

What's in a Face?

Extracting meaningful information from facial cues

Shruti Japee, PhD

March 4th, 2024





FACIAL INFORMATION

Who?

Identity

Age

Gender

Race/Ethnicity



Where?

Eye gaze direction
Head Orientation

What?

Facial expression
Mental state



FACIAL INFORMATION

FIXED or INVARIANT ASPECTS

Who?

Identity

Age
Gender
Race/Ethnicity



DYNAMIC or CHANGEABLE ASPECTS

Where?

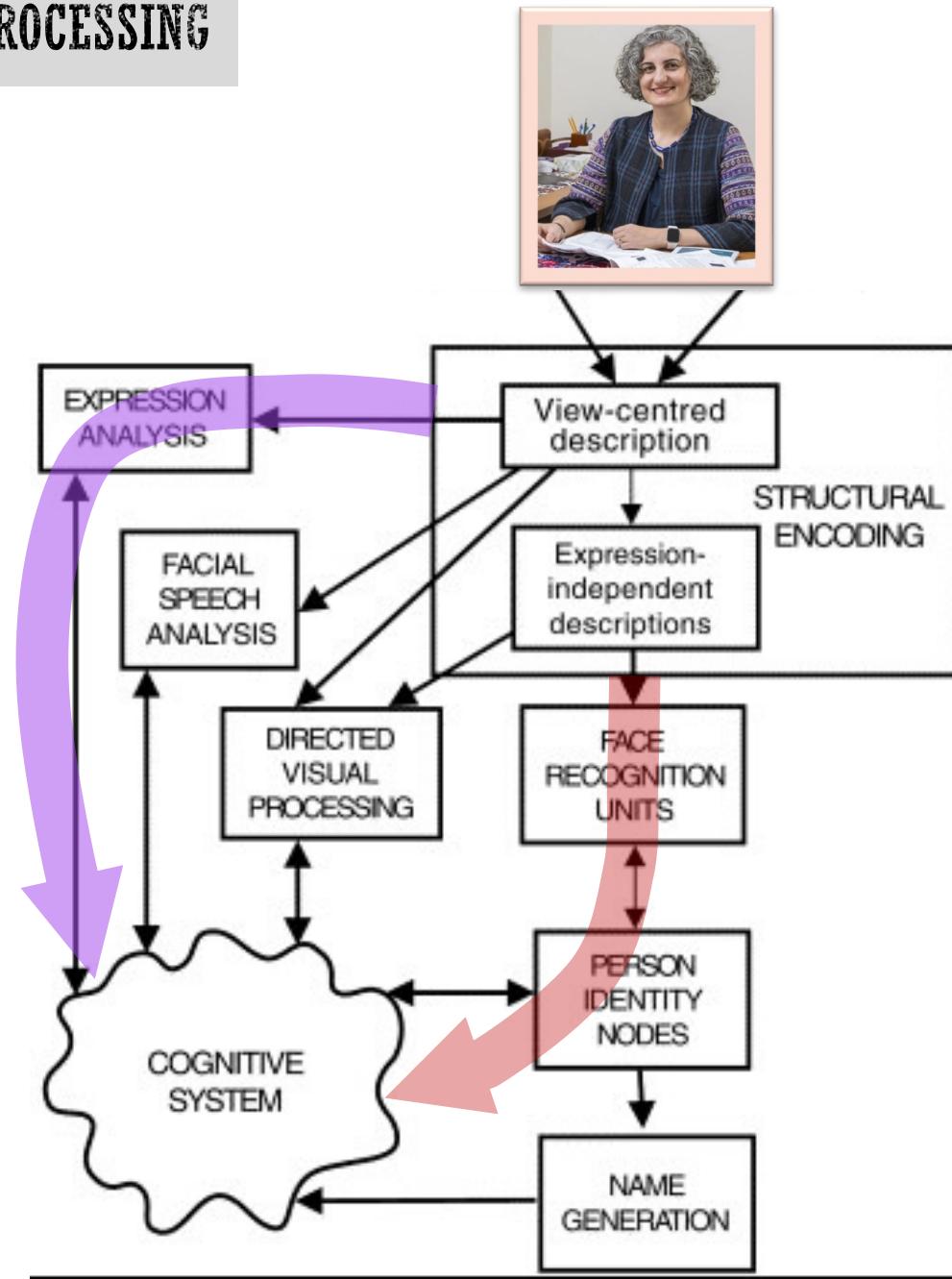
Eye gaze direction
Head Orientation

What?

Facial expression
Mental state



THEORETICAL MODEL OF FACE PROCESSING



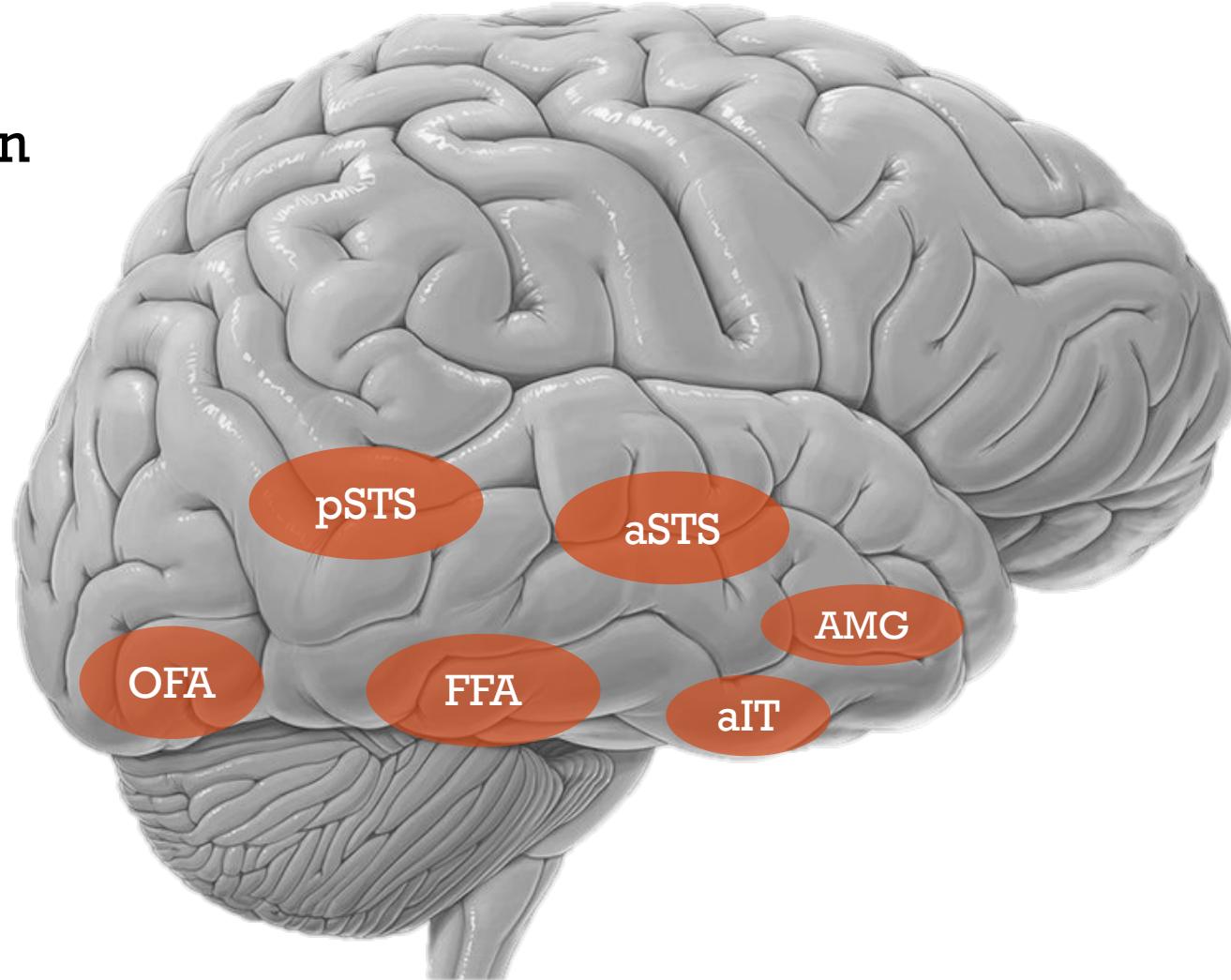
Bruce & Young (1986)



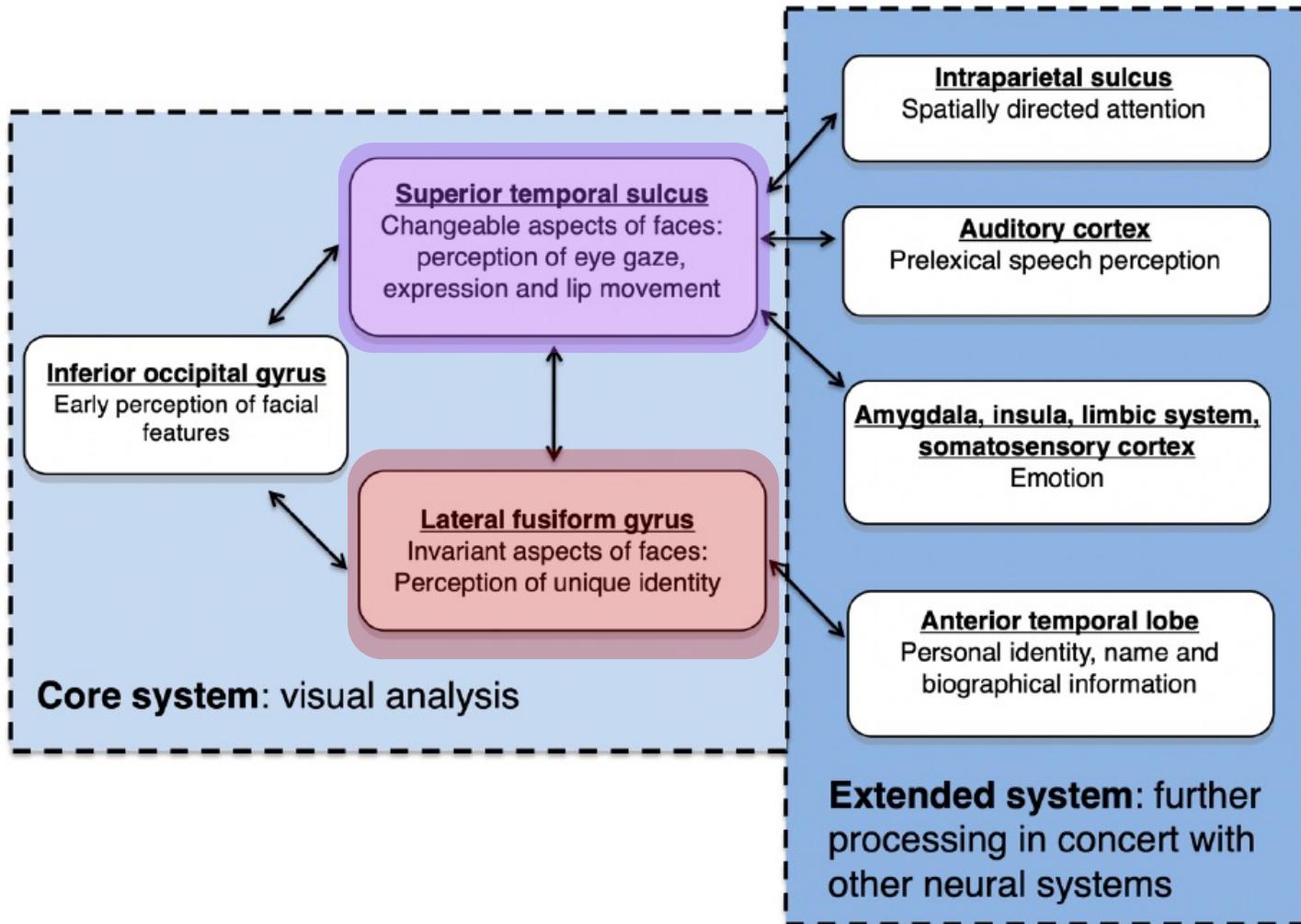
WHAT WE KNOW

Where faces are
processed in the brain

Network of **face preferring regions** in ventral and lateral temporal cortex

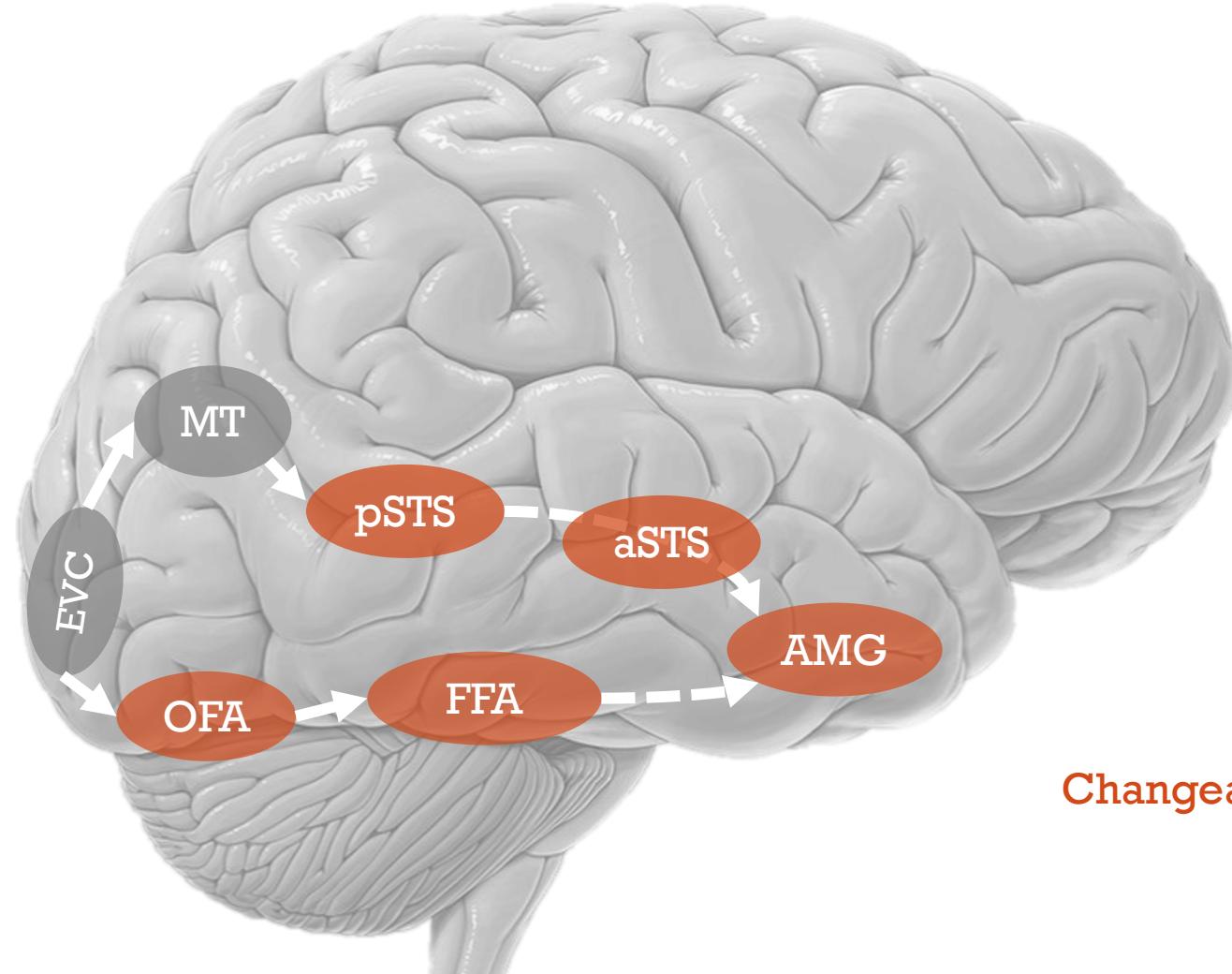


NEURAL MODEL OF FACE PROCESSING



NEURAL CORRELATES OF FACIAL ATTRIBUTES

Where are facial attributes processed in the brain?



Fixed: regions in ventral temporal cortex?

Changeable: regions along STS (third visual pathway)?



OUTLINE

- *Where* are facial cues processed in the brain?
 - fMRI in humans and monkeys to dissociate between regions
 - TMS to understand causal role of key regions
 - fMRI to distinguish between different types of dynamic aspects
- *When* are facial cues processed in the brain?
 - MEG to examine temporal differences between different cues
- Impact of **facial paralysis** on processing dynamic cues
 - Behavior and fMRI to characterize effect of experience on expression processing

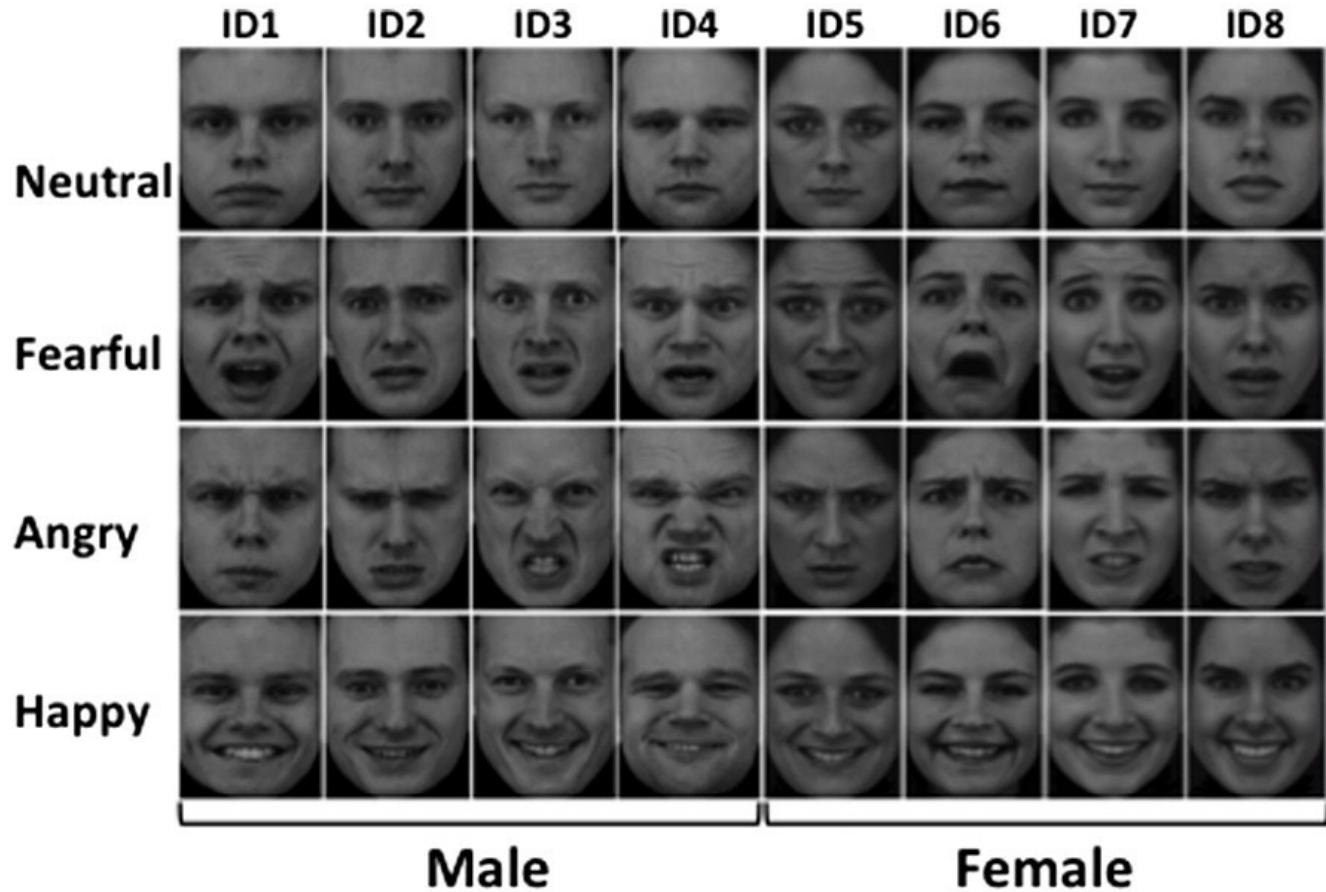
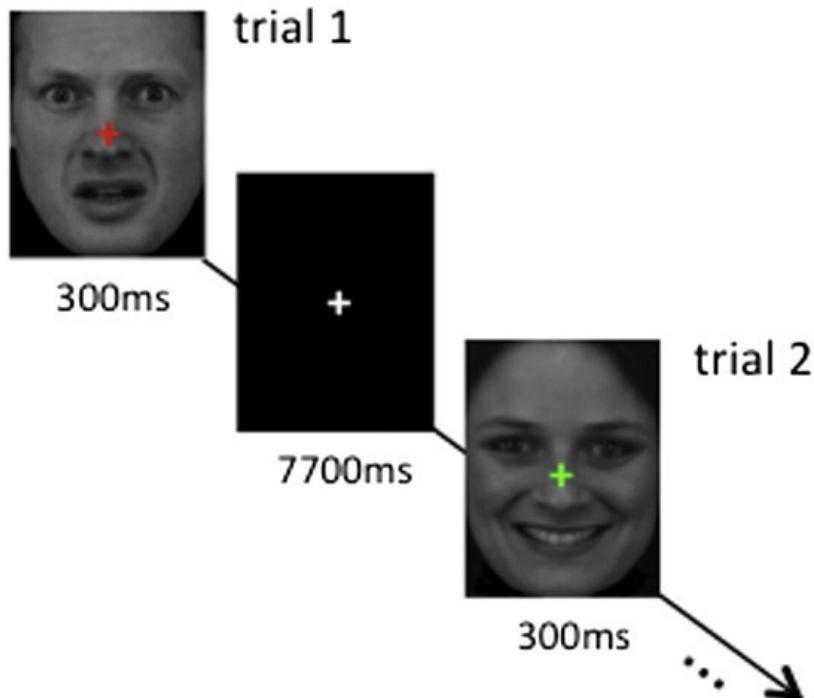


WHERE ARE FACIAL CUES PROCESSED IN THE BRAIN?



