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A theory for the formation of the neural representation of context in reinforcement learning

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Abstract: Reinforcement learning provides an elegant theory for understanding how animals choose their actions to maximize reward. Given the set of states of the environment, available actions, and reward signals, it is possible to find the policy that maximizes reward. A major limitation of this theory is that the set of states of the environment must be known a priori, fully observable, as well as representable by the agent. This is usually not the case in the real world, where the environment is partially observable, and its present state cannot be unambiguously inferred by the instantaneous available observations.
We propose a theoretical framework for the formation of mental states on the basis of the temporal statistics of the events that define the behavioral context. Contexts are assumed to be represented by patterns of reverberating activity, which are attractors of the neural dynamics. They are correlated to the neural representations of the temporally contiguous conjunctions of events, motor responses and their immediate value (reward or punishment) defining the behavioral context. Their formation is the consequence of a process of attractor concretion, driven by the merging of attractors that are sequentially activated. The learning rule to create these context representations, inspired by Griniasty et al. (1993), relies on: 1) mixed selectivity 2) a plasticity mechanism based on temporal contiguity. Mixed selectivity, defined as selectivity to combinations of the present mental state and the experienced stimuli, has already been shown to be crucial in recurrent neural networks that perform context-dependent tasks. In our framework, mixed selective neurons respond to conjunctions of present events and inner mental states indicating the most recent relevant events,

thereby encoding information about the present temporal context. Temporal contiguity drives the concretion of attractors by making the synaptic strengths proportional to the frequency with which the pre- and post-synaptic neurons are sequentially activated. High enough frequencies of sequential activation lead to the creation of neural populations able to sustain their activity to represent a context. Multiple systems encoding different frequencies of sequential activation can encode all relevant temporal contexts, generating the mental states that are needed to execute the most general context dependent tasks.
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