Sleep while sailing solo offshore – A brain-based guide to napping

Phil Haydon, Ph.D.

President, Sail For Epilepsy

philip.haydon@sailforepilepsy.org

Annetta and Gustav Grisard Professor and Chair of Neuroscience, Tufts University School of Medicine.

About the author: Phil is a neuroscientist who has made seminal discoveries about brain function in health and disease including the development of a drug that has been taken to clinical trials. In 2009 he discovered the mechanism that causes the brain to desire to sleep after a period of sustained wakefulness. He has a passion for offshore sailing and uses his knowledge about brain function to tailor his napping schedules. As a result of a head injury when he was 15 he developed epilepsy, which is now medically controlled. Recently he established a non-profit, Sail For Epilepsy, with the goal of inspiring those with epilepsy to live fuller lives by focusing on what they can do rather than what they can't. To learn more visit: sailforepilepsy.org

Introduction: *In my laboratory one of the areas of study is the control of sleep, as a consequence, I have integrated my scientific knowledge with sources of information provided by others to develop my own "checklist" to follow when I race offshore. Beneath I give some information about brain function that provides the foundation for napping strategies. I share this information in the hope that it will be helpful to other sailors and prevent them from making serious errors after prolonged periods of sleep deprivation.*

Why sleep? *Sleep is essential for life, but why we need to sleep is less clear. All organisms sleep including fruit flies, birds, mice and dogs. Some aquatic marine organisms sleep with one half of their brain at a time. For example, dolphins and whales have one eye open and one side of the brain is awake, while the other side exhibits the electrical activity of sleep. When we sleep several physiological processes occur and the electrical activity of the brain dramatically changes. One recently described process is a cleansing of the brain by the glymphatic pathway. This sleep dependent glymphatic pathway removes toxins from the brain including amyloid, a protein that accumulates during Alzheimer's disease. Studies are underway to ask whether it's possible to stimulate the sleep regulated glymphatic pathway as a treatment for Alzheimer's disease. In addition to not being able to "clean the brain" other consequences of sleep deprivation are the inability to store something one has learned into a long term memory. If, for* *example, you perform a task in the evening but then go through a prolonged period of sleep deprivation, your ability to consolidate the task that you learned into a long-term memory is significantly impaired. Some other consequences of sleep deprivation include irritability, a reduced ability to perform executive functions, and hallucinations.*

Sleep deprivation can cause disasters: *There are numerous examples of accidents in which sleep deprivation was a significant contributing factor. These include the Space Shuttle Challenger in which an investigation found that certain launch managers had only slept 2 hours before launch, arriving for work at 1am. The report included the statement "The willingness of NASA employees in general to work excessive hours, while admirable, raises serious questions when it jeopardizes job performance, particularly when critical management decisions are at stake." Other accidents where sleep deprivation was a contributing factor include the Chernobyl and Three Mile Island nuclear accidents, the Exxon Valdez oil spill as well as notable sailing accidents which will be mentioned later.*

Sustained sleep deprivation also causes sleep walking and hallucinations which can come in the form of audio hallucinations (I have had conversations in German, and I only speak English, with imaginary people on board), as well as visual hallucinations. I have seen a motor launch tie up to the side of my boat while I've been sailing offshore. Fortunately, I was tethered to the boat and didn't try to climb into the launch to go ashore. A young racer had been sailing for days without sleep, but he was ahead of the fleet in the Solitaire du Figaro, a grueling, singlehanded race off the coast of France. Sailing into the harbor to the cheers of the crowd, he stepped from his boat onto the wharf to accept their congratulation then his safety harness jerked him back. There were no crowds, no wharf. He was standing on the gunwale of his boat surrounded by empty ocean. Another skipper recounted to me how he sleepwalked and was urinating off the back of the boat, when he was woken by his tether pulling at him. Clearly, it's important to determine how to mitigate sleep deprivation and get sufficient rest for one's own safety as well as the safety of other vessels at sea.