MULTIVARIATE DECODING OF FACIAL ATTRIBUTES

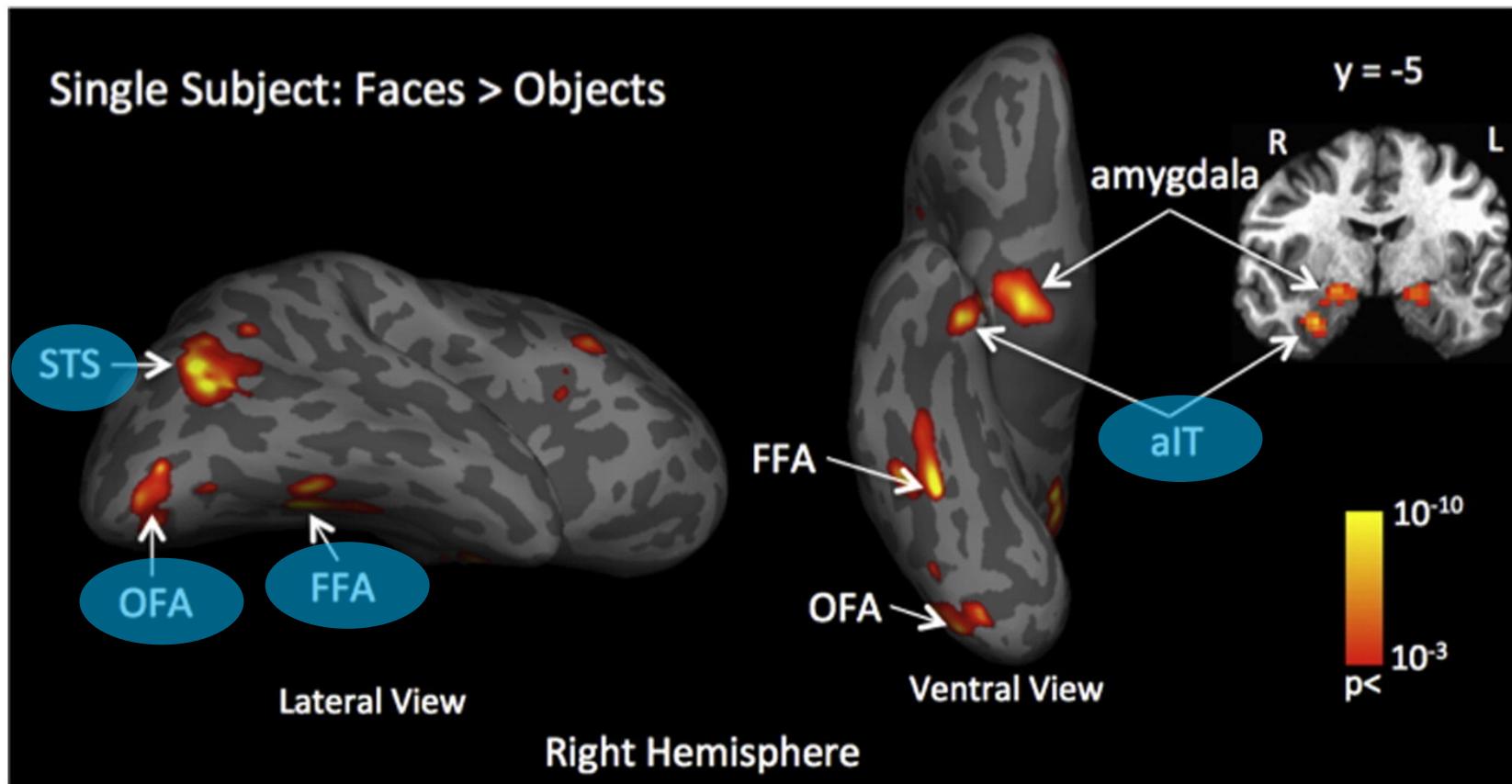
Hui
Zhang



- Slow event-related fMRI study in humans
- 4 expressions x 8 identities
- Fixation color change task

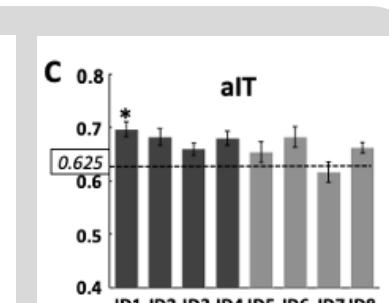
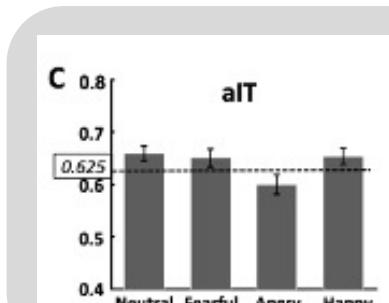
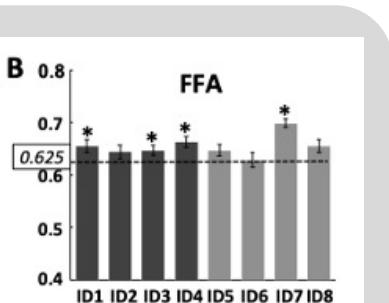
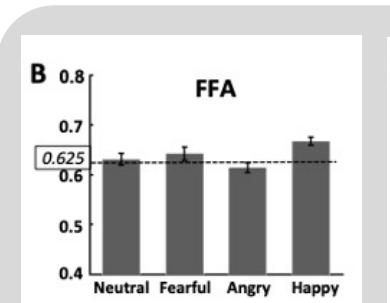
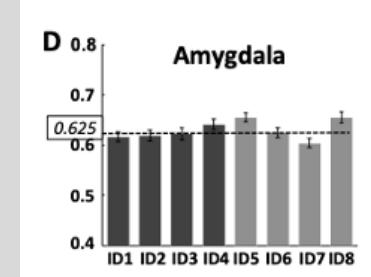
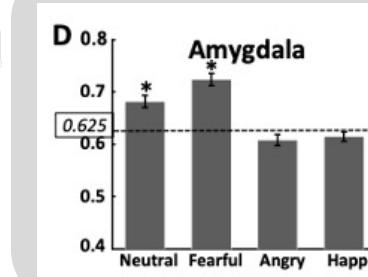
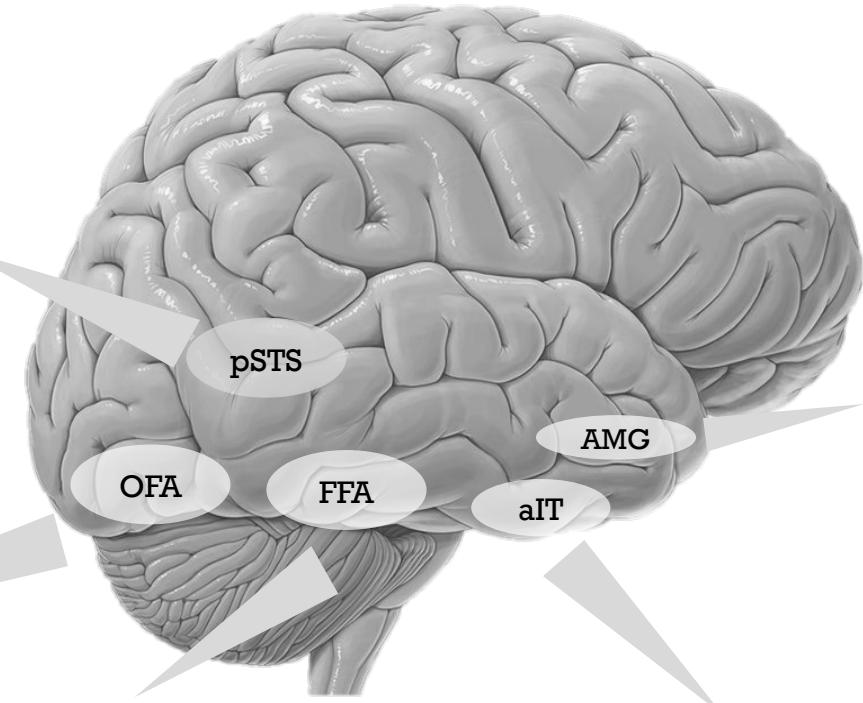
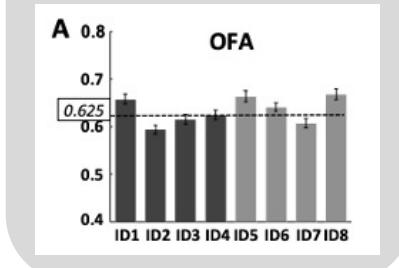
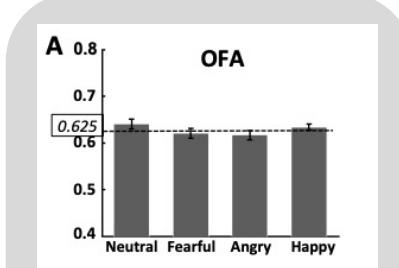
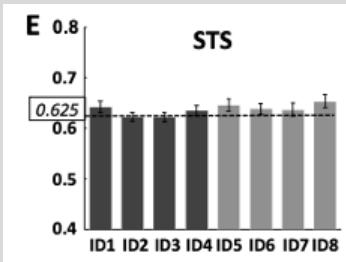
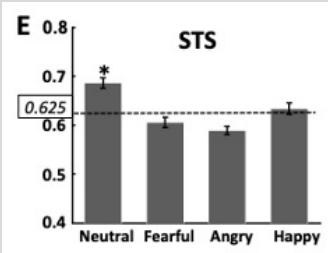
Zhang, Japee, et al., 2016 (*Neuroimage*)

- 2 runs of face localizer task
- Identified face-selective regions



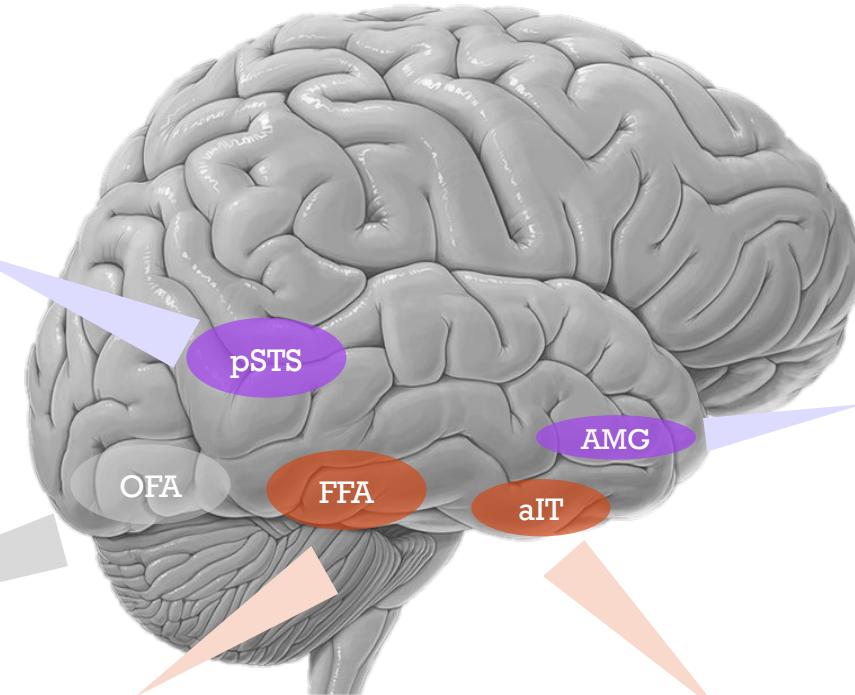
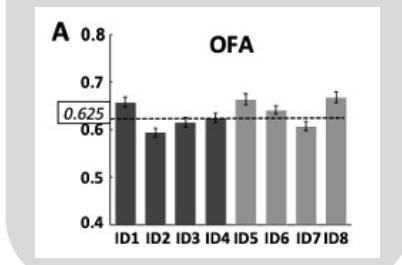
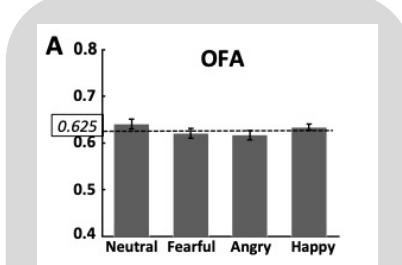
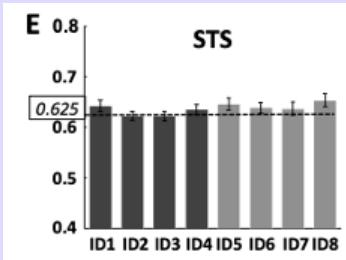
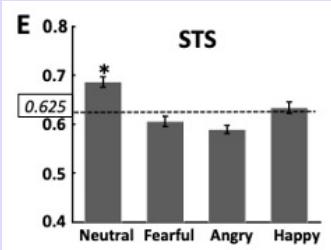
- Multi-voxel pattern analysis of ROI activity
- 1-vs-other support vector machine classification
- Bootstrapped permutation tests to determine significance above chance classification

DECODING WHO AND WHAT?

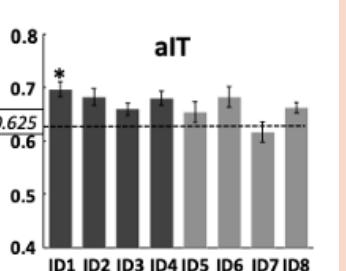
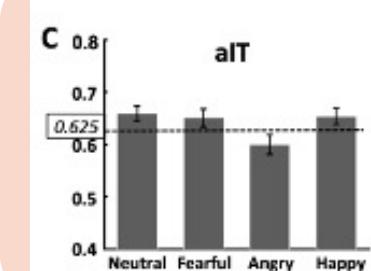
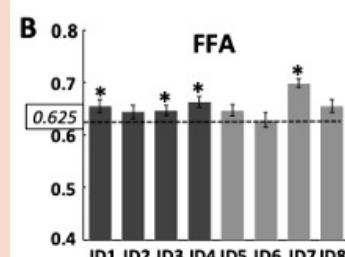
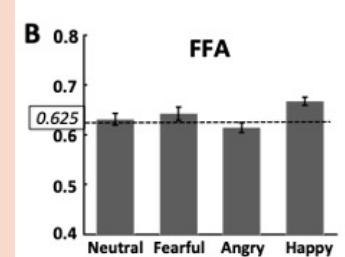


DECODING WHO AND WHAT?

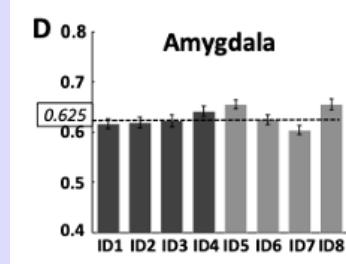
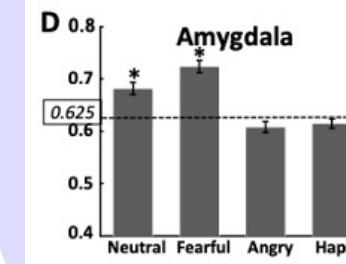
Expression



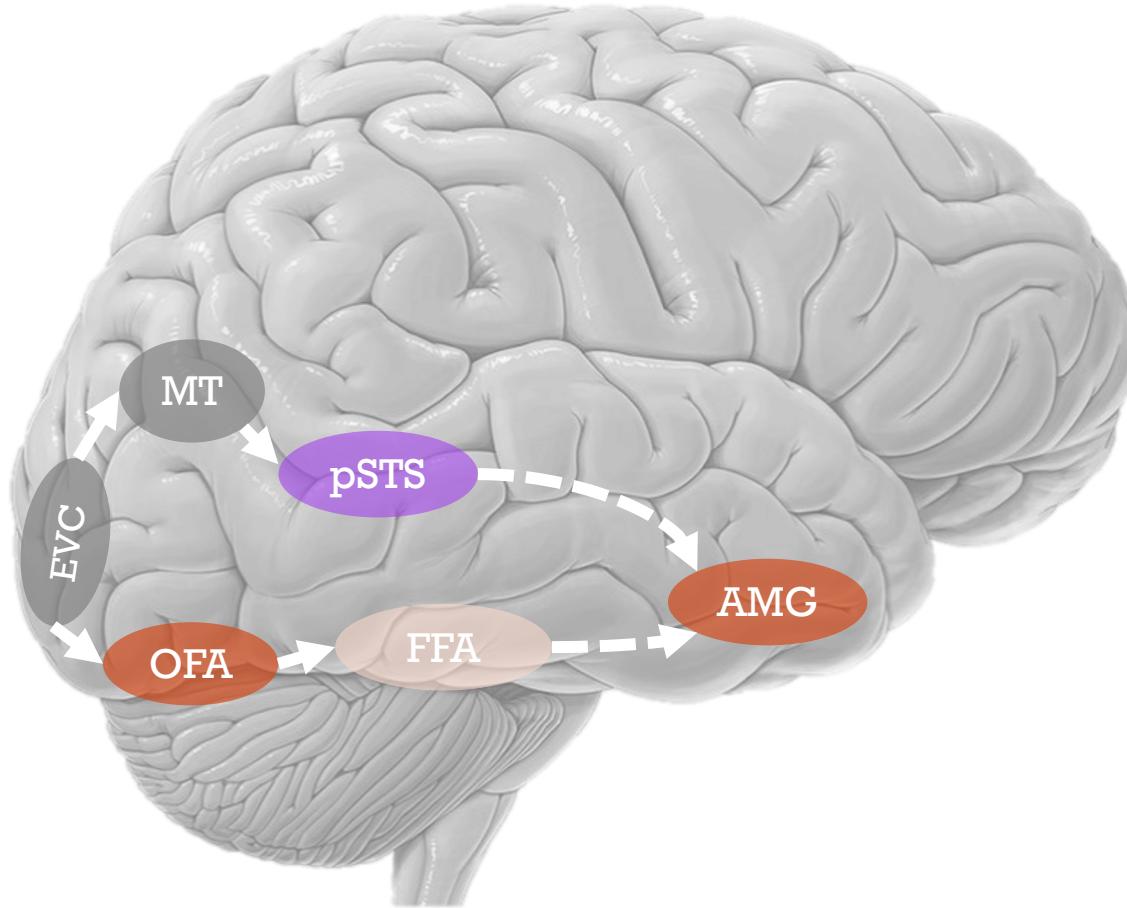
Identity



Expression



- Posterior STS in humans is sensitive to changeable aspects of a face such as expression
- Ventral temporal regions like FFA prefer fixed aspects of a face such as identity



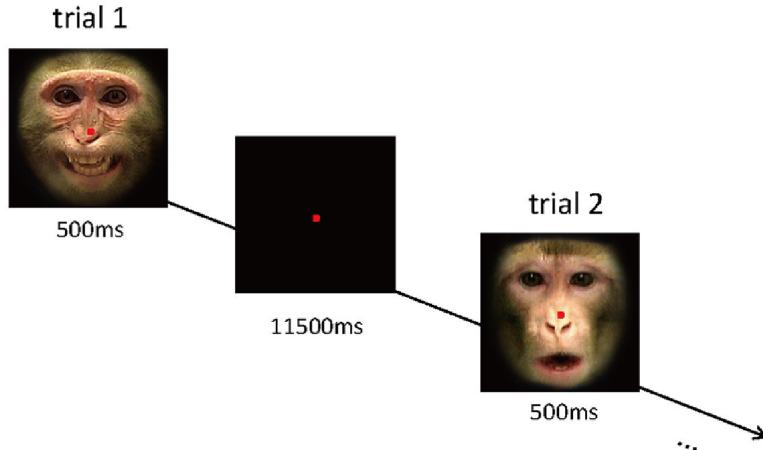
- Do regions in the monkey dissociate between expression and identity?



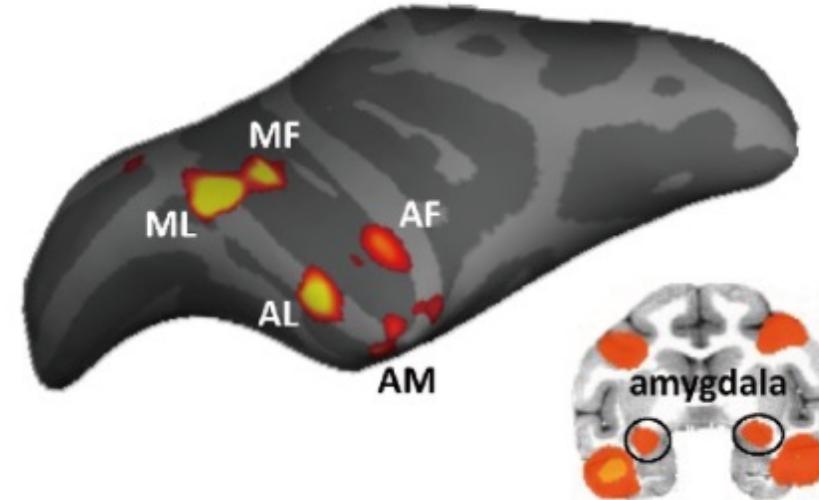
Event-related fMRI study in monkeys

Hui
Zhang

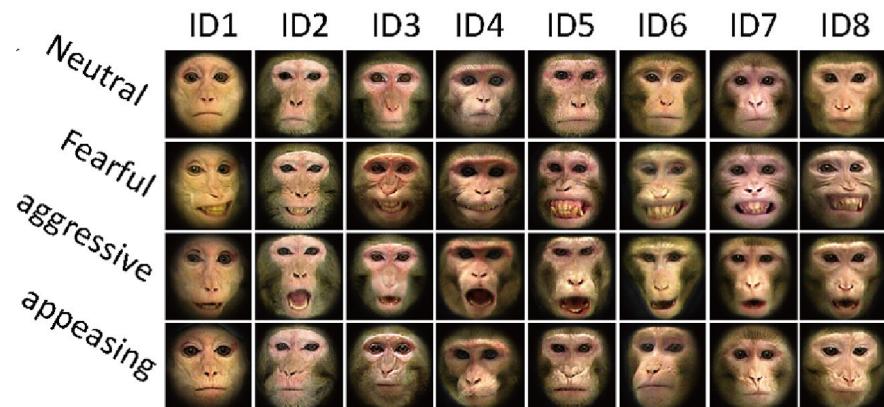
TASK:



Face-selective regions



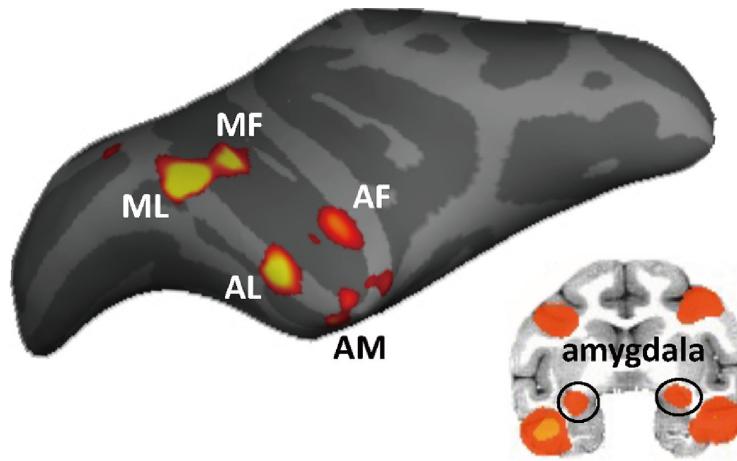
STIMULI: 4 expressions and 8 identities



2 sets

Zhang et al., 2023 (Neuroimage)

