

prefrontal cortex correlate with the size of social group in which individuals were housed. Remarkably, they were also able to demonstrate that, within social groups, there were correlations between the volumes of these same regions and the dominance ranks of individual monkeys.

The Sallet *et al.* results are important for two reasons. First, they confirm that the findings reported for humans apply more generally to other primates, thereby providing a unifying framework for the social brain hypothesis. Second, they suggest that the functional response might actually be quite labile: the fact that cortex volumes vary with housing conditions within the same laboratory colony for animals that were randomly assigned to groups implies considerable phenotypic adaptability, similar to that previously known only for the hippocampus in studies of London taxi drivers [9] and parasitic and caching birds [10].

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New approach illuminates how memory systems switch

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Whereas the classic view of systems consolidation involves an initial hippocampal-dependent memory later giving way to neocortical structures, a recent study using precisely-timed optogenetic silencing of key brain areas reveals a more complex and dynamic interaction between systems competing for control over the expression of contextual fear memories.

Goshen *et al.* recently reported a remarkable ability of the brain to switch between memory strategies when the hippocampus is silenced using optogenetic control [1]. This capacity was revealed in a study on memory consolidation in mice. In the systems consolidation literature, the classic observation is that hippocampal damage impairs recently acquired memories but spares remotely acquired memories [2]. Contrary to this standard, hippocampal silencing that was precisely timed during recall of a remotely acquired contextual fear memory blocked expression of the memory. However, with prolonged silencing for 30 minutes before testing and during the test, the remote fear memory was observed. Taken together, these results suggest that the hippocampus is critical to a memory representation that supports conditioned contextual fear; following consolidation, however, other brain areas that support a distinct and hippocampal-independent representation of that memory are engaged during the pre-recall silencing of the hippocampus.

A large literature supports the view that multiple memory systems compete to mediate a variety of learning performances in animals and humans. For example, learning a simple T-maze choice can be supported either by a hippocampus-dependent ‘place’ strategy, in which animals remember the location of previous reward experiences, or by a striatum-dependent ‘response’ strategy, in which animals learn to repeat reinforced left or right turns at the maze choice point [3]. After extensive training during which both strategies are acquired, lidocaine infused into the striatum just 2-3 minutes prior to the recall test switches memory expression from the turn strategy to the place strategy [3]. Goshen and colleagues’ results extend to contextual fear conditioning the observation that, when the dominant memory system is compromised, the brain can rapidly compensate by directing control to an alternate memory system and this compensation occurs only after consolidation is completed. But, for contextual fear memory, what is the alternate representational strategy and its supporting brain system, and what is the role of consolidation in determining when the alternate strategy emerges?

Fanselow [4] recently reviewed the literature describing paradigmatic conditions under which there are two forms of contextual fear memories, one dependent on and the other independent of hippocampal function. Notably, both forms can be characterized as involving memory for a ‘context’, defined as an integrated representation of multiple environmental stimuli. In other studies, two processes have been suggested to support the integration of

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multiple stimuli into memory representations: configural learning, whereby the perirhinal/postrhinal cortex binds multiple percepts into a unitized representation, and relational learning, whereby the hippocampus associates distinct percepts on the basis of their relevant relations [5]. Furthermore, configural representations and relational representations compete for control of memory expression in perceptual discrimination [5] and recognition memory [6,7]. Notably, remote contextual fear memories also depend upon the perirhinal and postrhinal cortices [8]. Thus, similar to the situation for other types of memory, we suggest that the perirhinal/postrhinal cortex supports configural representations of context, whereas the hippocampus supports relational representations of context, and these systems compete for control of conditioned fear expression via parallel connections with the amygdala.

In the Goshen *et al.* study, when the hippocampal silencing was initiated immediately upon remote recall, activation in the anterior cingulate cortex (ACC) and the basolateral amygdala (as measured by expression of the immediate early gene *c-Fos*) was decreased. Conversely, in the prolonged hippocampal silencing condition, ACC activation was increased. In addition, Goshen *et al.* observed that the ACC is not involved early after learning but becomes critical weeks later. One possibility, consistent with studies indicating a central role for prefrontal areas in resolving conflict between multiple cognitive processes [9], is that the ACC develops a processing scheme during consolidation that mediates the competition between multiple memory systems.

Combining all of these findings, a possible full scenario accounting for the Goshen *et al.* results is that a hippocampus-dependent memory normally predominates in supporting contextual fear expression and this dominant role is normally permanent. Through consolidation, a configural representation of context supported by the perirhinal/postrhinal cortex emerges along with the ACC processing scheme that governs how this configural representation interacts with the relational representation

formed by the hippocampus. After consolidation is complete, hippocampal silencing in the pre-recall period releases the ACC to direct control to the alternate configural memory system.

It is notable that, while the inactivation studies considered here have focused on neural dynamics over the course of minutes, recording studies have recently revealed sub-second switching between representations within a single structure [10]. Perhaps further studies using optogenetic control may be applied to characterize the full circuitry of the systems engaged during learning, the interactions between competitive systems, and the timing of these interactions.

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Attention and consciousness: related yet different

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A recent perceptual imaging experiment uses a rare 2×2 design to dissociate selective visual attention from visual consciousness. Its conclusions support the hypothesis that visual consciousness does not arise from neurons in primary visual cortex and forces a reinterpretation of numerous prior studies.

Many scientists consider the ancient mind-body problem to be the paradigmatic example of a problem that cannot be properly studied using empirical means. A recent paper by Watanabe, Cheng, Murayama, Ueno, Asamizuya, Tanaka and Logothetis [1] demonstrates otherwise. Most researchers closely link attention with awareness (equated here with the contents of conscious experience), arguing that the two always occur together. That is, attending to an object is