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Memory Replay of the Day

Memory studies performed in rats have shown that the sequence of neuronal firing in the hippocampus while the animal is learning a new task or experience is later also seen during sleep. When rat hippocampal neuron recordings are done in slow wave sleep, the same sequence of neuron firing is activated in a time compressed manner.[1] This can loosely be thought of as a compressed memory file uploading to the cortex of the brain. As a result, the temporary storage of the memory trace is now ready to process and link to other related memories.

This pattern of events has been seen in rats running on a wheel for the first time. The firing pattern seen during wheel running associated with the theta frequency in the hippocampus, is then later seen in embedded in the slower frequency of slow wave sleep, and not surprisingly, again seen during REM sleep.[2] This repeat firing of the same pattern during REM sleep as what was seen in slow wave sleep has also been confirmed in several other studies.[3] The pattern seen during sleep is then again replayed the following day during the same behavior as the rat is honing its skills.[4]

This process has not only been witnessed in rats running wheels and mazes but has also been seen in singing birds. In the song patterns of zebra finches, the firing patterns occur in the frontal lobe in an area that is roughly equivalent to the area that controls speech in our brains. The firing pattern during sleep closely resembles the pattern of activity present in the singing bird.[5]

These sequences or patterns of neuronal firing do not simply represent a snap shot of memory. These are memories that last several to many seconds in duration and are therefore memories that persist and change through time for at least several seconds. These memories are not snapshots but are more like movie trailers. They are experienced during the day and replayed during sleep.

Interestingly, the initial firing pattern seen during learning and then later during sleep are slightly different from the pattern seen during the sleep experienced prior to the learning event. The novelty affects only a part of the neuronal population responsible for the changes in the firing pattern.[6] In other words, it is likely that some of the things in the environment seen during learning were similar to things that the rat had already known. After all, it is learning this "new environment" in the same room, in the same cage, eating the same reward food, breathing the same air, etc. and only a few things are really different. It is presumed that the variations in the new firing pattern represent what is now different about the new environment. When the environment does not change for the rat from day to day, the firing sequences of neurons during sleep remain stable.[7]

A very interesting study of firing patterns of neurons in both the visual cortex and hippocampus during slow-wave sleep in rats found that spiking patterns not only in the cortex but also in the hippocampus were organized into frames. These can loosely be thought of as the frames of the movie trailer version of the memory. The firing sequences seen in these neurons during the waking experience of the rat were replayed during these frames in both the visual cortex and the hippocampus. Replay of these sequences during sleep in the sensory cortex and hippocampus were coordinated to reflect the same experience. The authors concluded that these results imply simultaneous reactivation of coherent memory traces in the cortex and hippocampus during sleep that may contribute to or reflect the result of the memory consolidation process.[8]

These firing sequences are first seen while the animal learns, again during slow wave sleep, and yet again later during REM sleep. At this time rats replay their newly learned experiences of running wheels and mazes and zebra finches replay singing their songs. This is the memory replay of the day.[9]

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