

Sleep: A Tool for Maximizing Health and Performance and Its Enhancement with Slow-Oscillatory Transcranial Direct-Current Electrical Stimulation (SO-tDCS)

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Walter Reed Army
Institute of Research

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Dr. Sara E. Alger is currently a Sleep Research Scientist and the Chief of Scientific Planning in the Behavioral Biology Branch at the Walter Reed Army Institute of Research (WRAIR). She received her doctorate in Cognitive Neuroscience from the Graduate Center at the City University of New York, conducting research on the role of sleep in memory processing at the Laboratory for Cognitive Neuroscience and Sleep. She then worked as a postdoctoral research associate at the University of Notre Dame in the Sleep, Stress, and Memory Lab, conducting research on the impact of emotion and aging on sleep and memory. Dr. Alger has been at WRAIR since 2017.

Her primary research interest is examining the relationships between sleep, cognition, and emotion regulation and using tactical napping in alternate sleep strategies to intentionally improve performance and health. She is also interested in pursuing advanced methods of monitoring fatigue, predicting performance, and developing interventions to reduce risk to the Warfighter.

John D. Hughes, M.D.



Dr. John D. Hughes received a Bachelor of Arts degree in Chemistry from Dartmouth College and subsequently received his medical degree from the University of Chicago/Pritzker School of Medicine under the Health Profession Scholarship Program (HPSP). Upon coming onto active duty in the US Navy, Dr. Hughes completed a Neurology residency at the National Naval Medical Center/National Capital Consortium (currently known as Walter Reed National Military Medical Center).

Dr. Hughes subsequently completed three outservice subspecialty fellowships in the following disciplines: Cognitive/ Behavioral Neurology and Neuropsychology at the University of Florida School of Medicine under the mentorship of Kenneth Heilman, Sleep Medicine at the University of Pennsylvania Perelman School of Medicine, and Electroencephalography/Clinical Neurophysiology and Epilepsy at the National Institutes of Neurological Diseases and Stroke (NINDS) at the National Institutes of Health.

Dr. Hughes is currently certified by the American Board of Psychiatry and Neurology in Neurology, Sleep Medicine, Clinical Neurophysiology, and Epilepsy, and by the United Council for Neurological Subspecialties in Behavioral Neurology and Neuropsychiatry.

Disclosures

- Dr. Alger and Dr. Hughes have no relevant financial or non-financial relationships to disclose relating to the content of this activity.
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The investigators have adhered to the policies for protection of human subjects as prescribed in AR 70-25.

Learning Objectives

At the conclusion of this activity, participants will be able to:

1. Identify the functions of the brain and body that are impacted by sleep loss.
2. Describe strategies to manage fatigue when sufficient sleep is not possible.
3. Analyze the physiological basis of the accumulation of homeostatic sleep drive during sustained wakefulness.
4. Summarize the physiology of Electroencephalogram (EEG) sleep slow waves and their role in sleep's restorative function.
5. Explain how Slow-Oscillatory transcranial Direct Current Stimulation can enhance the restorative properties of sleep.

Poll Instructions

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Poll Question 1

What percentage of Soldiers regularly obtain a sufficient amount of sleep during their duty week?



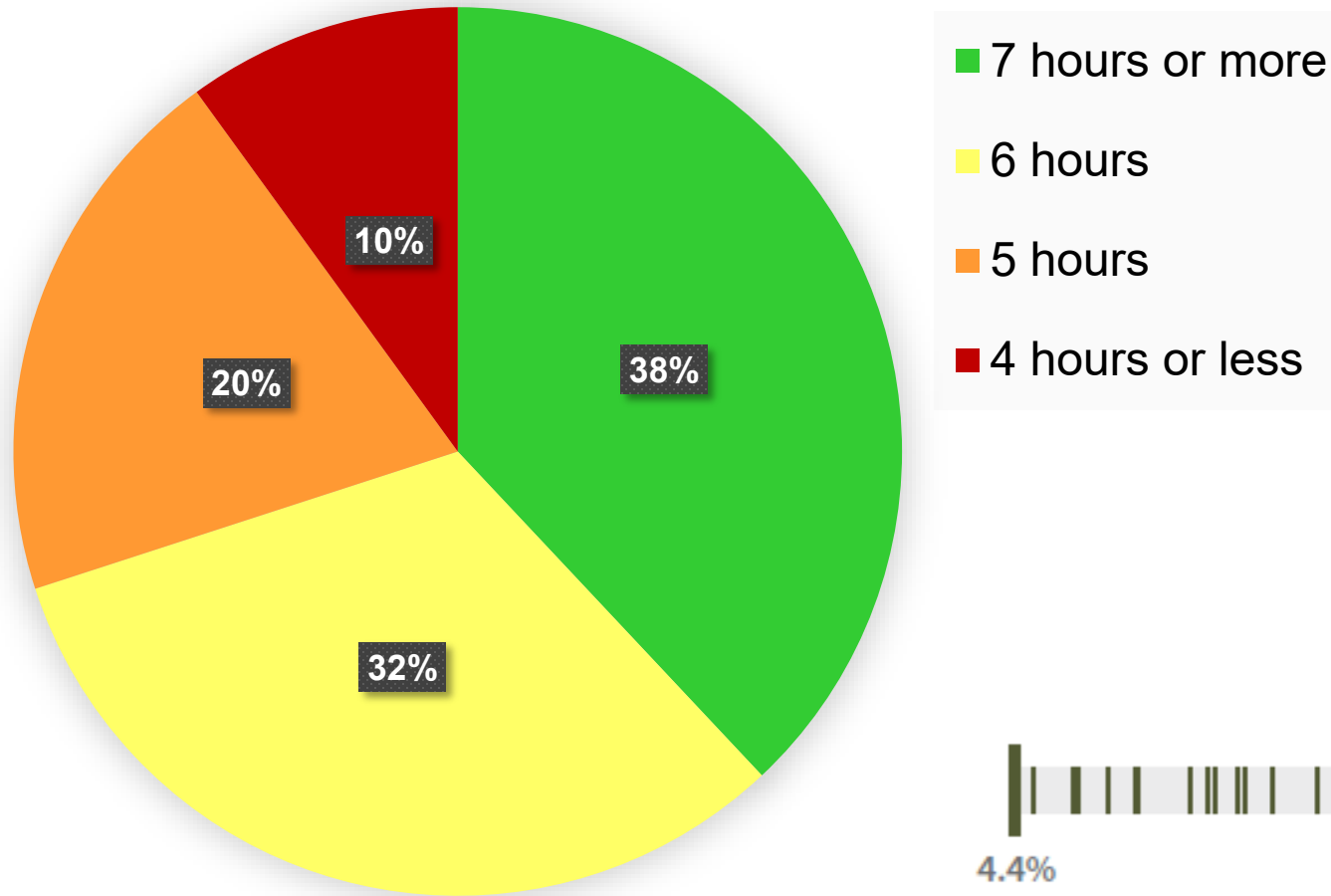
Poll Question 2

For adults, what is the recommended range of hours for daily sleep duration?



2021 Health of the Force

Average Sleep Duration During Duty Week



Better sleep correlated with:

- Healthy body composition
- Positive health behaviors
- Better fitness

Assessed sleep disorders like:

- Sleep apnea
- Insomnia
- Hypersomnia
- Circadian rhythm sleep disorder
- Narcolepsy

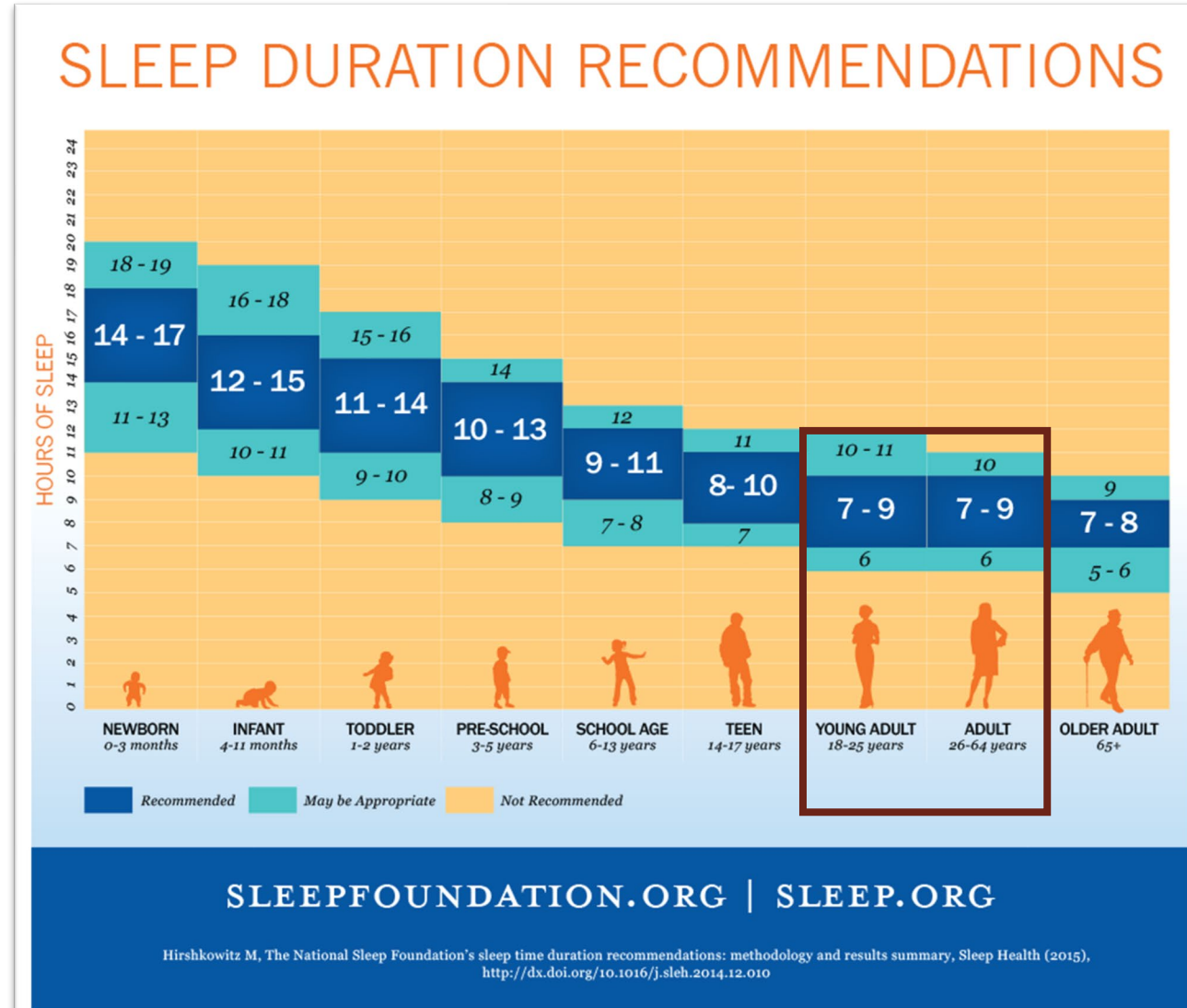


Overall, 9.0% of Soldiers had a sleep disorder.

