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Abstract

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Doctor of Philosophy

Top-down Modulation in Human Visual Cortex

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Human vision flaunts a remarkable ability of recognizing objects in the surrounding environment even in the absence of complete visual representation of these objects. This process is done almost intuitively and it was not until scientists had to tackle this problem in computer vision that they noticed its complexity. While current advances in artificial vision systems have made great strides exceeding human level in normal vision tasks, it has yet to achieve a similar robustness level. One cause of this robustness is the extensive connectivity that is not limited to a feedforward hierarchical pathway similar to the current state-of-the-art deep convolutional neural networks, but also comprises recurrent and top-down connections. They allow the human brain to enhance the neural representations of degraded images in concordance with meaningful representations stored in memory.

The mechanisms by which these different pathways interact are still not understood. I tackled this problem through a series of studies using brain imaging and deep neural network models along with blurring as an image degradation scheme. In this thesis, I present these studies concerning the effect of recurrent and top-down modulation on the neural representations resulting from viewing blurred images. I start in chapter 1 by introducing the perception process in humans and machines along with reviewing the current standing of the field. In chapter 2, I describe the experimental protocols used for measuring brain activity when viewing the blurred images and algorithms employed in the preprocessing and analysis throughout different chapters. In chapter 3, I present the first set of results arguing that recurrent and top-down pathways enhance neural representation of blurred images by means of sharpening them. In chapter 4, I present a different mode of integration between bottom-up and top-down signals where they give conflicting information that lead to misrecognition of the input stimuli. In chapter 5, I attempt to model the sharpening effect presented in chapter 3 by adding recurrent

and top-down connections to a trained feedforward neural network and investigate the resulting midlevel representations. Finally, in chapter 6, I present ongoing studies where I apply the methods and acquired knowledge to study disruptions in the visual system in schizophrenia.

In this thesis, I attempted to uncover the role of recurrent and top-down connections in human vision. The results presented challenge the notion of predictive coding as a mechanism for top-down modulation of visual information during natural vision. I show through brain activation data and modelling that neural representation enhacement (sharpening) appears to be a more dominant process of different levels of visual hierarchy. I also show that information in the visual recognition is achieved through a Bayesian-like process between incoming visual information and priors from deeper processing regions in the brain. The results presented offer novel results that contribute to the understanding of mechanisms of vision and cognition leading to better model of vision and tools for computer vision.