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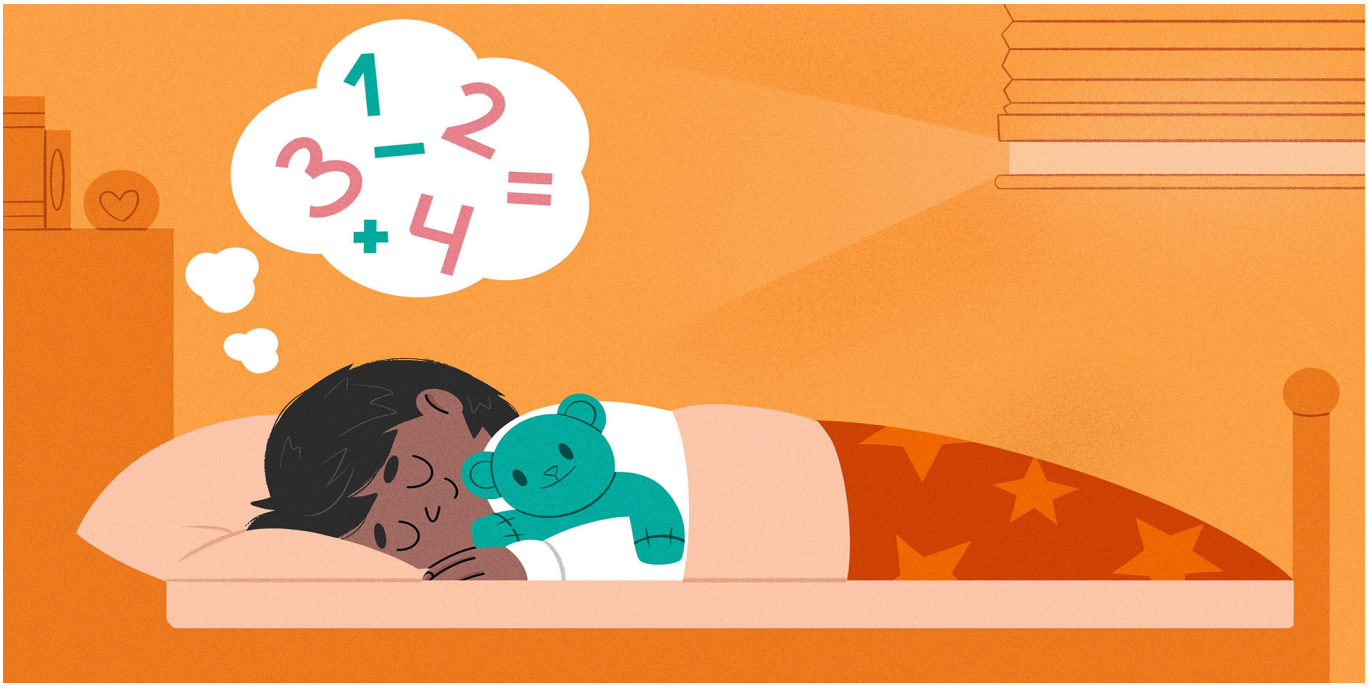

WHERE DID NAP TIME GO? WHY OLDER KIDS DO NOT NAP AT SCHOOL

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YOUNG REVIEWERS:


ADITYA
AGE: 11


ANVITHA
AGE: 11


CHI LOK
AGE: 13


KABIR
AGE: 9


SRINIKA
AGE: 12

Getting enough sleep is important not only for our health but also for learning. If sleep is good for us, why do children stop napping as they get older? Why do some children stop napping around their second birthday while others nap much longer? To answer these questions, scientists reviewed studies on how sleep, the brain, and memory develop. They took information from each area to create a new theory about why and when children stop napping. The scientists suggested a specific "memory area" in the brain, known as the hippocampus, develops as children grow up. Once the hippocampus can store the day's memories, it results in fewer "napping" signals sent to the body, causing fewer naps. Information about how and why children stop napping is important for parents and teachers so they can best support children's sleep needs.

YOU MIGHT BE ASLEEP, BUT YOUR BRAIN IS NOT!