Prevalence ranged from 4.4% to 19% across Army installations.

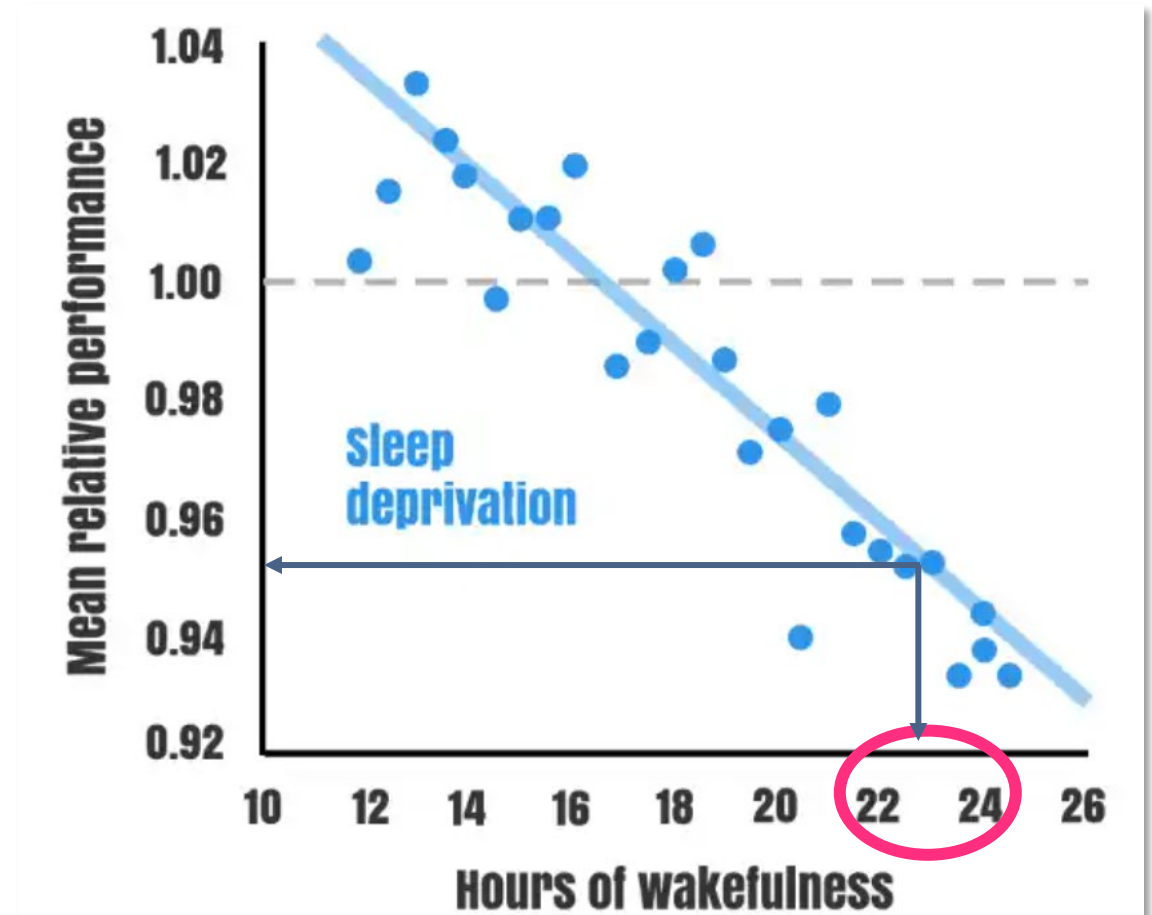
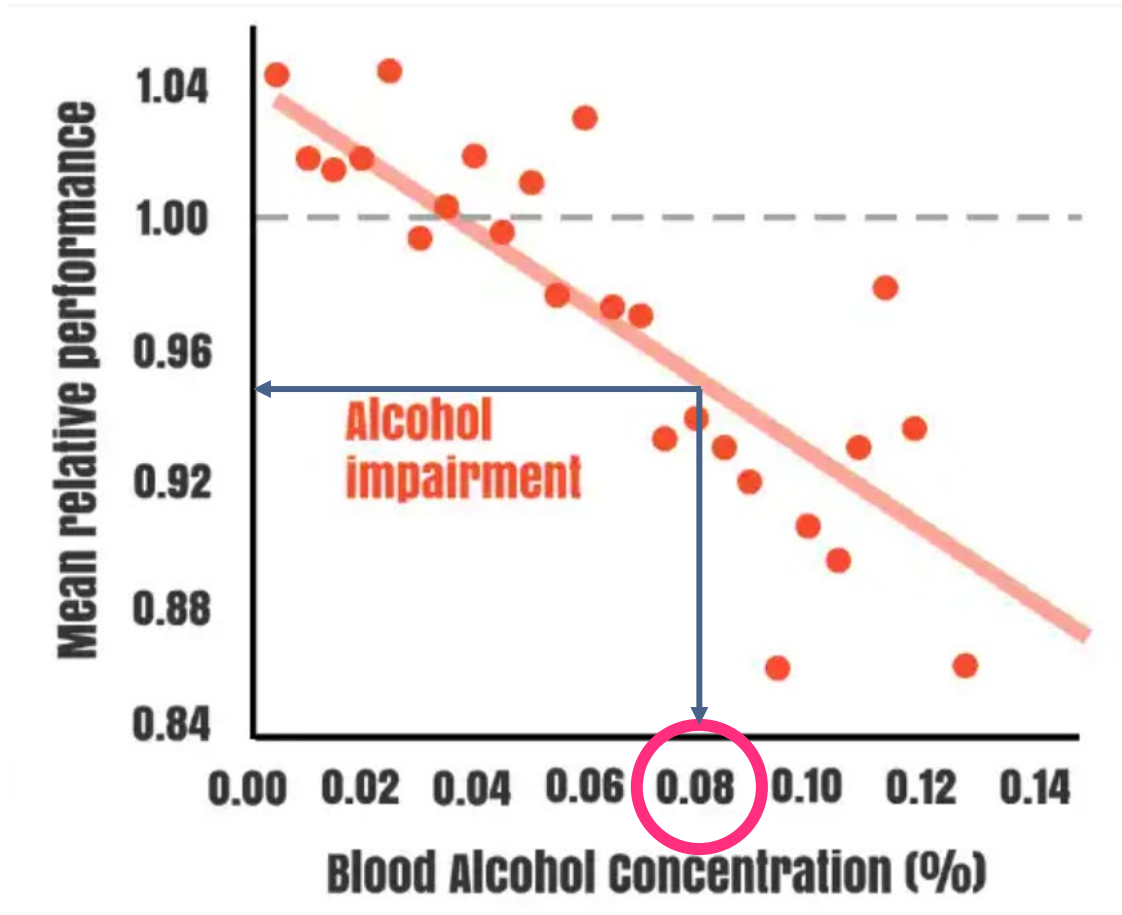
(WRAIR, 2021)

How Much Sleep Do We Need?



(sleepfoundation.org, n.d.)