Stages of sleep: when is it best to wake? *How is it possible to sail safely when solo given the importance of sleep? A professional mariner friend of mine says that "solo ocean racing should be banned since it is in violation of COLREGS [International Regulations for Preventing Collisions at Sea]. How does one maintain an effective lookout while sleeping?" Another mariner says that "solo sailing is dangerous, reckless and careless." While I won't debate the interpretation of COLREGS and whether AIS and radar alarms are an effective lookout when one is sleeping, I feel it's critical that we understand ways in which we can let the brain sleep to ensure optimal performance and vigilance while awake to obtain an as effective a lookout as is possible.*

Developing an effective sleep schedule first requires some understanding of how the brain works. A key difference between being awake and asleep is that sensory stimuli have limited ability to pass through the brain to arouse us. This is a result of a gate closing between two structures: the thalamus and the cortex. Sensory information enters the thalamus where, during wakefulness, it is routed to other regions of the brain

As we enter sleep the electrical activity of the brain changes dramatically from a state of high frequency asynchronous neuronal or electrical activity, to slow synchronous oscillations also known as slow wave activity. When we first fall to sleep the electrical activity of the brain activity consists of slow wave activity in what is termed non rapid eye movement (non-REM) sleep. We go through several stages of non-REM sleep (Figure 1 light blue), each resulting in deeper and deeper sleep that is more difficult to be aroused from. The gate between the thalamus and the cortex closes firmly shut as we progress through NREM stages. After several stages of deeper and deeper non-REM sleep we transition into rapid eye movement (REM) sleep. During REM sleep we enter into a distinct behavioral state consisting of dreams, paralysis and as the name suggests, rapid eye movements. One full period of NREM followed by REM sleep is called a sleep cycle. During the night we have ~5 sleep cycles, each one becoming lighter in depth until we wake.

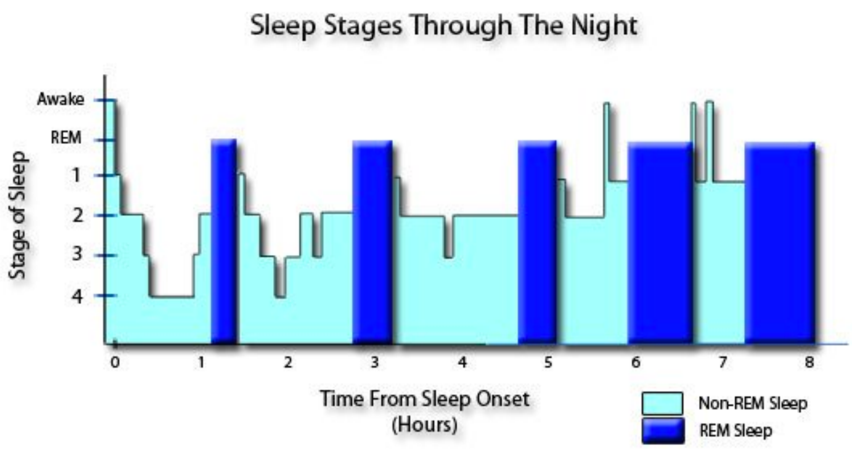

Figure 1: Stages of Sleep. Five sleep cycles are shown each consisting of several stages of Non-REM sleep followed by one stage of REM sleep. Each successive stage of Non-REM sleep in a cycle becomes a deeper level of sleep that is more difficult to be aroused from.

Each stage of non-REM sleep takes about 20 minutes and a full cycle of non-REM and REM sleep collectively takes about 90 minutes, although the exact duration is individual specific. Understanding the durations of these sleep stages is critical for allowing us to regulate napping while sailing.

Claudio Stampi and Polyphasic Sleep: *Our normal sleep pattern is called monophasic sleep in which we go to sleep at night then wake in the morning. Claudio Stampi developed the concept that one could sleep in short naps throughout the 24 hour day (polyphasic sleep) and that the beneficial effects of sleep would accumulate as a result. Stampi was an avid sailor and competed in two global sailing races including the 1981-2 Whitbread race. He collected empirical data from over 100 sailors. He observed the sleep patterns of different sailors and noticed that in general they sleep in several short periods of time which together allowed them to overcome some of the negative consequences of sleep deprivation. Subsequently, he worked with notable sailors such as Dame Ellen MacArthur, Mike Golding and Rich Wilson. Studying sleep while someone is sailing is not an easy task. Normally in a sleep lab we attach electrical recording devices to the scalp to measure the changes in brain waves that are associated with transitions between wakefulness and sleep. (These electrical recordings are called electroencephalograms; EEGs). Clearly, recording EEGs is not feasible when sailing offshore. Instead Stampi used a pair of accelerometers. One was attached to the boat and one was attached to the sailor and then he looked for differential signals that would indicate that the sailor was moving or awake. By* *comparing data from these recording devices, he was able to catalogue when people were mobile and immobile, which correlates well with wakefulness and sleep (although does not discriminate between non-REM and REM sleep). An example of Rich Wilson's sleep patterns during the Transat race are shown in Figure 2. The race commenced on May 31 and Rich had a halyard issue that night and achieved no sleep. Subsequently he rapidly established a good polyphasic sleep schedule consisting of short naps, often in the afternoon and longer periods of about 90 minutes of sleep during the nighttime.*

