Contrastive Multimodal Embeddings Expose Cardiopulmonary Alterations in a COVID-19-like Murine Model

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Introduction. SARS-CoV-2–infected individuals are highly vulnerable to systemic inflammation. In our cytokine-storm animal model, where systemic COVID-19-like inflammation is induced by a proinflamatory cocktail injection, rats exhibit acute renal and inflammatory activation with incomplete recovery. Yet it remains unclear whether such systemic stress is detectable in physiological signals. Here, we examine whether activity, ECG, and respiratory measurements encode latent cardiopulmonary markers distinguishing the control state from acute-injury.

Materials and Methods. The dataset includes two two-hour multimodal recordings acquired before and after injection from two rats, one control and one treated. Activity, ECG, airflow and respiratory volume signals were filtered, normalized and segmented into one-minute windows. Each modality was encoded with a lightweight 1D CNN trained contrastively with jitter, scaling and noise augmentations. Embeddings were concatenated and projected into a three-dimensional UMAP space.

Experiments and Results. Contrastive embeddings showed clear separation between pre- and post-injection states, especially in ECG and respiratory signals. UMAP and PCA projections revealed consistent displacement, with UMAP dissimilarity increasing from 0.04 to 0.05 and PCA from 0.035 to 0.06, indicating measurable cardiopulmonary and behavioral changes associated with injury.

Conclusions. Contrastive multimodal embeddings capture systemic physiological alterations linked to to systemic inflammatory injury, providing a compact and discriminative latent representation that complements traditional renal and inflammatory biomarkers in animal models.

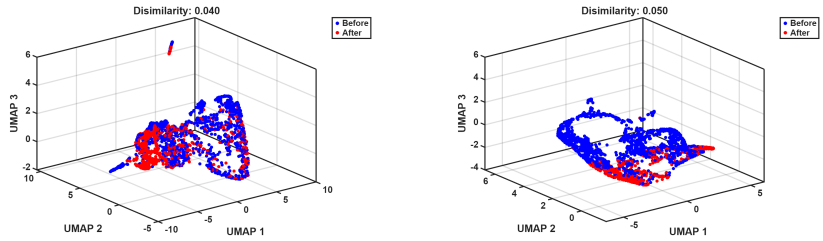

Figure 1: Contrastive latent spaces after UMAP projection for a control subject (left) and an acutely-injured subject (right). Blue (red) points correspond to pre-(post-)injection segments.