Sleep Loss = Intoxication



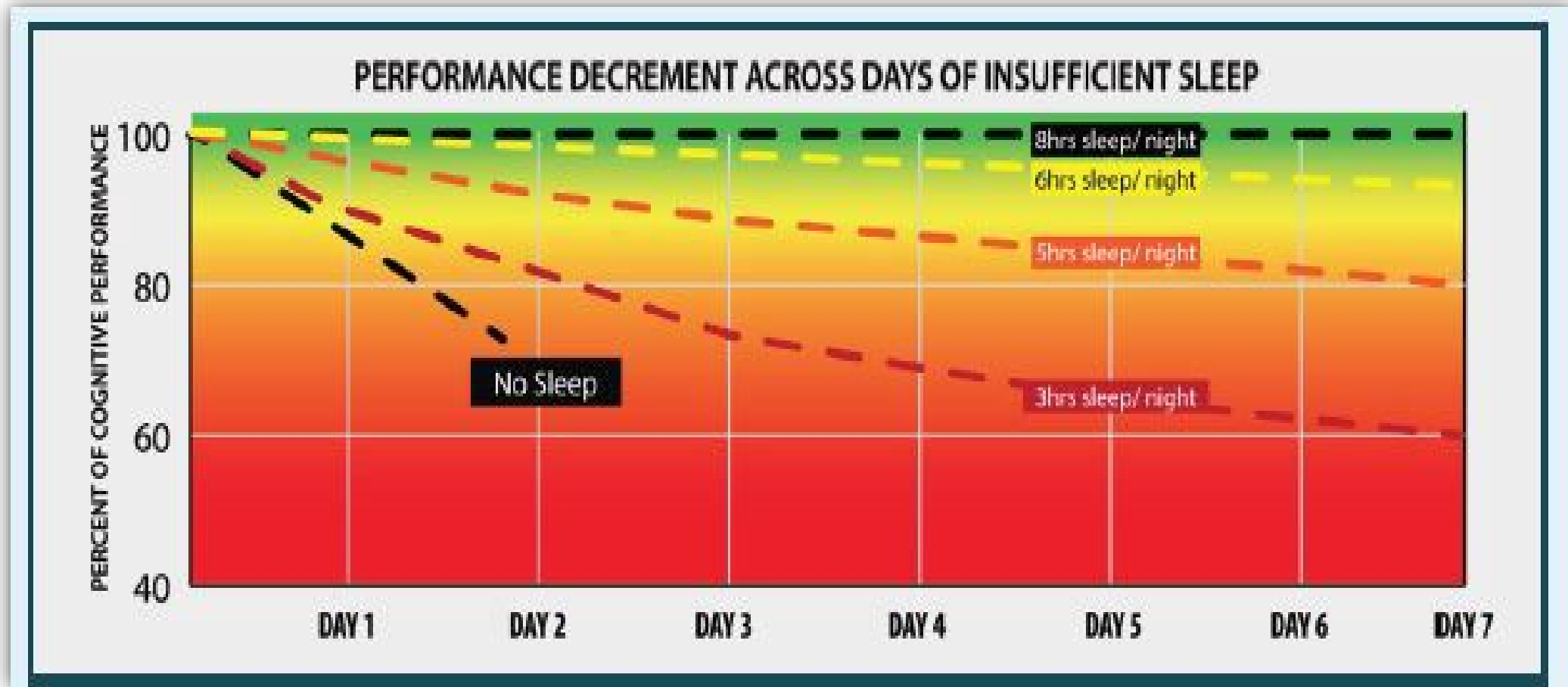
(Dawson et al. 1997)

What Does This Look Like?

- Zero-point zero eight percent:
 - Experience altered mood
 - Inhibitions lowered, more risky behaviors
 - Impairment in focusing on and visually tracking objects
 - Impaired alertness/reaction time
 - Impaired executive function (reasoning, judgment, self-control, concentration)
 - Impaired memory (formation, consolidation, and retrieval)
 - Less physical control over body (gestures, speech, focusing vision)
 - Impaired coordination (balance, speech)



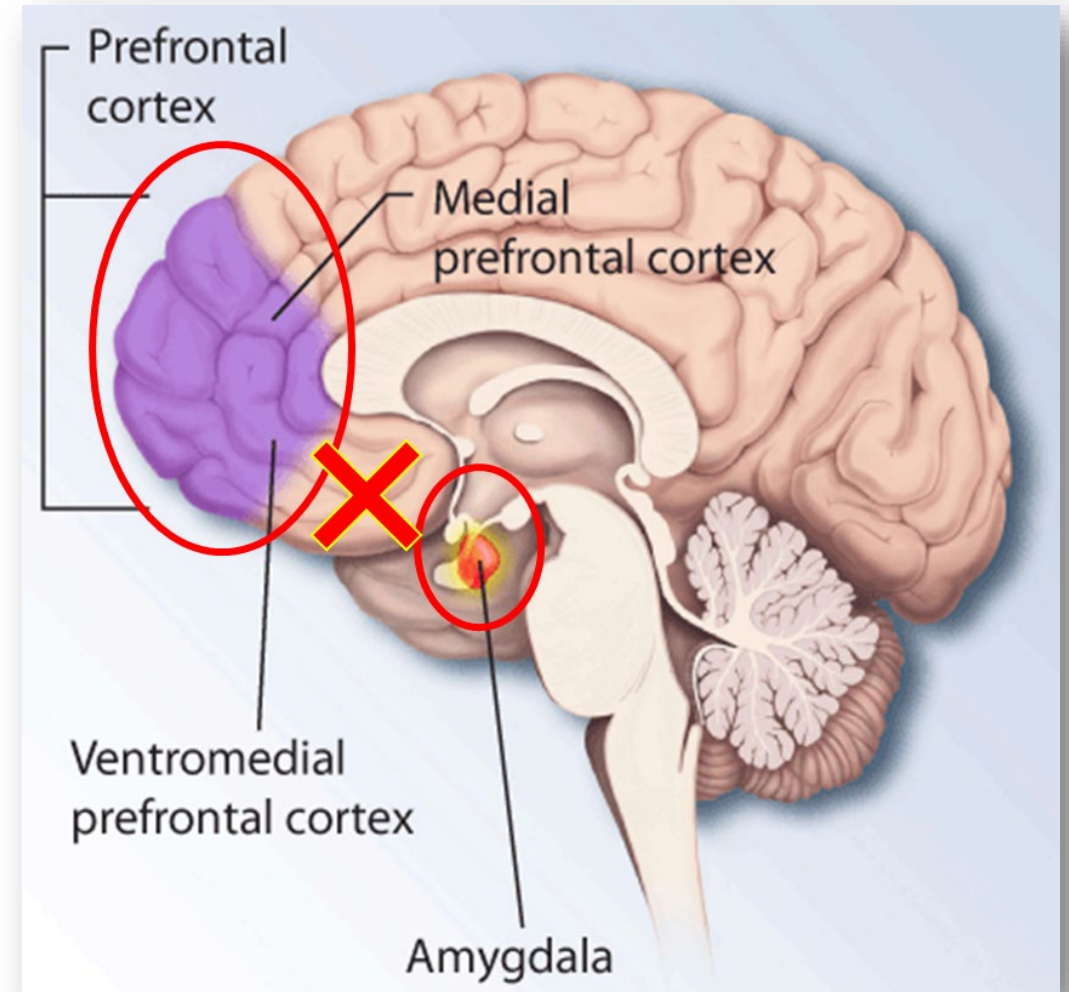
Cognition with Chronic Sleep Loss



(WRAIR, n.d.)

Sleep and Emotion Regulation

- With sleep, prefrontal cortex keeps your emotional brain, the amygdala, in check
- Sleep loss severs this top-down control, allowing over-active amygdala.
- Exaggerated emotional response, increases negativity
- Related – increased risk-taking behavior



(neurosciencenews.com/memory-distraction-7851/, n.d.)

Sleep and Mood / Emotion Regulation

Ranger Instructors and Soldier with more self-reported sleep issues reported:

- Higher anxiety
- More depressive symptoms
- Higher alcohol consumption
- Lower satisfaction with life
- More risky behaviors

www.psychologytoday.com/nz/basics/moral-injury, n.d.)



Hunger and Weight Gain

- Reduced insulin sensitivity
- Blood sugar changes
- Crave salty, sweet, and starchy foods
- Higher levels of ghrelin is equal to hunger
- Lower levels of leptin is equal to less appetite control
- Fifty percent higher risk for obesity with less than five hours of sleep per night



(shutterstock.com, n.d.)

Sleep Loss Increases Disease Risks

For those with less than five hours versus greater than seven hours of sleep:

- 36% increase in elevated lipids
- 62% greater risk of stroke
- 69% more hypertension
- 152% increase in heart attack
- 40% increased risk of diabetes

(hopkinsmedicine.org/, n.d.)



Sleep and Immunity

Lack of sleep linked to:

- Impaired inflammatory function
- Increased susceptibility to infection and disease
- Reduced ability to fight infection
- Decreased vaccine-induced antibody response

([merriam-webster.com/](https://www.merriam-webster.com/), n.d.)



People who average less than 7 hours of sleep per night are **3 times** more susceptible to infections, like COVID-19, and those who average less than 5 hours of sleep per night are **4.5 times** more susceptible.

Fatigue Management - Napping

- Take a 20-minutes daytime nap
 - Decreases subjective sleepiness
 - Increases alertness
 - Increases cognitive performance
 - Improves mood
- Longer naps (60-90 minutes)
 - Facilitates memory consolidation
 - Enhances creativity
 - Reduces stress
 - Strengthens immune function
- Thirty-sixty minutes naps
 - Can result in greater sleep inertia and grogginess
 - Use bright light or caffeine immediately afterward



(wexnermedical.osu, n.d.)



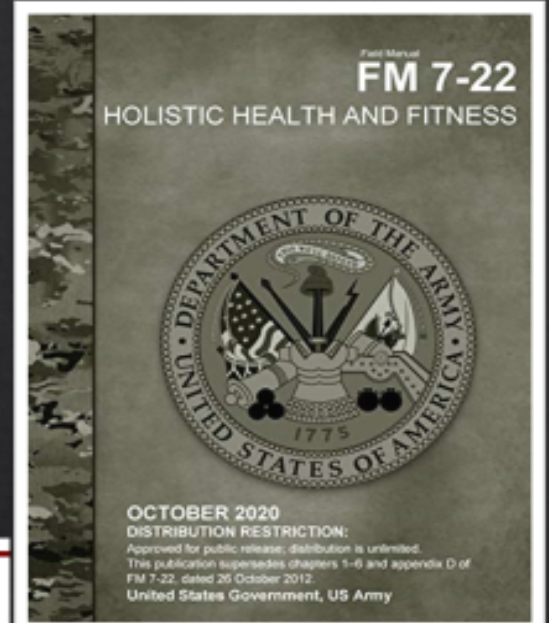
(wexnermedical.osu, n.d.)

In the News

The New York Times

The Army Rolls Out a New Weapon: Strategic Napping

Because fatigue can corrode mission performance, a new physical training manual tells soldiers to grab 40 winks when they can, part of a new holistic approach to health in the ranks.



'Tactical Napping' and Other Tips to Sleep Well On Deployment

Health.mil

Ready Medical Force. Medically Ready Force.
The official website of the Military Health System and Defense Health Agency.

