Adaptive seqNMF for Analysis of Zebra Finch HVC Neuronal Activity: Implications for the Central Pattern Generator Hypothesis

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Currently, seqNMF is the leading algorithm for extracting repeated temporal motifs from neuronal recordings. However, it is computationally expensive, requiring manual regularization tuning and multiple runs (~10–20) to produce reliable results, limiting reproducibility and efficiency. To this end, an adaptive seqNMF implementation in PyTorch is developed that dynamically adjusts the sparsity hyperparameter during optimization, eliminating heuristic tuning and improving stability of results. This approach requires only a single run to generate consistent outputs, significantly reducing the runtime. Using neuronal activity datasets recorded from zebra finch HVC slices on a microelectrode array, the method's performance was benchmarked across three stimulation regimes: no stimulation, optostimulation, and optostimulation with neuromodulators. Following this, the number of significant patterns detected in each regime was quantified into a distribution across 20 iterations to assess the effects of stimulation on motif generation. Results indicate that optostimulation and optostimulation with neuromodulators consistently increased the number of significant HVC patterns compared to no stimulation, supporting the hypothesis that HVC acts as a CPG. Benchmarking against the original MATLAB seqNMF revealed substantial runtime improvements by a factor of 6.3 and memory usage reduction by 82.9% on average, due to GPU parallelization and the elimination of multiple algorithm runs in tuning. These findings demonstrate a methodological advance and provide additional evidence for HVC's role as a CPG. Limitations include a need for larger datasets from more male zebra finches. These results advance the question of whether songbird nuclei other than HVC may also function as CPGs.

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