Understanding Cortical Face Selectivity

Submitted as: Face Module Activations Inform Non-Face Discrimination

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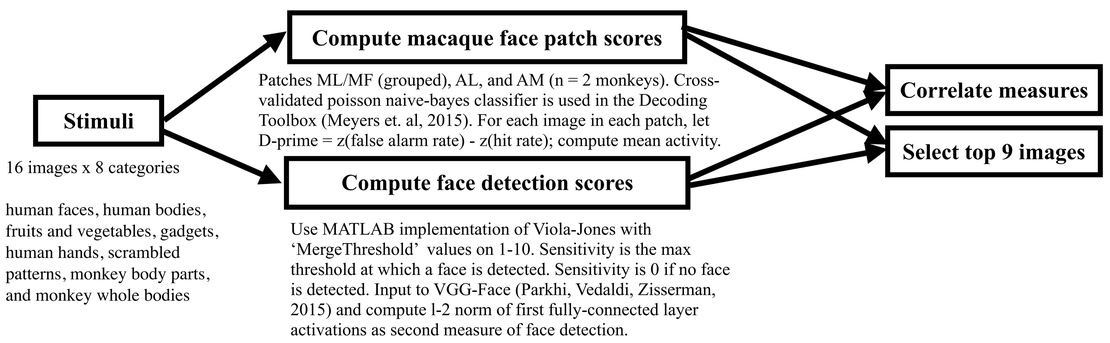
Introduction

- Faces elicit strong, localized responses in human and macaque visual areas (Kanwisher & Yovel, 2006). The location of these areas is highly consistent and thought to be closely linked to underlying neuroanatomy (Grill-Spector et. al, 2017). Thus, some have claimed that these regions constitute neural modules dedicated to face processing (e.g. Kanwisher et. al, 1997), gated by face detection (Tsao & Livingstone, 2008).
- However, there are reasons to doubt the modular interpretation, or to suggest that it is not necessary to explain current data
  - **Domain-general learning mechanisms:**
    - **Expertise:** Experts acquire similar neural selectivity for their domain of expertise, with activation in the fusiform gyrus proportional to their level of expertise (Gauthier et. al, 1999; Gauthier et. al, 2000). Face processing may be just one token of visual expertise.
    - **Self-organization:** An unsupervised domain-general learning mechanism can explain the emergence of a highly face-selective area in cortex from visual properties alone (Cowell & Cottrell, 2013). Modularity is not necessary to explain cortical selectivity.
  - **General topography underlying all object recognition**

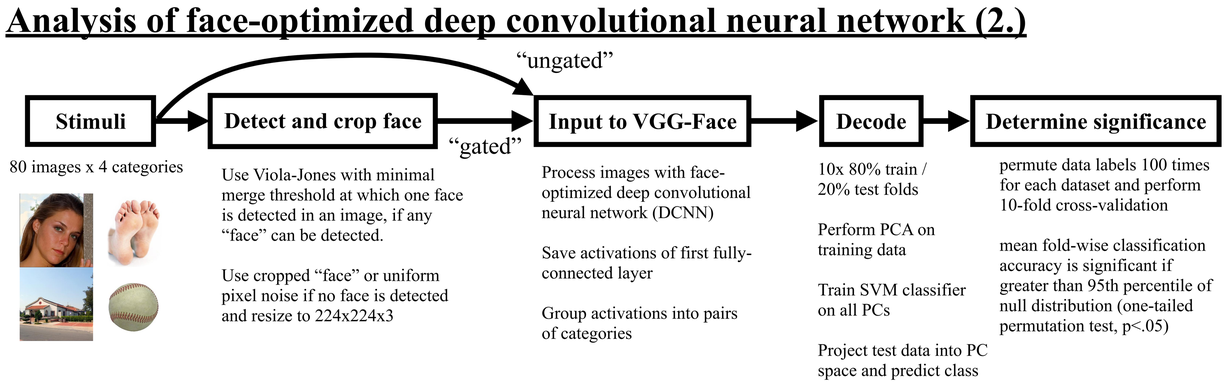
    fMRI responses in the human "Fusiform Face Area" inform non-face visual categorical discrimination (Haxby et. al, 2001), and neural populations within macaque face-selective patches inform non-face discrimination (Meyers et. al, 2015). Face-selective regions seem to be processing more than just faces, albeit with weaker responses.
- **Using computational modeling, we attempt to answer two questions:**
  1. Are face-selective regions gated by early face detection?
  2. Does visual processing in a face-specialized system inform non-face discrimination?