Pushups, run, plank and...tactical nap? Soldiers need more sleep, Army research says

By [Todd South](#)

ArmyTimes

Apr 27, 2022

★ Military News

Army Gives Its Official Support to the Time-Honored Practice of Field Napping

Fatigue Management - Caffeine

- Caffeine can temporarily boost energy and performance.
 - Adenosine binding to receptors results in sleepiness
 - Caffeine acts by blocking adenosine receptor
- Use caffeine strategically to increase performance.
 - Do not need caffeine when you are already rested (e.g., in morning after good sleep, after nap)
 - Stop using caffeine at least six hours before bedtime to prevent sleep disruption
 - 2B-Alert can predict timing and amount of caffeine needed for optimal performance



(worldofchemicals.com, n.d.)



(2b-alert.web, n.d.)



([alamy.com/stock-photo/](https://www.alamy.com/stock-photo/), n.d.)

Fatigue Management – Sleep Banking

- When leaders anticipate periods of insufficient sleep, promoting sleep banking can mitigate performance deficits
- Increase hours of sleep per night (greater than 9 hours) in anticipation of restricted sleep or continuous operations
 - Up to two weeks in advance
- Physical and cognitive performance will decline slower and recover faster

Other Fatigue Management Tips



([gyminsurancehq.com](https://www.gyminsurancehq.com/)., n.d.)



([stock.adobe.com/](https://www.stock.adobe.com/), n.d.)



([avwatersolutions.com/](https://www.avwatersolutions.com/), n.d.)

- Take frequent breaks throughout the workday
- Hydrate
- Exercise
- Get plenty of light, preferably natural sunlight

Habits for Healthy Sleep

THE DOs

-  Keep a regular sleep schedule. Go to bed and wake up at the same time even on off-duty days.
-  Schedule enough time to get 7 or more hours of sleep a night.
-  Establish a routine. Start an hour before bed to calm the body and brain.
-  Only use your bed for sleep and not work or entertainment.
-  Exercise regularly during the day, but only light exercise closer to bedtime.
-  Get out of bed if you cannot fall asleep to avoid connecting your bed with stress.

& DON'Ts

-  Use electronic devices in bed or within an hour of bedtime.
-  Go to bed hungry, thirsty, or too full.
-  Consume caffeine within 6 hours before bed or more than 400mg/day.
-  Drink alcohol before bed because it disrupts healthy sleep cycles.
-  Nap too close to bedtime or too long if you have trouble sleeping at night.
-  Focus on not being able to sleep (e.g., repeatedly checking the time).

(WRAIR, n.d.)

How's Your Sleep *SLANT*?

Environmental factors can degrade sleep.
Improving these factors can boost the recuperative value of sleep.



SURFACE

S

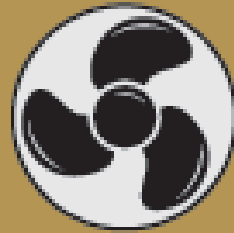
Aim to have a soft, yet firm sleeping surface, including mattress, cot and pillows.



LIGHT

L

Use darkening shades, if possible. Get 1 hour of bright light exposure upon awakening.



AIR QUALITY

A

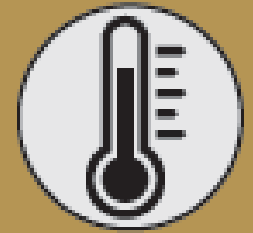
Clean/replace air filters regularly.
Sleep away from burning waste.



NOISE

N

Use white noise, loud fans or earplugs. Sleep away from military operations.



TEMPERATURE

T

Use A/C or heat, if available (65-67° F is optimal). Use blankets and insulation.

(WRAIR, n.d.)

Sleep as a Weapon

“Sleep is not only critical for ensuring our lethality on the battlefield, but for ensuring the safety of our crews and aircraft. To that end, sleep is truly a weapon.”

- Colonel Thomas Burke, 25th ID
Combat Aviation Brigade
Commander

(marinecorpstimes.com, n.d.)

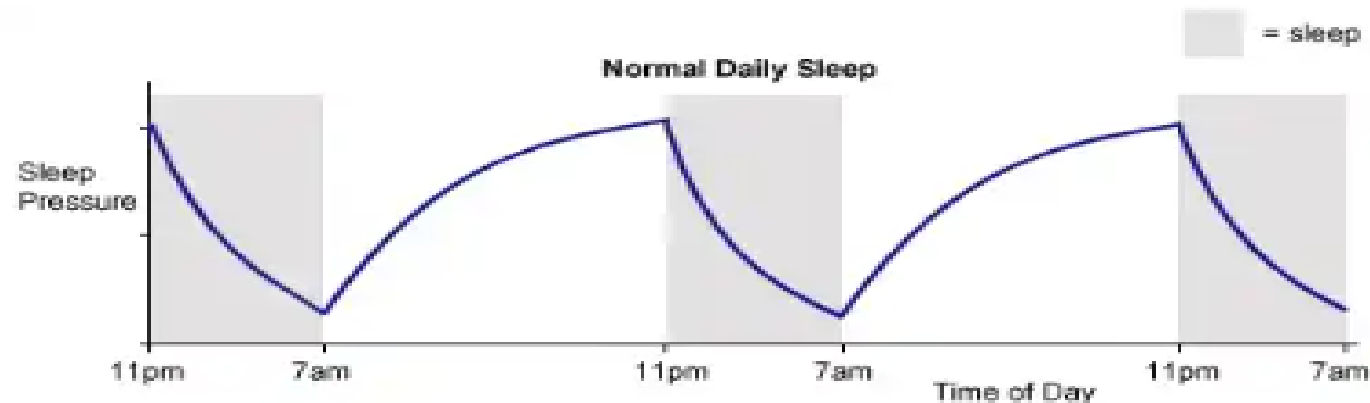


An Introduction to the Neuroscience of Sleep's Restorative Function and It's Enhancement with Transcranial Electrical Stimulation (SO-tDCS)



The function of sleep:

- William Dement: The function of sleep is to alleviate sleepiness (Max et al. 2010)
- “Homeostatic” sleep drive accumulates over a period of sustained wakefulness (Borbely et al. 1982)
- Sleep drive is gradually dissipated during sleep.



(chop.cloud-cme.com, n.d.)

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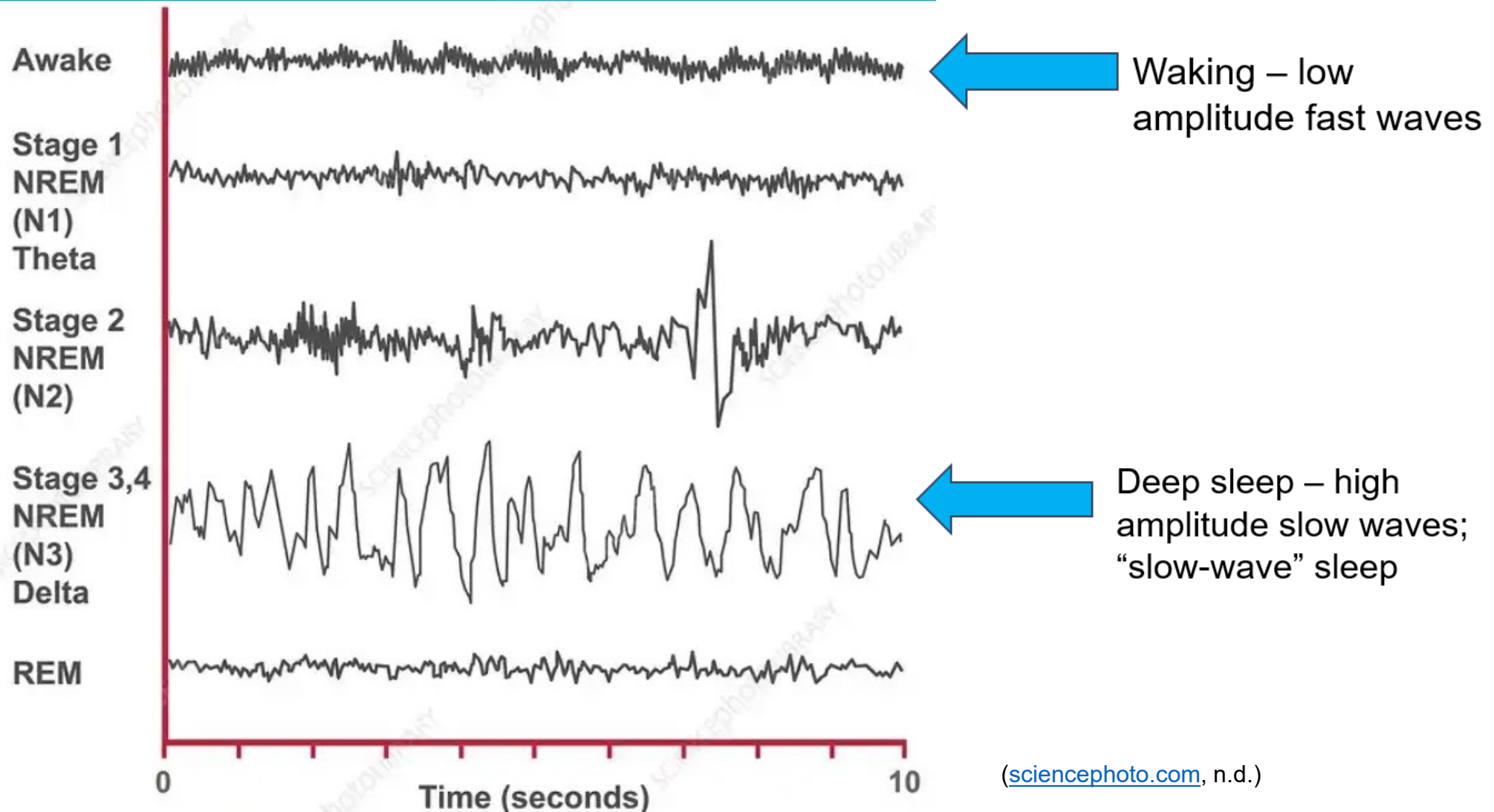
Poll Question 1

True or False:

Rapid eye movement (REM) sleep is the is the most recuperative stage of sleep.