Your parents might not let you stay up late at night—but neither will your body! When we sleep, our bodies heal, restoring our energy and "packaging" our memories from the day. Memory lets us travel back in time in our minds. We can remember events, activities, and information from earlier in our lives. Sleep not only protects our memories, but it also helps save our memories for later, which is known as **memory consolidation**. Without proper storage, our memories are fragile and can be easily forgotten. In adults, memories can be stored with a good night's sleep. However, in young children, naps act like "pit stops", packaging memories more often to help children remember the day's events. Infants and toddlers take multiple naps a day because of how much they learn and how much their brains grow. As children start going to elementary school and their brains "grow up", they take naps less often. You might remember this from your own life: when you were in preschool, you might have had nap time. But, when you got to elementary school, you probably did not have nap time anymore. These are changes teachers make, but how do they know what best helps children learn and remember?

CONSOLIDATION

The process of packaging our memories and "moving" them to different parts of the brain to be stored long term.

HOW DOES NAPPING CHANGE AS WE GET OLDER?

Newborns sleep for 20 h each day, but not all at once. Instead, they sleep many times during the day. By 4–6 months, most babies take three naps during the day and then sleep for a longer time at night. At 9 months, most babies move to two naps and nighttime sleep. By the time children are 1–2 years old, they usually have just one nap plus nighttime sleep. Sometime between 2 and 7 years, naps go away, and children sleep like adults—just overnight! This transition out of nap times is different for every child.

CIRCADIAN CLOCK

The body's internal clock, which keeps you in time with the 24-h day/night cycles.

MELATONIN

A chemical produced by the body that makes one feel sleepy and prepares them for sleep.

WHY IT IS HARD TO SLEEP DURING THE DAY

Why do we sleep at night and stay awake during the day? It all boils down to an internal machine in our bodies known as the **circadian clock**. The circadian clock is like a regular clock, except it goes around every 24 h instead of 12 h. During certain times of the day, our bodies release special chemicals that either help us sleep or stay awake. The circadian clock is sensitive to temperature, sound, and most importantly, light! At night, when the sun is down and there is no light, our bodies release a chemical called **melatonin**, which makes us sleepy. In the morning, when the sun is up and there is plenty of light, our bodies release other chemicals that help us stay awake.

HOMEOSTAT

Parts of the body that maintain a state of balance within the body. This can apply to temperature, blood pressure, and sleep.

In addition to an internal clock, our bodies also have an internal **homeostat**. A homeostat is like a thermostat that keeps our homes at a steady temperature. Our homeostats make sure that we have

a stable environment in our bodies. For example, if the temperature within our bodies increases, the homeostat triggers sweating to bring it down. If the temperature within our bodies decreases too much, the homeostat brings it up by shivering. The same can happen for sugar levels, blood pressure, and sleep need.

HOW DO THE CIRCADIAN CLOCK AND HOMEOSTAT WORK TOGETHER?

Both the circadian clock and homeostat keep our bodies healthy and active (Figure 1). From going to school, playing outside, or doing any daily activity, the circadian clock and homeostat work together to ensure that we can maintain an internal balance and perform tasks smoothly and on time.

