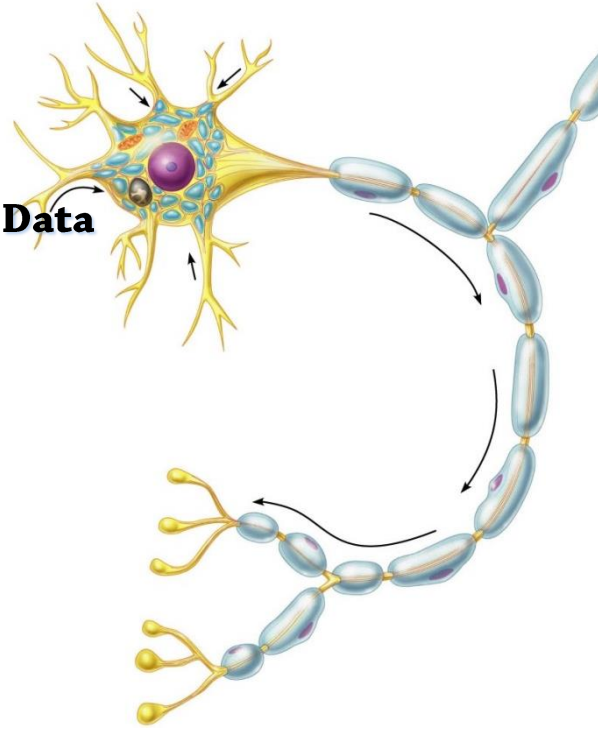
MOOC: Exploring Neural Data
Final Project



Contents

1 Description Of The Data

The data of this project were taken from the Sleep EEG Data Project, conducted by Dr. Mary Carskadon. The dataset is consisted of two sleep nights from each one of the four subjects that took part in the experiment. One of the sleep nights is considered the baseline sleep and the other one the recovery sleep, where the subject is actually recovering following sleep deprivation.

Brain signaling was recorded through 4 EEG channels, positioned based on the 10-20 EEG System, 2 EOG Channels and 3 EMG Channels. The whole data set was saved in a two dimensional array (where rows serve as channels and columns as samples of the signal).

2 Hypotheses

Sleep is the default state of the brain – default in the sense that it develops self-organized or spontaneous state without an external supervisor. During sleep stages, oscillations temporarily stabilize brain dynamics. The neurons' spiking content of these stages should be predictable from the initiating conditions owing to the deterministic nature of oscillations. Perturbation of the spiking patterns by events that occur during a waking experience may change the initiating conditions and, therefore, the content of spiking patterns during sleep [1].

