Surprises are mistakes:
An EEG source localization study of prediction errors

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The ability to recognize a familiar sequence, use that sequence to predict future events, and then monitor the prediction’s accuracy comprise core cognitive skills whose neural underpinnings are poorly understood. To characterize neural responses associated with prediction-violating events, we asked subjects to learn novel visuomotor sequences. In this task, subjects viewed a disk that traversed a quasi-random sequence of five linear motion components, and then tried to reproduce the disk’s path from memory.

The fidelity of subjects’ imitations improved over four presentations of each sequence. To create unexpected, prediction-violating stimuli, deviant segments were occasionally inserted into a sequence with which the subject had become familiar. A high-density scalp EEG system examined the difference between signals evoked (i) by an expected, predictable motion component, and (ii) by an unexpected component.

A realistic head model localized sources of neural activity generated as subjects viewed the two types of motion components. Although ventral pre-frontal areas were active throughout viewing of both expected and unexpected segments, the timing and location of other sources differentiated the two. Cerebellar areas were active only during segments whose directions were expected, beginning approximately 150 ms after the disk began to move. In contrast, during unexpected segments, anterior cingulate cortex showed activation, beginning approximately 300 ms after the disk began to move. The time course of such activation may shed light on processes that integrate sensory input with top-down predictions.

Our results suggest that the mechanisms responsible for monitoring the validity of visual predictions for motions in a sequence are similar to those that detect errors in responses, as demonstrated previously in simpler, discrete motor tasks.

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