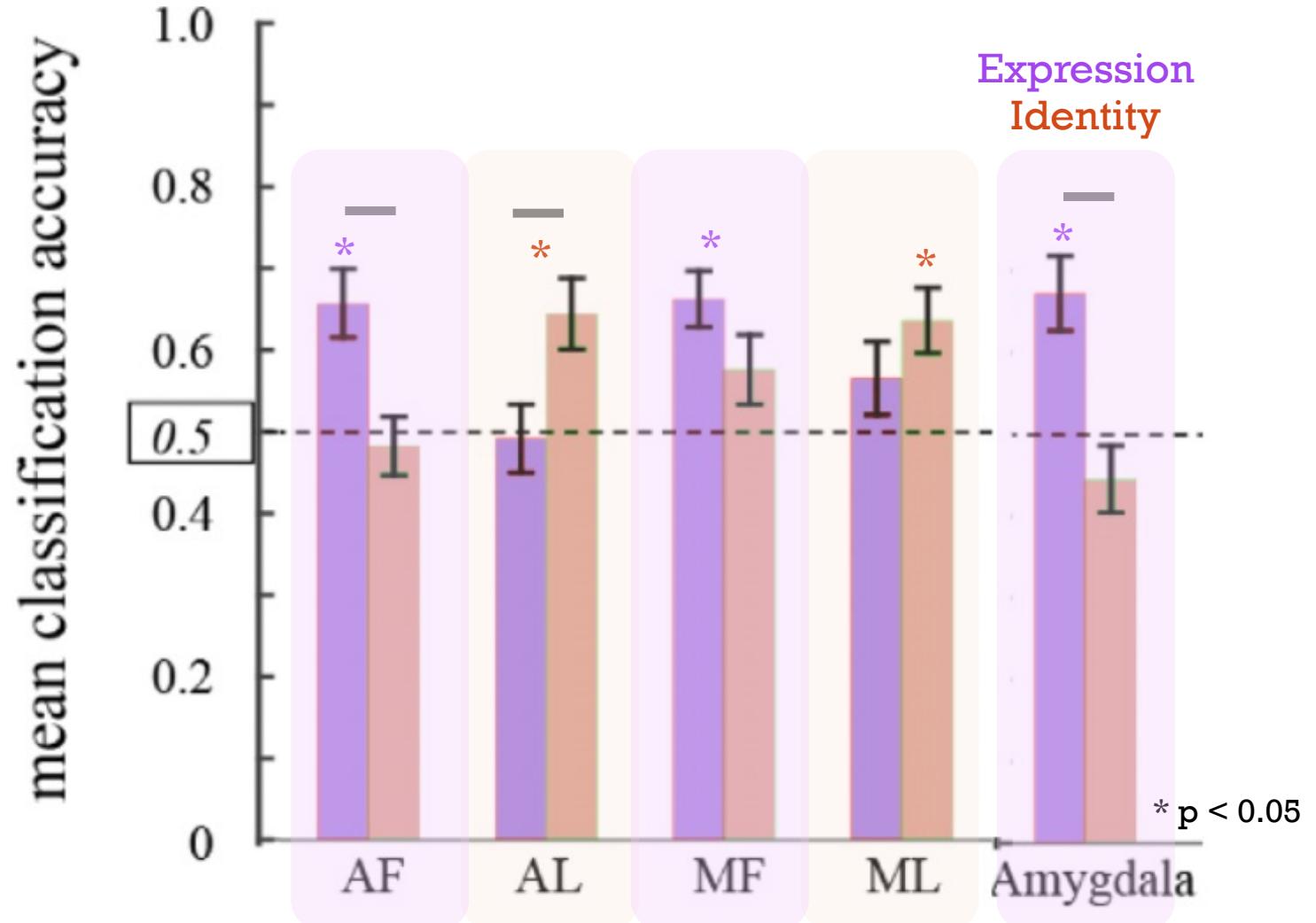
FMRI DECODING OF IDENTITY AND EXPRESSION



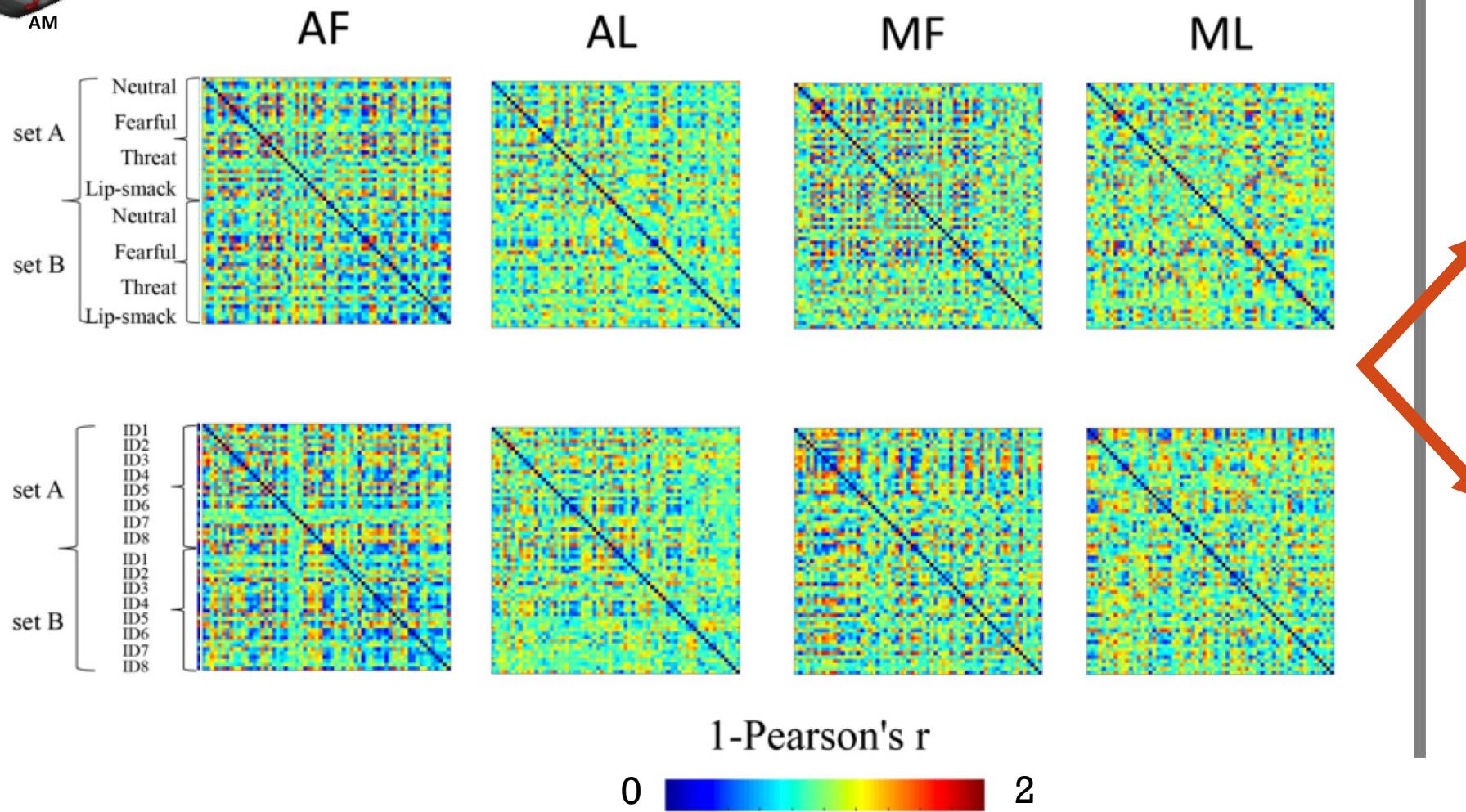
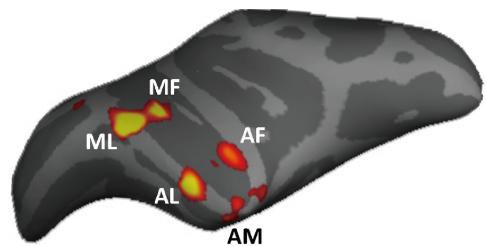
ANALYSIS:

Pairwise SVM

Leave-one-
identity/expression
cross-validation

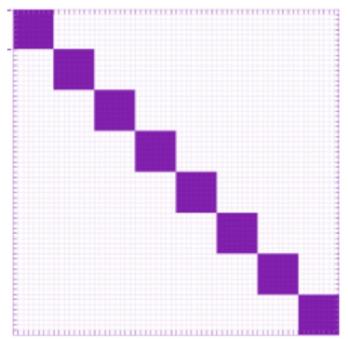


Representational Similarity Analysis of fMRI data

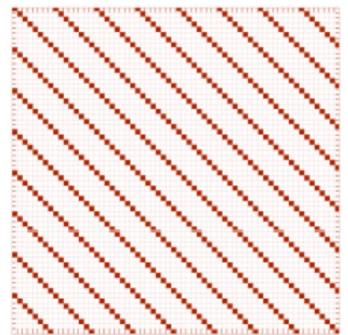


Model RDMs

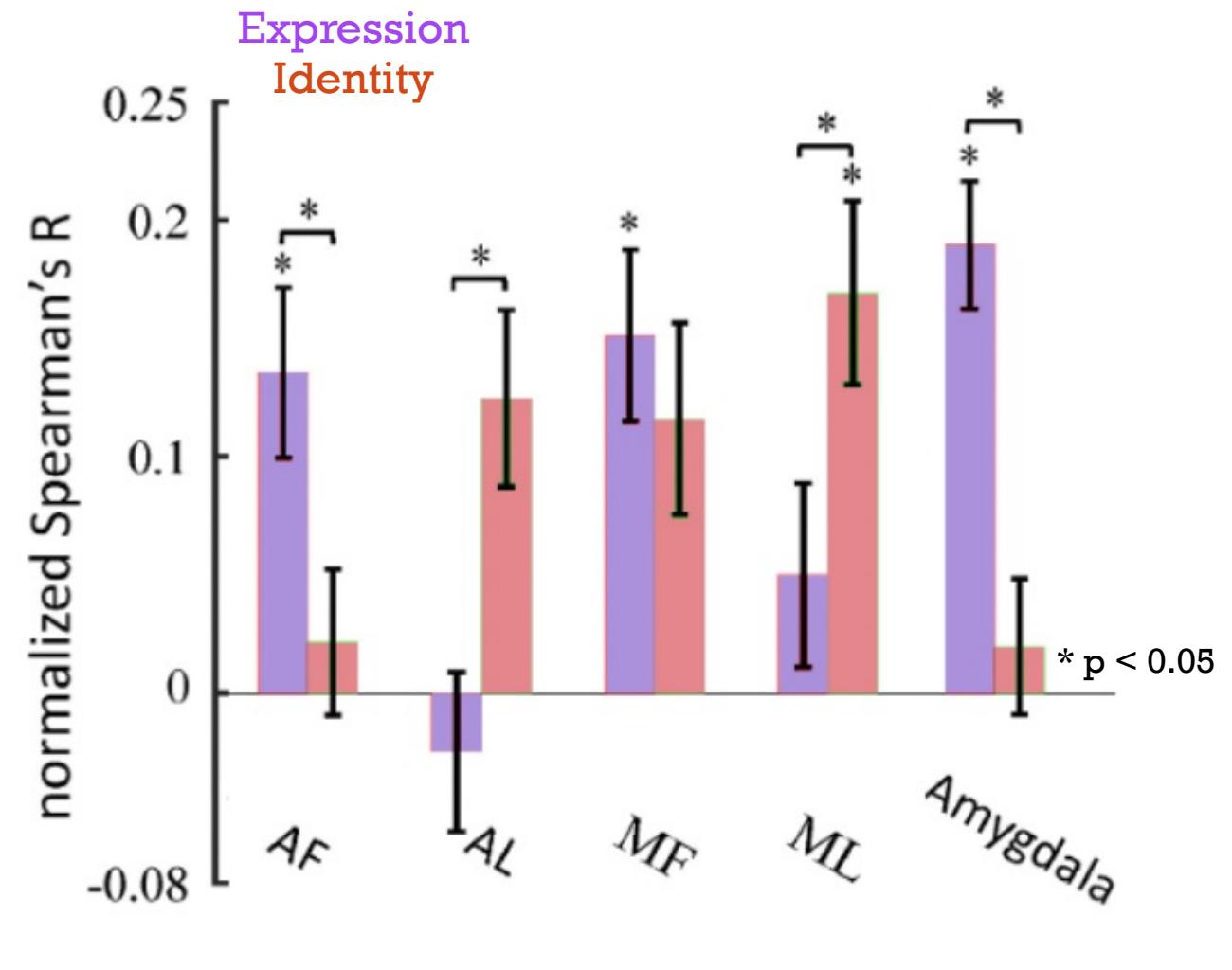
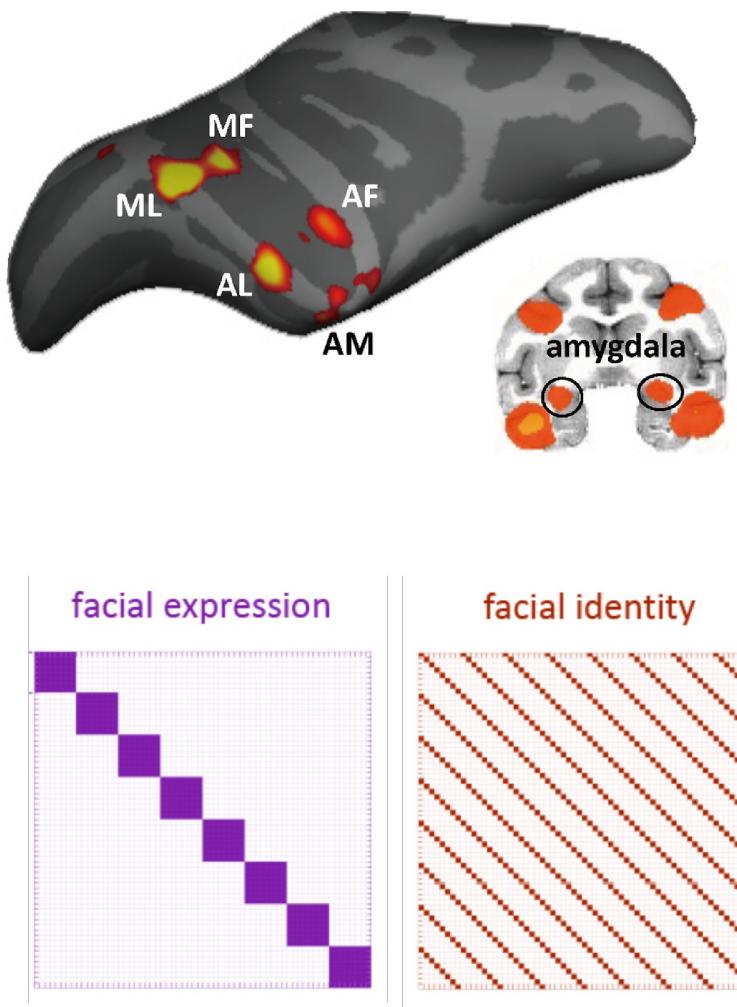
facial expression



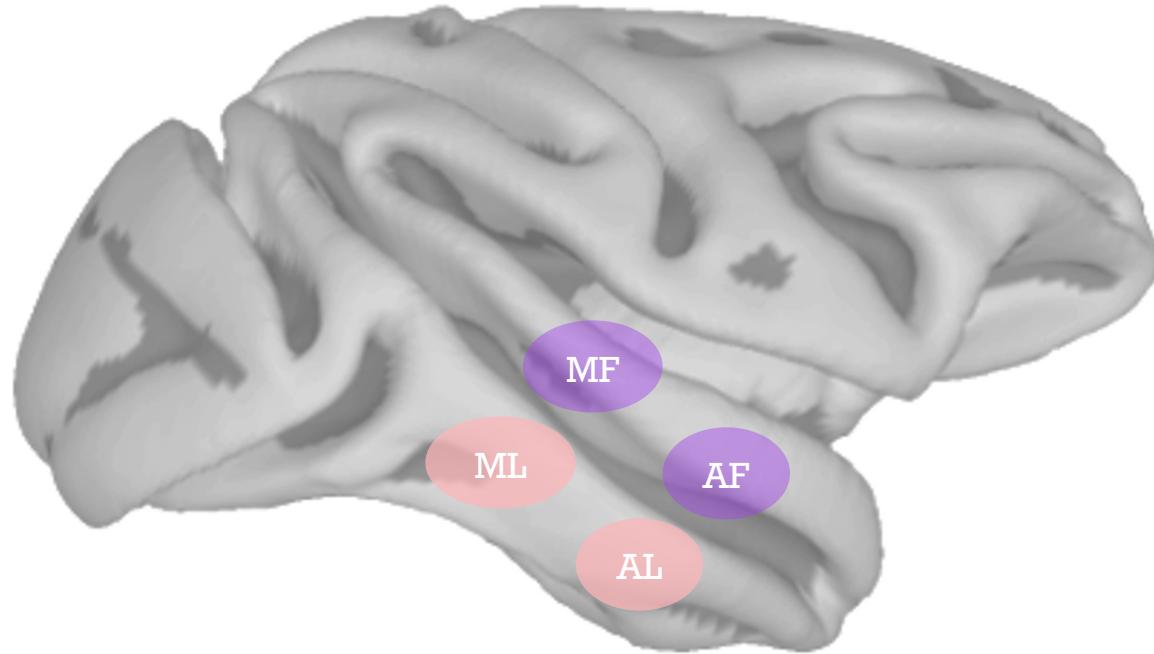
facial identity



Correlation of fMRI RDMs with model RDMs



- In monkeys, fundus regions of STS are sensitive to **changeable** aspects of a face such as **expression**
- Lateral STS regions prefer **fixed** aspects of a face such as **identity**



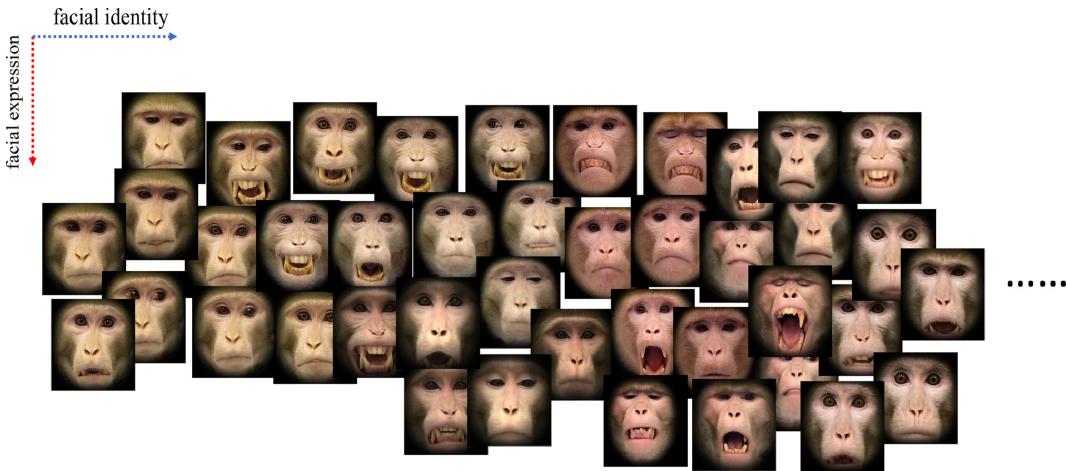
-
- Can we model extraction of identity and expression information using neural networks?



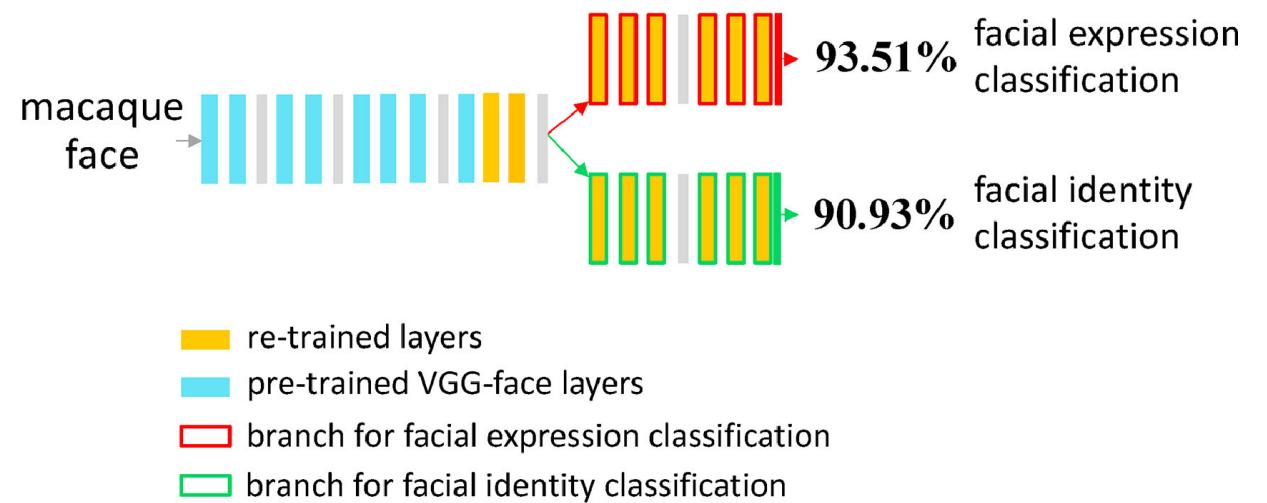
TRAINING A NEURAL NETWORK

large macaque face image dataset

16K macaque face images with 4 expressions and ~80 identities



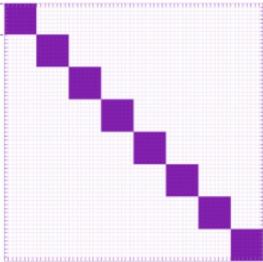
Dual-branch DNN trained for expression and identity classification



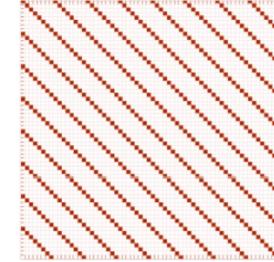
Ability of DNN layers to categorize expressions and identities