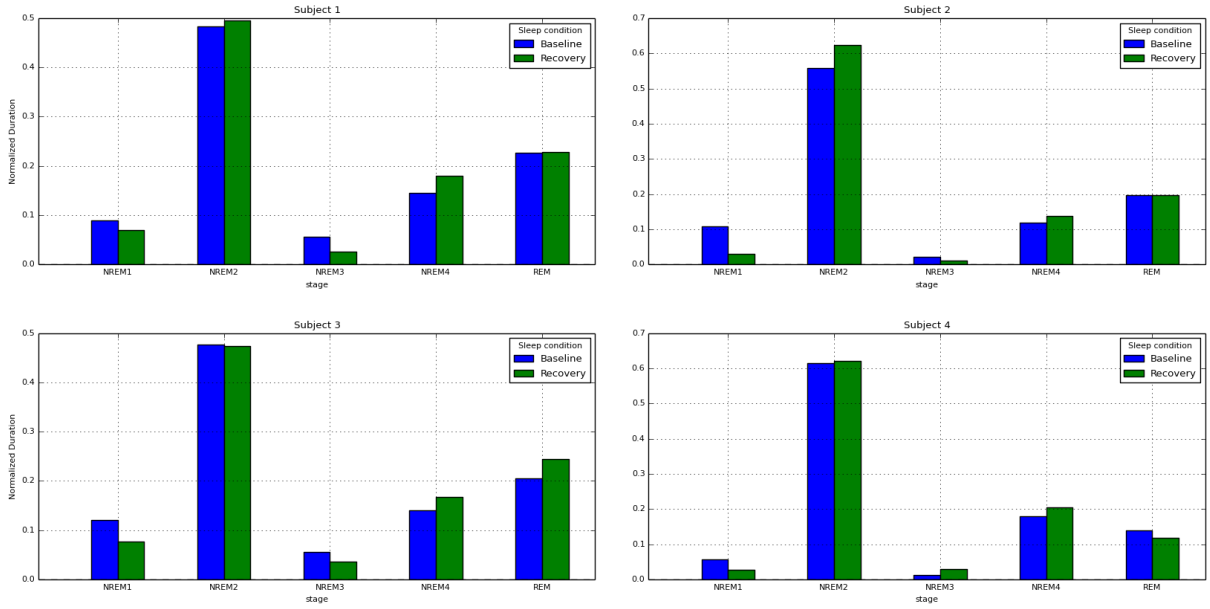
According to the above statement, the first question I formed had to do with how the brain would reflect its effort to recover from the fatigue of its previous day. If it is true that the waking experiences of a person serve as initial conditions for the content of her dream, then a day with a good night's sleep as opposed to a day with a total lack of sleep would impact in a different way on the mechanism of sleep.

During different stages, different frequency bands – known as brain rhythms – are dominant (i.e. occur more often). We still don't know in a precise way how different brain rhythms actually affect the brain and what is their role in its functioning, but what if some rhythms were more apparent during a recovery sleep, as it was characterized in the previous section, compared to their appearance in the baseline sleep? Accordingly, the sleep stages that are mainly consisted by these rhythms should be more dominant during the sleep of a person who is recovering from loss of sleep. Thus, my first formed hypothesis was: If some sleep stages help a person to recover and stabilize her brain dynamics, then the duration of these stages should be larger related to the duration of the same rhythms during baseline sleep. In a sense, my first purpose is to explore how the overall duration of each stage is different between the two kinds of sleep.

But even if the subject is passing the same overall amount of time in each stage during the night, does this mean that the coordination between the different stages throughout the night doesn't play any role in the process of healing? Or even more, that this coordination couldn't be destructed because of the initial conditions fed to it with respect to the baseline sleep. Consequently, the second part of my hypothesis had as a goal the further investigation of how sleep stages succeeded one another with focus on the change that sleep deprivation would bring to this sequence.