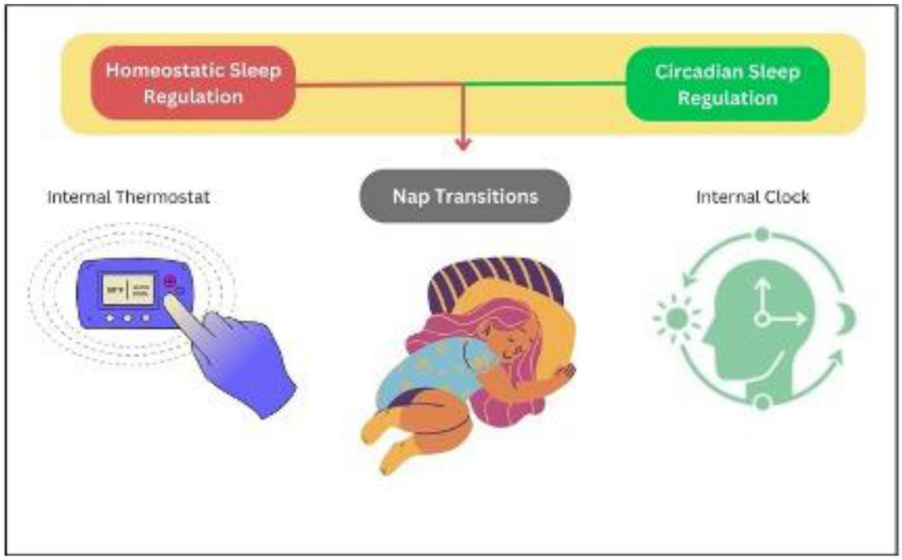

Figure 1

Figure 1

In our bodies, we have an internal thermostat called a homeostat that keeps our body temperature stable. We also have a 24-h internal clock called a circadian clock, which keeps our sleep stable. These regulators work together to determine how much sleep we need based on the time of day, how much energy we used that day, and how much sleep we got the night before. These regulators also work together when children transition out of naps.

If you always followed your circadian clock, you would fall asleep at the same time every day, regardless of when you woke up. However, this is not the case. For example, think of a time you stayed up late to do homework or watch movies with friends. If you only had a circadian clock, you would wake up the next day at the same time you always do, and go to bed at your usual time the next night. But you probably woke up later and wanted to sleep earlier the following night because you were so sleepy! That is your sleep homeostat at work: the longer it has been since you slept, the more **homeostatic sleep pressure** you have. This pressure goes down only when you sleep again. **Slow wave activity (SWA)** is a type of brain activity during sleep that is associated with sleep pressure. It is highest at the beginning of sleep but decreases as you sleep, and it is also higher when you are sleep deprived (such as when you stay up late). SWA is also related

HOMEOSTATIC SLEEP PRESSURE

A sleepy feeling that builds up the longer one stays awake.

SLOW WAVE ACTIVITY (SWA)

Activity in the brain that is thought to reflect the amount of "pressure" there is to sleep.

to learning, so more SWA accumulates in parts of the brain that have been busy during wake.

In young children, sleep pressure builds up faster than it does in older children. We think sleep pressure is related to why young children need to nap more at younger ages and why they nap less as they get older.

WHY DOES SLEEP PRESSURE CHANGE WITH AGE?

To understand why sleep pressure changes with age, we came up with a hypothesis [1]. Storing memories temporarily fills up the **hippocampus**, an area of the brain that is really good at holding memories in the short-term. The hippocampus fills up with memories similar to a bucket filling up with water (Figure 2). In younger children, their "bucket" is small and fills up quickly with memories and would also have high SWA (since SWA is associated with learning). When children nap, they can empty their memory buckets and reduce their sleep pressure (that is, SWA). As children get older and their brains change, the hippocampus "bucket" grows larger and can hold more memories, and accumulate less SWA, without sleeping as much. In other words, with bigger buckets, older children do not need to nap as much, because they have more space to fill. Eventually, when the bucket gets big enough, we can stop napping all together and wait to empty it until we go to sleep at night!

HIPPOCAMPUS

A part of the brain responsible for memory and learning.

