Generating Predictions during sleep

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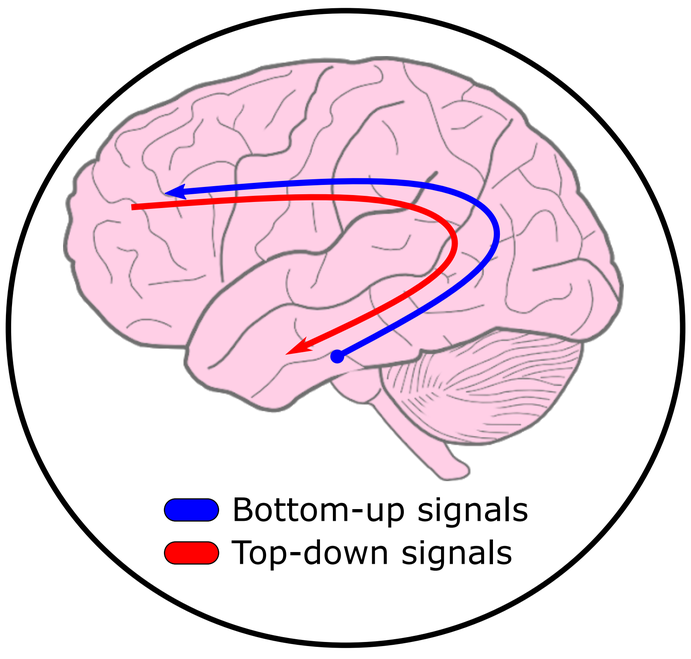
If I say the word "Sleep" 2 consecutive times and then ask you to guess what would be my next word, you would probably say "Sleep". If I repeat the word 3 times then ask what would be my next word, you would be even more sure that the word is going to be "Sleep".

If you did say sleep, then you were able to use your memory to anticipate my behavior. But how did you do that? and why?

The HOW

As our cortex is hierarchically organized, information flow inside our brain in two main directions:

1) Bottom-up: as sensory stimuli (i.e. sounds) travel from primary sensory areas where low-level processing occurs to higher cortical areas where they undergo more abstract levels of processing. 2) Top-down: as our past experieneces that are stored as memories travel to lower cortical areas as predictions providing conceptual contexts.



The WHY

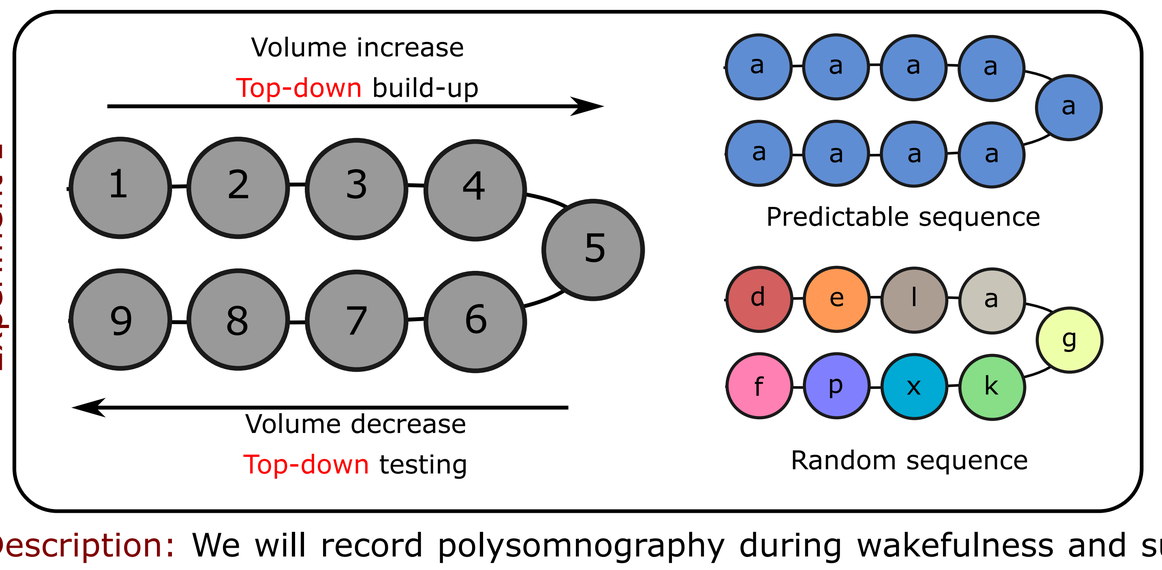
In order to process sensory information as efficiently and accurately as possible, our brain uses the knowledge (memories of past experiences) it has collected to generate (top-down) predictions to anticipate and explain sensory stimuli from the surrounding environment (i.e. bottm-up sensory signals). By doing this, the brain reduces its enegry consumption as well as time required to make sense of, and respond to sensory stimuli.[1,2]