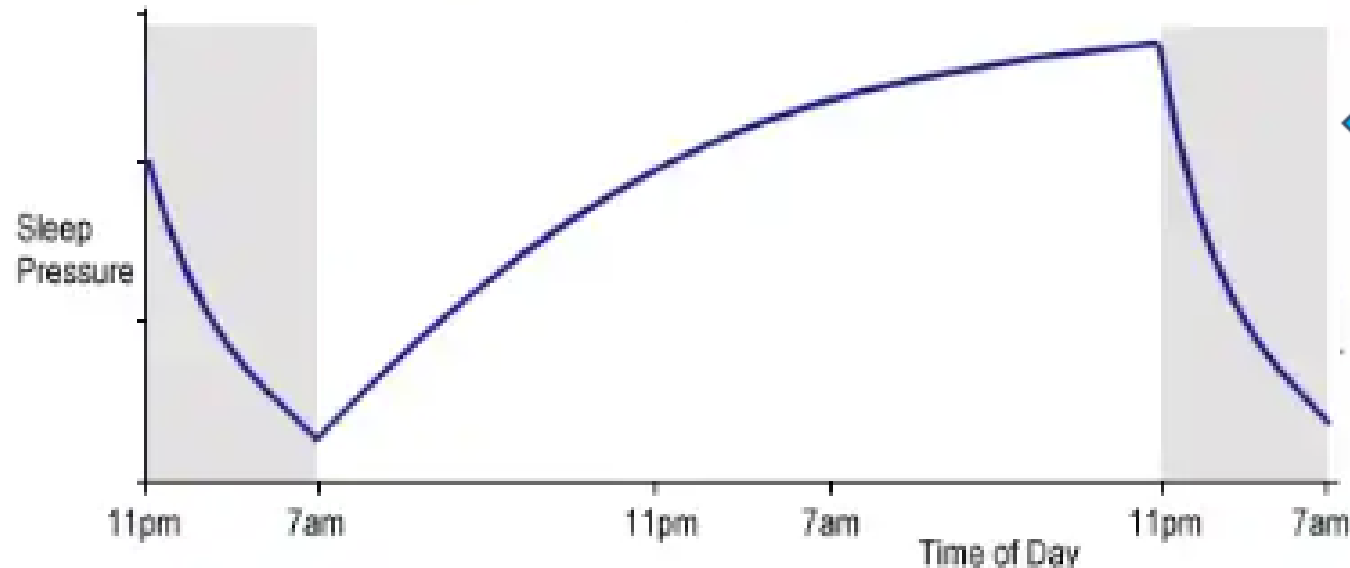
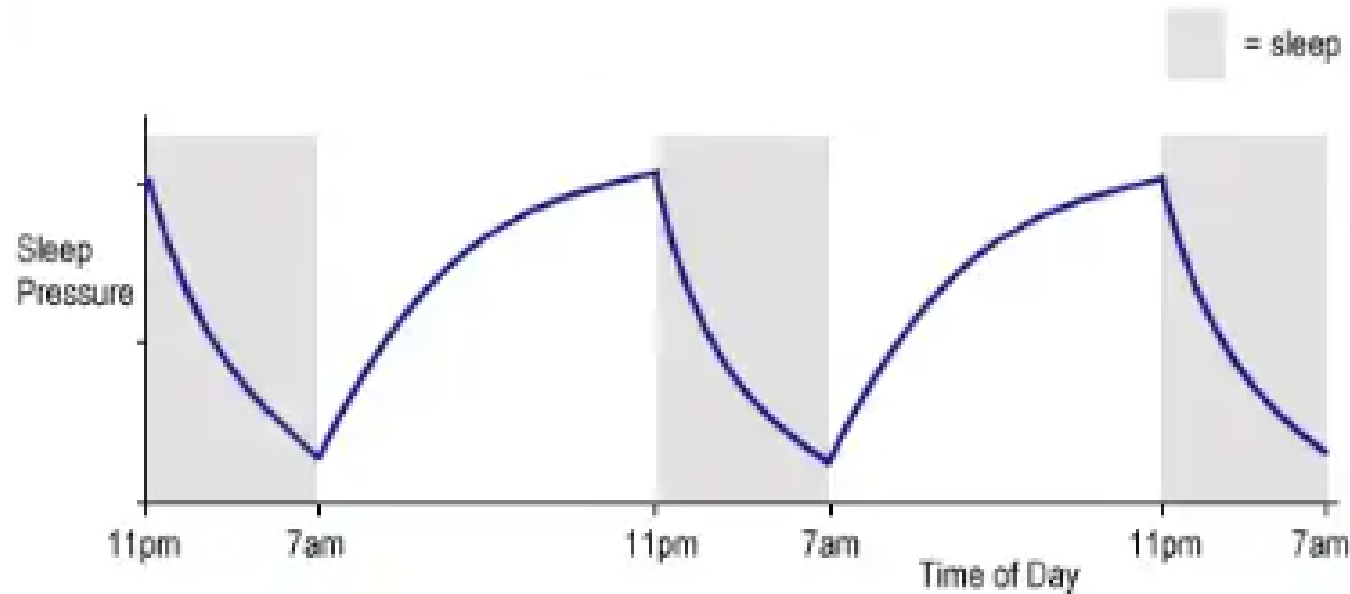


EEG during different brain states:



Slow-wave Activity

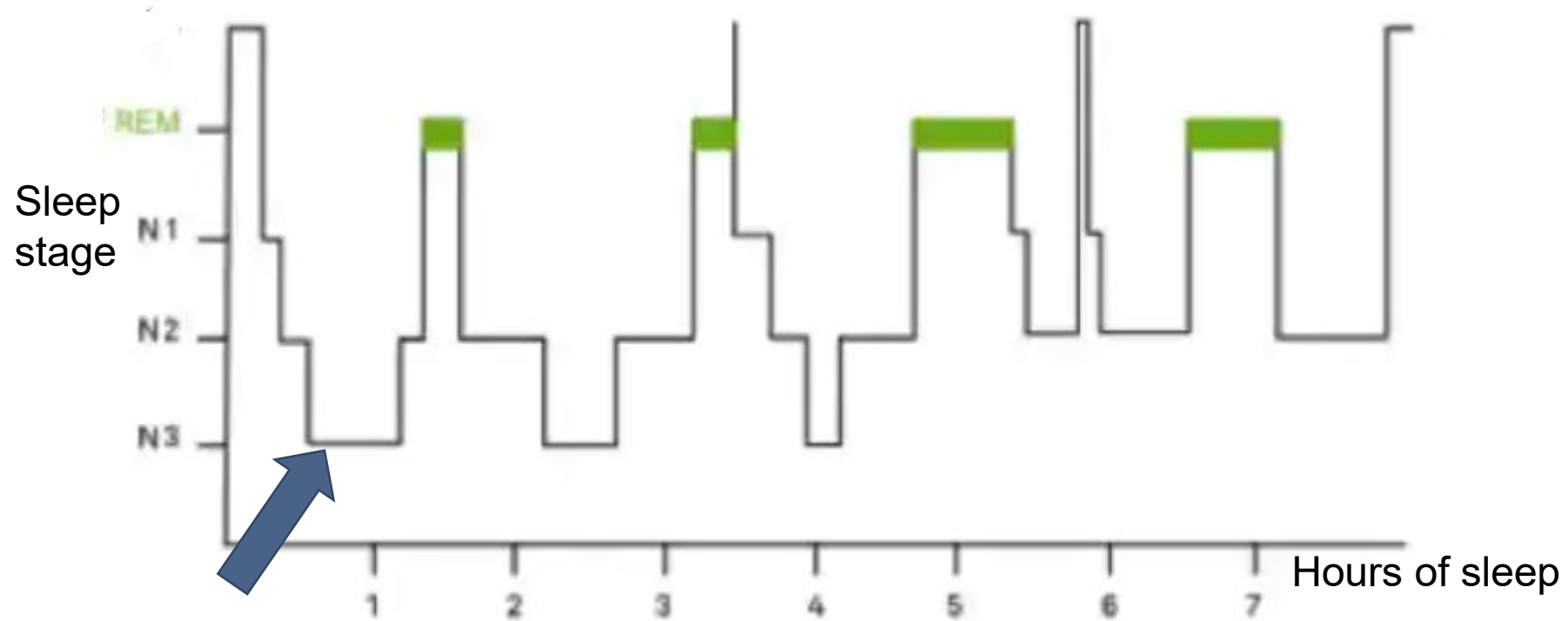
Slow-wave power during a sleep period is a function of the duration of prior sustained wakefulness.



We would record significantly more Slow-wave activity during this night of sleep versus those in the upper figure.

(sommeilmedicamenteux-sommeilnaturel.health.blog, n.d.)