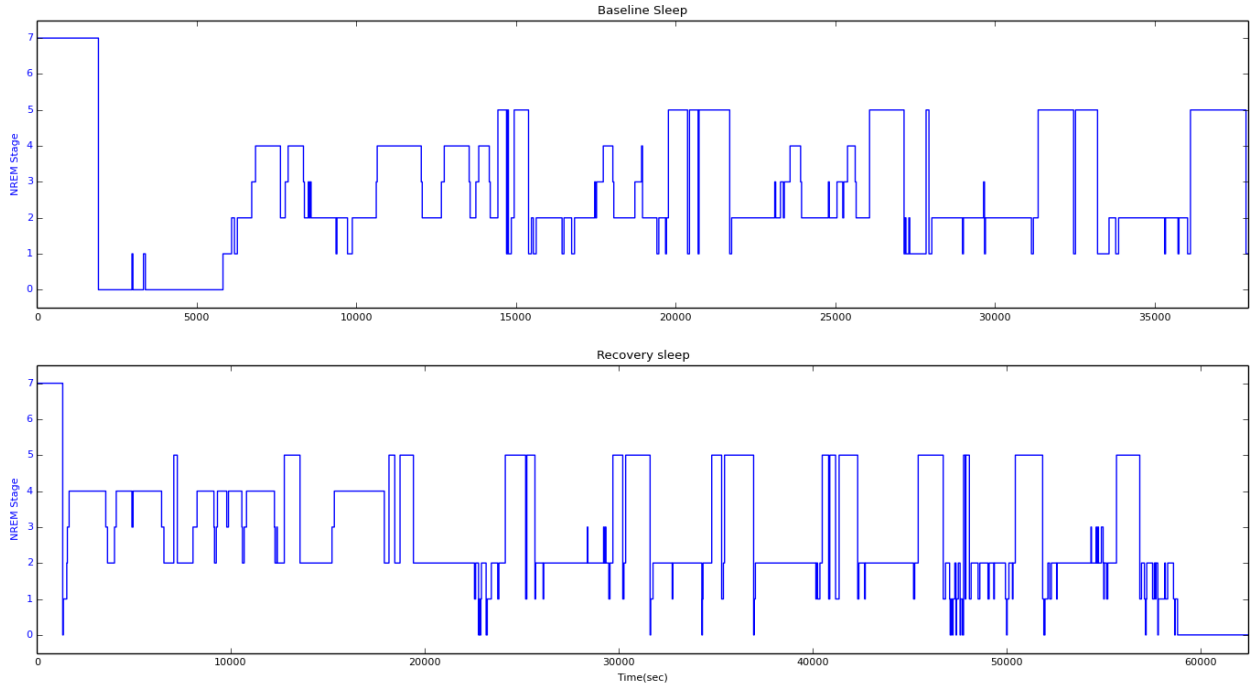
3 Findings

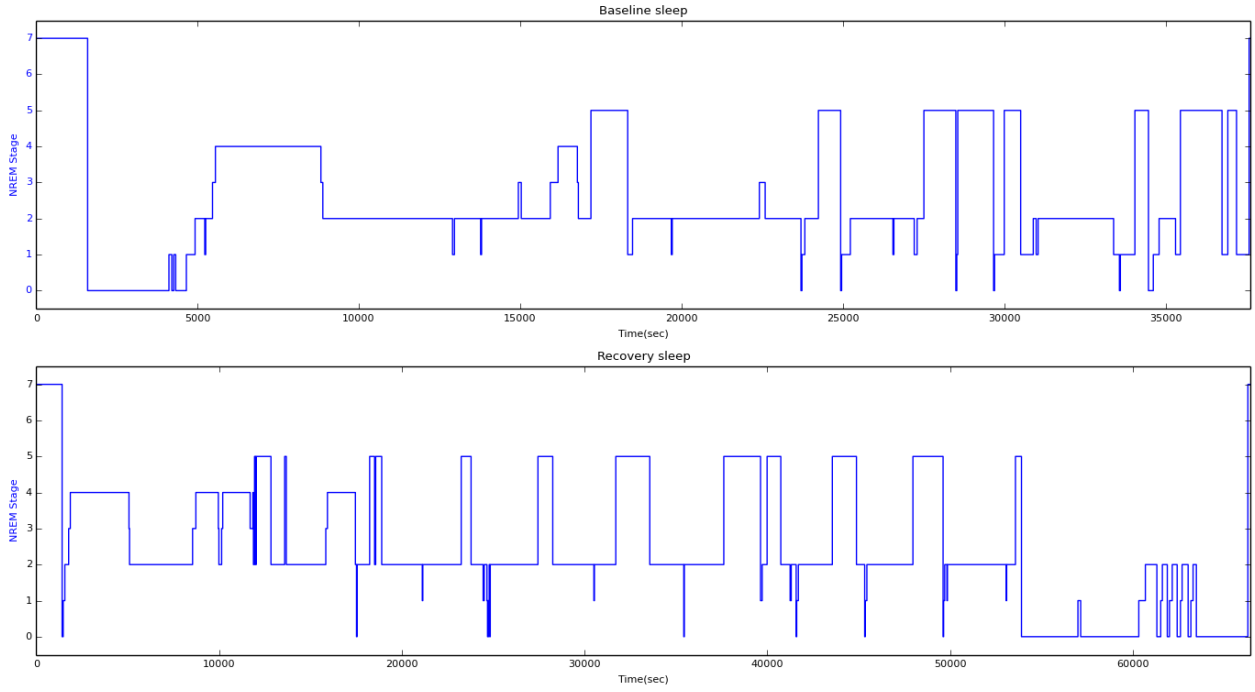
The first part of my hypothesis required a clear way that could help to easily contrast the duration of each stage during one sleep night with this of the other night. As the duration of each sleep night wasn't the same neither for each subject with relevance to the others nor for the same subject between her two different sleep stages, normalization of the duration for each stage of the data samples was necessary. According to the former notice, the following histogram was constructed.