Correlation with model RDMs

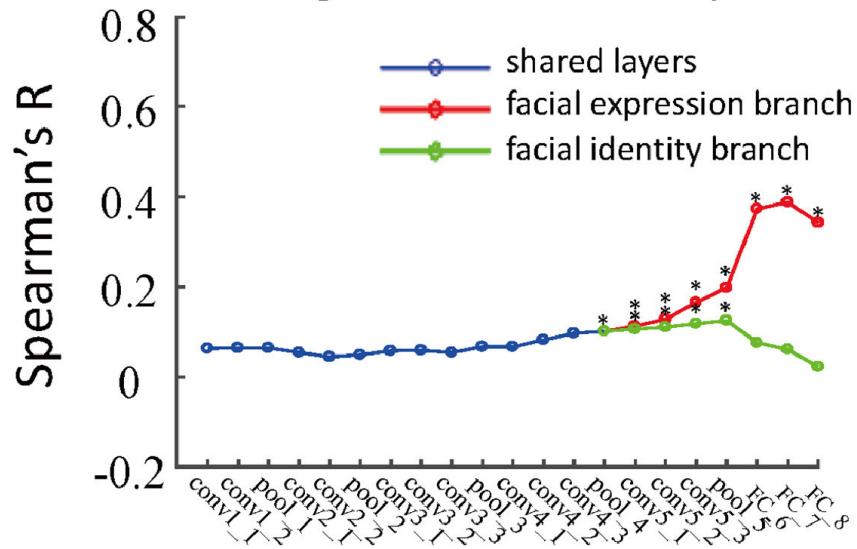
facial expression



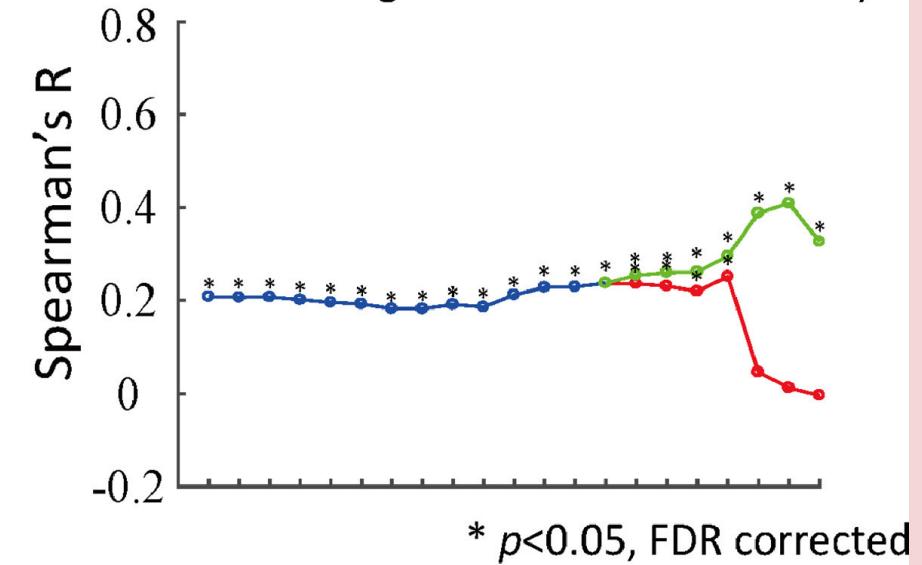
facial identity



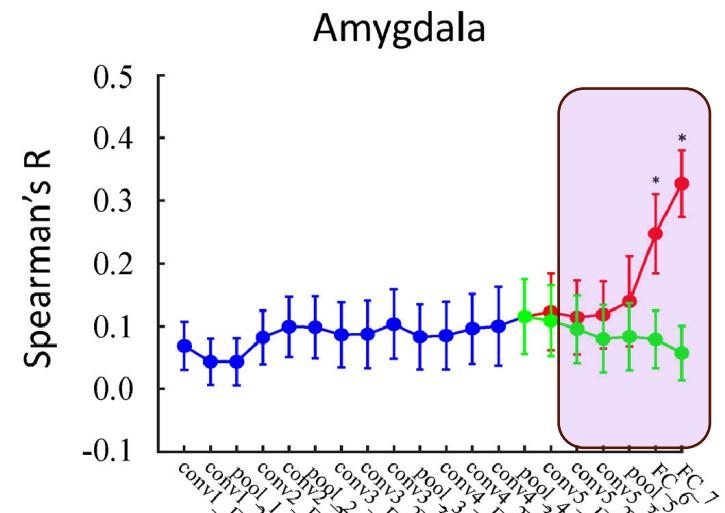
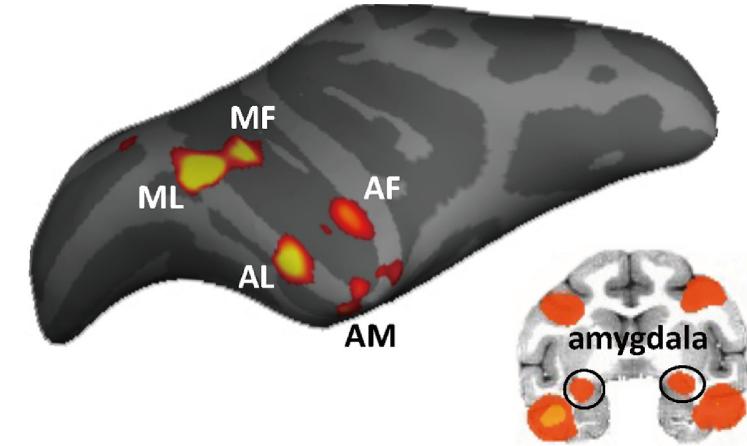
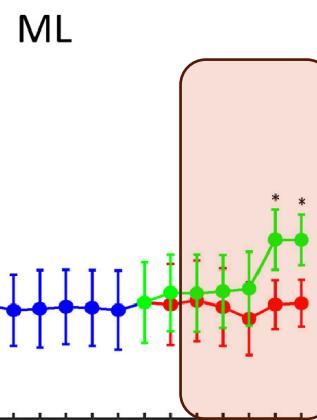
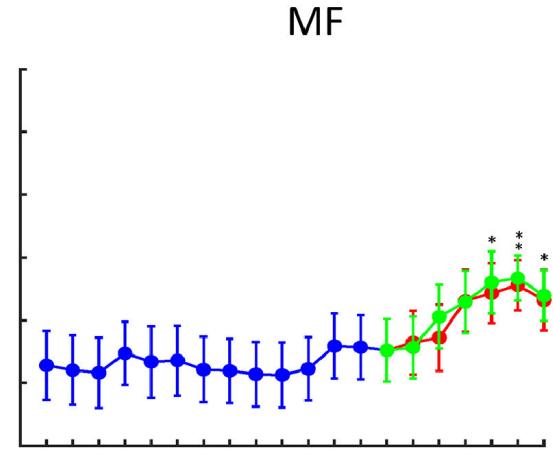
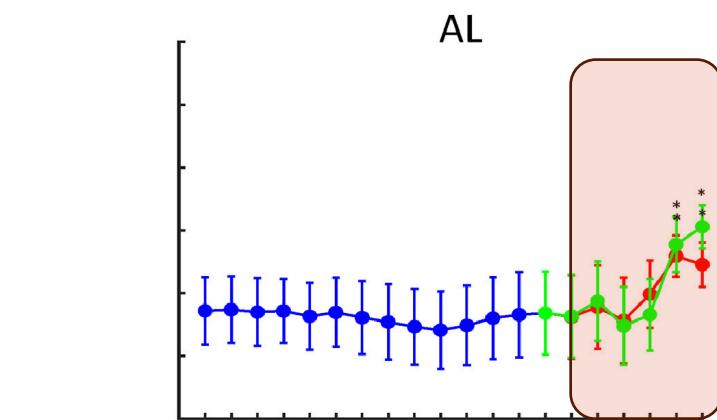
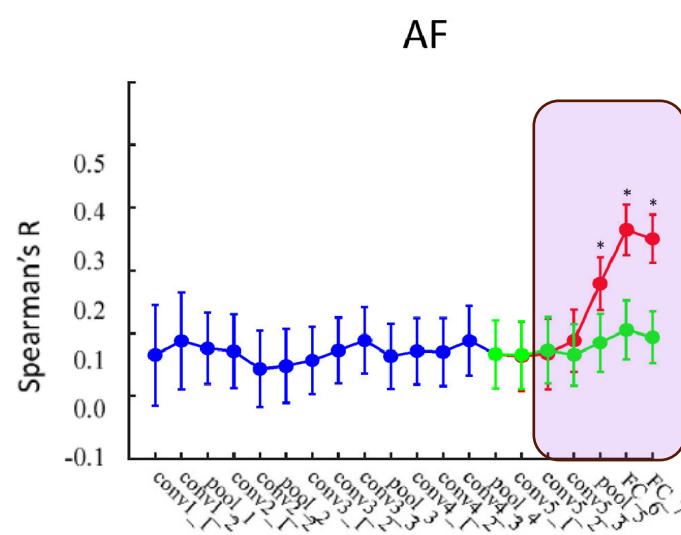
categorization of facial expression



categorization of facial identity



Representational correspondence between the DNN layers and brain ROIs

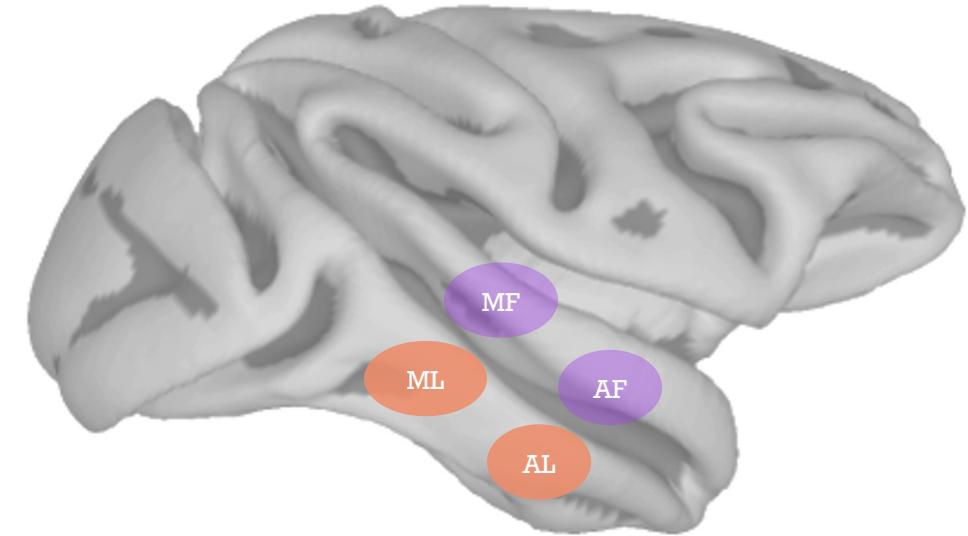
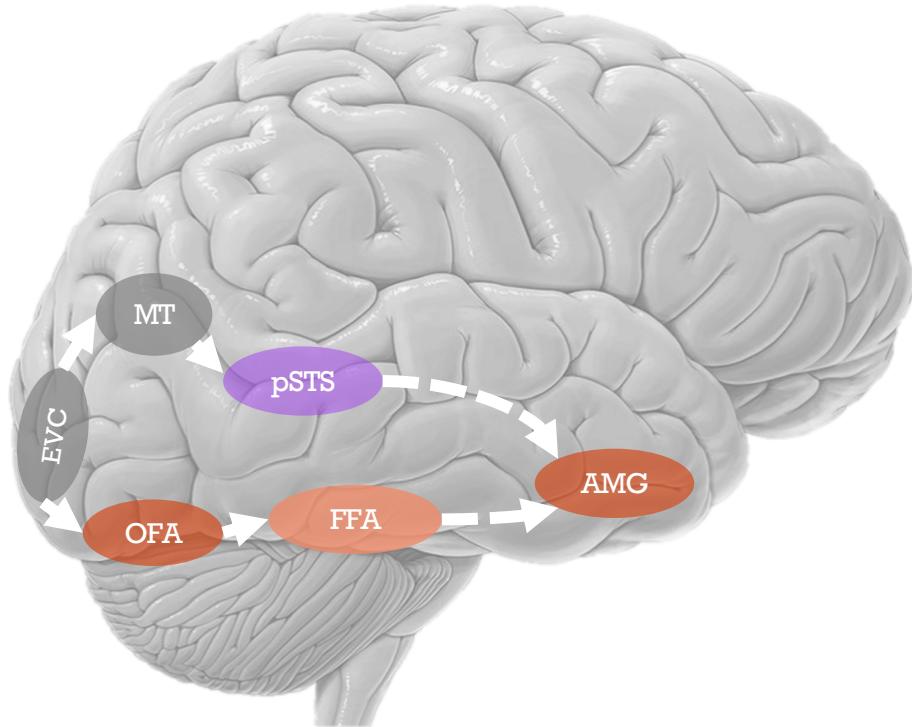


—●— shared layers

—●— facial expression branch

—●— facial identity branch

- Both monkeys and humans show dissociation of identity and expression processing
- STS regions in both species show preference for changeable aspects such as expression



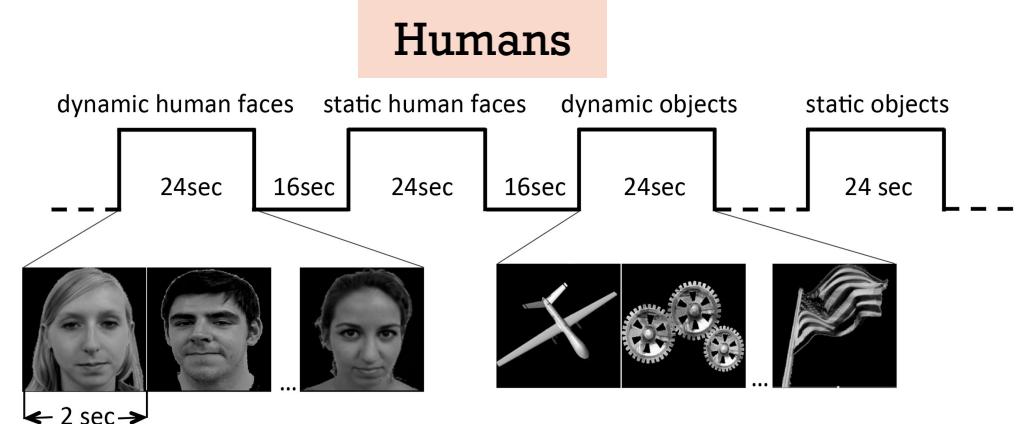
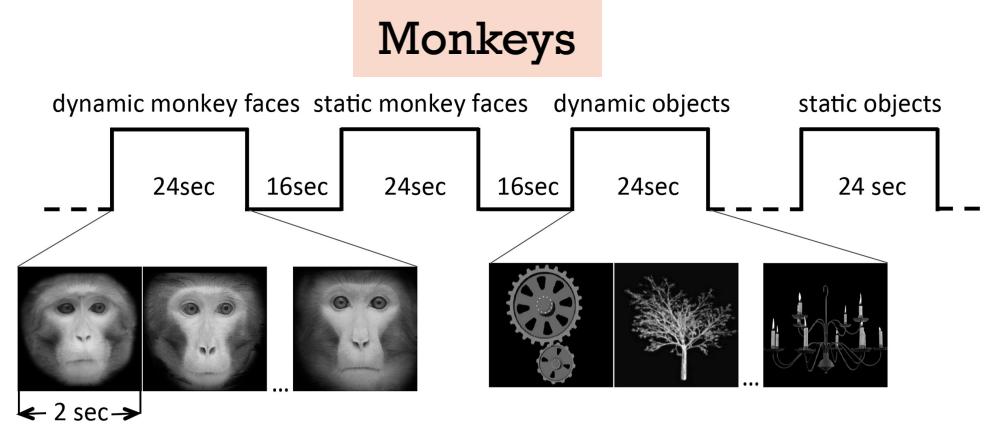
- Are regions in STS selective for facial motion?



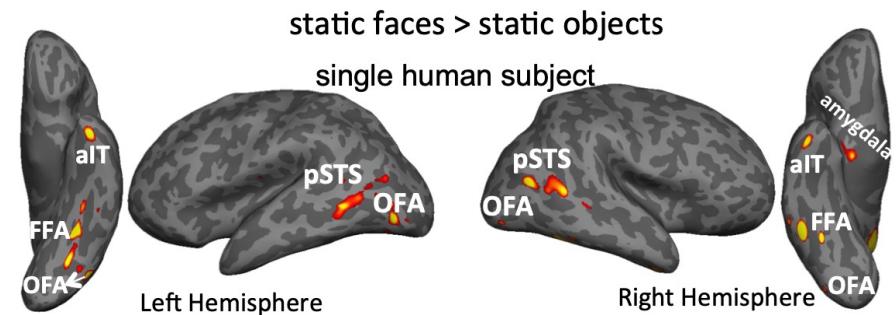
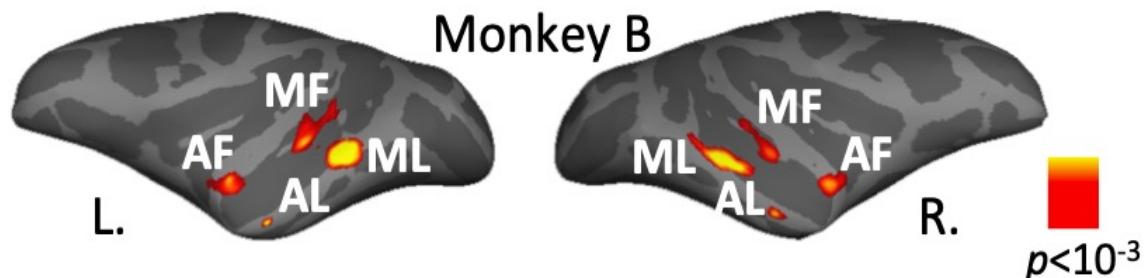
FACIAL MOTION SENSITIVITY

Hui
Zhang

fMRI study of facial and object motion in monkeys and humans

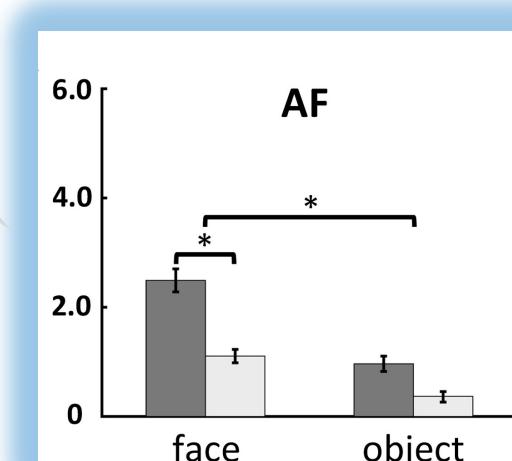
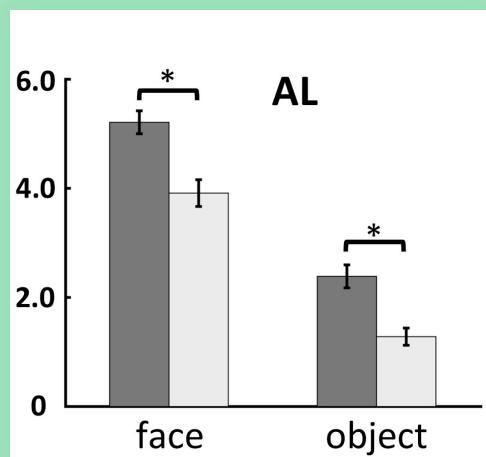
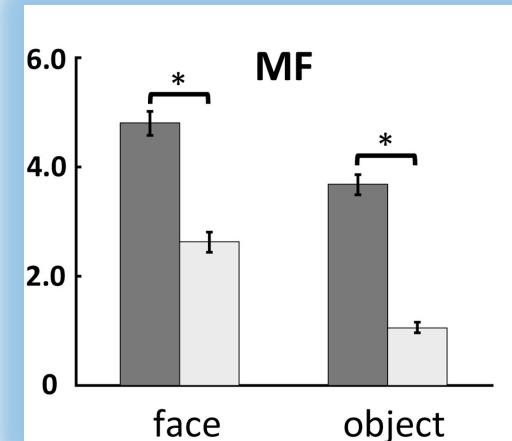
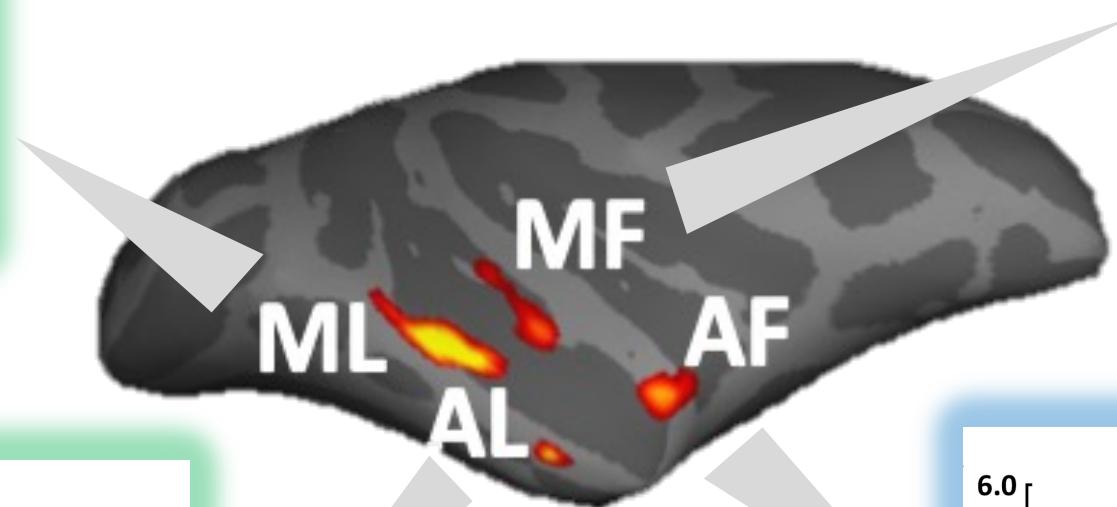
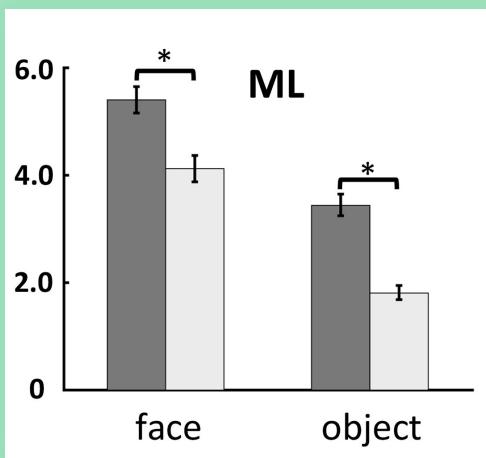


