. Since this study reinforced previous trends, it was confirmed that the SED-S is a reliable source for measuring emotional

development in adults. This article is significant to my research proposal, which investigates the role of sleep quality in shaping early emotional developments specifically, the functional connectivity between the prefrontal cortex and the amygdala. With its support of the idea that connects emotional development to its neurological components, this study and its methods can be used to analyze the impact of sleep quality on the functional connectivity of the infant's brain subregions.

Killgore W. D. (2013). Self-reported sleep correlates with prefrontal-amygdala functional connectivity and emotional functioning. *Sleep*, 36(11), 1597–1608.

<https://doi.org/10.5665/sleep.3106>

This correlational study examined the relationship between the amount of sleep, emotional functionality, and neural connectivity between the prefrontal cortex and the amygdala in adults. In this study, 65 healthy adults self-reported the duration of their sleep, completed a few emotional intelligence assessments, and had resting-state MRI scans taken. The results showed that the longer the individual slept, the more connected the various parts of the brain, like the prefrontal amygdala, were in terms of controlling emotions and keeping them in check. These patterns were seen especially in situations where the PFC prevented the overactivation of emotion suggested by the amygdala. In addition, individuals with a stronger prefrontal-amygdala connection also displayed greater emotional intelligence and fewer symptoms of psychological distress. This study supports my research proposal because it shows that sleep quality is linked to the connectivity of various key brain regions like the prefrontal cortex and the amygdala which are responsible for emotion regulation. While this study focused on adults instead of infants, it still provided support to the idea that sleep influenced PFC-amygdala connectivity and as a result, this impacts emotional regulation.

Tham, E. K., Schneider, N., & Broekman, B. F. (2017). Infant sleep and its relation with cognition and growth: a narrative review. *Nature and Science of Sleep*, 9, 135–149.  
<https://doi.org/10.2147/NSS.S125992>

This narrative review analyzed the impact of sleep on the cognitive development and physical growth of infants. The researchers peer-reviewed articles from 2005 to 2015 and observed that better sleep, which included both the quality and duration, of the infant was associated with increased memory, better language development, more advanced cognitive skills, and overall stronger cognitive development. In contrast, the researchers also found a connection between poor sleep and limited or slower development of thinking and learning skills. While this study does not look directly at emotional development, it supports my research on the impact of sleep quality on the emotional development of infants because it proves that quality of sleep directly relates to cognitive advancement. The more advanced cognition supports the processing of more advanced emotions, making the child emotionally mature. This review supports my research proposal by emphasizing the role of sleep as a developmental regulator during infancy. It strengthens the argument that quality sleep may influence the development of neural circuits like those that include connecting the prefrontal cortex and amygdala which further enhance emotional processing and regulation.

Vandekerckhove, M., & Wang, Y. (2017). Emotion, emotion regulation, and sleep: An intimate relationship. *AIMS Neuroscience*, 5(1), 1–17.  
<https://doi.org/10.3934/Neuroscience.2018.1.1>

This research studied the complex relationship between sleep and emotional processing and highlights how daily emotional experience can influence the type of sleep one gets. The emotions felt throughout the day may influence different aspects of a person's sleep like sleep patterns,

quality, and physiology, and can go deep into influencing REM sleep and dream content. In addition, the quality and duration of sleep are also key factors in the processing and regulation of emotions. Individuals who suffer from poor sleep may also have trouble regulating their emotions and are more likely to suffer from increased stress and increased emotional reactivity. The authors propose that REM sleep, in particular, plays a key role in emotional processing by helping individuals manage negative emotions and build emotional resilience. Overall, the review highlights the importance of sleep in maintaining emotional well-being and the potential consequences of sleep disturbances on emotional health. This review contributes to my research proposal by supporting the foundational claim that sleep quality is tightly linked to emotional development. Although the focus of this article is not the infant population, it strengthens the justification for analyzing how sleep may influence early neural mechanisms, specifically the prefrontal-amygdala circuit and emotional regulation.

