The geometry of primary visual cortex representations is dynamically adapted to task performance

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Perceptual learning requires brains to change the representations of sensory inputs to optimize perception and facilitate discrimination and generalization. Although these mechanisms' biological implementation remains elusive, recent advances in the analysis of large neuronal population recordings suggest that the geometry of the sensory representations is key to this process by preparing population activity to be read out at the next stage. Notably, it has been suggested that learning a discrimination task lowers the dimensionality of the representations to facilitate their linear separation. To test this hypothesis, we investigated the changes in dimensionality and representational geometry of perceptual manifolds in mice performing an orientation discrimination Go/NoGo task. The task's difficulty was varied progressively by making the NoGo orientation closer to that of the Go. We used calcium imaging data recorded in the V1 of trained mice performing the task, as well as naïve mice passively viewing the same stimuli. This design allowed us to compare the representations of stimuli with variable separability, in the context of task performance and passive viewing. We found that the dimensionality of the responses increased with the similarity of the stimuli in both trained and naive animals. Strikingly, the dimensionality was lower in animals performing the task, suggesting that the biological implementation of the task relies on reducing the representations' dimensionality. Accordingly, using the raw high-dimensional neuronal activity to classify the responses with SVMs and ANNs vastly outperformed the animals, but using dimensionally reduced responses captured the mice's performance. However, while the dimensionality of responses to visual cues predicted task performance across difficulty levels, differences in dimensionality at the same

difficulty level did not explain performance variability. Instead, we found that the separability of the representations in their embedding space is a better predictor of the individual performance. This was evidenced by measuring the neural manifold's capacity and their geometric properties including manifold dimension and manifold radius. These results confirm that learning changes the geometric properties of early sensory representations in a way that would favor linear readout mechanisms.