Maximized directed information transfer in neuronal networks at criticality

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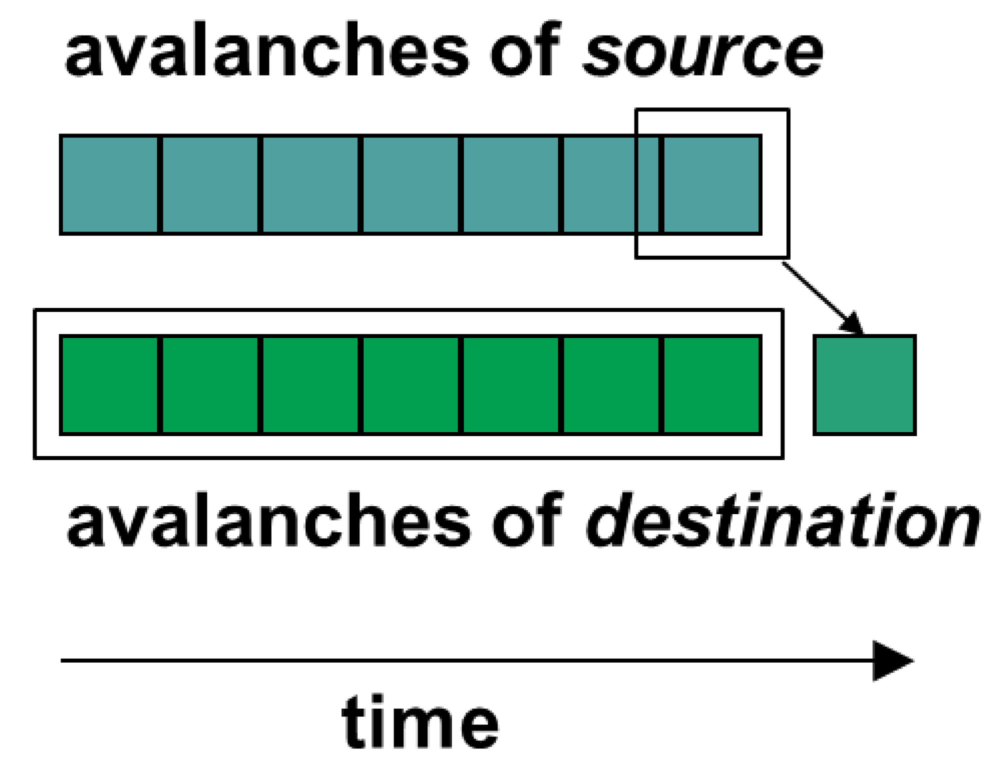


Summary

We describe three novel transfer-entropy [1] based measures of directed information transfer in neuronal avalanches.

We apply our measures to compute directed information transfer in large, sparse, modular networks of leaky integrate-and-fire neurons with spike timing-dependent synaptic plasticity and axonal conduction delays.

All three of our measures peak at criticality in all examined networks.

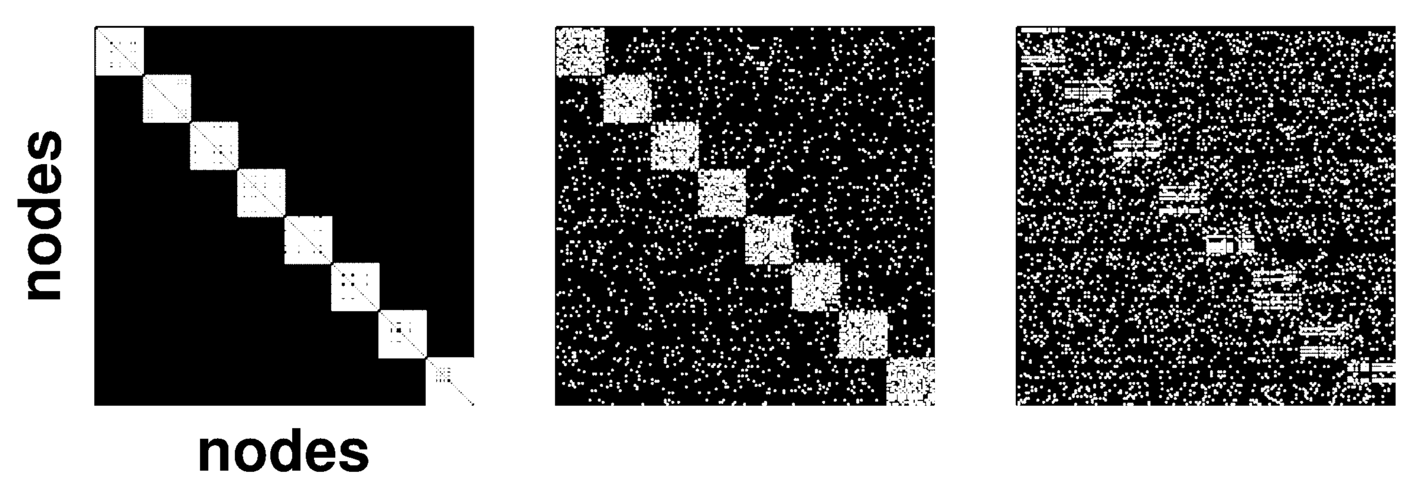
We hence show that directed neuronal information transfer is maximized at criticality in our model. Our findings pave the way for applying our measures to multielectrode recording data.