Localization of face-selective regions

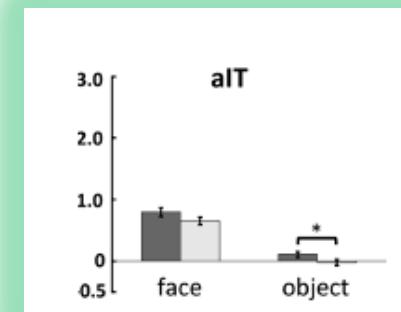
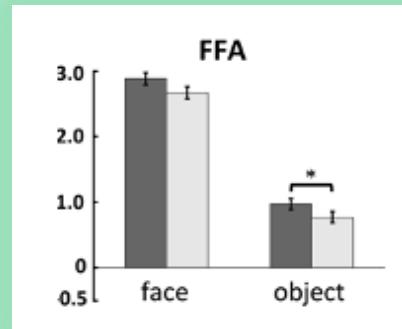
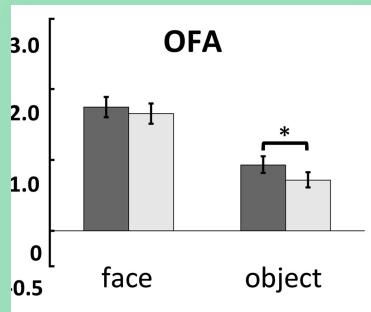
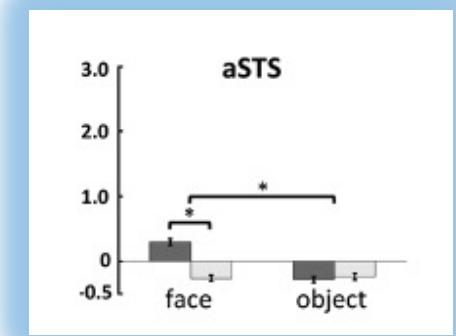
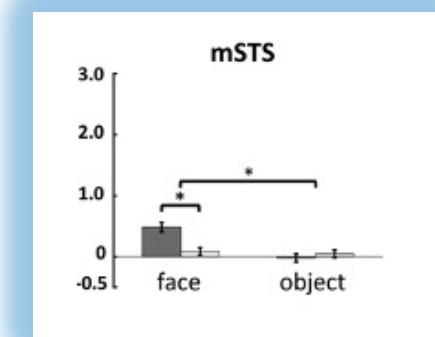
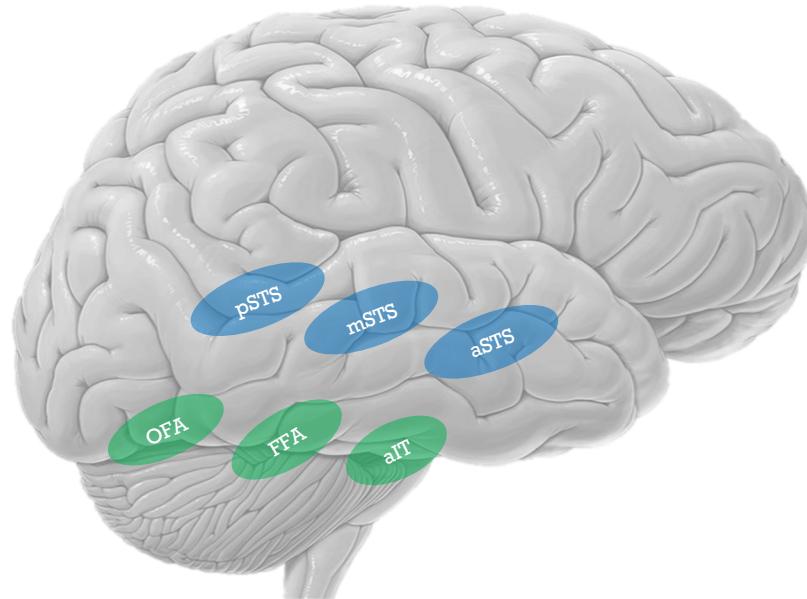
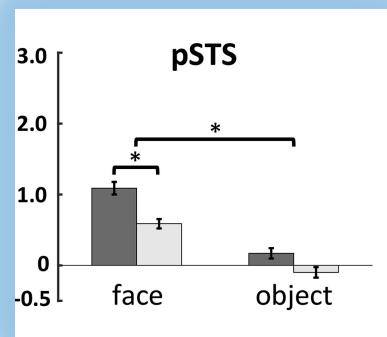


Zhang, Japee, et al., 2020 (Neuroimage)

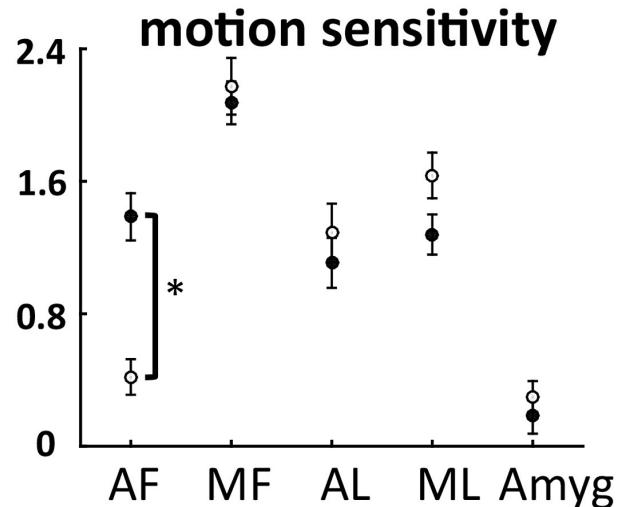
MONKEYS: Face and object motion preference in STS regions



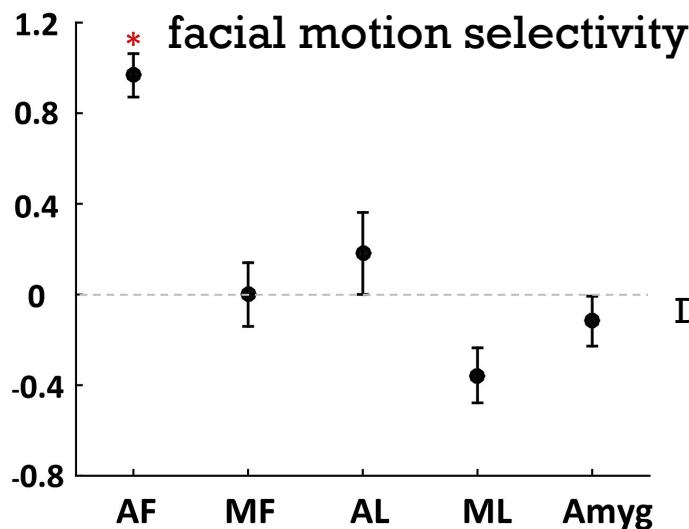
HUMANS: Face and object motion preference in lateral STS and ventral temporal regions



Monkeys

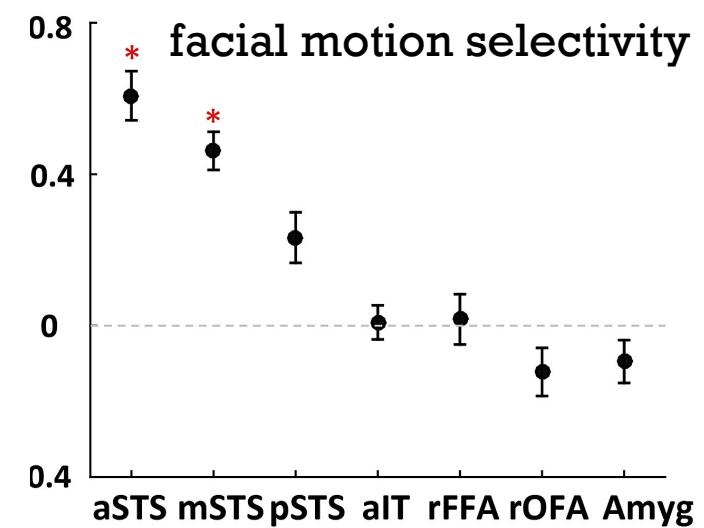
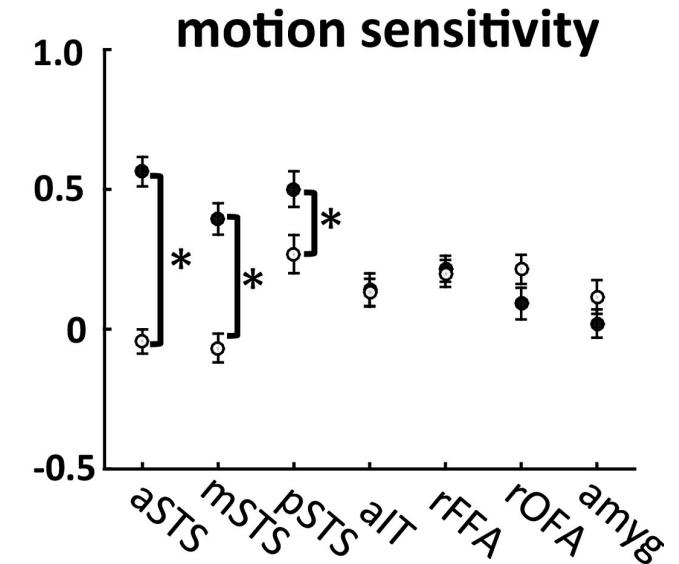


● facial motion ○ object motion
Dynamic – static



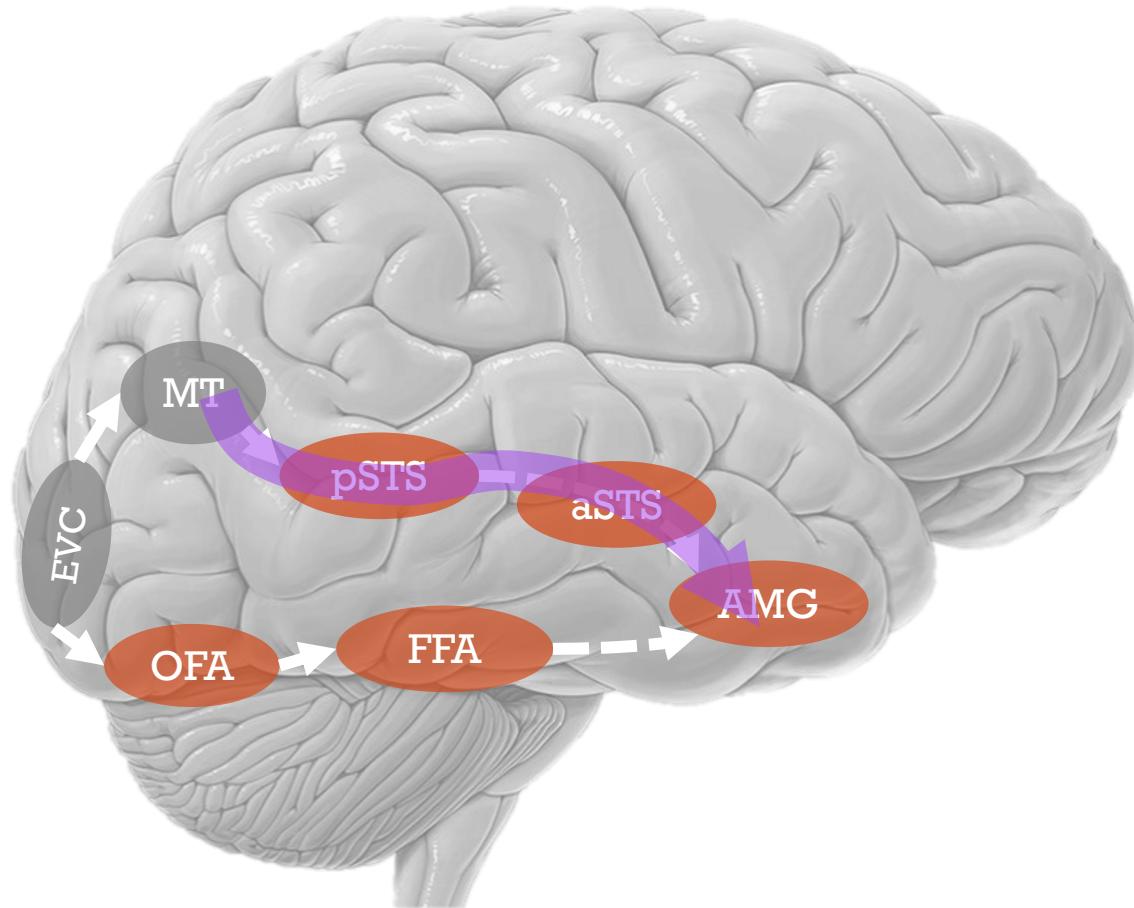
Dynamic faces – static faces
-
Dynamic objects - static objects

Humans



* $p < 0.01$

- STS regions in monkeys and humans are sensitive to facial motion
- Anterior regions prefer facial motion over object motion



- Is posterior STS critical for processing facial motion?

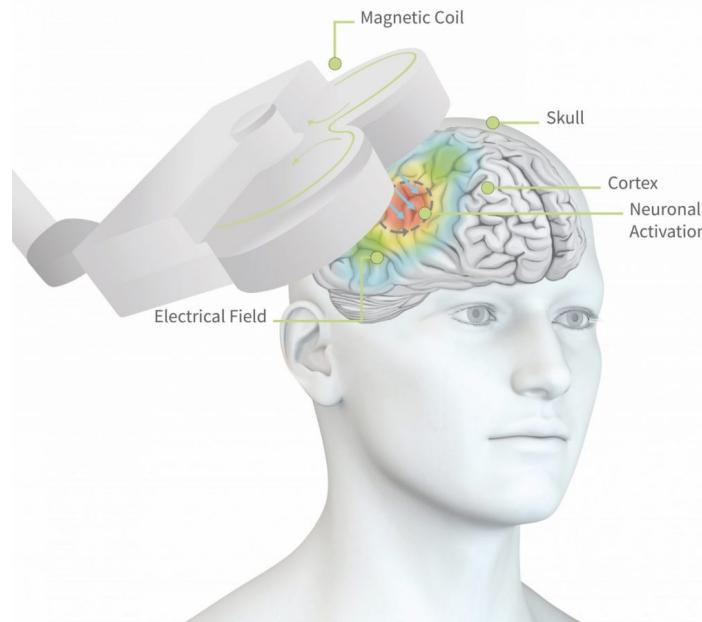


ROLE OF STS IN FACIAL MOTION

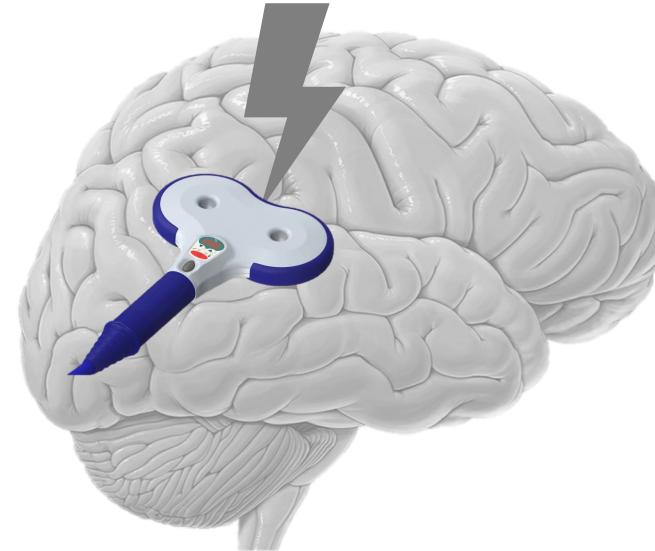


David Pitcher

Use transcranial magnetic stimulation to disrupt activity in pSTS and examine effects downstream



Theta-burst TMS over right pSTS or vertex combined with fMRI scans



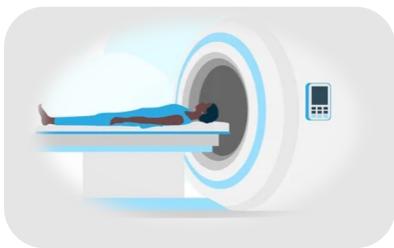
3 pulses at 50 Hz repeated at 200 ms intervals for 60 s train of 900 pulses

Pitcher, Japee, et al., 2017 (*J Neuroscience*)



ROLE OF STS IN FACIAL MOTION

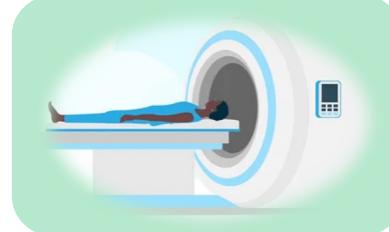
Session 1



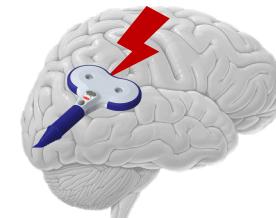
Face, Body and Object Localizer

Session 2

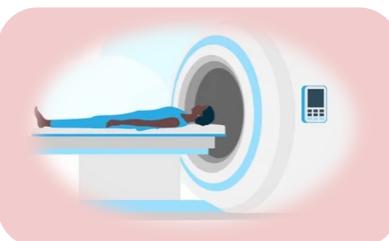
Pre-TMS Baseline Scan



TBS over right pSTS



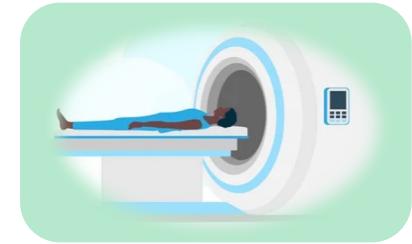
Post-TMS pSTS Scan



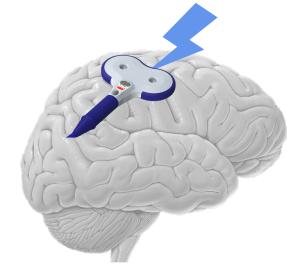
counter-balanced
across participants

Session 3

Pre-TMS Baseline Scan



TBS over vertex



Post-TMS Vertex Scan

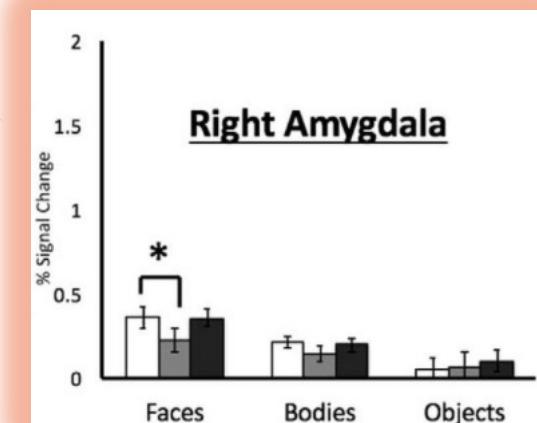
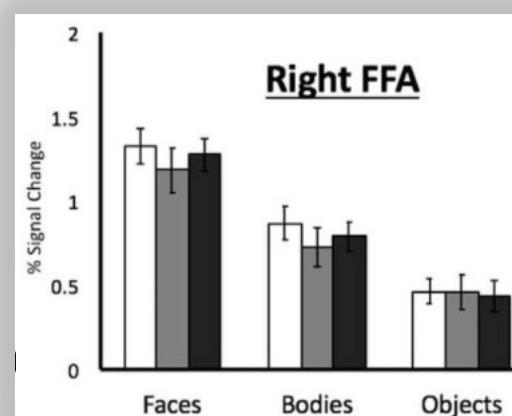
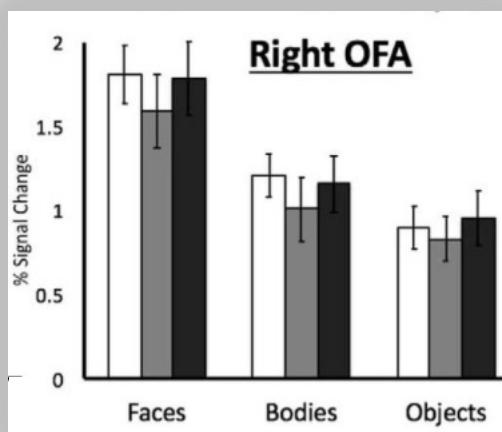
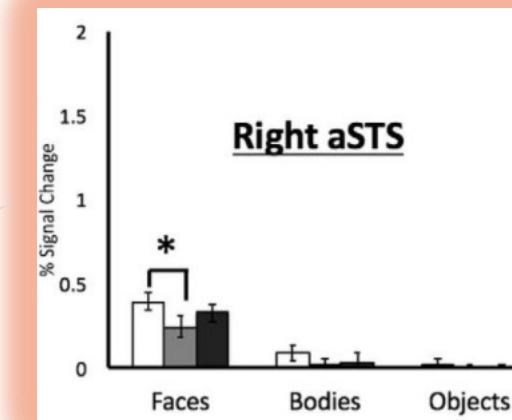
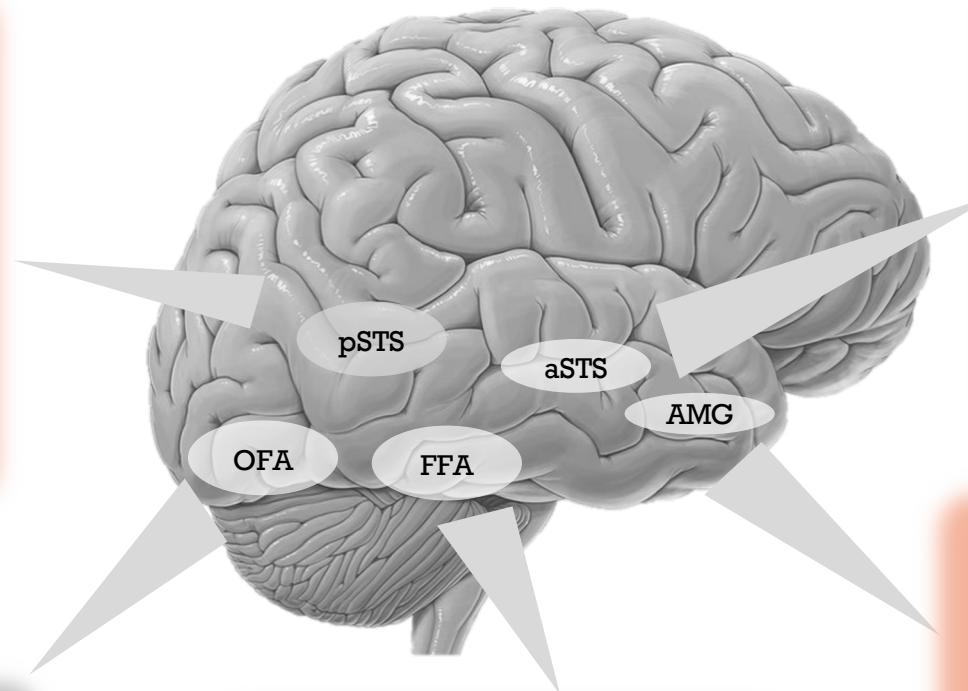
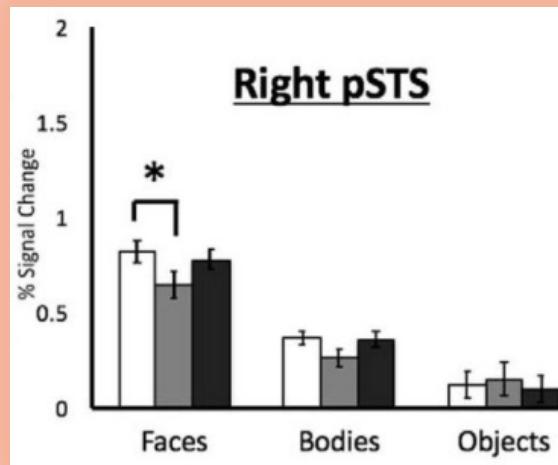


SCANS: Block-designed fMRI scans

STIMULI: 18 s blocks of videos of faces, bodies and objects
TASK: one back on identity of actor, body or object)

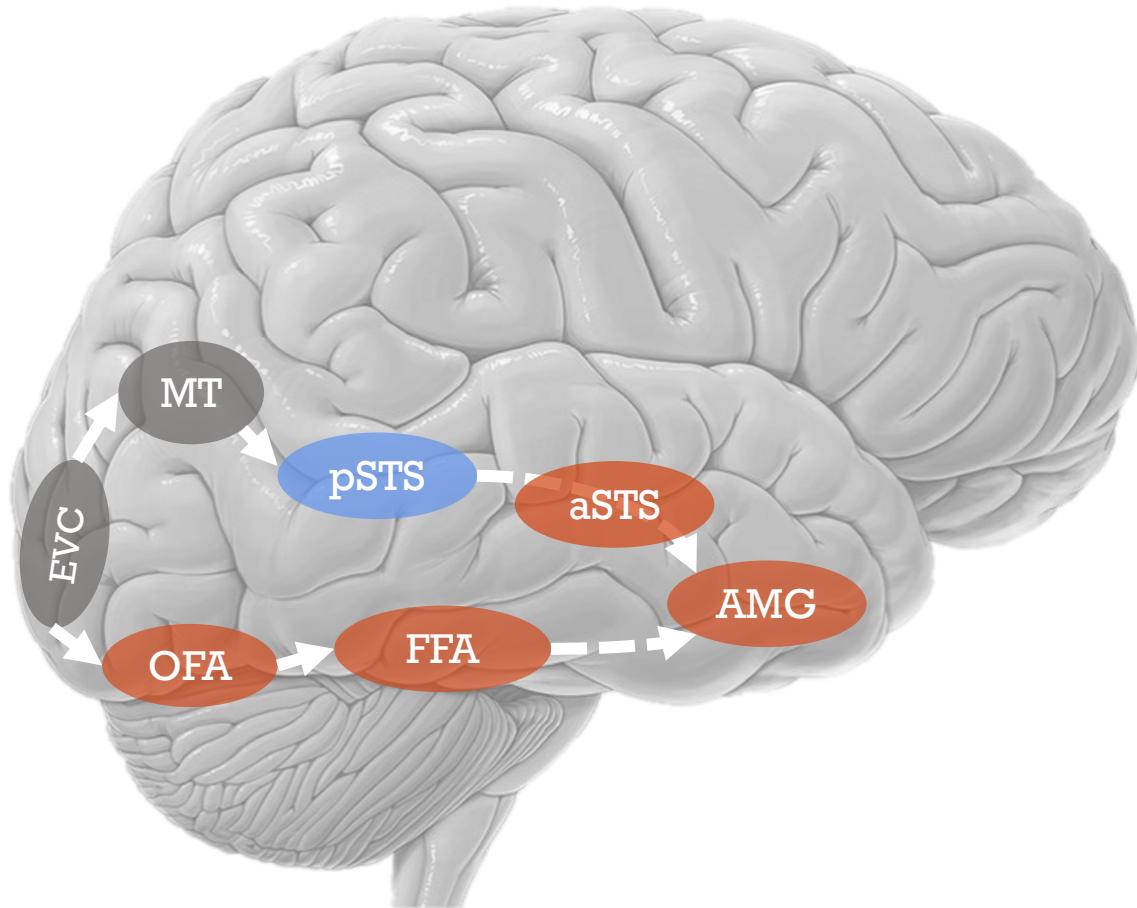


ROLE OF STS IN FACIAL MOTION



- Pre TBS Baseline
- Post TBS to rpSTS
- Post TBS to Vertex

Posterior STS is critical for processing of facial motion



- Are all types of facial motion processed similarly?