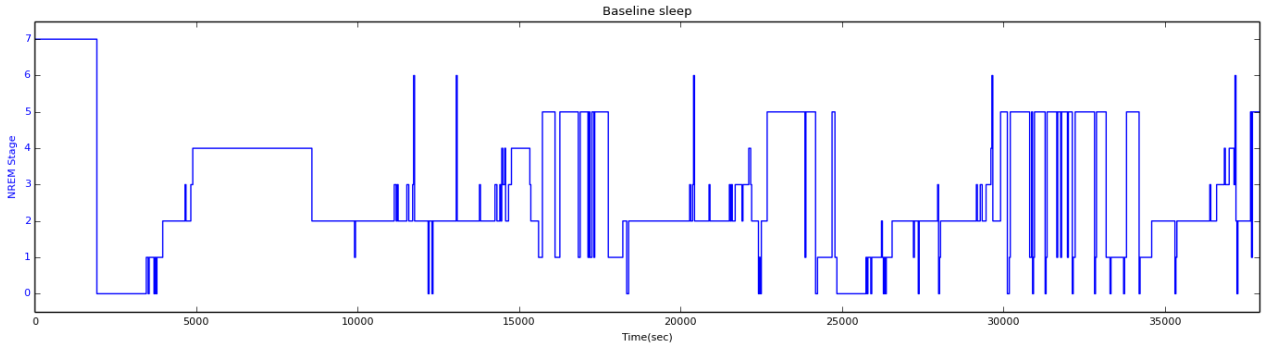


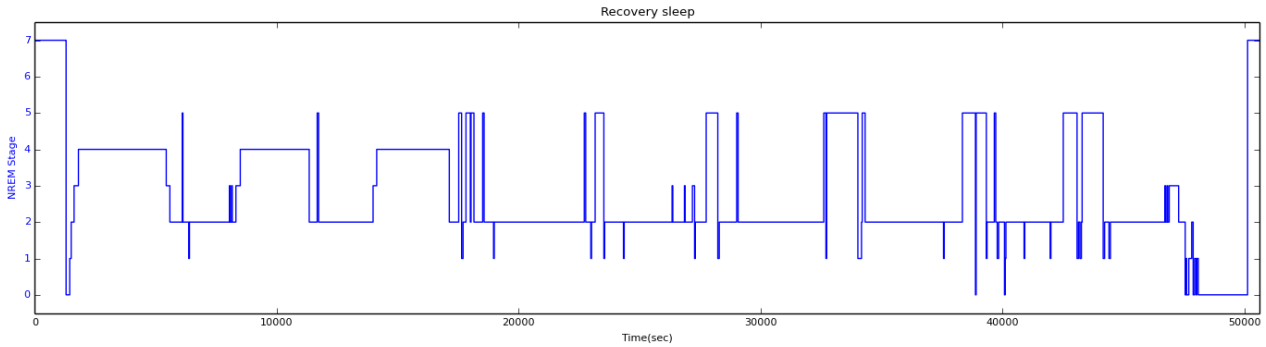
At first glance, no serious increase or decrease is happening to any of the sleep stages. Nevertheless, it is noticed that the duration of NREM stage 2 stays at around the same level or slightly increases and also the duration of NREM stage 4 increases for all the subjects. Whereas the exact opposite is happening for the NREM stages 1 and 4, as the duration of each one of those is decreased during the recovery night(with the exception of subject 4 for stage 3). Opposingly, NREM stage shows no obvious pattern in order for someone to argue that the brain is trying to compensate for the previous night's lost sleep through this stage.

