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Sequential Temporal Anticipation Characterized by Neural Power Modulation and in Recurrent Neural Networks

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Complex human behaviors involve perceiving continuous stimuli and planning actions at sequential time points, such as in perceiving/producing speech and music. To guide adaptive behavior, the brain needs to internally anticipate a sequence of prospective moments. How does the brain achieve this sequential temporal anticipation without relying on any external timing cues? To answer this question, we designed a 'premembering'task: we tagged three temporal locations in white noise by asking human listeners to detect a tone presented at one of the temporal locations. We selectively probed the anticipating processes guided by memory in trials with only flat noise using novel modulation analyses. A multi-scale anticipating scheme was revealed: the neural power modulation in the delta band encodes noise duration on a supra-second scale; the modulations in the alpha-beta band range mark the tagged temporal locations on a sub-second scale and correlate with tone detection performance. To unveil the functional role of those neural observations, we turned to recurrent neural networks (RNNs) optimized for the behavioral task. The RNN hidden dynamics resembled the neural modulations; further analyses and perturbations on RNNs suggest that the neural power modulations in the alpha-beta band emerged as a result of selectively suppressing irrelevant noise periods and increasing sensitivity to the anticipated temporal locations. Our neural, behavioral, and modelling findings convergingly demonstrate that the sequential temporal anticipation involves a process of dynamic gain control –to anticipate a few meaningful moments is also to actively ignore irrelevant events that happen most of the time.

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