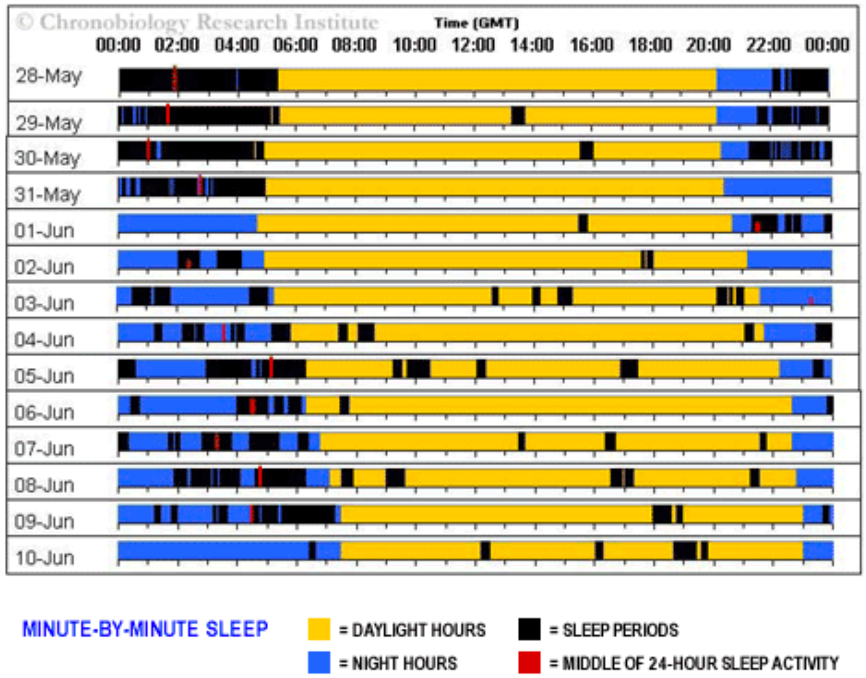

Figure 2: Sleep periods while sailing. Black marks represent when Rich Wilson slept. The width of each bar represents the duration of the sleep epoch. Note the presence of clusters of short naps as well as periods of longer duration sleep. (Rich Wilson's Sleep Patterns prior to and during the Transat Race https://www.sitesalive.com/ocl/private/04s/sleep/slp040608.html)

Many of us may have taken an afternoon nap and find that after waking one feels incredibly groggy. This is likely because you have napped for too long! As discussed previously, there are several stages of non-REM sleep in one sleep cycle and each period of non-REM sleep gets deeper and deeper and more difficult to be aroused from. Thus, if one takes a brief 20-minute nap one achieves the restorative effects of sleeping but you don't enter into a deep enough sleep to be groggy when you're awoken. <u>Appreciating that short naps are restorative and that you can wake quickly from them is a key ingredient in solo offshore sailing</u>. Thus, one can nap, wake after 20 minutes, have a lookout for other vessels and check sail trim, then immediately take another 20-minute nap should conditions permit. Like the first nap, this second will be light which is also easy to be aroused from since the sleep cycle will have been reset by the brief waking period. If you lie down for a 20 min nap, and something awakens you early, such as a change in motion of the boat, you should get up and deal with whatever it is, then, assuming conditions permit, lay back down and start the 20 min clock again. If you look at Rich's napping schedule you can see several clusters of short naps especially during daytime.

