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Slow wave sleep oscillations coordinate neural ensembles during memory consolidation.

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The brain routinely integrates polymodal sensory inputs into a coherent representation of events, which is subsequently stored in memory. A long-standing question in neuroscience is how fleeting experiences can modify neural networks to produce memories that are long-lasting, stable, and robust to interference. The advent of new recording technologies allows investigators to monitor and manipulate activity in hundreds or thousands of neurons simultaneously in vivo, during behavior. While this can be used to establish links between neural network activity and brain functions, two issues complicate this endeavor. First, neural activity patterns typically are quantified over milliseconds-to-minutes timescales, while behaviors evolve over longer timescales (seconds, days, or even years). Second, it is not obvious what features of network dynamics constitute a "signal"associated with a specific brain function, vs. "noise"which is irrelevant to that function.The Aton and Zochowski labs have recently developed metrics to characterize how hippocampal network dynamics change as a function of new learning in mice, during active long-term contextual fear memory formation. We have found that after new information is encoded in hippocampal area CA1 (i.e., following one-trial contextual fear conditioning [CFC]), network dynamics in this area become increasingly stable. This can be demonstrated statistically by calculating changes in mean CA1 network stability (from baseline) across a 24-h period following CFC, and compared this with stability changes in animals which either 1) have undergone CFC, but had subsequent memory formation disrupted through brief post-CFC sleep deprivation (SD), or 2) have undergone a sham behavioral procedure instead of CFC (i.e., where no contextual fear memory is expected). We find that mean stability increases with memory formation, that this increase is disrupted (particularly during slow wave sleep [SWS]) following SD, that these changes are sustained for at least 24 h after learning, and that changes to stability during SWS can predict an individual animal's behavioral contextual fear memory recall 24 h after learning. We also find that the same pattern of network connectivity is consistently repeated for several hours during post-CFC SWS. One feature of SWS which makes it unique from other states is the presence of high-amplitude, low frequency network oscillations in various brain regions. Based on experimental data in which SWS network oscillations in either the hippocampus are transiently disrupted (or mimicked in awake animals), we find that network stability is strongly linked to presence of network oscillations. We propose that stabilization of network dynamics by SWS oscillations could serve as a mechanism to promote long-term memory storage.

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