Trends in
Cognitive Sciences

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Spotlight

When the Memory System Gets Ahead of Itself

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Humans are adept at learning and exploiting statistical regularities to predict future events from current experience. A recent paper by Sherman and Turk-Browne demonstrates that statistical regularities bias the hippocampus toward representing future states over current experience and reduce the degree to which current experience is encoded into memory.

> 'All his life has he looked away... to the future, to the horizon. Never his mind on where he was … what he was doing.' Yoda

Imagine you are watching a movie with your partner. The film is formulaic, with familiar characters and plot devices. In an effort to impress your partner, you share your predictions for various plot twists. However, your partner admonishes that you should stop trying to predict what will happen next and instead focus on what is happening now. Put another way, whereas you are busy fast-forwarding to the next scene, your partner is focused on recording the current scene. This tension between the movie-watching styles of you and your partner parallels an important tension that the memory system faces: a tension between statistical learning and episodic memory.

Statistical learning refers to learning regularities in the environment that transcend specific examples (Figure 1A). If you are a cinephile, you can draw from past experiences, from regularities in well-tread plots, to predict plot twists in a new movie (e.g., the villain-turned-hero trope; Figure 1B,C). By contrast, episodic memory emphasizes specific instances over generalities: remembering the specific actors or locations that distinguish otherwise similar movies. Although statistical learning and episodic memory are often studied in isolation, a recent paper by Sherman and Turk-Browne [1] tested whether these forms of memory directly compete with each other; that is, whether the very structure that allows you to make predictions about the future disrupts your ability to encode details of present experience.

In a series of human behavioral studies and a separate fMRI study, Sherman and Turk-Browne had subjects view pictures of scenes such as beaches, fields, and forests. Each individual scene was novel, but certain categories of scenes appeared in a predictable sequence (e.g., fields might be consistently followed by beaches). Subjects were not explicitly informed about these sequences, but the researchers expected subjects to implicitly learn the regularities, a hallmark of statistical learning [2]. After viewing the scenes, subjects completed a surprise memory test in which specific scenes were presented and subjects indicated whether they had previously viewed that particular picture (e.g., 'Did you see this field before?'). The critical question was whether scenes that were from a predictive category (e.g., fields) would be less well remembered than scenes from a nonpredictive category (i.e., a category that did not predict the upcoming category). Indeed, the authors found that predictive scenes were less likely to be remembered than were nonpredictive scenes. In other words, when a scene afforded a statistical prediction about the future, it was less likely to be encoded into episodic memory.

These behavioral findings suggest that statistical regularities nudged the memory system toward predicting upcoming scenes at the expense of encoding current scenes (Figure 1B,C). This interpretation was bolstered by findings from the fMRI study. The study focused on the hippocampus, a brain region implicated in both statistical learning and episodic memory [2]. By measuring the activity pattern associated with each category of scenes, Sherman and Turk-Browne discovered something surprising: when viewing a predictive stimulus (e.g., a field), activity patterns in the hippocampus carried information about the upcoming scene category (e.g., beaches) instead of the current scene category. In effect, the hippocampus had already fast-forwarded to the predicted ending. This tendency for the hippocampus to jump ahead to the next scene was also directly related to memory for current experience: subjects who exhibited stronger prediction effects in the hippocampus also exhibited poorer memory for predictive scenes.

Taken together, the findings from Sherman and Turk-Browne paint a compelling picture of a tradeoff between statistical learning and episodic memory encoding. These findings complement prior evidence of competition between episodic memory and other forms of memory [3], but specifically highlight the cost of making predictions about the future. These findings also parallel recent evidence of tradeoffs between episodic memory encoding and episodic memory retrieval [4–6]. Just as statistical regularities may bias the memory system to be forward-looking (i.e., to generate predictions), other factors and experiences may bias the memory system to be backward-looking (i.e., to retrieve memories of past events). In fact, whereas Sherman and Turk-Browne found that the hippocampus was biased toward representing future events over current experience, another recent study found a hippocampal bias to represent past events over current experience [7]. In either case, whether the memory system is looking