Hallucinations can be a problem for those who are sleeping in these 20 minute naps. A full cycle of sleep, with several non-REM stages and a period of REM sleep, is essential for preventing hallucinations. Some people can exist on just the 20-minute naps, but others, including myself, do need an occasional full 90-minute sleep cycle to obtain REM sleep in order to prevent hallucinations.

Each person's brain is different and while some can and do only exist on 20-minute naps, others find 30 minutes works better for them. So, the 20 and 90 recommendations are a guideline, and one needs to determine for oneself the durations that work best for you. Do you need 90 minutes to achieve REM sleep? What duration of short naps works best for you?

Regulators of wake/sleep: coordination between the circadian rhythm and sleep homeostat: *We have two major sleep regulatory mechanisms that control wakefulness and sleep: the circadian rhythm and the sleep homeostat, which are each controlled by independent brain circuits. These two mechanisms are referred to as process C and process S, respectively (Figure 3). The circadian rhythm is an intrinsic clock that recurs naturally on a twenty-four-hour cycle, even in the absence of light fluctuations: during the daytime the circadian rhythm is promoting wakefulness but during nighttime its ability to stimulate wakefulness declines. This is why we normally sleep during the nighttime. As a side note, the circadian oscillator of nocturnal animals promotes wakefulness during the dark period that we refer to as nighttime. In addition to the circadian rhythm is the sleep homeostat which tracks the amount of time that we are awake, regardless of whether it's in the day or nighttime. As the homeostat measures more accumulated wakefulness it provides a pressure or drive for the brain to enter sleep. Imagine the homeostat is similar to a balloon: as we stay awake air is filling the balloon and the balloon is getting bigger and bigger and the pressure for the air to come out (sleep pressure) is increasing.*

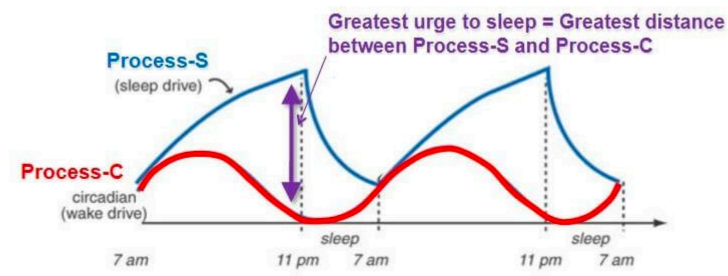

Figure 3: Sleep is regulated by two processes, a circadian rhythm (process C) and a sleep homeostat (process S). The longer one is awake the more the sleep homeostat provides a pressure or drive to sleep. The circadian rhythm promotes wakefulness during the daytime. The greater the separation between the two curves the greater the urge to sleep. Here sleep occurs between 11pm and 7am. During that period the sleep drive by Process S declines (air is being let out of the balloon while sleeping). At 7am Process C is promoting wakefulness and Process S provides little sleep drive, together promoting wakefulness.

If we consider our normal daily activity, we are awake during the day when the circadian rhythm is promoting wakefulness, and the sleep homeostatic is detecting that we are awake. Then as the wake promoting effect of the circadian rhythm declines the "pressure" in the sleep homeostat increases and is trying to push us to sleep because we've been awake for many hours. Therefore, it's easier to fall asleep at night rather than during the daytime: The rhythm and homeostat are both supporting sleep. If, however we stay up late, for example till 3am, the sleep homeostat will have detected that we have been awake for a very long period of time and will provide a greater pressure to go to sleep. Therefore, the latency to go to sleep will be very short if we don't sleep until 3am rather than our normal 10pm.

Imagine the scenario where we stay awake all night, pulling an all-nighter, so to speak. Our sleep homeostat will have integrated all of that daytime and nighttime wakefulness and will be wanting to push us to sleep but our circadian rhythm will now be trying to wake us. If we stay awake all night and now want to go to sleep at 10am, it's more difficult than at night because of the opposition of the *circadian rhythm and the homeostat: the circadian rhythm wants us to wake while the homeostat wants us to sleep.*

A critical feature of the sleep homeostat is that even a short nap will reduce the pressure to sleep. Returning to the balloon analogy: as we stay awake air is filling the balloon and the balloon is getting bigger and bigger and the pressure for the air to come out (sleep pressure) is increasing. But if we now sleep for 20 minutes this allows some of the air to come out of the balloon and reduce its pressure. Therefore, by alternating brief naps with brief periods of wakefulness we can reduce the overall pressure that is in that balloon – understanding this is the key to napping and sailing solo. Our circadian oscillator will always be trying to promote wakefulness during the day and not at night, but we can manage the pressure to sleep by taking short naps and releasing a little air out of the sleep pressure balloon. A longer nap would allow more air to come out of the balloon. However, it's important to remember that with a longer sleep one will get into a deep sleep and then it will be very difficult to wake up, unless a full sleep cycle of non-REM and REM sleep can be achieved.

