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Spatiotemporal patterns of neocortical activity around hippocampal sharp-wave ripples

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Neocortical-hippocampal interactions during off-line periods such as slow-wave sleep are implicated in memory processing. In particular, recent memory traces are replayed in hippocampus during some sharp-wave ripple (SWR) events, and these replay events are positively correlated with neocortical memory trace reactivation. A prevalent model is that SWR arise 'spontaneously' in CA3 and propagate recent memory 'indices' outward to the neocortex to enable memory consolidation there; however, the spatiotemporal distribution of neocortical activation relative to SWR is incompletely understood. We used wide-field optical imaging to study voltage and glutamate release transients in dorsal neocortex in relation to CA1 multiunit activity (MUA) and SWR of sleeping and urethane anesthetized mice. Modulation of voltage and glutamate release signals in relation to SWRs varied across superficial neocortical regions, and it was largest in posteromedial regions surrounding retrosplenial cortex (RSC), which receives strong hippocampal output connections. Activity tended to spread sequentially from more medial towards more lateral regions. Contrary to the unidirectional hypothesis, activation exhibited a continuum of timing relative to SWRs, varying from neocortex leading to neocortex lagging the SWRs (± ~250 msec). The timing continuum was correlated with the skewness of peri-SWR hippocampal MUA and with a tendency for some SWR to occur in clusters. Thus, contrary to the model in which SWRs arise spontaneously in hippocampus, neocortical activation often precedes SWRs and may thus constitute a trigger event in which neocortical information seeds associative reactivation of hippocampal 'indices'.

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