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Estimating and measuring brain temporal latencies

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Abstract:
Time-delays in communication between brain regions greatly impact brain function, which requires precise timing of the arrival of neural spikes and signals that propagate along axons. Our aim is to develop methods for measuring and estimating brain network latencies. Here, axon diameter distribution (AAD) measured via MRI are used to estimate conduction velocities, while transcranial magnetic stimulation (TMS) evoked potential (EP) via electroencephalography (EEG), as well as time-series analysis of the magnetoencephalography (MEG) and EEG recordings, provide complementary information with which to estimate latencies. The connectivities and latencies obtained from time-series analysis are typically inferred from time-shifted signals compared in a pairwise manner. Establishing connectivity usually relies on Wiener-Granger causality, which ascribes the improvement in linear prediction or information gain to the inclusion of the potential “causal” source time-series. Our approach is different, as we rely on unpredictable events in time-series and treat them as perturbations for which we try to infer the propagation of their influences. These events are defined as the time points where the time-series falls outside a very stringent confidence interval (e.g., z>5 or larger) for any prediction scheme that we use. Our latency estimation procedure has three steps: 1) identifying “trigger” times at which the onset of unpredictable event occurs; 2) using bi-variate analysis on the count data to determine significant pairs and temporal delays at which the “casual” propagation occurs; 3) using tri-variate mediation analysis to remove the “indirect causes”. We previously tested this procedure on simulated data (a non-linear network of neurons, using only auto-regressive linear prediction) and showed that very

long recordings of activity (many hours) can lead to the correct identification of the majority of the intrinsic latencies in the network. Here, we extend this analysis to a variety of machine learning prediction schemes and ultimately apply all these methods to 4-hour EEG recordings. In these pilot studies, we were able to identify significant latencies, but only in the range between 100 and 300 ms, and with the uncertainty that is larger than 10 ms. In trying to measure latencies, it is important to distinguish between the temporal differences in neural events and delays incurred solely by signal conduction, which we seek to infer. Our results further emphasize the need to supplement time-series analysis with the structural axon diameter and conduction velocity information and with TMS+EEG measurements.
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