Equipped with this knowledge we're now able to develop the method to sleep while sailing solo. We know there are times in the 24h day where it's harder to sleep because the circadian oscillator (process C) is stimulating wakefulness. And we know the short naps reduce the pressure to sleep or let air out of the balloon. Mini transat sailors documented when they took naps. In Figure 4 you can see that the frequency or propensity with which the napping occurred was greatest at night and then by early morning napping decreased. Also note there's a small window of time, around 2pm in the afternoon, where one can take naps. Then in the evening around 8pm the ability to sleep again increases. Armed with this knowledge one is then able to plan the 24 hour day of when you will be most vigilant and when to perform tasks. At 8am and 6pm you will be quite alert, and this is a good time to do a full system check of your boat. This of course assumes that the need for sail changes and the timing of squalls doesn't interfere with your schedule. Regardless, one can develop a framework of when to nap and wake.

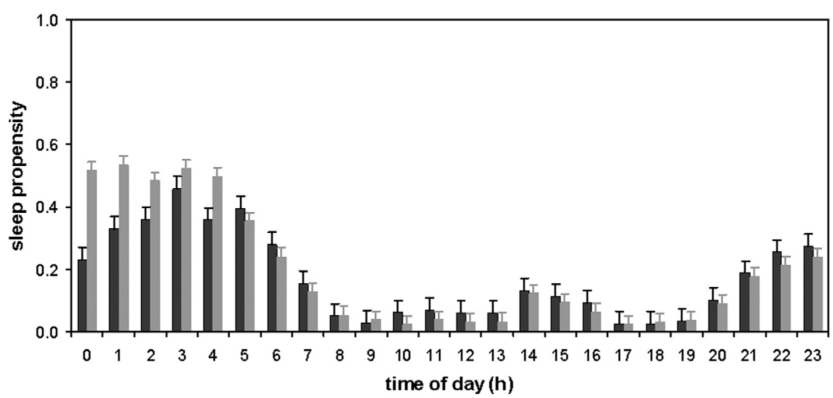

Figure 4: Sleep propensity by time of day. Means (and standard errors) for the fraction of sleep observed in each 1hr block are shown as a function of time of day for the first leg (black) and the second leg (gray). From Hurdiel et al 2012 Sleep and Biological Rhythms 10: 270–277

Caffeine – good or bad, that is the question? *Many of us find caffeine to be very helpful by causing us to stay awake. However, <u>by promoting wakefulness, caffeine is preventing the restorative consequences of taking naps</u>. Caffeine only provides a short-term gain in alertness. When we are awake the signal that is* *being released in the brain that promotes sleep pressure is called adenosine. Caffeine prevents adenosine from acting on its receptor. Adenosine is still being released; caffeine is just blocking its short term effects. Thus, if there is significant reason to be awake during a normal nap period, caffeine is fine: it will help you stay awake, but the effects of sleep deprivation will not be prevented. Since the half-life of caffeine in the body is about 4 hours, it may be difficult to get to sleep for an extended time period thereafter.*

When I sail, I use caffeine in the morning and stop any caffeine intake by noon. Therefore, the evening and night hours are caffeine free to increase the chance of taking restorative naps.