Sleep Hypnogram:



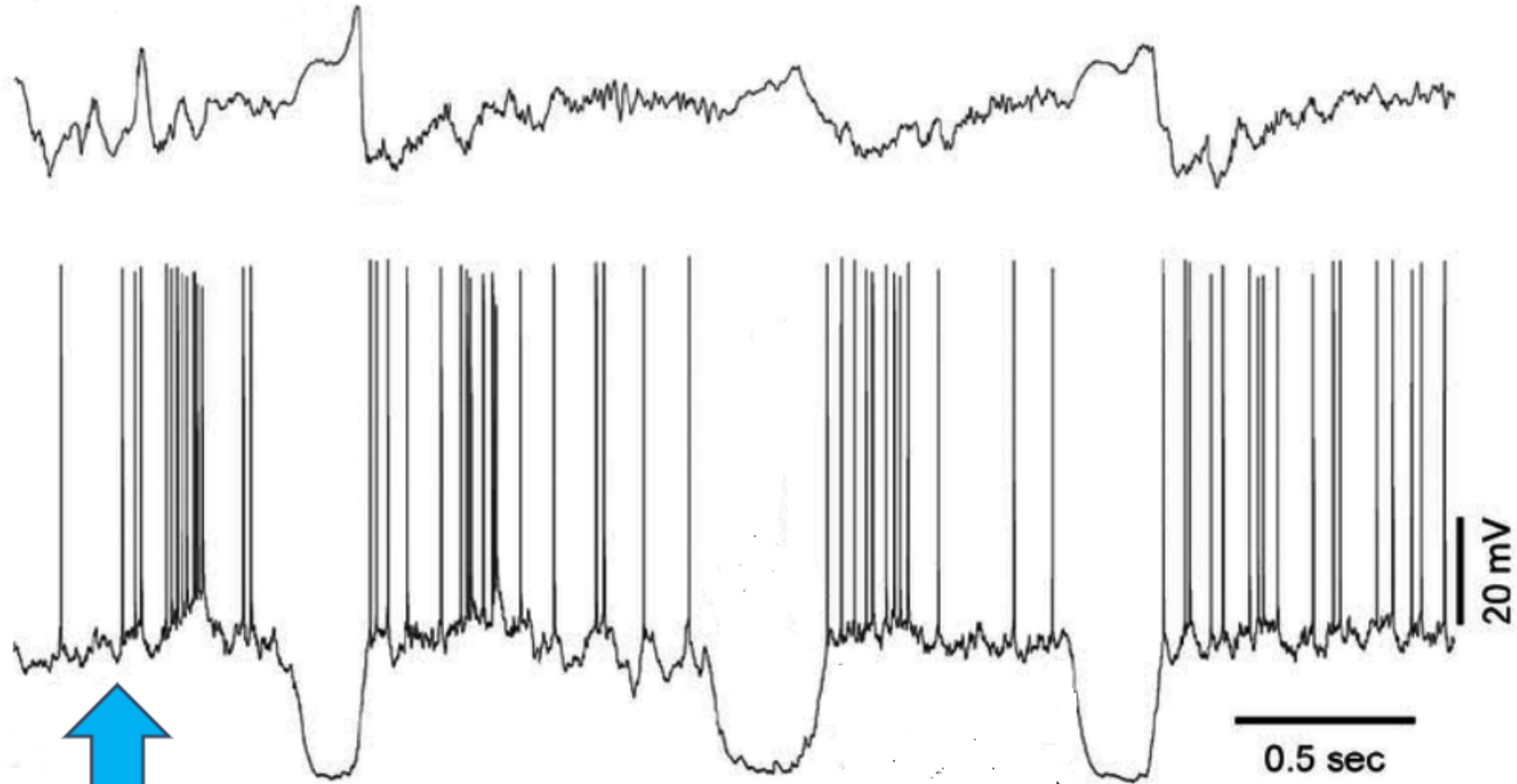
- Sleep alternates between Non-rapid Eye Movement (NREM) and Rapid Eye Movement (REM) stages, several such cycles per night.
- Slow waves are concentrated in deep NREM sleep – stage N3 (about 20% of sleep).
- Even deep sleep may have as little as 20% slow waves.

(ronfless.com/en/sleep-a-vital-function/, n.d.)

Slow-wave physiology (Steriade et al. 1993):

- Slow waves consist of two phases per cycle:
 - “UP states” are periods of neuronal excitation and firing of action potentials like brief (several hundred millisecond) periods of wakefulness.
 - “Down states” are silent periods of neuronal inhibition.
- Slow waves alternate between UP and DOWN states.
- Slow waves are highly synchronized among all neurons across the cortex.
- Slow waves are concentrated in deep sleep (20% of nocturnal sleep).

Slow-wave physiology (Steriade, 1993):



UP state (depolarized)

DOWN states
(hyperpolarized)

Poll Instructions

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Poll Question 1

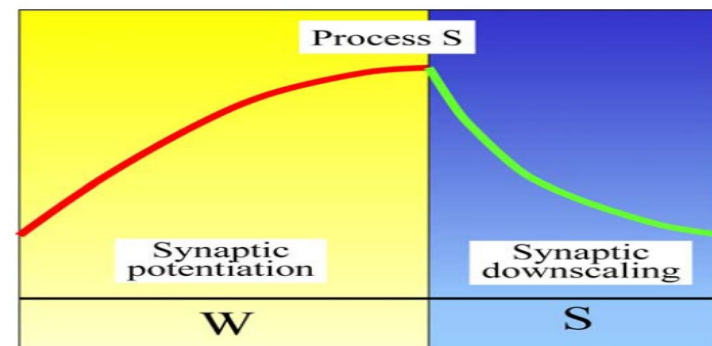
True or False:

Rapid eye movement (REM) sleep is the is the most recuperative stage of sleep.



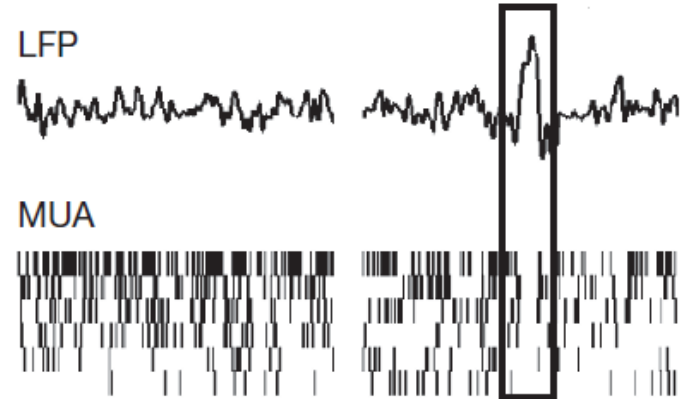
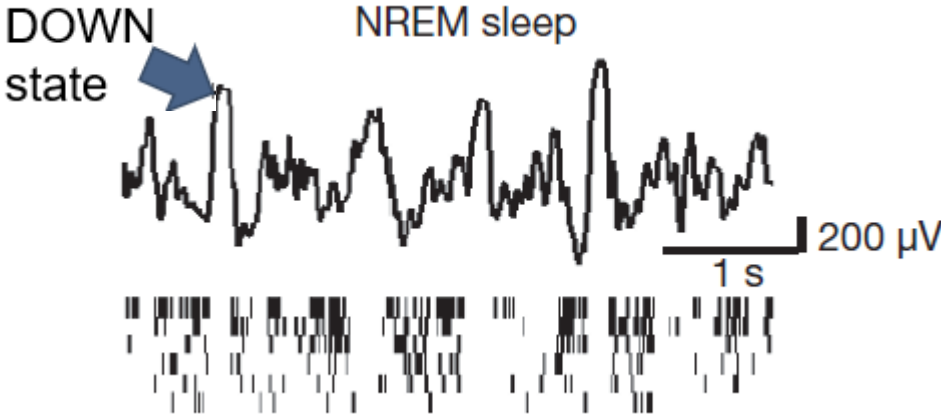
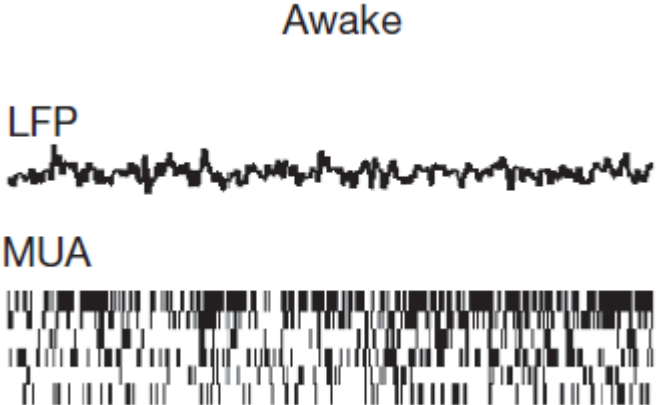
Slow-wave physiology:

- Homeostatic sleep drive is due to:
 - **Neuronal Damage: deoxyribonucleic acid (DNA)** damage that requires repair (Vyazovskiy et al. 2013)
DOWN states provide an inactive period necessary for repair.
 - **Sensory experience:** increased excitatory synaptic connectivity in the cerebral cortex.
- Increased synapses (connections between neuron) and strength of synapses (Tononi et.al 2006).
- This increased connectivity (hyperconnectivity) makes information processing inefficient.
- The increased excitatory synaptic strength predisposes to seizure activity.
- The alternation between UP and DOWN states weaken synapses that have not been tagged for maintenance based to salience of information.

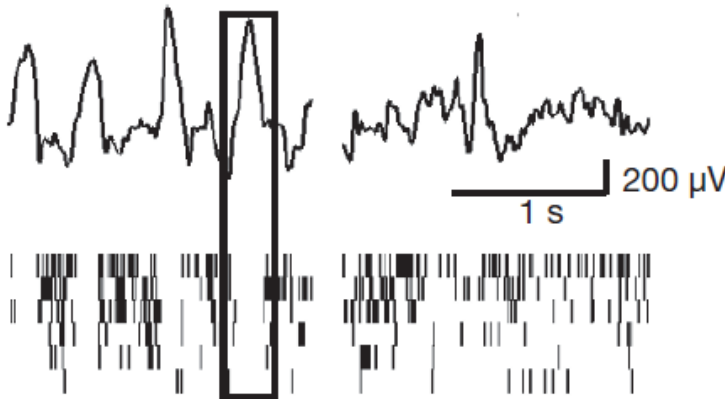


(semanticscholar.org, n.d.)