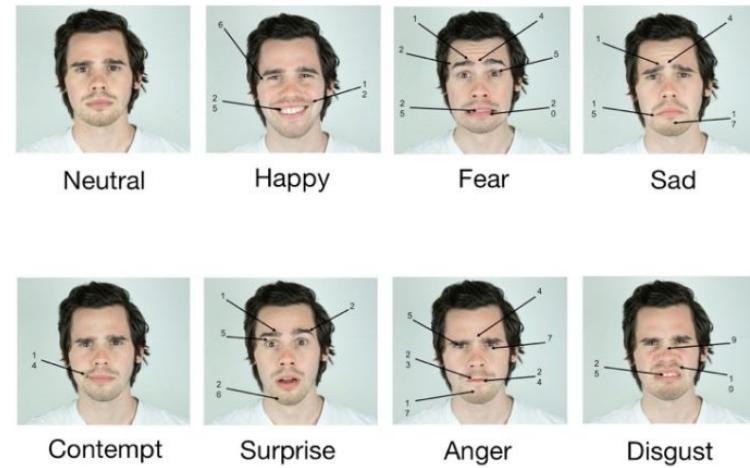


ARE ALL DYNAMIC ASPECTS OF A FACE PROCESSED SIMILARLY?

Head Orientation:
a type of dynamic change in a face
where feature spacing is preserved



Facial Expression:
a type of dynamic change where
feature shape and spacing changes



Action Unit's (AU)

- 1 = Inner Brow Raiser
- 2 = Outer Brow Raiser
- 4 = Brow Lower
- 5 = Upper Lid Raiser
- 6 = Cheek Raiser
- 7 = Lid Tighten
- 9 = Nose Wrinkle
- 10 = Upper Lip Raiser
- 12 = Lip Corner Puller
- 14 = Dimple
- 15 = Lip Corner Depressor
- 17 = Chin Raiser
- 20 = Lip Stretcher
- 23 = Lip Tighten
- 24 = Lip Pressor
- 25 = Lips Part
- 26 = Jaw Drop

© 2019 ElAGroup.com

whole-face motion

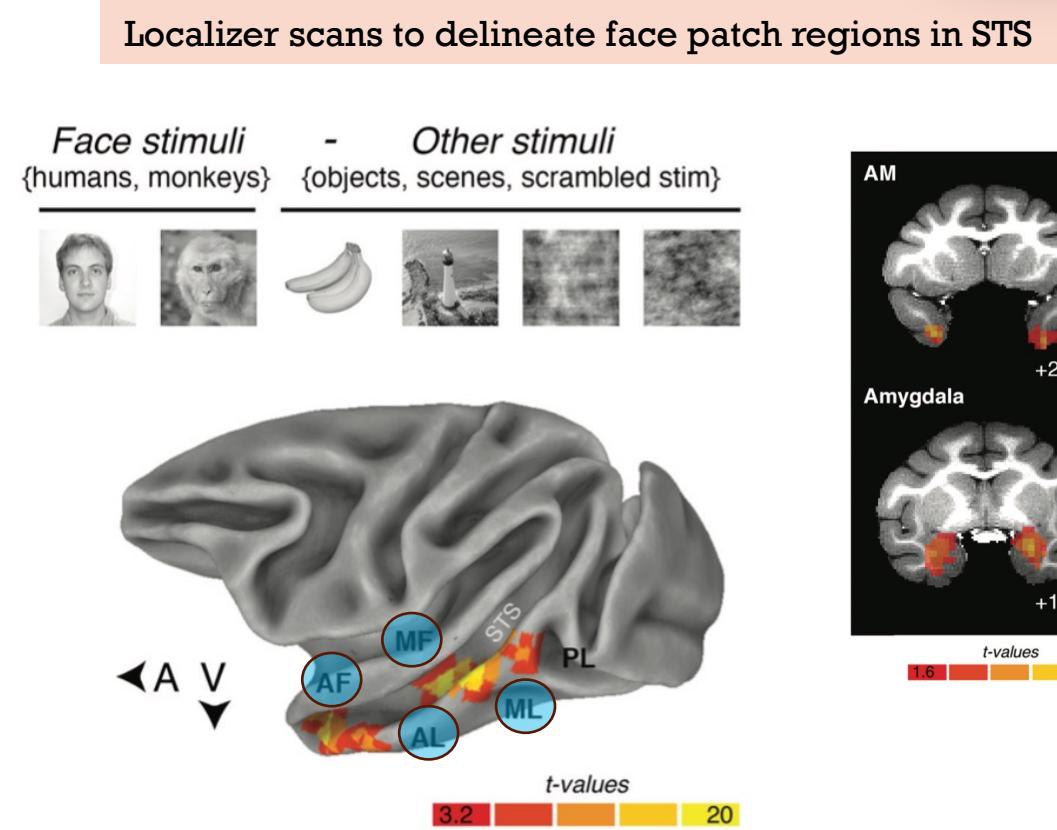
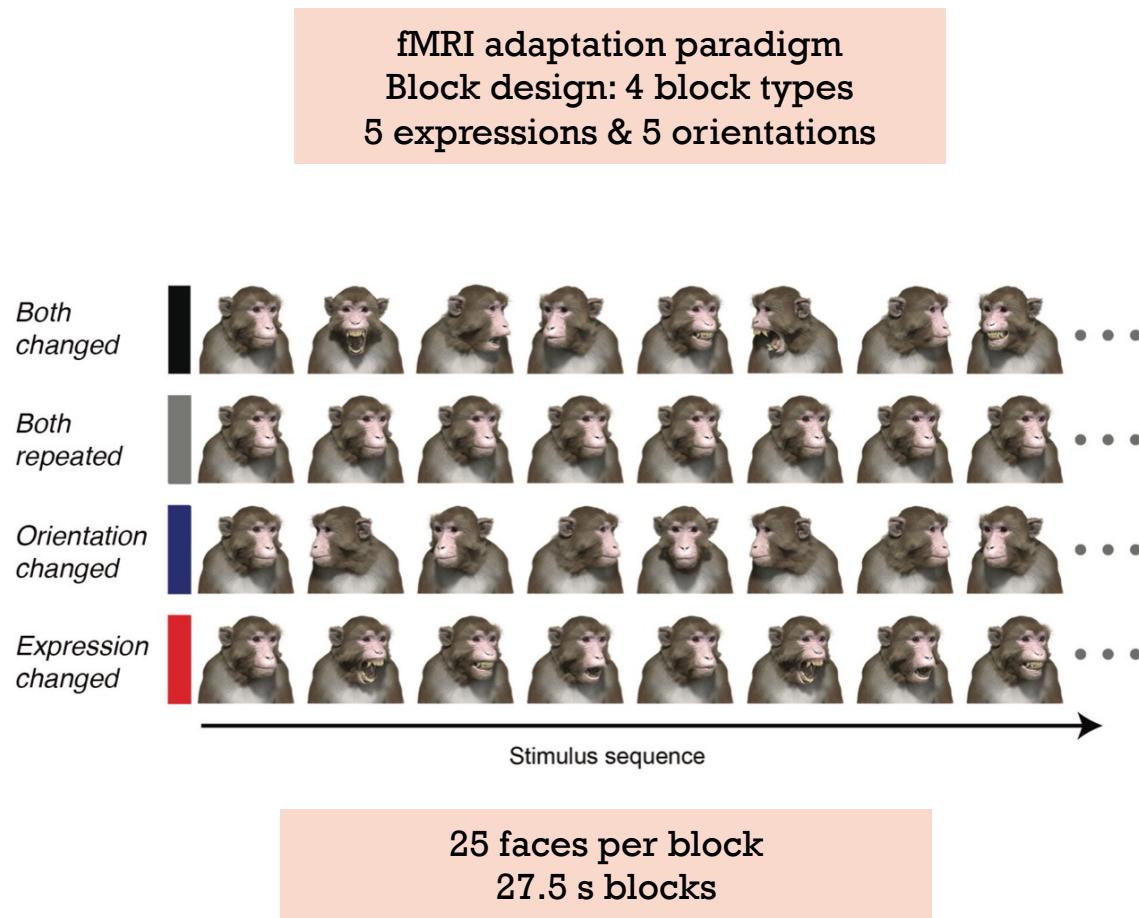
within-face motion



PROCESSING OF HEAD ORIENTATION & FACIAL EXPRESSION



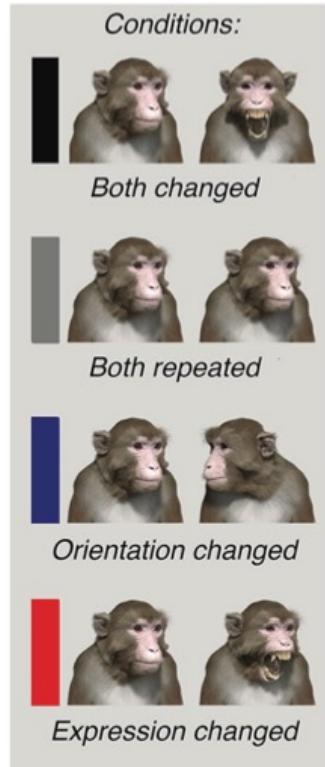
Jess Taubert



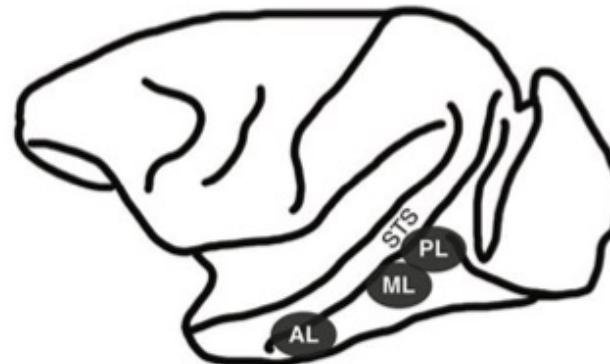
Taubert, Japhee, et al., 2020 (J Neuroscience)



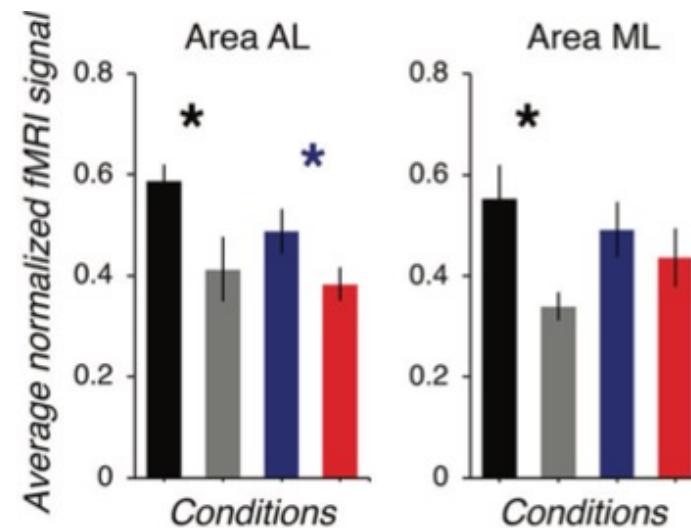
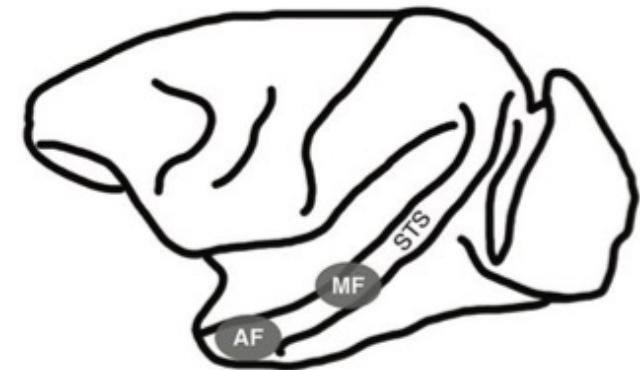
DISSOCIATION BETWEEN FACE PATCHES



Lateral Edge Patches

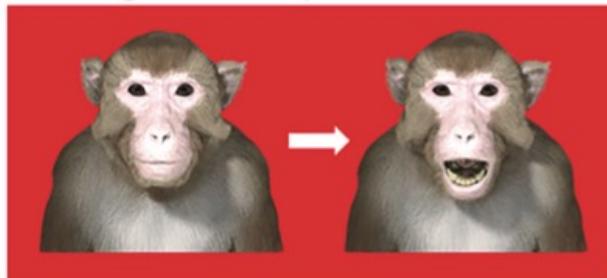


Fundus Patches

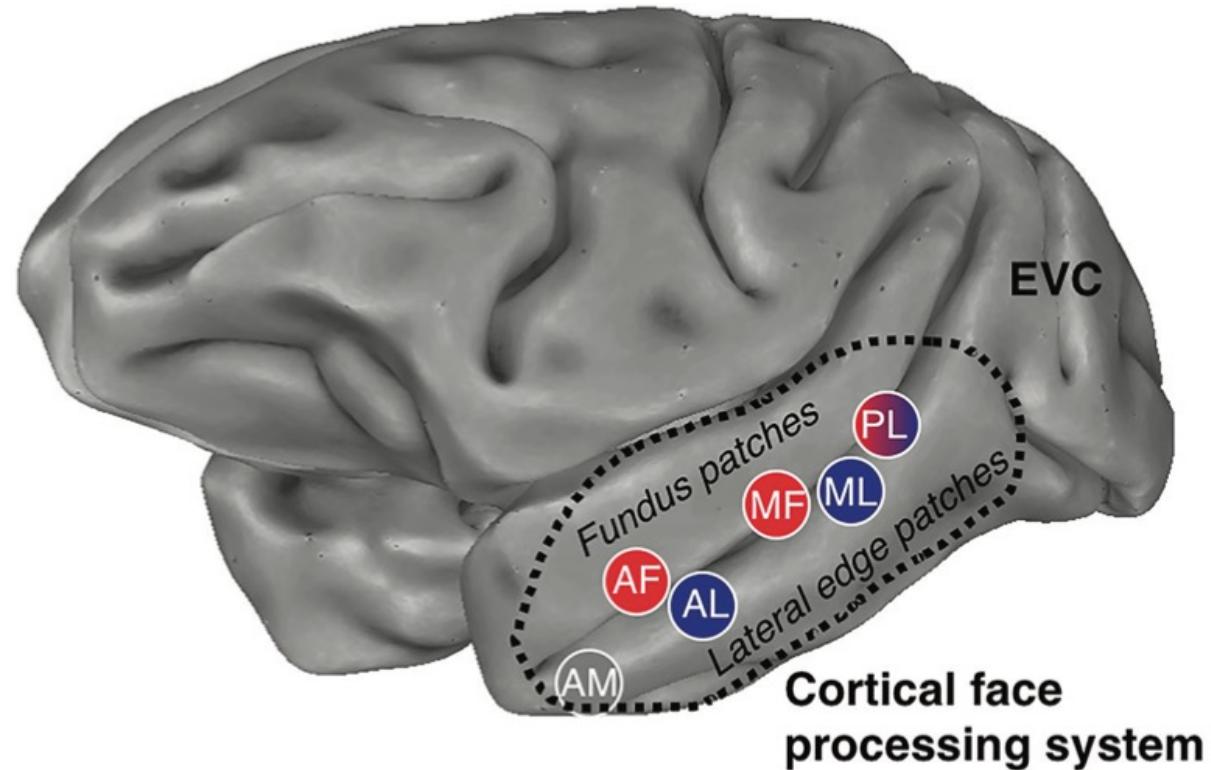
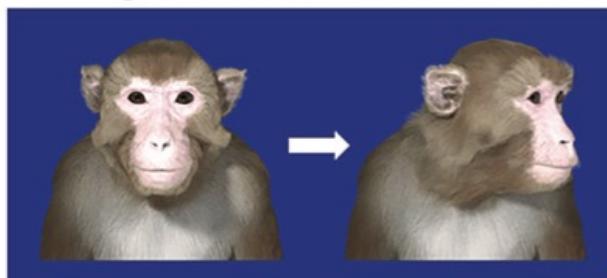


Functional dissociation between fundus and lateral edge face patches in STS for orientation and expression processing

Changes in expression

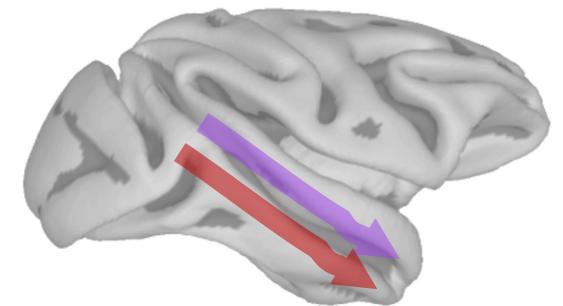
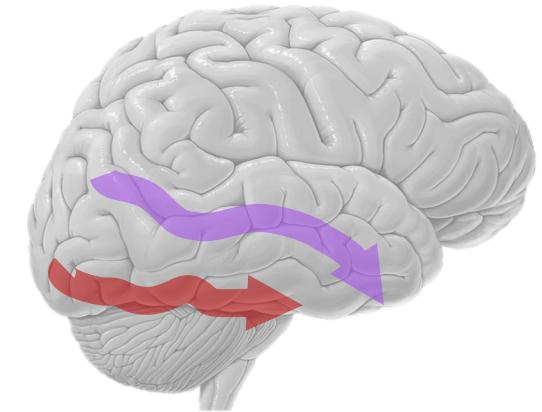


Changes in head orientation



RECAP SO FAR

- *Where* are facial cues processed in the brain?
 - HUMANS:
 - STS regions are sensitive to changeable aspects such as expression
 - Ventral regions such as FFA prefer fixed aspects such as identity
 - pSTS is critical for facial motion processing
 - MONKEYS:
 - STS fundus regions are sensitive to changeable aspects such as expression
 - STS lateral edge regions prefer fixed aspects such as identity and head orientation

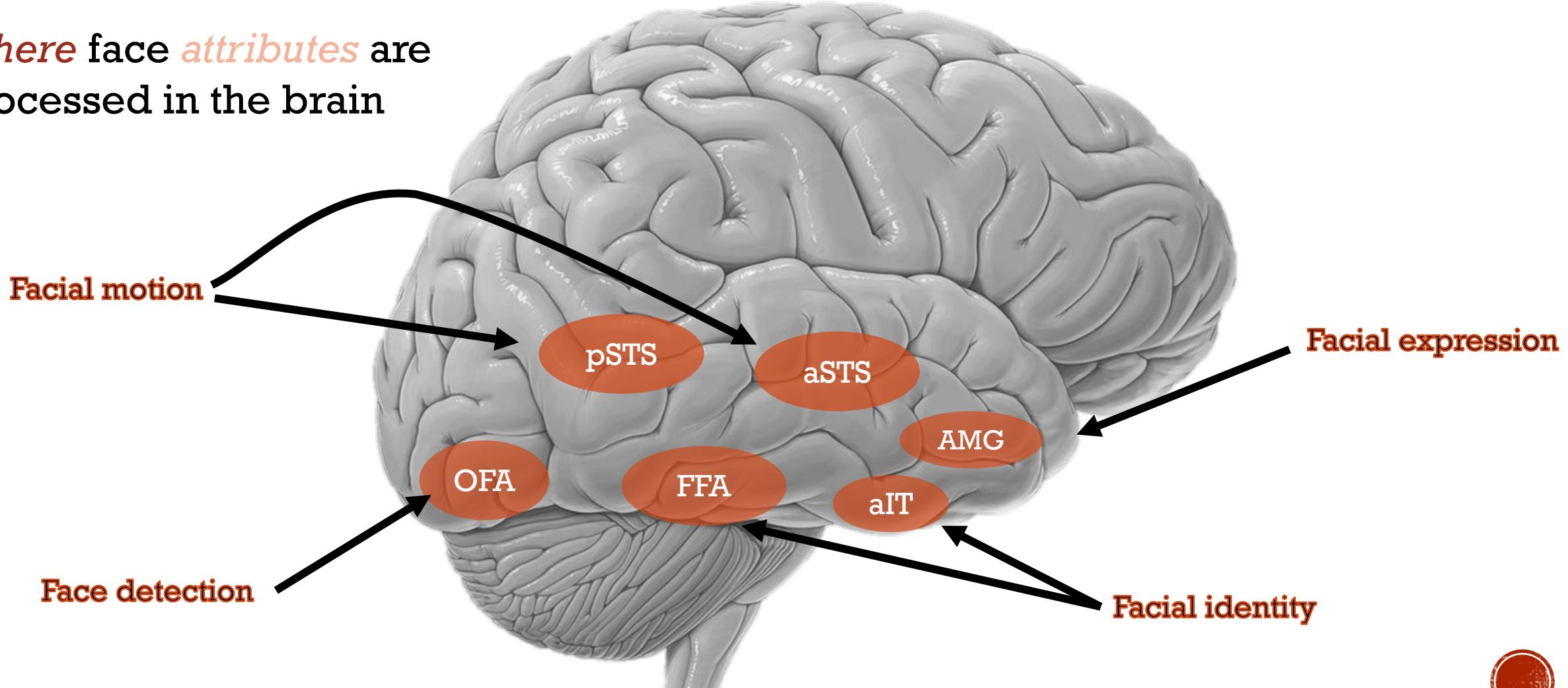


WHEN ARE FACIAL CUES PROCESSED IN THE BRAIN?



