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Internally Generated Remindings and Hippocampal Recapitulations

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Abstract

A hippocampal phenomenon known as the sharp wave is correlated with a cell firing pattern that recapitulates an earlier cell firing pattern. The earlier cell firing pattern is driven by external stimuli while the recapitulative cell firing arises spontaneously from within the hippocampus. We postulate that the sharp wave associated cell firing that occurs in the awake state provides the basis for several well-known phenomena that involve self remindings. The hypothesis explains the resolution of cognitive impasses by hypothesizing an explicit, localized, internal mechanism that reminds one of an initially unsuccessful memory retrieval. Combining this hypothesis with ideas expressed by others provides a two-fold view of sharp wave associated cell firing: Recapitulative cell firing (1) mediates the consolidation of intermediate hippocampal memory into long-term neocortical memory during slow wave sleep, and (2) drives implicit (unconscious) neocortical reprocessing of unresolved issues.

Introduction

Many cognitive phenomena involve unfinished business, that is, tasks that are unresolved and that one may return to even in the absence of external reminders. These include the Zeigarnik phenomenon, tip-of-the-tongue (TOT) states, incubation effects, self-initiated retrieval in prospective remembering, and reminiscence effects. These phenomena share one notable characteristic: self-initiated remindings appear to restart previously discontinued tasks in such a way that the chances of successful task resolution may be enhanced. The mechanism responsible for reminding one to resume an unresolved task could be cuing from encounters with stimuli associated with the unresolved task, a mechanism rooted in cue-dependent memory theory.

Based on neurophysiological observations in rats, we propose an alternative mechanism. The microscopic electrophysiological event named the *sharp wave* arises spontaneously within the hippocampus during slow wave sleep and when animals perform repetitive motor tasks of great familiarity (e.g., feeding, grooming). Analysis of single cell firing during brief sharp wave events of slow wave sleep reveals a fast playback of cell firing patterns experienced earlier in the day. This earlier cell firing was driven by a novel repetitive task that engaged the hippocampus. The rapid refirings during slow wave sleep are postulated to be the re-teaching of neocortex that leads to long-term memory. The patterned, high speed refiring occurs because of earlier associative modification of excitatory synapses in the hippocampal region CA3 and decreased inhibition in the hippocampus just preceding the sharp wave.

Because sharp wave events are correlated with condensed recapitulations of prior hippocampal activities, such events could serve to remind the neocortex of unresolved issues. Our hypothesis states that engagement in repetitive motor activity will lead to hippocampally produced recapitulations of unresolved questions. These remindings include recapitulations of unresolved TOT states, unsolved problems, and prospective memory reminders. There is a sharp contrast between cuing theories and the hypothesis here. Cuing theories depend upon the introduction of external stimuli to remind the subject of an unresolved impasse; the sharp wave based hypothesis requires no such external cues to remind the subject of the impasse. In fact, sharp wave events appear more likely to occur during informationally impoverished situations (e.g., grooming and eating).

If sharp wave "remindings" occur under stimulus conditions (and neocortical states) different from those in which impasses occurred, then the recapitulated questions will be processed differently. As a result of this difference there is a better chance to resolve the impasses than if remindings recur in the same context previously associated with the impasses.

The internal reminding theory does not rely on related stimuli to reinitiate progress on unresolved questions, and it gives a plausible physiological mechanism for unprompted remindings. It also leads to experimental predictions.For example, it explicitly predicts an electrophysiological correlate of TOT. resolution, and suggests that the probability of such resolutions could be enhanced by biasing behavior for situations that bias for sharp waves in the awake state. This later prediction contrasts with the prediction of cuing theories that rely on remindings externally cued by an information-rich environment.

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