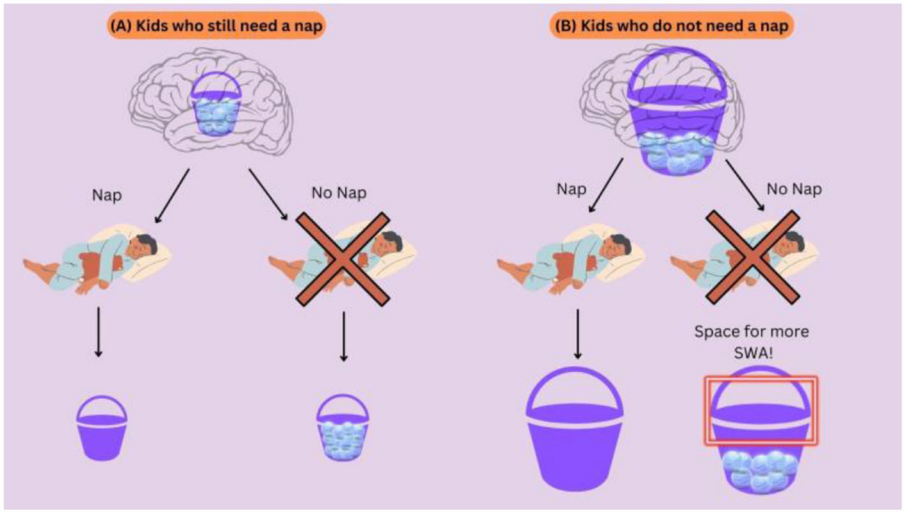

Figure 2

We can think of the hippocampus as a bucket. **(A)** When children are young and their buckets are small, they get full very quickly as children create memories throughout the day. When they nap, they empty their buckets so they can fill them with more memories when they awaken. If they do not nap, the bucket stays full, and it becomes difficult to make new memories. **(B)** Children who no longer nap have more mature hippocampuses, or larger buckets. Naps still help them empty their buckets, but because their buckets hold more memories, they can skip nap time and still have space for more memories.

WHAT EVIDENCE SUPPORTS THIS IDEA?

Three main kinds of research evidence all support the idea that naps are related to storing memories.

First, children who have grown out of their naps have better performance on memory tests than children who naturally still nap every day, even if these children are the same age [2]. Non-nappers remember more numbers and words, which shows that their ability to hold memories is stronger.

Second, children who naturally nap every day forget things more quickly when they skip their naps compared to children who have stopped napping, even if they are the same age [3]. Remember, napping helps children "dump out" memories and reduce the sleep pressure (or SWA), so their brains can collect new memories as they move through their day. Picture this: you have two children that are the same age, one who still naps every day and one who does not. Both of them are asked to stay awake, even if the napper really wants to take a nap. What happens? The napper will actually forget *more* of their memories than the non-napper! This may be because the napper cannot hold all their memories in their bucket for so long—they need the nap to help them keep their memories. However, children who have stopped napping can hold all these memories for a longer time. So, they do not need a nap to protect their memories.

Third, children who naturally nap every day have different-sized hippocampuses compared to children who have stopped napping, even if they are the same age [4]! Remember, as our brains develop, the size of our "bucket" changes. This supports the idea that nappers and non-nappers store the day's information in different ways.

CAN THE ENVIRONMENT, CULTURE, OR PARENTS MAKE A DIFFERENCE?

Parents often work with the circadian clock and homeostat to get their children to nap. For example, parents often have a consistent nap schedule and darken the room when they want their children to nap. But some parents do not want their children to nap, either for cultural reasons or because the child will be starting school soon. So, they keep the room well lit, and do not encourage their children to nap. But what does preventing nap time mean for children's memories and brain development? What if the child's memory depends on those naps to develop? That is the next question we want to address with our research, and one reason why it is important for parents and educators to know about what sleep does and why it matters in children's early development!

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

ADITYA, AGE: 11
Aditya is an almost—mad almost—scientist who likes watching things explode (his other hobbies include reading, eating, drawing and sleeping). Unfortunately, he still does not know what he want to be when he grows up—but if you find any vacancies for an astronaut—lawyer, let him know!

ANVITHA, AGE: 11
My name is Anvitha and I think polar bears are awesome! I also love music; dancing to it, making it or just listening to it. I enjoy learning about what is going on in the world, so I am really happy to be a young reviewer for the journal Frontiers in Young Minds.

CHI LOK, AGE: 13

I have an interest in science, maths, cybersecurity, and coding, and like to spend my free time reading and playing piano. I am the medal winner of ICAS Science, champion of CSIRO Cybersecurity Competition 2021 and 2022, reviewer for Frontiers for Young Minds, and published several science articles in Australian Mensa Journal TableAus. I have joined the CSIRO mentorship program on cybersecurity and AI and am now looking for mentorship opportunities in science and cybersecurity in US, UK, and Australia.