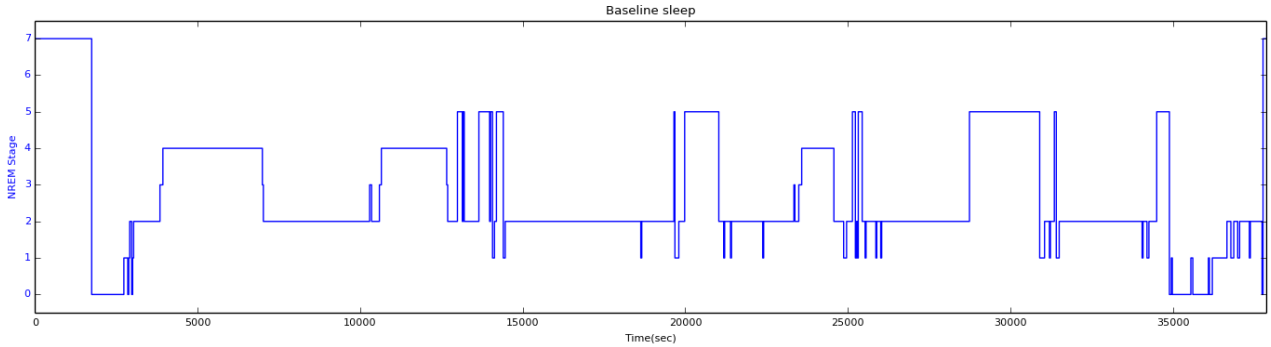
For the second part of my hypothesis, I had to present the sequence of sleep stages throughout the night for each subject. The best way to do this was proved to be a hypnogram, where seven stages of sleep appear (according to researchers' description of the experiment). These are 0=awake, 1=NREM Stage 1, 2=NREM Stage 2, 3=NREM Stage 3, 4=NREM Stage 4, 5=REM, 6=Movement time, 7=Unscored. Below, a hypnogram for each subject, starting with the first, is presented for both of her kinds of sleep.

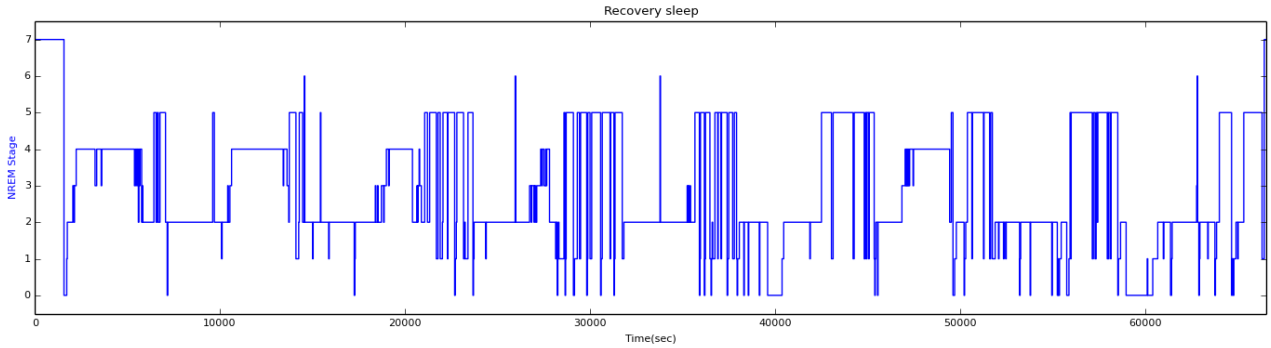

Baseline Sleep
NREM Stage
0
1
2
3
4
5
6
7
0
5000
10000
15000
20000
25000
30000
35000
Recovery sleep
NREM Stage
0
1
2
3
4
5
6
7
0
10000
20000
30000
40000
50000
60000
Time(sec)