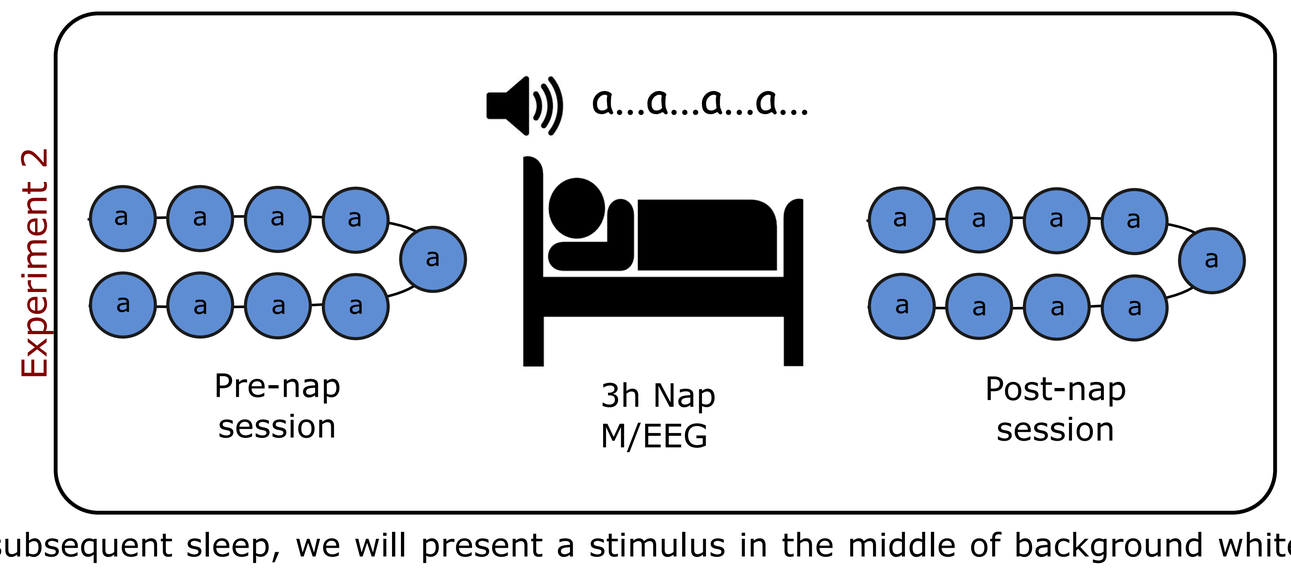
The QUESTION: What happens when we go to Sleep?

Recent evidence has shown that we not only remain aware of our surrounding when asleep, but also process external sensory information during all sleep stages[3,4,5]. However, there is no evidence so far for top-down signalling nor for the mechanism of information processing during sleep.

Research question: Does the sleeping brain generate top-down predictions? What is the functional significance of top-down signalling during sleep?

The EXPERIMENT





Description: We will record polysomnography during wakefulness and subsequent sleep, we will present a stimulus in the middle of background white noise. While the volume of the white noise is always constant, the volume of the stimulus (bottom-up signals) increases gradually (1-4) till maximum clarity (5), then decreases gradually (6-9). This allow us to measure brain activity during the build up of top-down predictions as well as their utilization at low levels of bottom-up sensory signals. We will use the same stimulus (predictable sequence) or different stimuli (Random sequence) to disentangle true predictions from spurious brain processes. Then, in a second experiment we will show that generating top-down signals during sleep influences ongoing memory processes to optimize performance (faster generation of more accurate predictions) upon awakening.

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Significance: Our results will provide empirical evidence for top-down processing during sleep and its significance as well as provide insights on the mechanism of information processing durng sleep as compared to wakefulness.

1) Bar, M. (2009). The proactive brain: memory for predictions. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1521), 1235-1243. 2) Friston, K. (2010). The free-energy principle: a unified brain theory? Nature Reviews Neuroscience, 11(2), 127. 3) Blume, C., Del Giudice, R., Wislowska, M., Heib, D. P. J., & Schabus, M. (2018). Standing sentinel during human sleep: Continued evaluation of environmental stimuli in the absence of consciousness. NeuroImage, 178, 638–648. https://doi.org/10.1016/j.neuroimage.2018.05.056. 4) Legendre, G., Andrillon, T., Koroma, M., & Kouider, S. (2019). Sleepers track informative speech in a multitalker environment. Nature Human Behaviour, 3(3), 274–283. https://doi.org/10.1038/s41562-018-0502-5. 5) Perrault, A. A., Khani, A., Quairiaux, C., Kompotis, K., Franken, P., Muhlethaler, M., Schwartz, S., & Bayer, L. (2019). Whole-Night Continuous Rocking Entrains Spontaneous Neural Oscillations with Benefits for Sleep and Memory. Current Biology, 29(3), 402-411.e3. https://doi.org/10.1016/j.cub.2018.12.028