Liquid state computing in neuronal cultures: effects of connectivity modularity on response separation and generalisation in numerical simulations and experiments

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Abstract

Attempts are being made to use biological neuronal networks to create artificial learning and processing machines. However, networks of biological neurons differ significantly from the abstract ideations used to develop artificial neural networks: they are intrinsically noisy and have non-trivial physical embeddings. It is thus unclear to what extent biological neurons are usable for artificial intelligence applications. Intuitively, a basic requirement for a system to be a good (artificial) learning machine is the potential to respond distinctly to different time-dependent inputs, yet reproduce similar activity when presented with similar stimuli. This property is explicitly utilised in liquid state and reservoir computing.

In this study we show, in a numerical model of neuronal cultures, that network activity is indeed different in response to different inputs and similar for similar inputs. Moreover, we investigate the influence of modular connectivity on the network responses, and on the robustness of learned classifications to additive noise and network alterations. We find that modular connectivity increases the separation between responses to differing inputs, and that modular networks are more robust to noise and network alterations.

Lastly, we explore these results *in-vitro* using primary neuronal cultures on high-density micro-electrode arrays, showing the possibility to use neuronal cultures for liquid state computation.

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