Visual Category learning by means of Basal Ganglia

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Visual Category learning operates at the interface from vision to cognition, as it provides meaning to the stream of visual data. Traditional models of category learning have been related to rule learning, prototype learning and exemplar-based learning by mathematical operations on an abstract visual representation simplifying from details of visual perception (for review Richler & Palmeri, 2014). Other, more recent models, aimed at modeling the visual hierarchy of the ventral pathway transforming the raw image across multiple stages into a high level feature space, which allows to generalize across different variations (for review Serre, 2016). However, these models typically require at least one layer of supervised learning, e.g. a projection of the feature space onto category labels that may be represented in the prefrontal cortex (PFC) and thus simplify the learning problem by relying on machine learning techniques.

Inspired by recent experimental data that suggests an active involvement of the basal ganglia (BG) in category learning (Seger & Miller, 2010; Antzoulatos & Miller, 2011), we developed a neuro-computational model of category learning where the BG train the PFC to develop category selective cells. The BG module is based on previous work (Schroll et al., 2014) and includes all major BG pathways. Importantly, the visual (IT) to PFC projection learns only on basis of an unsupervised Hebb'ian learning rule and thus requires the influence of the BG onto the Thalamus to bias PFC via the cortico-thalamic loop. While the BG learns fast, based on RL via dopamine, it trains the slow IT to PFC connections to generalize.

We initially verified our model by replicating macaque single cell recording data of category selectivity in PFC and striatum obtained by Antzoulatos & Miller (2011). Further, we verified a novel model prediction which is that the fast learning striatum in the BG looses its category selectivity when trained with an increasing number of stimuli, as the variance of its neural responses increases. Then, we tested the model by learning to distinguish between faces of Clinton and Bush from youtube videos, while early to mid-level vision up to IT is mimicked with a deep neural network but without using the final classification stage. Our results (Fig. 1) show that the model learns a clear projection form the 100 IT cells to the 18 PFC cells.

Concluding, our neuro-computational model provides a new account to link vision to cognition. The model replicates for the first time data of neural cell recordings in striatum and PFC and has been verified on a simple real-world task.

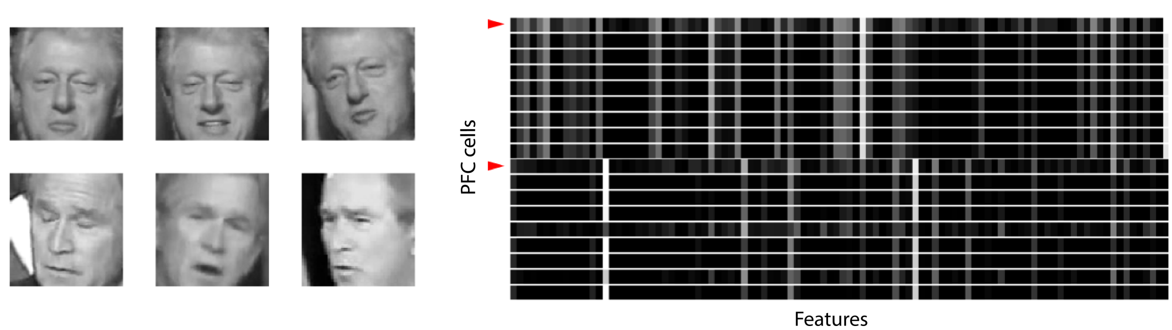

Fig. 1, Left: Example images of each category. Right: Learned projection matrix from 100 features (IT cells) to 18 PFC cells (sorted for category selectivity). The arrow points to the two sets of category selective PFC cells.

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