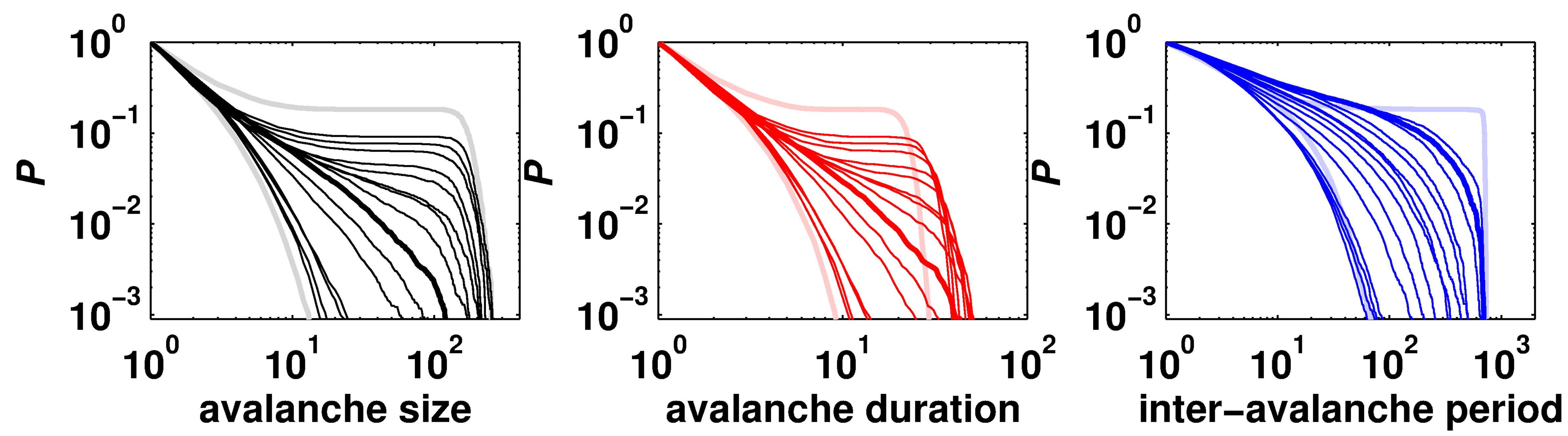
Measures

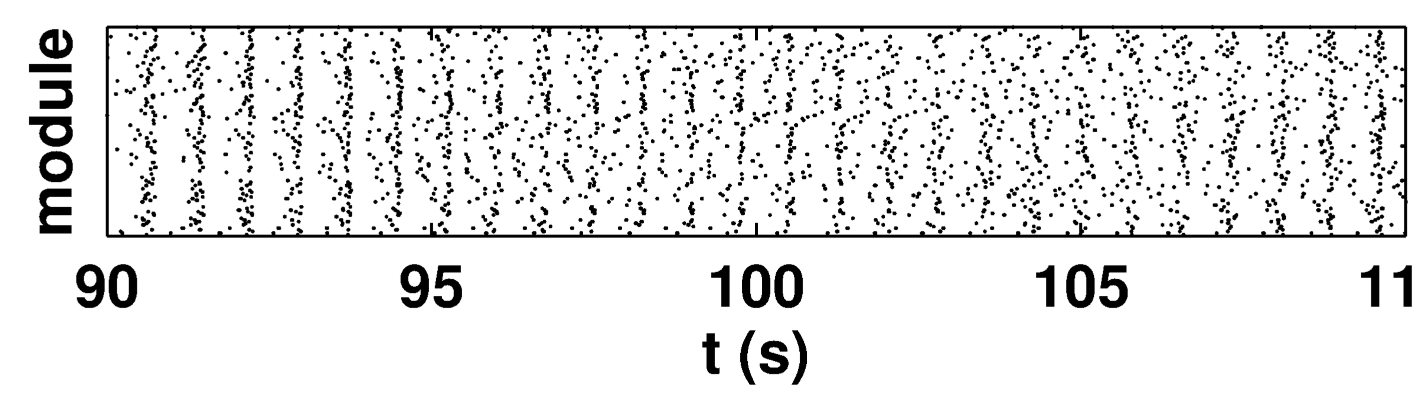
Our measures compute the amount of predictive information present in avalanches properties (avalanche size, avalanche duration and inter-avalanche period) of the source region about avalanche properties of the destination region.

