Modulation of ERP components P3 and N2 during intentional visual sequence learning

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The ability to forge statistical models of the sensory environment and the patterns that arise within it is central to adaptive behavior. This faculty is especially important when intentionally learning the order of a set of relevant events. It has been established that certain components of the human event related potential (ERP) - The N2 and P3 – provide an index of "surprise," or the degree to which a viewed stimulus was unexpected. Although one of the most intuitively obvious sequelae to progressive improvements in sequence learning is that transitions are rendered more certain, there has been no direct neurophysiological evidence of the progressive reduction of surprise over learning.

Most previous studies on sequence learning have focused on the difference between intentional and incidental learning. As subjects are commonly asked to simply observe a progression of stimuli within incidental learning tasks, these experiments do not allow for continuous testing of performance. Therefore, individual differences in learning curves and their correlation to ERP components has so far not been investigated. The N2 has, however, been suggested to be smaller in subjects with explicit knowledge. A correlation between P3 and explicit learning has to our knowledge not been found.

Other studies on sequence learning have shown that the inclusion of mistakes in the sequence (ungrammatical stimuli) elicits enlarged ERP components, even if the subject has not yet learned the particular part of the sequence. This may indicate that surprise-related effects on P3 and N2 may proceed conscious learning experiences.

In this study, we examined whether N2 and P3 are modulated in the course of intentionally learning a sequence. Our hypothesis was that, as learning develops, stimuli would progressively becomes 'less surprising', which would in turn imply a decrease of both N2 and P3 components.

To examine the neural correlates of intentional sequence learning, we recorded ERPs while subjects observed and memorized a complex sequence of visual stimuli.

We therefore continuously evaluated learning performance and ERP amplitude over time during a visual sequence learning task. 17 subjects were asked to observe and memorize a sequence of 16 visual stimuli, which appeared at eight different locations around a circle. The sequence was repeated three times in five purely visual blocks. At the end of each block, declarative knowledge of the sequence was assessed via a verbal score. Each of these blocks was followed by an additional block during which subjects were asked to point at targets (motor learning block). EEG was recorded during the whole experiment and ERPs a were computed for each subject and block. Trials were categorized as 'hits' or 'misses' based on the verbal reports. Average ERPs for hits and misses were averaged and compared across all subjects. In a second step, we computed pearson correlation coefficients between the ERP amplitudes of one block and the corresponding verbal report in each single subject. R and p values were calculated for each electrode at each time point.

EEG was acquired during motor learning blocks, but not evaluated on a trial-by-trial basis, as the data was confounded by motion artifacts.

Despite the fact that all subjects were exposed to the same sequence of stimuli and were able to correctly repeat it eventually, individual learning curves differed in their shape and slope. The ERP analysis showed that both the N2 and the P3 amplitude correlated significantly with individual performance. Both components showed a reduced amplitude with learning.

These results add to evidence that the N2/P3 ERP components index the degree of surprise and for the first time provide electrophysiological verification that as transitions within a sequence are more concretely learned, surprise is correspondingly reduced.