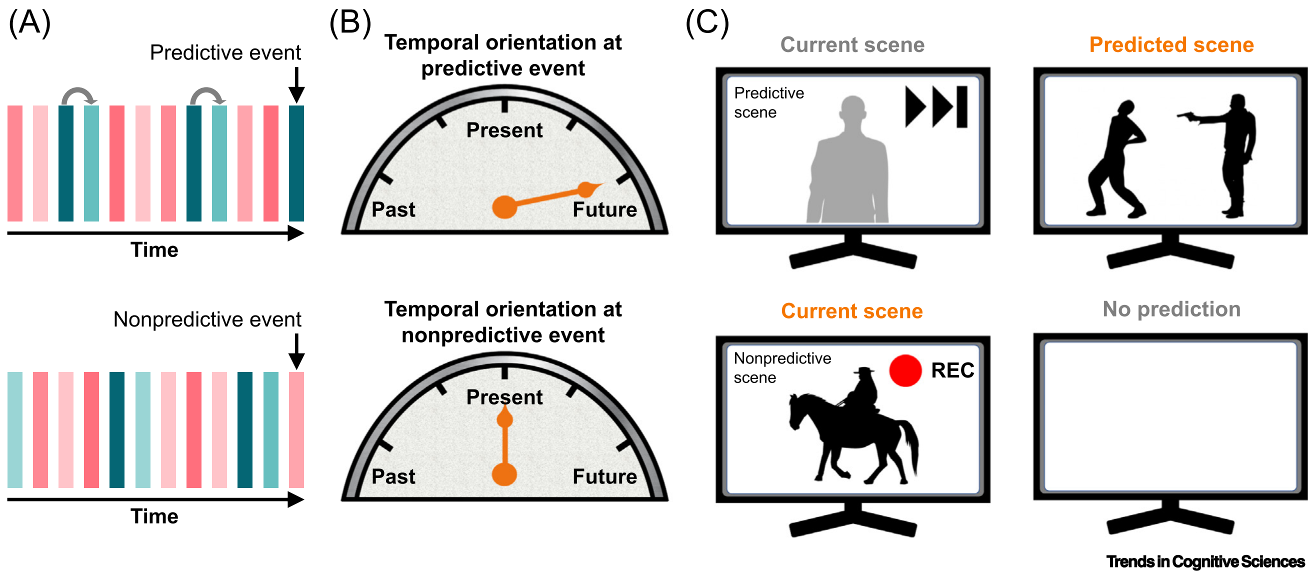

Figure 1. Statistical Regularities Bias the Memory System toward the Future. (A) Schematic representation of statistical regularities. Different color bars represent different categories of events. When categories occur in a regular sequence, this allows for predictions about upcoming categories. (B) Sherman and Turk-Browne show that predictive events bias the memory system toward predicting future states, and away from encoding present experience [1]. (C) When watching a formulaic movie, statistical regularities in the plot may bias the memory system toward generating predictions about (or 'fast-forwarding' to) the upcoming scene. Nonpredictive scenes (bottom) will be associated with better encoding (recording) of current experience.

to the future or to the past, this has the potential to interfere with encoding present experience. More generally, these examples reflect a tradeoff between processing external sensory experience versus processing internal representations (memories or predictions) [8]. Better understanding the environmental and neurobiological factors that govern shifts between external and internal states represents an important and exciting objective for the field [3–8].

One factor not addressed in the studies by Sherman and Turk-Browne is whether episodic memory is influenced by the accuracy of predictions. When predictions are violated (prediction errors), this may influence the receptiveness of the hippocampus to encoding new information [9]. In the studies by Sherman and Turk-Browne, predictive categories were always followed by the same (predicted) category, meaning that prediction errors were not feasible to interrogate. However, another recent study [10] used a reward prediction task (as opposed to a statistical learning paradigm) and found that prediction errors influenced memory for stimuli that were present when error signals were generated, but they did not influence memory for preceding or following stimuli. To the extent that this finding applies to statistical learning, it may be the case that the accuracy of predictions has relatively little influence on episodic memory for predictive events. Rather, impaired episodic encoding of predictive events may be fundamentally explained by a shift of the memory system toward a 'prediction state', and away from an encoding state. To end with our own prediction: future studies will further clarify how regularities in our experiences shape our memories for the details of these experiences.

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