Methods

Analysis of macaque face patch data (1.)



Analysis of face-optimized deep convolutional neural network (2.)



1. Are face-selective regions gated?

Figure 1. correlations between face patch activity and face detection scores

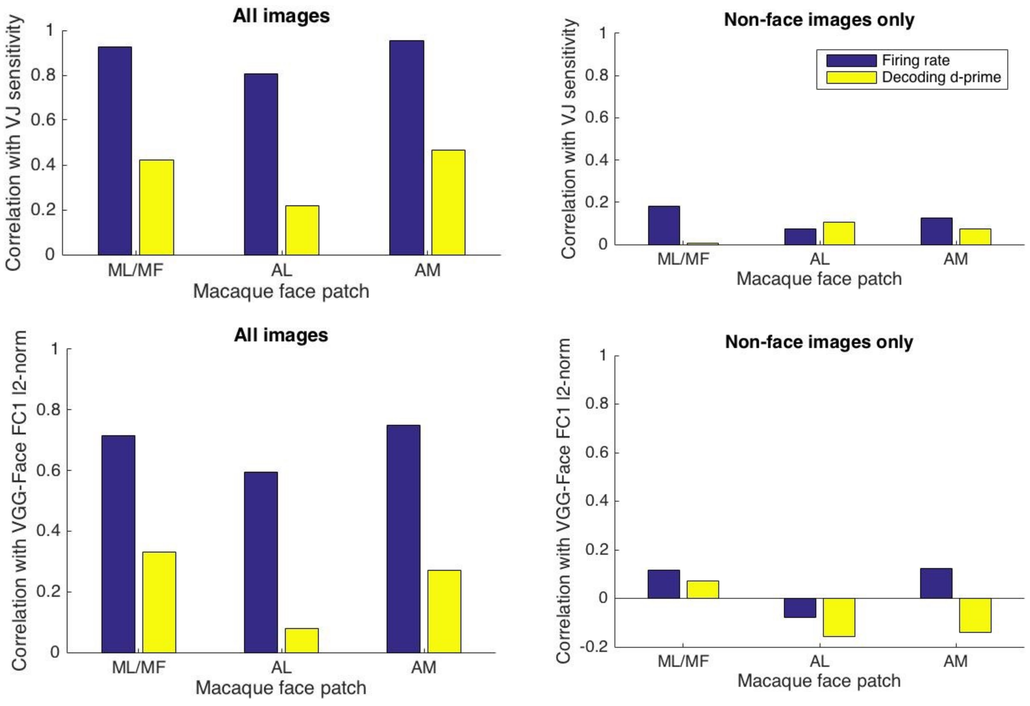
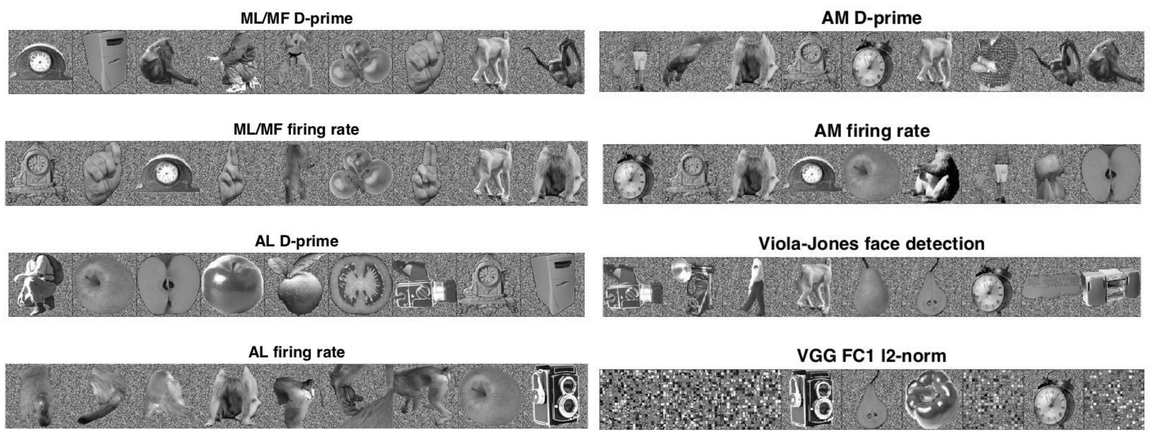


Figure 2. top non-face images



Summary

- Mean neural activity within face patches correlates highly with face detection, but informational content does not; correlations are very weak when face images are removed.
- Round objects and animal bodies are the preferred non-face images in face patches.
- This suggests that processing in face-selective cortical areas is not gated by early face detection, either sub-cortically (i.e. preceding ML/MF), or cortically (i.e. preceding AM). Rather, shape and visual proximity to faces seem to predict non-face information patterns.