Baseline sleep
NREM Stage
0
1
2
3
4
5
6
7
0
5000
10000
15000
20000
25000
30000
35000
Time(sec)
Recovery sleep
NREM Stage
0
1
2
3
4
5
6
7
0
10000
20000
30000
40000
50000
60000
Time(sec)


Baseline sleep
NREM Stage
Time(sec)


Recovery sleep
NREM Stage
Time(sec)


Baseline sleep
NREM Stage
Time(sec)


Recovery sleep
NREM Stage
Time(sec)

In the above plots, there are some easily distinguished and expected things to notice. First of all, the subjects are more easily asleep and also much more easily destructed during their sleep (periods of awakening or movement) in their recovery night. Another interesting point is that all of them are reaching to REM stage much earlier during the night than they would in the normal sleep.

With reference though to the hypothesis that was made in the previous section, the following observation was made: Even though the amount of time spent in each stage is relatively the same between the two nights, it's easy to see that the subjects can't stay for too long in each stage during their recovery night. Each stage, and more evidently, the REM Stage is much more fragmented than the corresponding one in the baseline sleep which can lead to the next question, that of causality discussed in the follow-up analysis (see section 5).

4 Programming Tricks and Challenges

During the present project I managed to get more in depth with the PANDAS Python library. I was able to organize my data in ways that plots and histograms, like the one posted here, could easily be extracted from them without the need of reconfiguring my plot each time. For example, naming the columns and having indices in my dataframe causes the plot to grab information from it in order to create the necessary legend and x label without any additional input from me, which is quite useful when you need to store something in a way that you can try new ways of plotting it without having to indicate again what is being plotted.

The biggest challenge I faced during the exploring of the data was mainly my philosophical approach of facing a problem because of my programming background. I am used to taking into consideration all the restrictions and attributes of a problem before I start digging more into it, which in the case of brain data is simply not possible. I had to eliminate at first a lot of variables and stay with the few ones that I needed in order to experiment the hypothesis I had set. I realized that this kind of research and problem solving requires small, if not tiny, steps unless you want to get lost in your head or even worse get biased by conventions you accidentally make in order to cope with all the kind of questions that are being created during the process of thinking. I managed to stay low at my expectations and see what I can do with the tools I had at the moment. Hopefully, these tools will become more and more as the time goes by.

5 Follow-up Analysis

As a result of the previous observations and conclusions into which I reached, new questions were formed. First, it is a question based on the finding that the same subject can't stay for that long under a specific sleep stage during recovery night. On the contrary, subject seems to change quickly from one stage to the other. That finding occurred because of the hypothesis that was involved: What if a specific sleep stage is responsible for the recovery process? The result was that none of the known stages seems to be dominant in order to be regarded as vital for the specific process, but what arises from that is the following: Is this quick alteration of the sleep stages a consequence of the lost equilibrium of the brain or a way for it to gain back its lost equilibrium. I realize that this is a complex problem, as it involves questions of causality which inside the brain can be proved quite tricky, but it would be nice to consider the

possibility that the brain actually loses its stability and brings chaos into its oscillations in order to bring back the order [3].

Another question, that occurred during the present project, or a different approach to find out which stage maybe plays a more important role during the recovery night would be how the amplitude of signals in the frequency domain is changing between the two kinds of sleep. Maybe some stages could require more neurons to fire, so as to have bigger amplitude as a result of the bigger cluster. In this way, a conclusion could be reached about if and in which sleep stages the brain has to try harder and even more, in which areas it has to do it.

6 References

[1] Rhythms of the Brain – György Buzsáki – Oxford University Press – 2006

[2] Python for Data Analysis – Wes McKinney – O'Reilly Media 2012

[3] Antifragile: Things that gain from disorder – Nassim Nicholas Taleb – Random House – 2014