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Tracking the neural footprints of memories in the human brain

Challenge

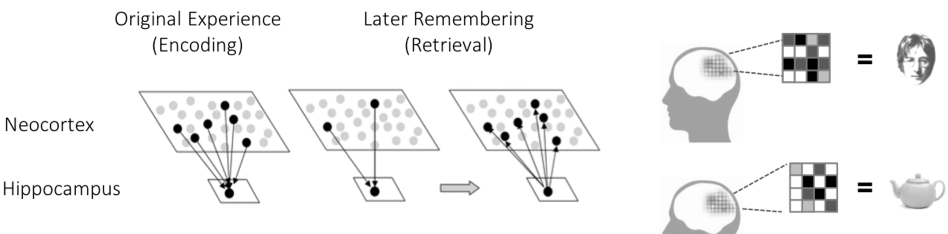
In the Adaptive Memory Lab (led by Dr Maria Wimber), we study how the human brain brings back to mind memories of complex past events. We are particularly interested in how memories are represented in large-scale neural patterns, and how the representation of a unique memory changes over time and with repeated reactivations.

The main challenge for our projects is to isolate those patterns that represent a unique event from the complex, ongoing patterns of human brain activity, and to then track these “neural footprints of memories” over time.

Background

Computational models have long assumed that there are two complementary learning systems in the human brain: a slow-learning neocortex which represents our ongoing experiences; and the fast-learning hippocampus, which continuously stores an index pointing to those experiences in neocortex. When remembering a previously stored event, the hippocampal index can “ping” neocortex and re-instantiate the stored representation of this event.

Recent advances in the use of multivariate neuroimaging methods have made it possible to directly test these models in the human brain. We use electrophysiological (e.g. EEG or MEG) and functional neuroimaging (fMRI) methods to record brain activity while subjects encode new information into memory, and recall this information at a later point in the experiment. We then use machine learning algorithms or representational similarity approaches (RSA) to detect patterns of brain activity that are consistently active when participants see a certain type of stimulus (e.g. John Lennon’s face), and test whether the same patterns are reactivated when participants are later recalling the same stimulus from memory.



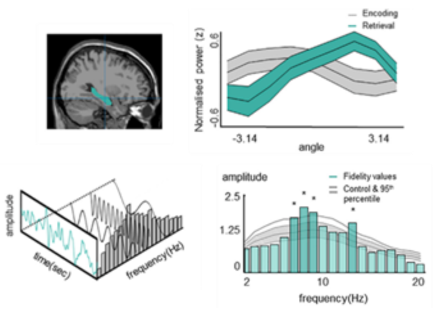
Teyler & DiScenna (1986), McClelland et al. (1995), Alvarez & Squire (1994), Norman & O’Reilly (2003)

Results

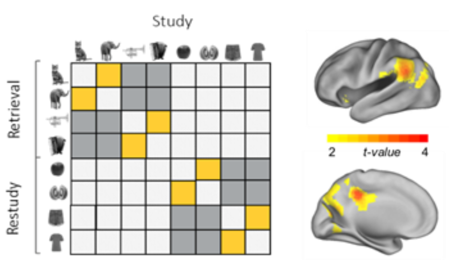
Using these multivariate methods, we demonstrated that it is possible to decode individual event memories from the recorded neural patterns, and to track them over time. Our latest findings show several important characteristics of how, when and where memories are reactivated in the human brain.

For example, we demonstrate that memory reactivation is rhythmic and tightly coupled to the phase of a hippocampal 7-8Hz theta oscillation (Kerrén et al., 2018, Current Biology). We also show that when an event is reconstructed from memory, the fast information flow through the brain is reversed compared to its initial perception (Linde-Domingo et al., in press, Nature Communications). On a slower timescale, we also find that memories adaptively change across repeated reactivations, such that the most relevant information is gradually enhanced over time (Ferreira et al., 2018, bioRxiv), and irrelevant or distracting information is gradually suppressed (Wimber et al., 2015).

Rhythmic fluctuations in memory decoding
(Kerren et al., 2018)



Adaptive changes in memory patterns
(Ferreira et al., 2018)



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Product Used

BEAR Compute
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