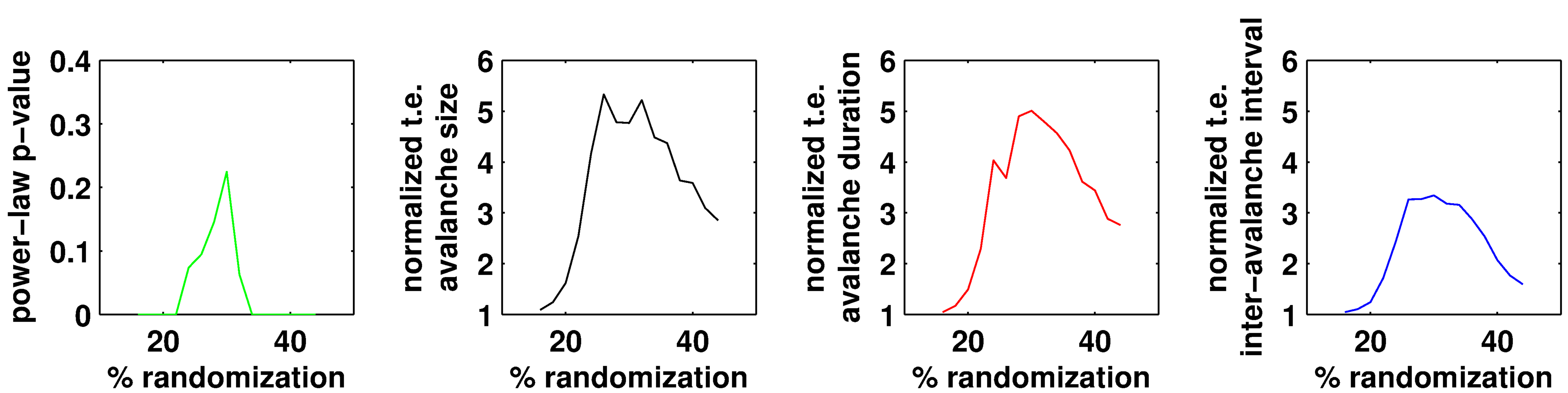
Our measures are suitable for detecting information transfer at multiple spatial scales, from individual neurons to neuronal ensembles.

Connectivity matrices









Introduction

Critical dynamics in complex systems emerge at the transition from random to ordered dynamics and are characterized by power-law distributions of spatial and temporal properties of system events.

The occurrence of critical dynamics in neuronal networks is increasingly supported by multielectrode array recordings of spontaneous activity in organotypic cortical slice cultures [2].

System events in these neuronal networks are typically defined as activations of neuronal ensembles, or “neuronal avalanches”.

Studies have not previously examined the directed nature of information transfer in these networks.

Model

Our networks comprise 12800 neurons organized into 128 modules [3].

We characterize network dynamics by probability distributions of module avalanche sizes and durations, and assess these distributions for power-law scaling.

We compute directed information transfer between two halves of each network, and normalize this by information transfer in a null-model of rotated ava-

References: [1] Schreiber T (2000) Phys Rev Lett 85:461–464; [2] Beggs JM, Plenz D (2003) J Neurosci 23: 11167; [3] Rubinov M, Sporns O, Thivierge JP, Breakspear M (2011) PLoS Comput Biol 7:e1002038.

Funding: JSMF 22002082 (MR, MB); CSIRO ICT Centre (MR, JL, MP); NHMRC 510135, ARC TS0669860 (MB).