2. Does face specialized processing inform non-face discrimination?

Figure 3a. decoding face-detection gated face-optimized DCNN representations

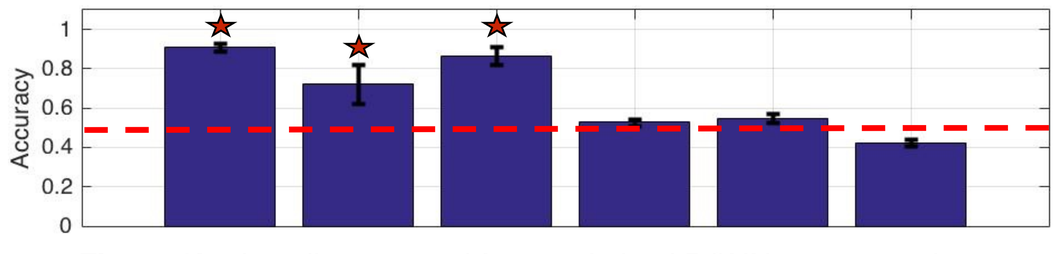
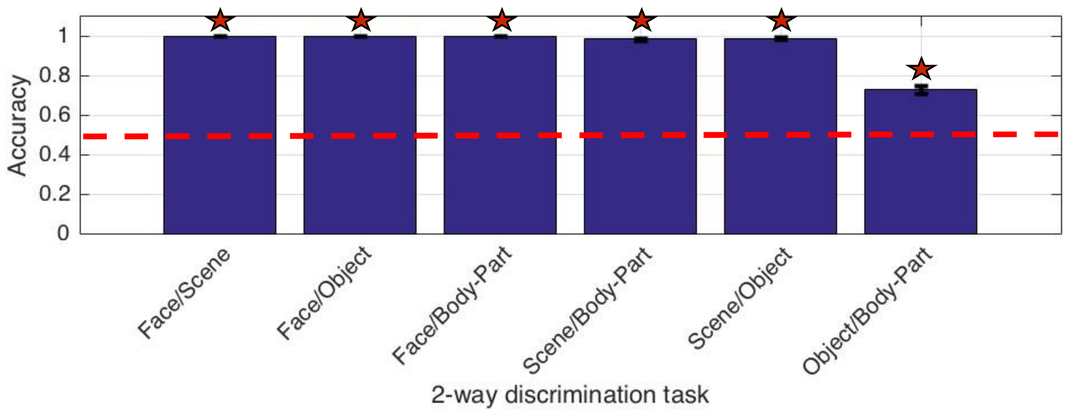


Figure 3b. decoding ungated face-optimized DCNN representations



Summary

- Face-detection gated face-optimized representations discriminate between face and non-face categories but not between two non-face categories.
- Ungated face-optimized representations discriminate all face/non-face and non-face pairs.

Discussion

- Our results demonstrate that decodable non-face information (as in Haxby et. al, 2001; Meyers et. al, 2015) is produced by an ungated, but not gated, face-specialized processing mechanism, and that information in macaque face patches is unlikely to be gated by face-detection.
- We speculate that recurrence — driven by social interactions, for example — may drive further processing in face-selective areas for faces detected in a first pass of ungated processing.
- VGG-Face captures the essence of face-specialized processing with optional gating, but is not a formal model of primate face processing. Because VGG-Face was trained on faces cropped using detection, we must ask how a face-specialized processing mechanism could emerge without gating non-face information?
- A face-specialized *processing* mechanism may arise largely through domain-general *learning* mechanisms, such as unsupervised self-organization (Cowell & Cottrell, 2013) combined with supervised acquisition of deep specialized representations under behavioral demand for expertise (e.g. Tong, Joyce, & Cottrell, 2008).
- Evolution may have also selected for domain-specific biases leading to the development of specialized brain systems for face processing. Intriguing areas requiring further research include:
  - An innate face-orienting mechanism (reviewed by Johnson, 2005)
  - An innately specified white-matter "wiring diagram" optimized to support face recognition, which is disrupted in congenital prosopagnosia (Thomas et. al, 2009).

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Supported by NSF Award Number 1640681

Thanks to Doris Tsao for sharing data, and to Ethan Meyers, Neil Stillings, Rosie Cowell, Gary Cottrell, Patrick Sadil, and Dave Huber for helpful discussions.