Neuronal Activity During Different Brain States:



Early Sleep Deprivation (SD)



Late SD

(Vyazovskiy et al. 2011)

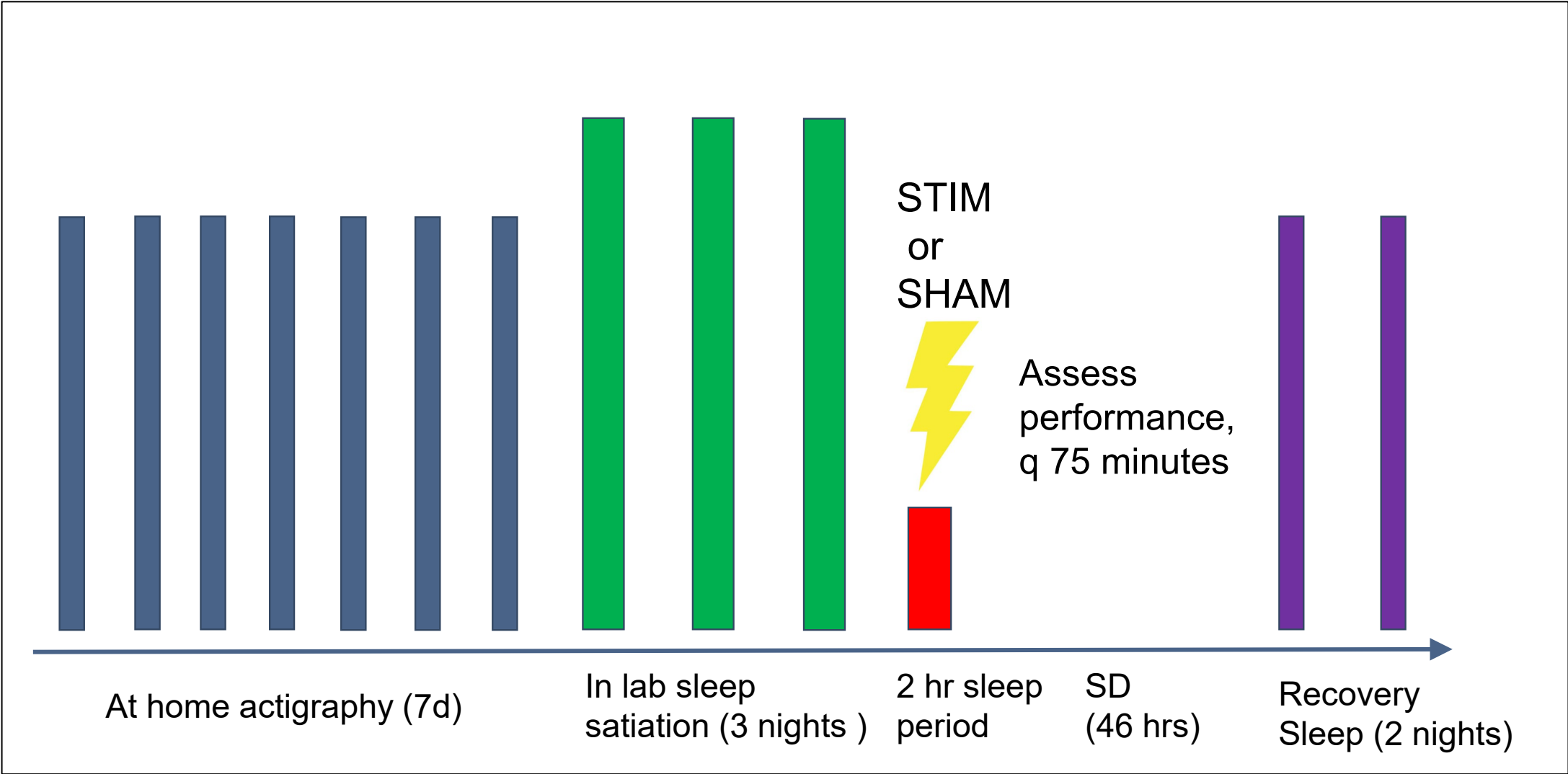
The potential value of slow-wave enhancement:

- Active-duty personnel experience restricted sleep opportunity (less than four hours).
- The following brain disorders are associated with reduced slow-wave activity:
 - Traumatic Brain Injury (TBI)
 - Stroke
 - Multiple Sclerosis
 - Alzheimer's Disease
 - Post-traumatic Stress Disorder
 - Major Depressive Disorder
 - Schizophrenia

Research Hypothesis:

- Can we administer a weak current oscillating at the peak slow wave frequency (0.75 Hz) to the scalp to “stimulate” the neurons of cerebral cortex to oscillate with the current?
- Enhance slow-wave power during a sleep period to accelerate the restorative process.
- Transition light NREM sleep into deep slow-wave rich NREM sleep.

Study Design



(WRAIR, n.d.)

Stimulation procedure (SO-tDCS):

- Stimulation at 0.75 Hertz (Hz) for 60 minutes, consisting of five-minute periods of oscillatory stimulation alternating with one-minute interstimulus intervals (Marshall et al. 2006).



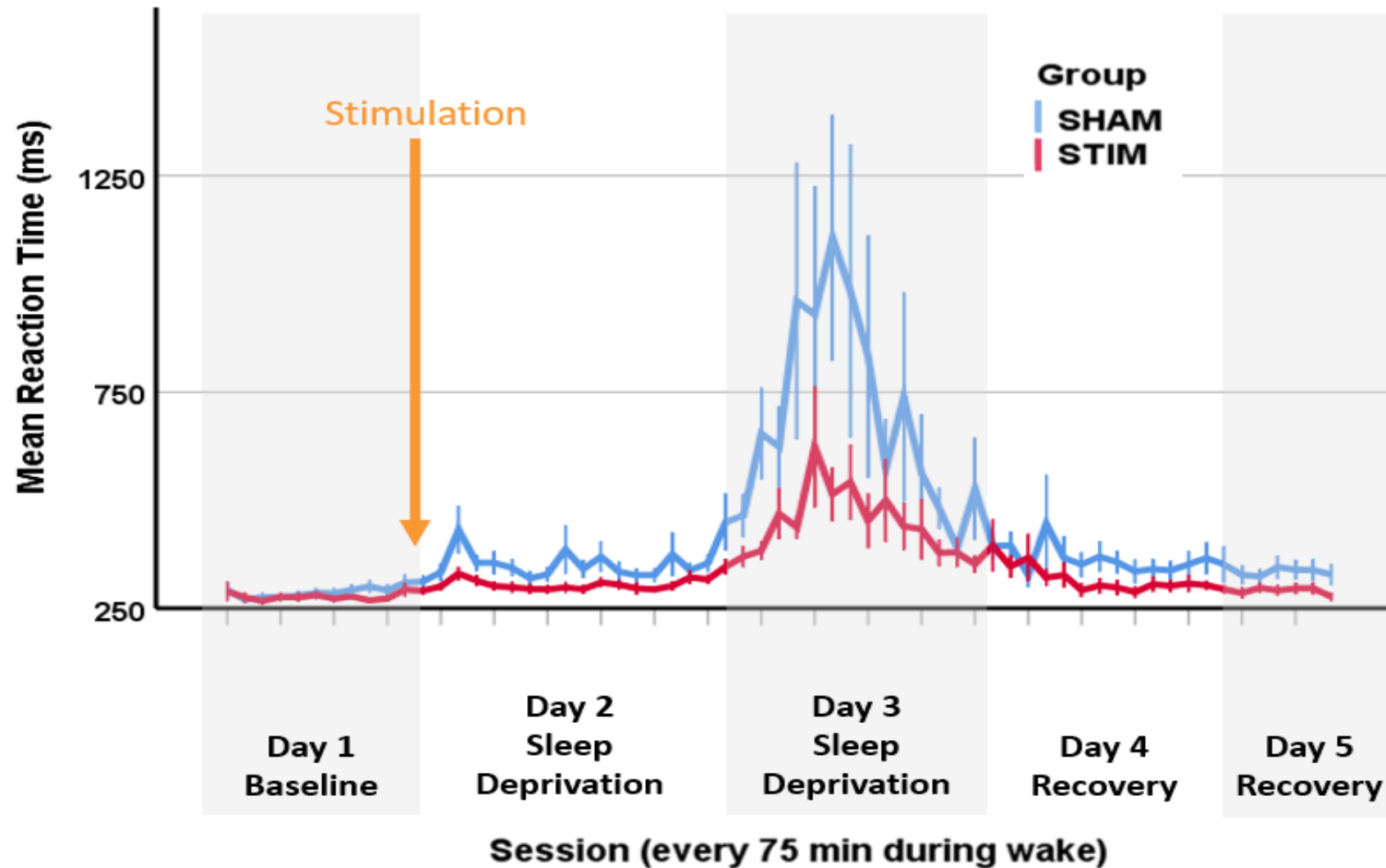
- Current oscillates between 0 and 260 microampere (μA).
- Sham stimulation consists of a 60-minute stimulation at zero ampere (amp) current.
- Electrode configuration: anodes at F3, F4 and cathodes at M1, M2.