KABIR, AGE: 9

My name is Kabir! I am a rising 4th grader. I like to do math, art, and be creative. I enjoy creating things out of cardboard with my dad. At home, the friends I play with are my stuffed dogs. I imagine that they talk, move, and even have special superpowers! I also like to play board games, and bike with my parents. When my dad is home, we play piano, and we all have fun talking while eating dinner!

SRINIKA, AGE: 12

My name is Srinika, and I love trying new things. I love playing chess, drawing, and biking. I also love the outdoors. My favorite subjects are math and science. I hope, that someday in the future, I become a doctor.

AUTHORS

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Darshini is an undergraduate at the University of Maryland (UMD) majoring in neuroscience and minoring in disability studies. She loves being around kids, from playing with them at daycares to launching homemade rockets. Through the research lab she is a part of, she has been able to spend even more time with kids and learn about how they develop! After graduating from UMD, Darshini aims to pursue a career in medicine and become a pediatrician.

MEGHNA PANDEY

Meghna is an undergraduate student at the University of Maryland (UMD), majoring in neuroscience and criminology. Her interest in neuroscience was first sparked in middle school and she has been pursuing it since as a research assistant at the Neurocognitive Development Lab at UMD. Meghna has always enjoyed interacting with kids and has had the wonderful opportunity to do so through research and volunteer opportunities. After graduating from UMD, she aspires to attend medical school and become a physician. *mpandey1@terpmail.umd.edu

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Tracy is a Professor of Psychology at the University of Maryland. She received her Ph.D. from the Institute of Child Development, University of Minnesota, and postdoctoral training from University of California, Davis and the University of Maryland School of Medicine. The goal of her research program is to better understand how changes in the brain and changes in memory relate to each other

across development. This research uses a combination of research tools including examining children's behavior and their brain structure and function. Off campus, she enjoys kayaking, pickleball, and spending time with her husband, three children and three cats. *riggins@umd.edu

REBECCA M. C. SPENCER

Rebecca Spencer is a professor in the Department of Psychological and Brain Sciences at the University of Massachusetts, Amherst. She received her Ph.D. in neuroscience at Purdue University, followed by postdoctoral training at the University of California, Berkeley. Her research program aims to understand the function of sleep, particularly brain functions, and how changes in sleep with development and aging relate to these sleep functions. Her work has been funded by the National Institutes of Health for the past 20 years and has been featured in many media outlets including the New York Times, Washington Post, and the Netflix series "Babies." She also enjoys trail running, triathlons, and time with her family.

RHEA TIWARI

Rhea is a post baccalaureate IRTA Fellow at the National Institute on Aging. She majored in physiology and neurobiology at the University of Maryland (UMD) and graduated in 2023, taking 2 years before medical school to do research. She was a research assistant in a neurocognitive development lab at UMD while also volunteering at a pregnancy aid center for underserved and minority patients. Rhea's passion for medicine stems from the inequalities she has seen for patients of color under the healthcare system, and she strives to be an advocate for all patients as a physician and woman in STEM.

MARK WEHLAND

Mark discovered his passion for working with children when he was in high school. After graduating high school in 2020, Mark started his undergraduate work at the University of Maryland, where he majors in neuroscience. He has continued his passion for helping children by working in two research labs on campus, working in a doctor's office, and volunteering. After graduating from Maryland in December of 2023, Mark's dream is to go to medical school so that he can become a pediatric neuro-oncologist.

SONYA LEIKIN

Sonya is a senior Psychology B.S. student with a minor in both Human Development and Neuroscience. She is an Undergraduate Research Assistant and Psychology Honors student in the Neurocognitive Development Lab at the University of Maryland College Park under the mentorship of Dr. Tracy Riggins. Passionate about fostering healthy development and providing resources for children to thrive, she is also President of the College Mentors for Kids chapter at the University of Maryland. A non-profit student organization that brings two different elementary schools to campus to provide free enriching after school activities and one-on-one mentorship between college students and elementary schoolers.