Zhang, Y., Banihashemi, L., Versace, A., Samolyk, A., Taylor, M., English, G., Schmithorst, V. J., Lee, V. K., Stiffler, R., Aslam, H., Ashok Panigrahy, Hipwell, A. E., & Phillips, M. L. (2024). Early Infant Prefrontal Cortical Microstructure Predicts Present and Future Emotionality. *Biological Psychiatry*, 96(12), 959–970.  
<https://doi.org/10.1016/j.biopsych.2024.04.001>

This study explored the microstructural properties of the prefrontal cortex (PFC) in infants and their connection to infants' emotional development. Taking a different approach, these researchers used Neurite Orientation Dispersion and Density Imaging (NODDI) to measure both the Neurite Density Index (NDI) and Orientation Dispersion Index (ODI) of certain PFC regions of 3-month-old infants. They used these measurements to assess the connection between the reported positive and negative emotionality of the infant at both 3 months and again at 9 months.

Researchers found that infants who had greater ODI and NDI in the anterior cingulate cortex (ACC) region of the brain also expressed greater negative emotionality at both 3 and 9 months; in fact, there was an increase in negative emotionality at 9 months. Overall, this study found that the greater structural complexity of the ACC region directly correlated with an increase in negative emotionality and allowed researchers to possibly create a path in which these tests could be used to predict and prepare solutions for children who show a greater likelihood of being at risk for expressing greater negative emotionality. This study supports my research proposal by reinforcing the link between emotional outcomes and early neural development, specifically the structural characteristics of regions like the PFC and their functional role in emotional development and regulation and its methods can be used to conduct my suggested research.

### **Outcomes or Conclusion**

This research will help bridge a critical gap in knowledge for infants regarding the impact of sleep on the prefrontal-amygdala connection and emotional development and regulation. After conducting this study, based on my narrative review, I predict that infants who experience better or higher quality sleep will show a more developed prefrontal-amygdala connection and advanced emotional regulation. In addition, I predict that infants who experience better quality sleep will also develop greater emotional maturity as they are more likely to have advanced cognitive development. I expect this connection between the brain sub-regions to start developing earlier or maybe even faster in infants who are getting better sleep however I am unsure as to what effect the duration of sleep will have on this process. Since infants naturally sleep for long periods, it will be important to examine sleep patterns, such as sleep continuity and nighttime awakenings, to better assess how different aspects of sleep relate to emotional development. On the contrary, I predict that infants who experience poor or insufficient sleep

will develop weaker emotional regulations or this development will take longer to fully mature along with the infants' cognitive.

This research topic is important because it helps us better understand the developmental process that infants go through and brings attention to an underexplored area of infant neurodevelopment. It is difficult to conduct research on infants because there is limited accessibility to them, despite most research being observational. Additionally, infants are rapidly developing and changing while being sensitive to both internal and external influences. These complexities make it difficult to isolate one variable, like quality of sleep, and determine its direct effects on the emotional and neural development of infants. However, by focusing on specific brain circuits like the prefrontal-amygdala pathway and a measurable environmental factor like sleep quality, this study offers a clear and more realistic analysis of early developmental neuroscience. The results of this study will help researchers, scientists, and physicians, in identifying emotional dysregulation early on and propose solutions before the conditions worsen and result in mental health issues like anxiety and depression. This early intervention plan will help the infants both during the present and in the future as it further highlights the importance of sleep not only in infants but also in older children and young adults since their prefrontal cortex is still developing.

In addition to all the important outcomes and findings that will come from this research, this research is necessary because very few existing studies examine the relationship between infant sleep quality and prefrontal-amygdala connectivity. Most research conducted on the emotional development of individuals or on the impact of sleep focuses on adolescents or adults. Even from the research focused on the older population, there are very few studies that focus on the prefrontal-amygdala connectivity in relation to sleep with barely any research focused on

infants despite infancy being a time of significant neurological development. In addition, the brain is a complex organism and it is important to analyze it from birth through old age. The brain is constantly changing and developing and as a key organ in our body, it is important to understand it fully so that we can understand what affects it and what it affects. The complexity of the brain will not be understood through a couple of simple studies; however, it will help us better understand our body and how we can better take care of it or overcome current challenges. By exploring this foundational connection between sleep and emotion, a critical step can be taken towards improving lifelong mental health outcomes and improving emotional stability, starting from the very first months of life.

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