Outcome Measure: (1 of 4)

Psychomotor Vigilance Test (Dorrian et al. 2004):

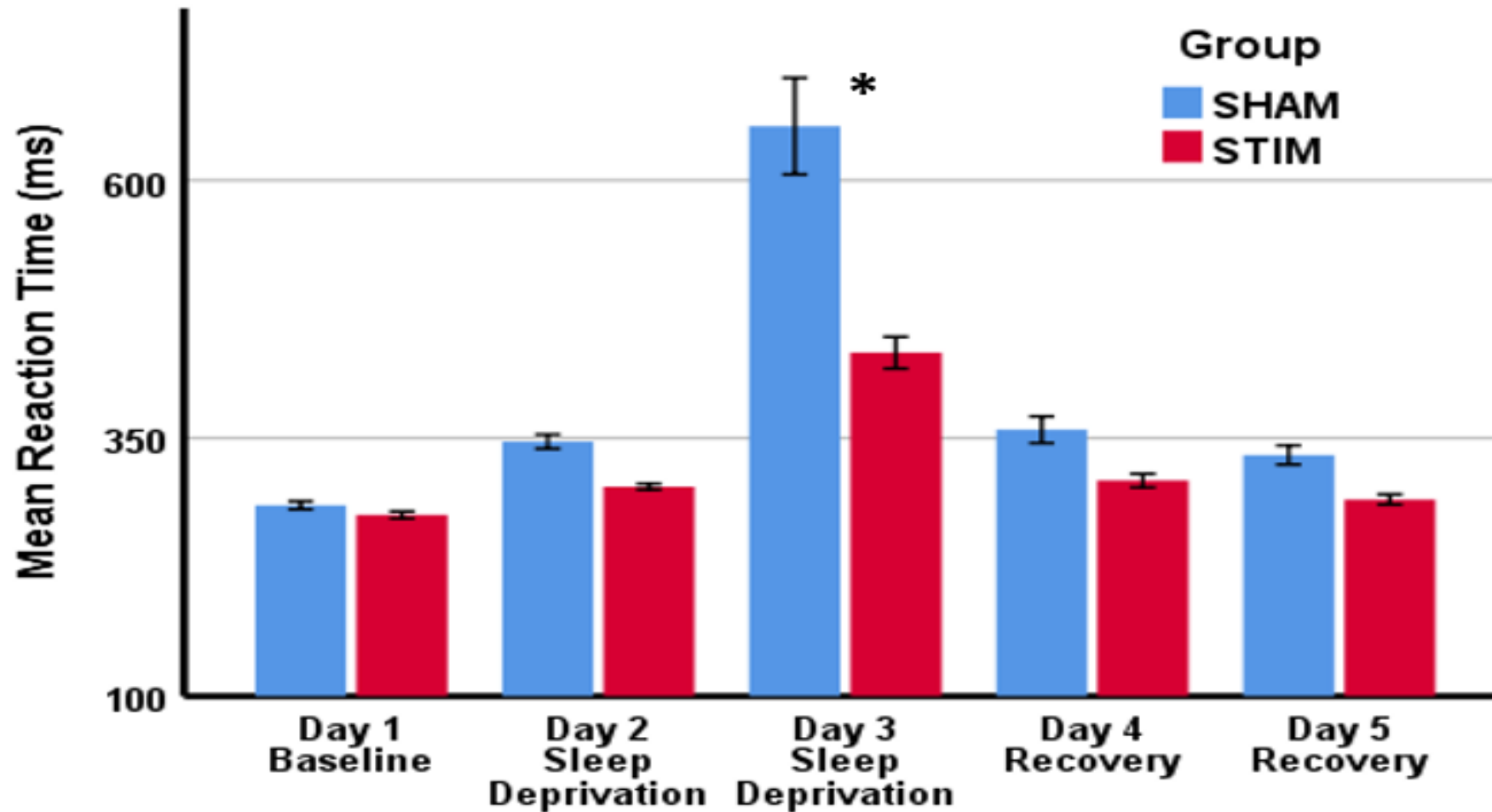
- Administered every 75 minutes while awake and in lab.
- Targets appear on a computer screen at varying interstimulus intervals.
- Participants press key when they perceive target.
- Reaction times determined for all targets over a 10-minute period.
- Reaction time very sensitive to sleep loss.

Outcome Measure (2 of 4)



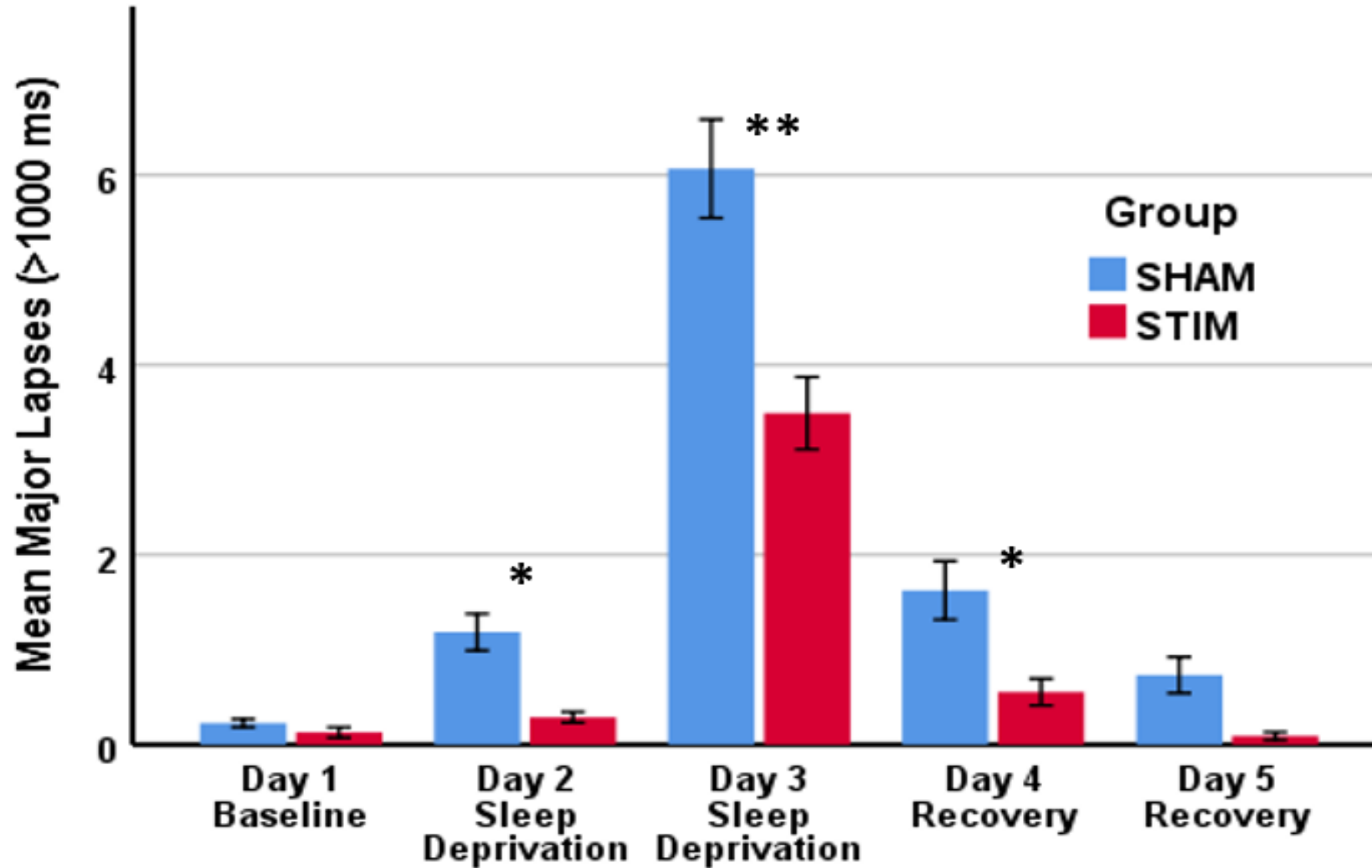
(WRAIR, n.d.)

Outcome Measure (3 of 4)



(WRAIR.com)

Outcome Measure (4 of 4)



(WRAIR, n.d.)

Conclusions:

- SO-tDCS during a portion of a restricted period of sleep enhances sleep's restorative properties and thus accelerates the dissipation of sleep drive, so that less sleep duration is required to attain a certain level of recuperation.
- SO-tDCS also allows less post-SD recovery sleep to return performance to baseline.
- SO-tDCS may have therapeutic potential to treat neurological and psychiatric disorders characterized by reduced Slow-wave power, including mild traumatic brain injury (mTBI) and Post-traumatic stress disorder.

Key Takeaways

- Sleep is not only important for feeling less tired but, rather, is crucial for many facets of health and performance.
- There are habits that can be adopted that promote healthy sleep and an optimal sleep environment.
- Homeostatic sleep drive accumulates gradually during sustained wakefulness and alleviated by slow waves (DOWN states).
- Sleep drive can be conceptualized as a drive to experience the restorative properties of slow waves (DOWN states), which intrude into the EEG of wakefulness if an inadequate quantity occur during sleep, due to insufficient sleep duration or a pathological decrease in slow wave production.
- Slow Oscillatory transcranial Direct Current Stimulation (SO-tDCS) can enhance slow wave activity and accelerate the dissipation of sleep drive during a short duration period of sleep.
- Slow wave sleep enhancement has the potential to improve sleep in a variety of neurological and psychiatric disorders.

THANK YOU!!!

RESOURCES

- Our Resource Page - checklists, infographics, and research overviews

<https://wrair.health.mil/Biomedical-Research/Center-for-Military-Psychiatry-and-Neuroscience/CMPN-Training-Products/>

- Our Recruitment Page – current studies and phone and email info

<https://wrair.health.mil/Join-a-Study/Sleep-Research-Center/>

- Walter Reed Army Institute of Research Sleep Research Center (WRAIRSRC) on social media



Questions?



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2. Search for your course using the Catalog, Calendar, or Find a course search tool.
3. Click on the REGISTER/TAKE COURSE tab.
 - a. If you have previously used the CEPO CMS, click login.
 - b. If you have not previously used the CEPO CMS click register to create a new account.
4. Follow the onscreen prompts to complete the post-activity assessments:
 - a. Read the Accreditation Statement
 - b. Complete the Evaluation
 - c. Take the Posttest
5. After completing the posttest at 80% or above, your certificate will be available for print or download.
6. You can return to the site at any time in the future to print your certificate and transcripts at: <https://www.dhaj7-cepo.com/>
7. If you require further support, please contact us at: dha.ncr.j7.mbx.cepo-cms-support@health.mil