Are there long-term consequences of polyphasic sleep? *The short answer is yes. However, studies are few and far between and today it would be difficult with current regulatory processes to get more studies approved. Although polyphasic sleep allows us to maintain a lookout while gaining restorative effects of brief naps it is becoming clearer that long term use of polyphasic sleep is not necessarily a good strategy for life. By way of one example, Stampi conducted individual subject sleep experiments in which he controlled polyphasic sleep. The subject was allowed to sleep for short naps for a total of 3h per day for 2 months. After waking, the subject had cognitive tests to perform. With polyphasic sleep they performed surprising well. However, an area that showed deterioration was in the ability to wake from their naps after this prolonged period of polyphasic sleep despite loud alarms. Sleep pressure was preventing them from waking (an alarming example can be seen in this YouTube video made by Stampi - watch between 08:25 and 09:30 for the inability to wake). Is this why there are examples of solo sailors who have crashed onto the rocks, run aground, or hit other vessels near the end of long races? Or was it that their alarms failed as they claim?*

Sleep while sailing solo offshore - summary

Sleep consists of several phases. When we fall to sleep, there are several 20 minute stages of non-rapid eye movement (non-REM) sleep: in each phase of non-REM sleep the sleep gets deeper and harder to wake from, until one enters into rapid eye movement (REM) sleep which lasts for about 10 minutes. REM sleep is where we dream. Without REM sleep we start to hallucinate and this can occur in two forms, both audio (hear people talking to you, for example) and visual (I have seen a motor launch tie up to my boat 100nm offshore). I have suffered both without sufficient and appropriate types of napping.

Thus, doing the math, about 80 minutes of NREM sleep is required to achieve REM sleep. A total of about 90 minutes is required to achieve REM sleep and a full sleep cycle. This is the basis for the sleep patterns I use while sailing offshore.

20 minute naps – allows restorative effects of sleep to be achieved, but to sleep lightly enough that one can wake and easily do tasks such as a quick lookout and check sails. I normally set an alarm for 25 minutes, to give me time to get into NREM sleep.

90 minute naps – not everyone needs a 90 minute nap. I do otherwise I have wild hallucinations. I set an alarm for 100 minutes to allow me to get to sleep and to ensure that I get through a full sleep cycle. I *often use biofeedback to control when I take a longer nap. I might notice an audio or small visual hallucination. I use this to alert me to the need of a 90 minute nap.*

Depending on conditions and activities you need to perform, if you can, go straight back to sleep after waking from a 20 minute nap and having a look around. Two short naps are better than one and will let more air out of the homeostat balloon without entering into deep sleep.

***The first day of the B1-2 is different.** On the first day of the solo race the adrenaline is flowing. We have been preparing for this race for a long time. This makes an afternoon nap difficult. However, remember that the race is a marathon not a sprint. Thus, any rest you can get now could pay dividends on the last day of the race. I will take at least one afternoon rest, with the hope that I can nap, on the first race day. In the first 24h of the race there is likely to be significant sea traffic with other race boats nearby as well as fishing vessels since one will not yet have left the continental shelf. Thus, it is not prudent to try to get a 90-minute nap especially since some of the sea traffic will not be using AIS.*

Additionally, rest in preparation for the end of the race. As one gets closer to the finish, the density of fishing vessels will increase. Make sure you have some sleep credit for when you get close to shore again. Also, even with the same sleep credit, if you are approaching the finish at night, it will be more difficult to stay awake and alert than during the daytime due to your circadian rhythm promoting wakefulness only during daytime. One of our B1-2 skippers recounted to me their experience near the end of the return leg to Newport from Bermuda which reinforces the importance of getting sleep credit: "on the return leg I was blithely confident about arriving at Brenton Reef in the early evening, so much so that I didn't bother to sleep much during the day; but of course, the wind shifted, slowed my VMG dramatically, and I paid the price by sleepwalking at 2 AM."

It is my hope that by providing an understanding of the brain control processes that regulate wakefulness and sleep that it will enable you to prepare a sleep/nap strategy. All of this theory being said, there will be times when you are tired, and if the conditions permit, take a nap! As I believe Claudio Stampi would say "If the sleep train comes to the station, hop aboard."

Some articles about Sleep

Claudio Stampi *Wikipedia entry*

Sleep Performance and Public Safety

Sleep deprivation accidents and disasters:

Sleep Engineering Offshore – an article that discusses the use of accelerometers to monitor sleep/wake of Dame Ellen MacArthur while sailing

Acknowledgments: *I am grateful for comments on this article and to many discussions about sleep and sailing with Joe Cooper, Peter Becker, Rick Rohrer and Lauren Zike. My research on Sleep is supported by grants from the National Institutes of Health.*