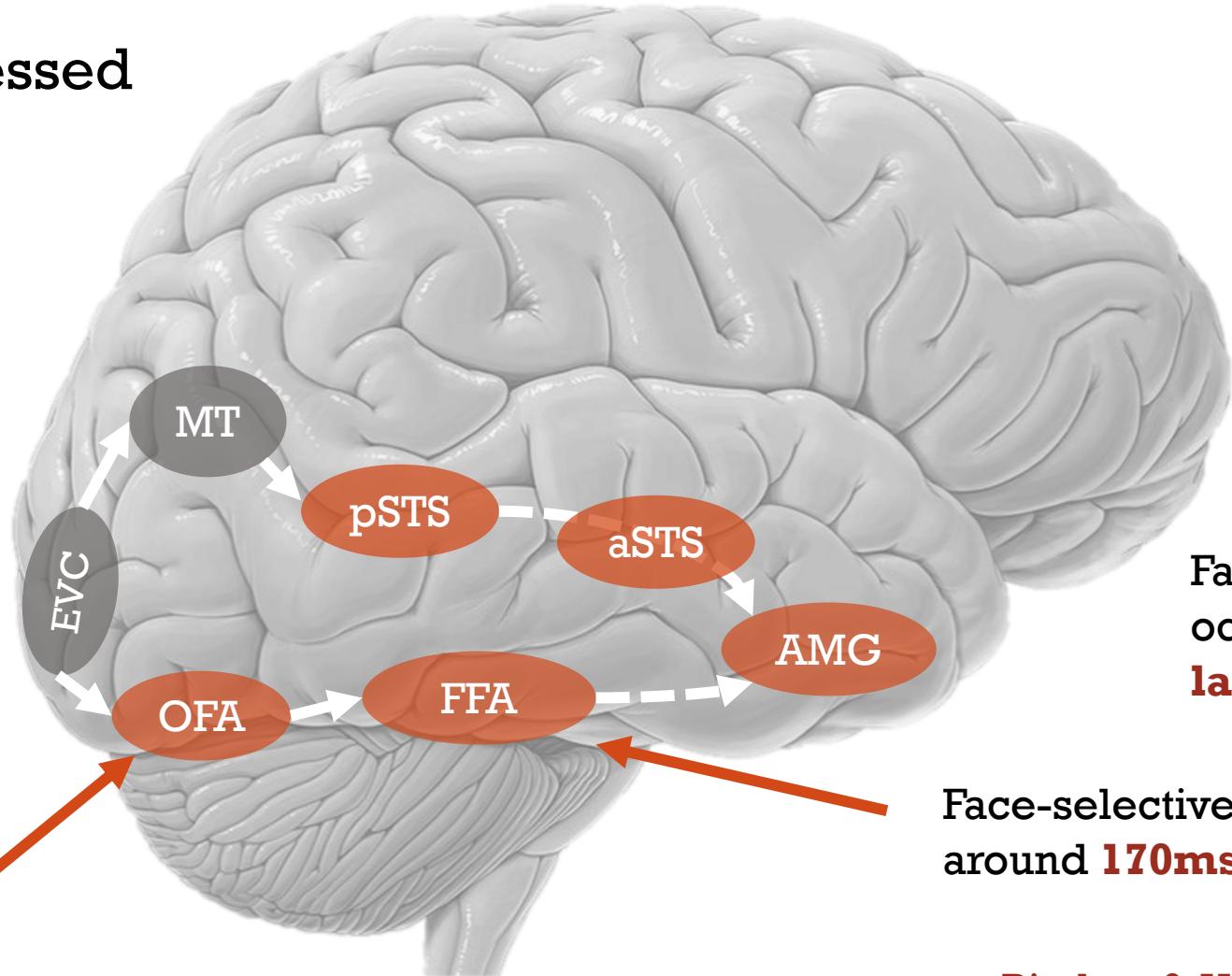
WHAT WE KIND OF KNOW

Where face *attributes* are processed in the brain



WHAT WE SORT OF KNOW

When faces are processed
in the brain



Earliest processing of faces
occurs around **90ms**

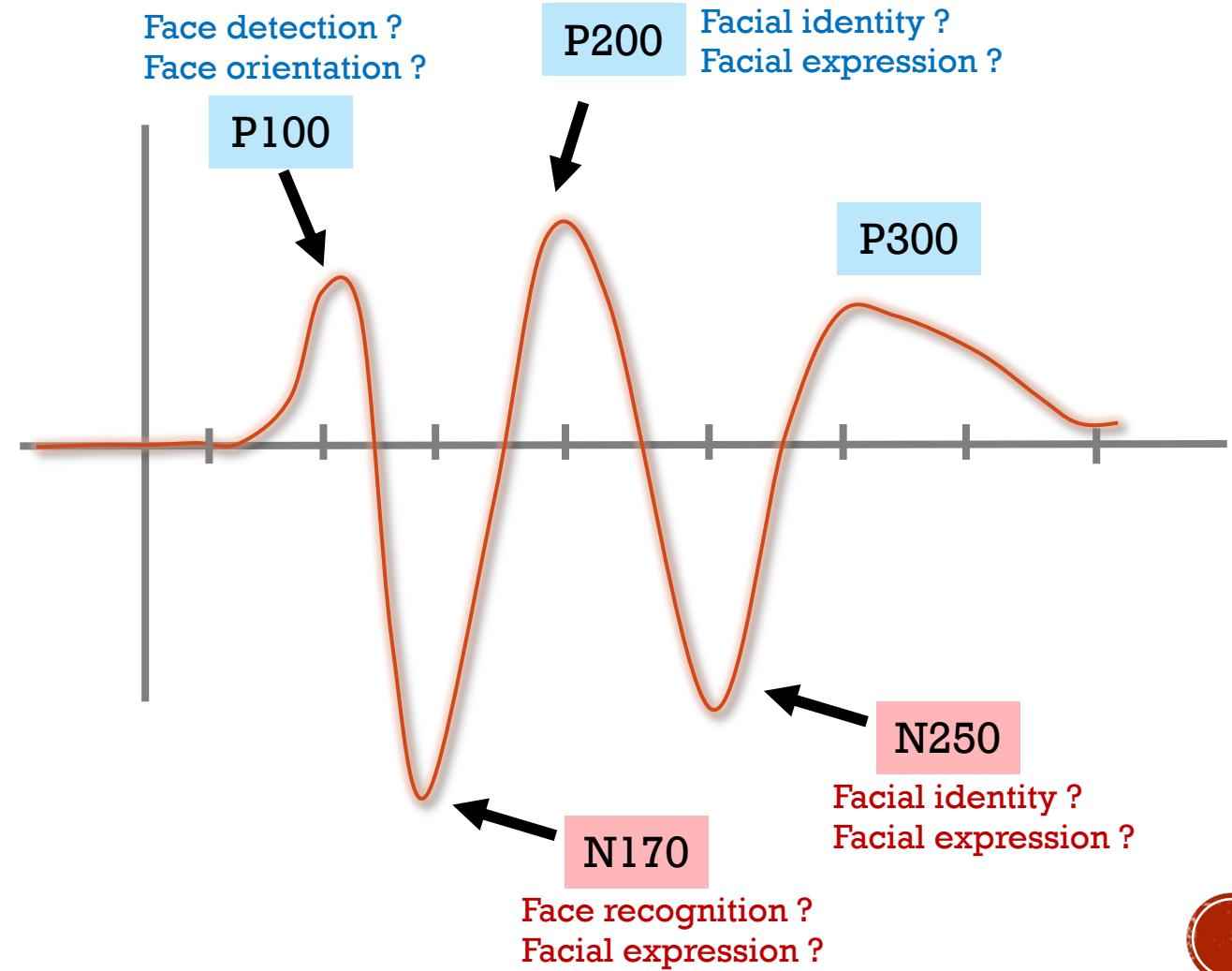
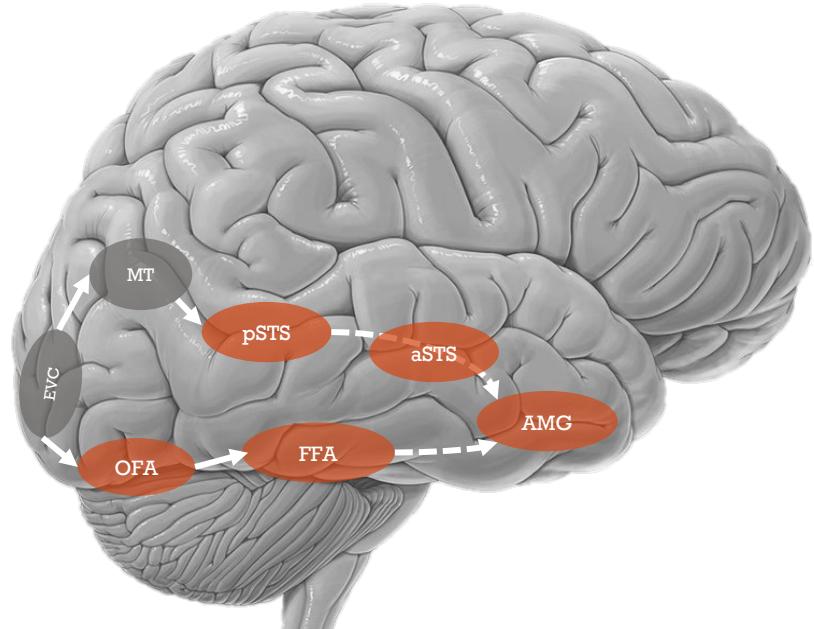
Face recognition may
occur around **250ms or
later**

Face-selective response occurs
around **170ms**



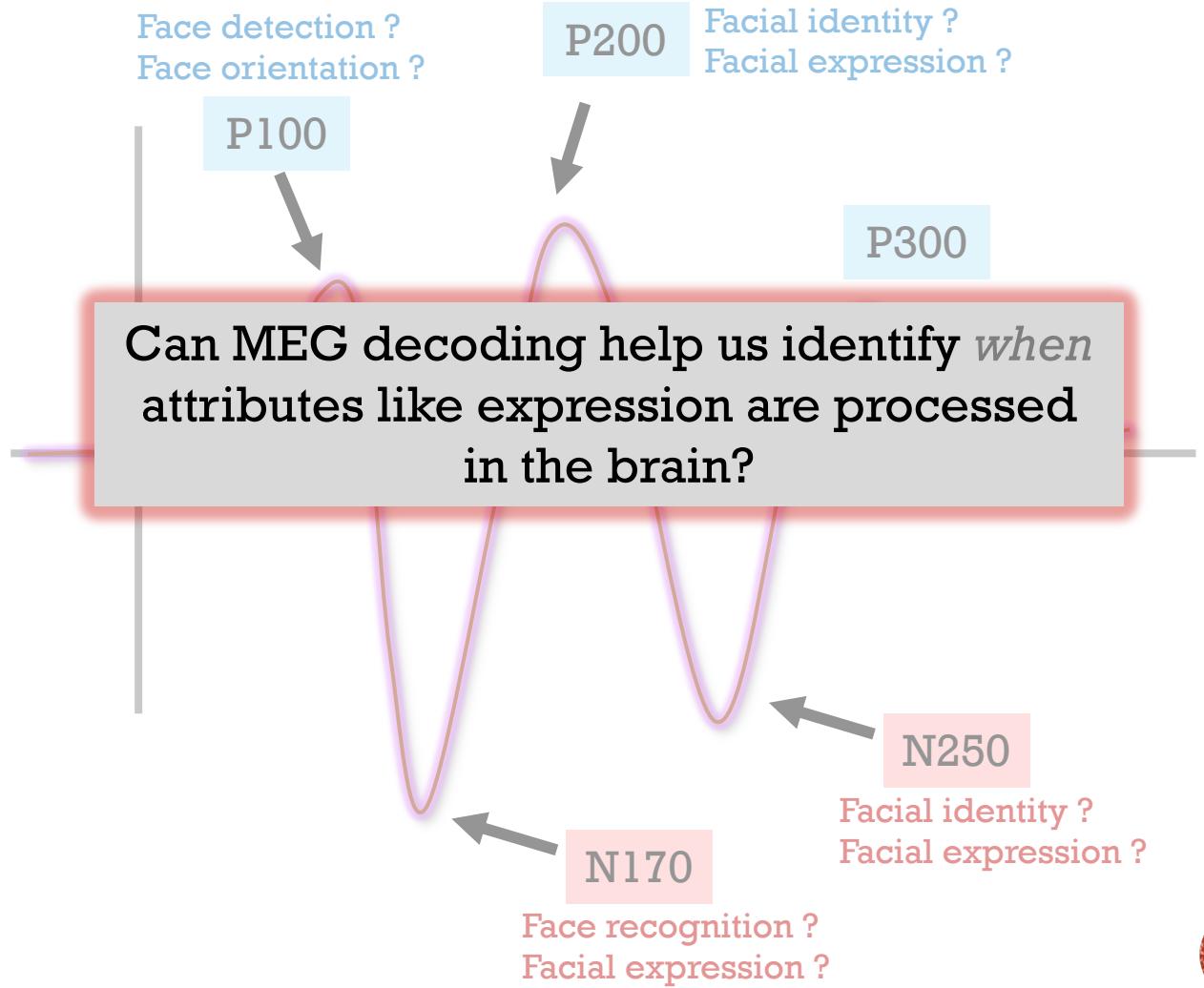
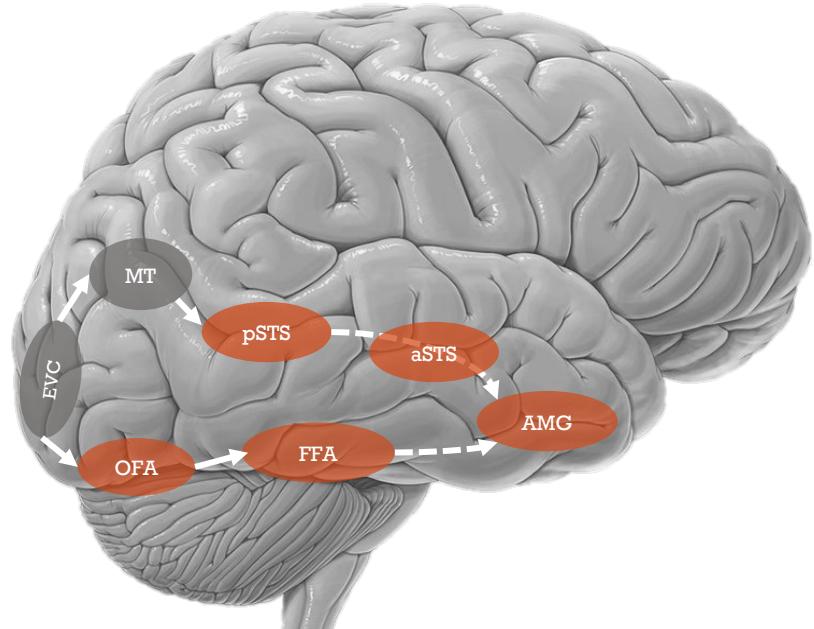
WHAT WE DON'T REALLY KNOW

When particular face attributes
are processed in the brain



WHAT WE DON'T REALLY KNOW

When particular face attributes
are processed in the brain



WHEN DOES INFORMATION GET EXTRACTED FROM FACES?



Rohini Kumar

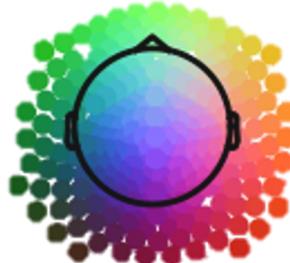
- Use magnetoencephalography to measure brain activity



- Present dynamic face stimuli that show various identities and expressions



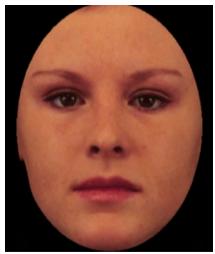
- Use sensor activity patterns at each timepoint to decode dimensions of interest
 - SVM classification with cross-validation



DECODING FROM DYNAMIC FACES

STIMULI:

6 Identities



Neutral to 6 Expressions



Happy



Surprised



Angry

X



Fearful

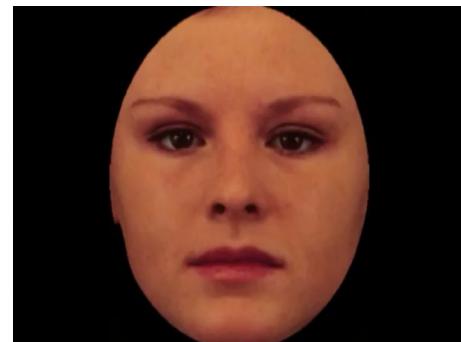


Disgusted

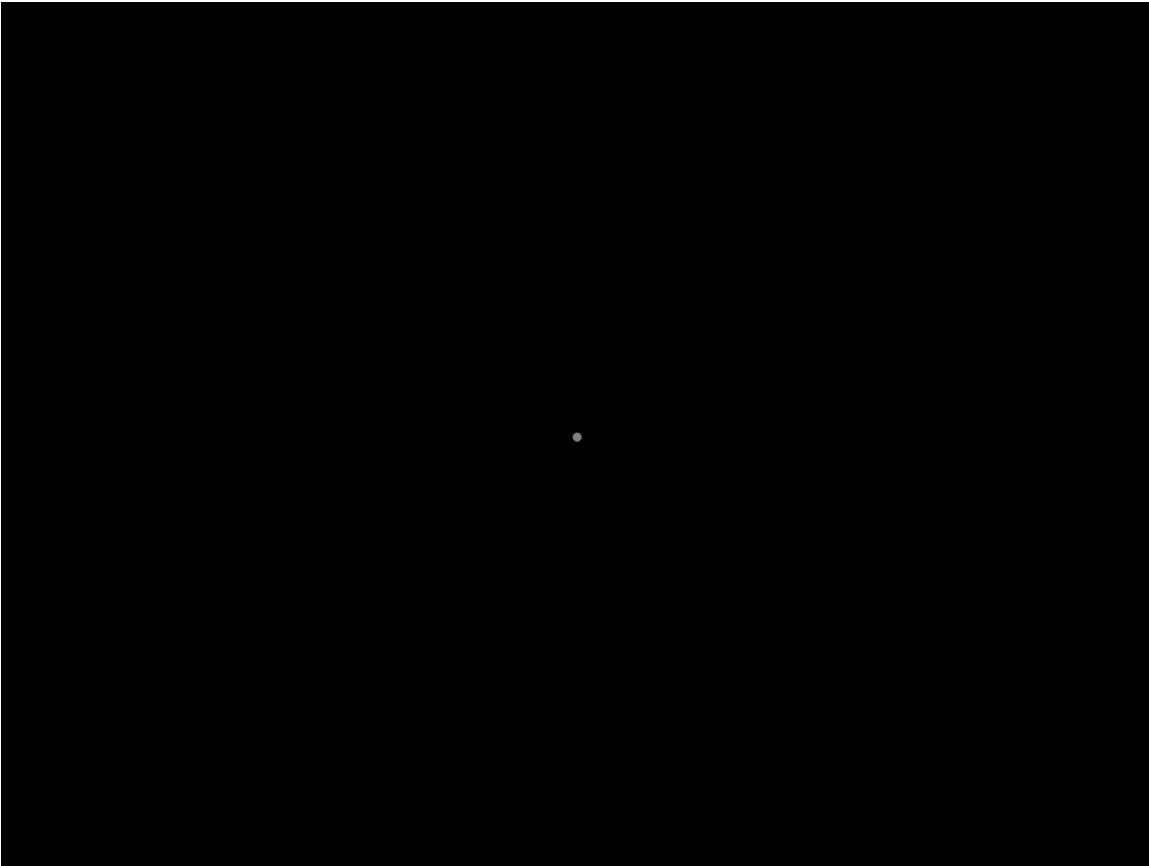


Sad

1 second videos of expressive and non-expressive facial motion



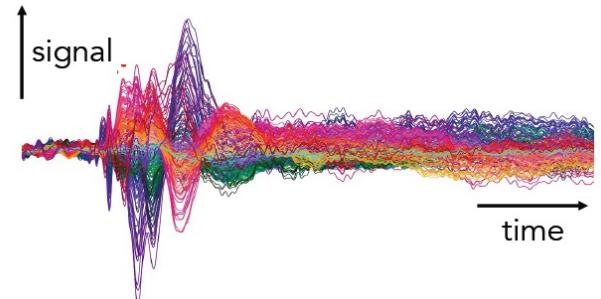
DECODING FROM DYNAMIC FACES



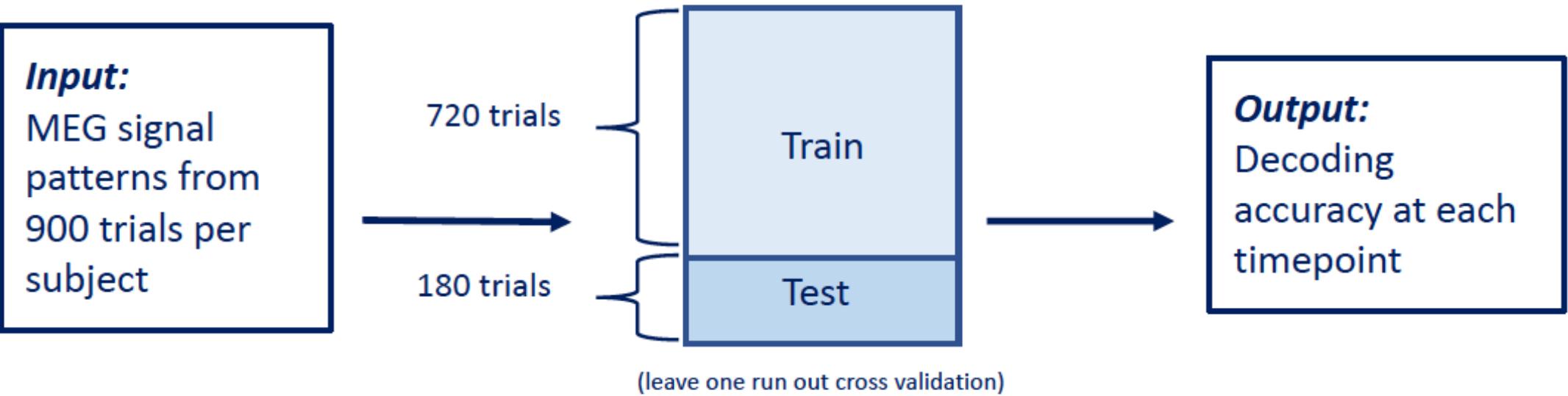
TASK:

Detection of artificial facial motion

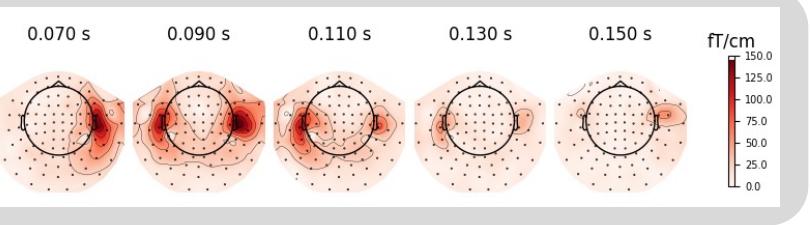
MEG: Continuous acquisition at
1200 Hz



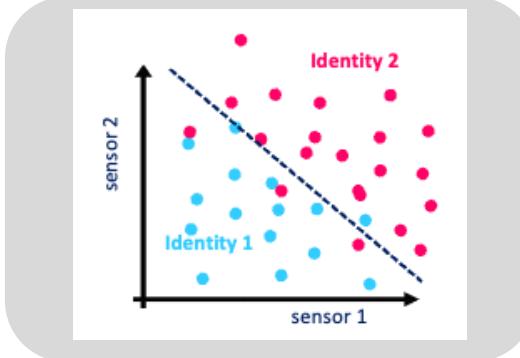
DECODING FROM DYNAMIC FACES



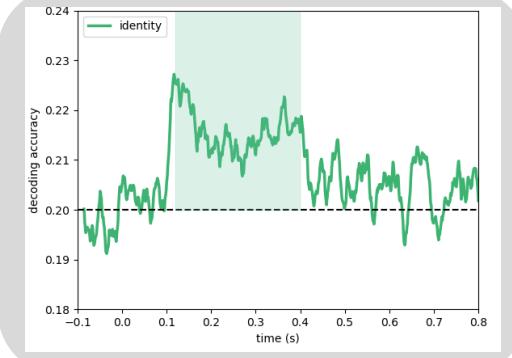
MEG sensor patterns



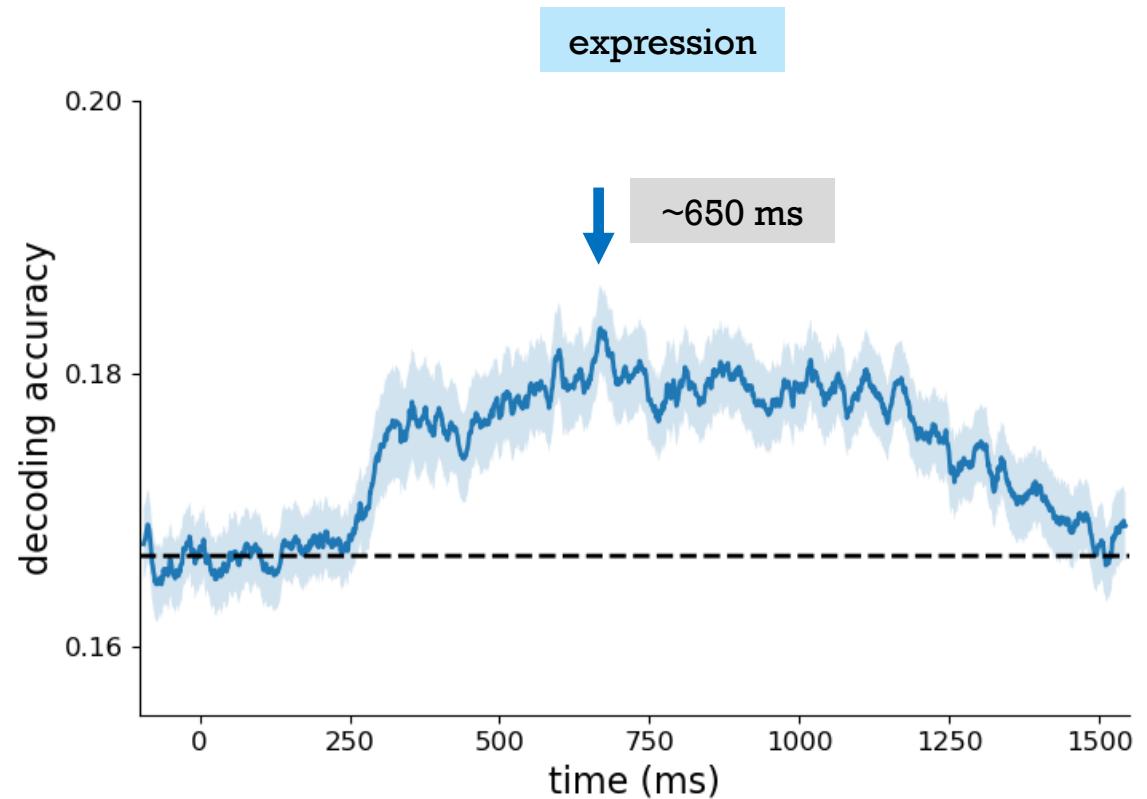
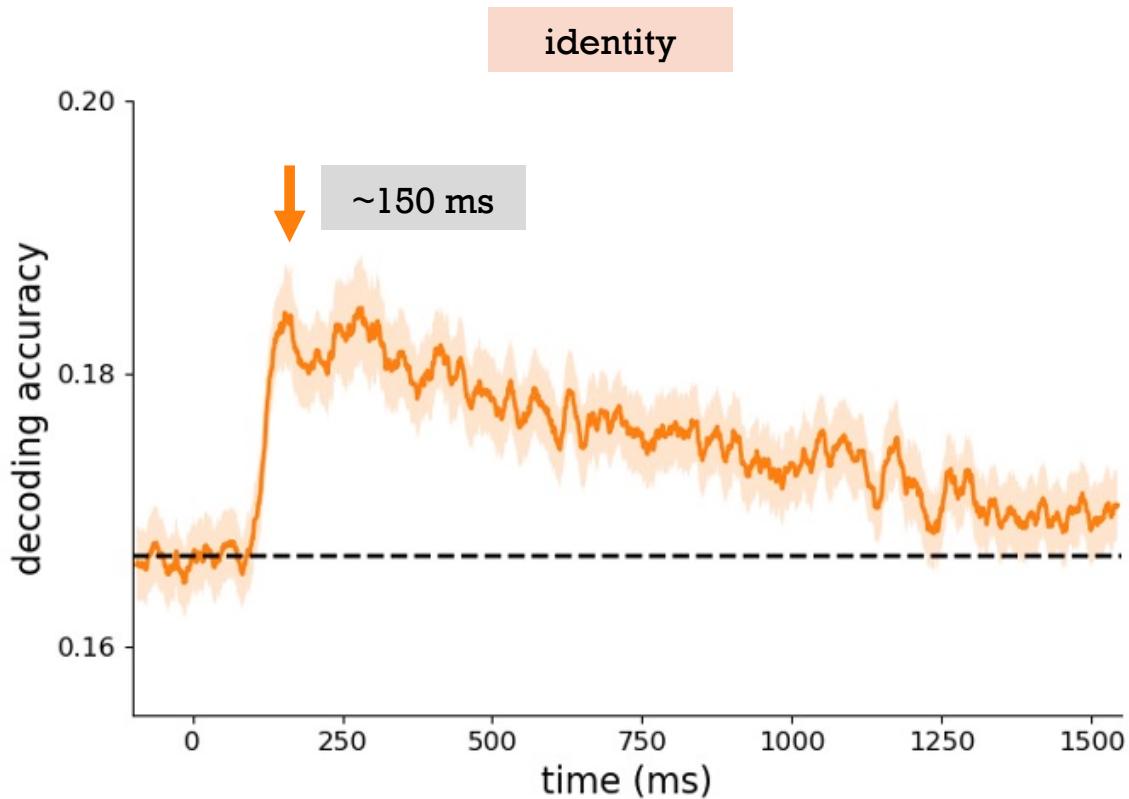
Support Vector Machine



Time-resolved decoding



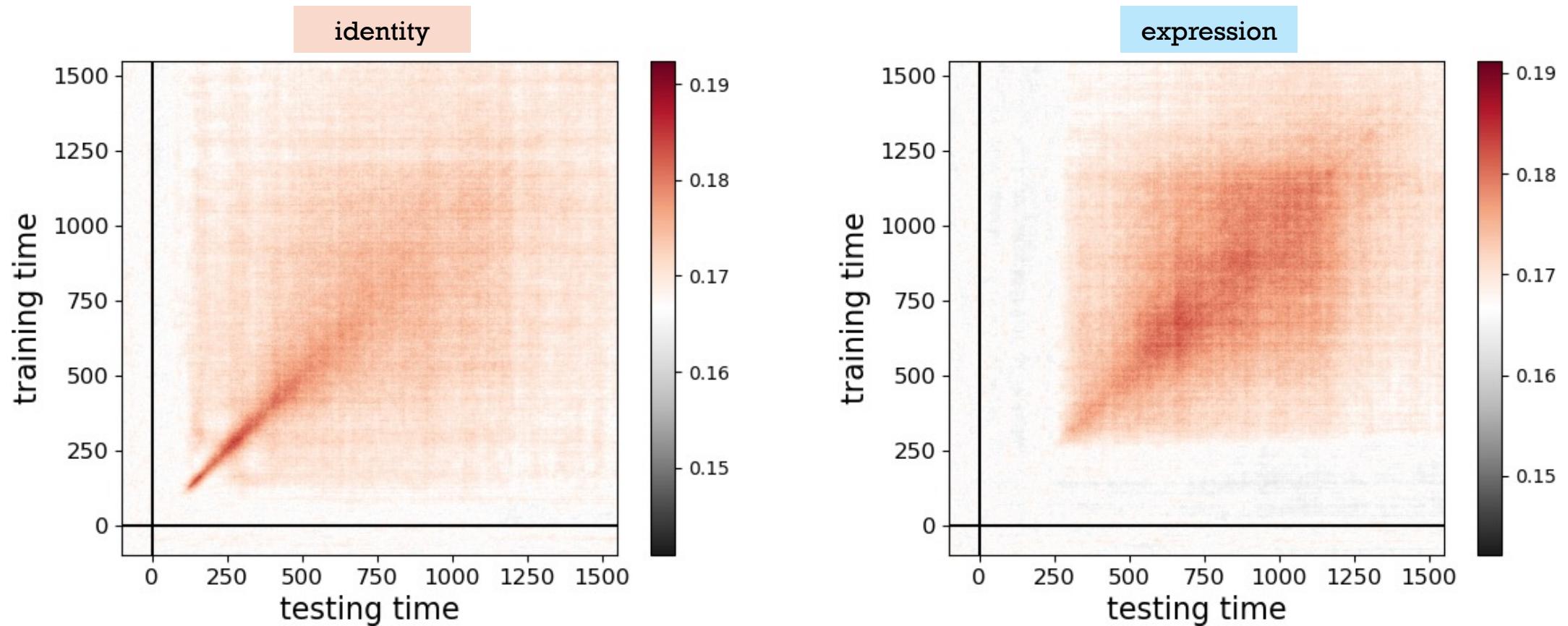
TIME-RESOLVED DECODING



Identity decoding peaks earlier than expression



TEMPORAL GENERALIZATION

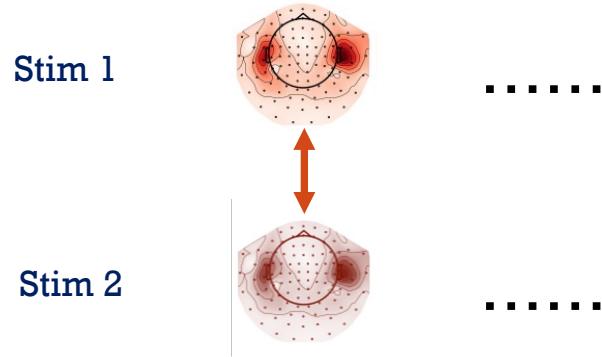


Temporal generalization shows more stability
for expression representation over time

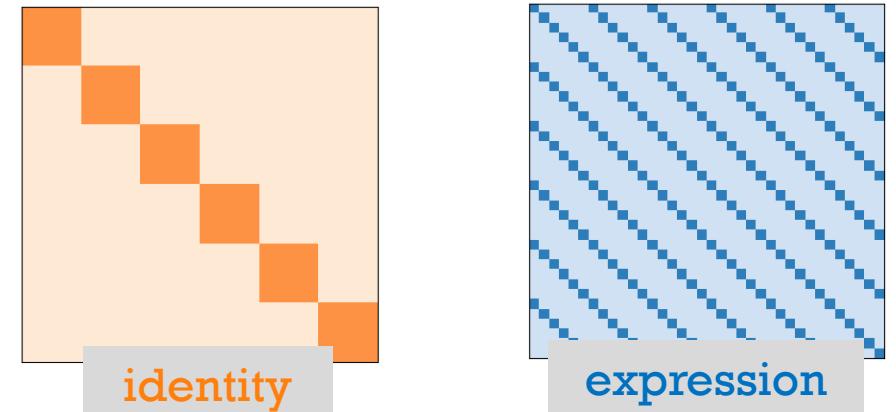


REPRESENTATIONAL SIMILARITY ANALYSIS

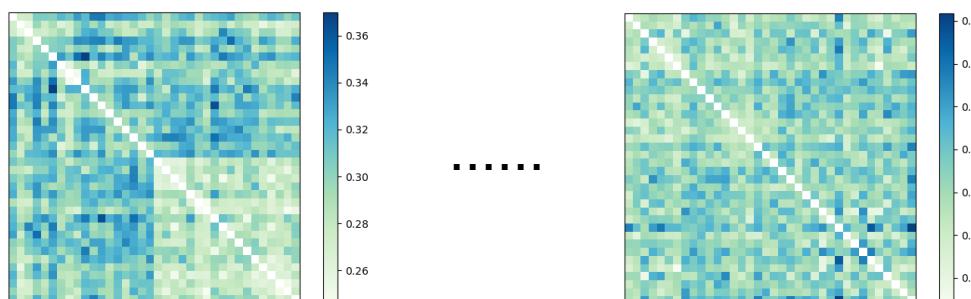
Pairwise correlation between sensor patterns at each time point



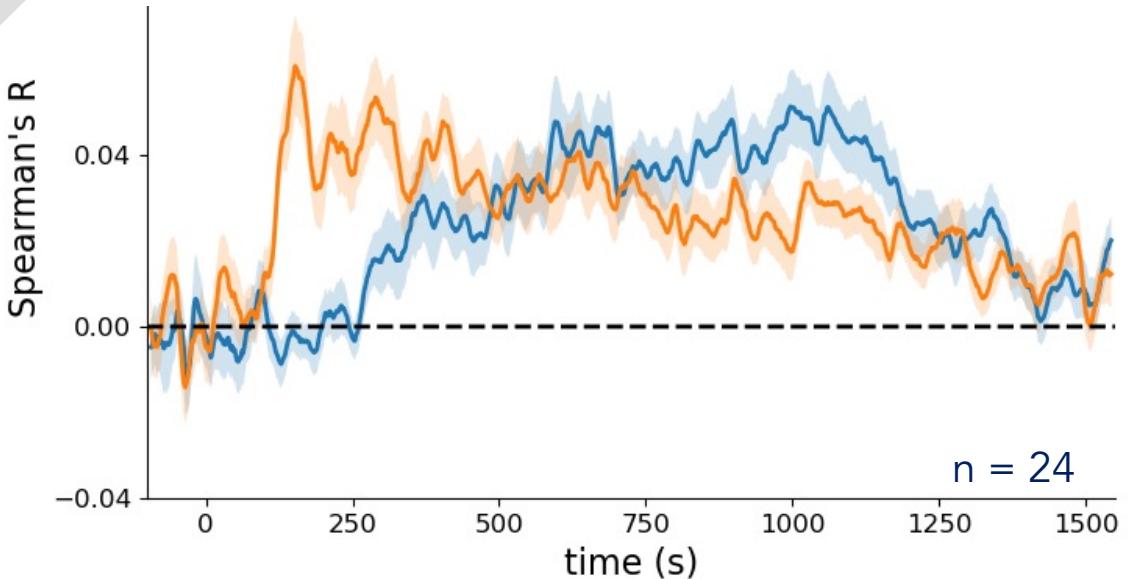
Model RDMs



MEG RDMs

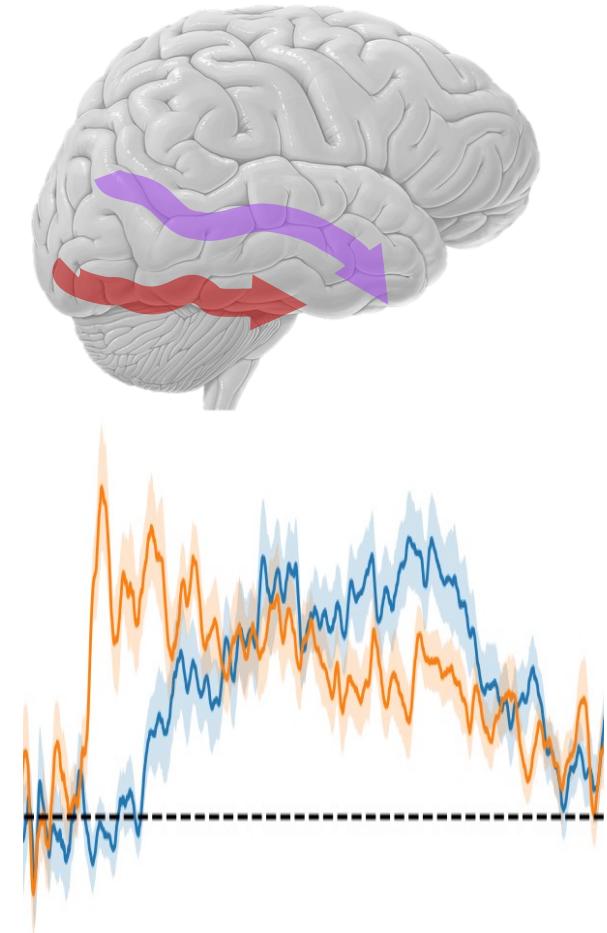


Spearman's R



RECAP SO FAR

- *Where* are facial cues processed in the brain?
 - lateral regions are sensitive to changeable aspects such as expression
 - Ventral region prefer fixed aspects such as identity
 - pSTS is critical for facial motion processing
- *When* are facial cues processed in the brain?
 - Identity information can be decoded earlier than expression
 - Expression representation remains stable for longer period of time relative to identity



EFFECT OF FACIAL PARALYSIS ON FACIAL EXPRESSION PERCEPTION

Evidence from Moebius Syndrome



WHAT IS MOEBIUS SYNDROME?

MOEBIUS SYNDROME FACTS

Moebius Syndrome is a rare neurological condition that primarily **AFFECTS THE MUSCLES THAT CONTROL FACIAL EXPRESSION AND EYE MOVEMENT.**

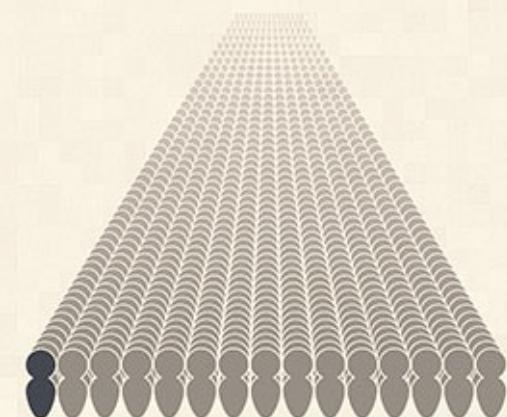
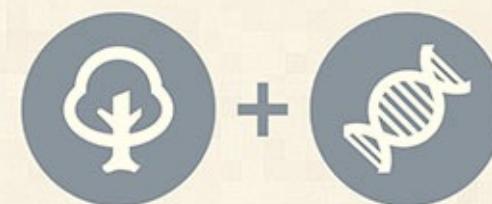
Other signs/symptoms include:

- weakness or paralysis of the facial muscles
- hearing problems
- visual impairments
- speech difficulties



Moebius syndrome is caused by the absence or **underdevelopment of the 6th & 7th cranial nerves.**

Not much is known about Moebius syndrome, and is most likely a combination of environmental & genetic factors.



The condition is rare, and estimated to affect **1 in 50,000 to 1 in 500,000** newborns.

Sources: U.S. National Library of Medicine;
National Institute of Neurological Disorders and Stroke

MOEBIUS SYNDROME AND FACIAL EXPRESSIONS

- **7th nerve palsy** – results in inability to smile, frown, pucker the lips, raise the eyebrows or close the eyelids



Smile

X



Angry

X



Fearful

X

Individuals with Moebius Syndrome cannot make facial expressions

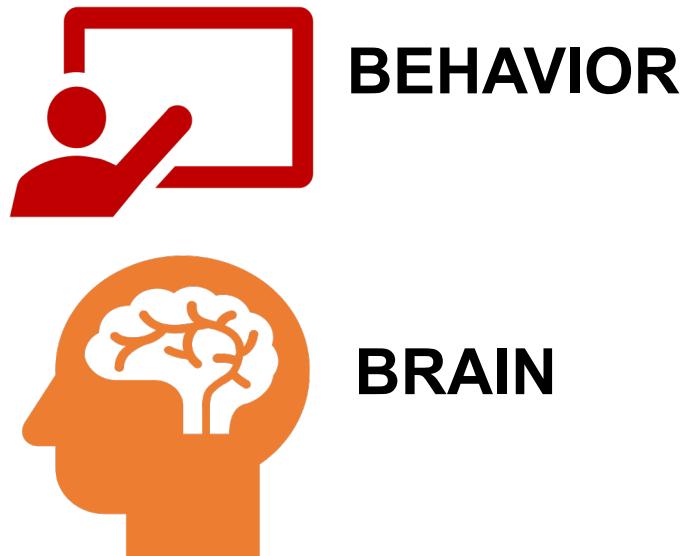
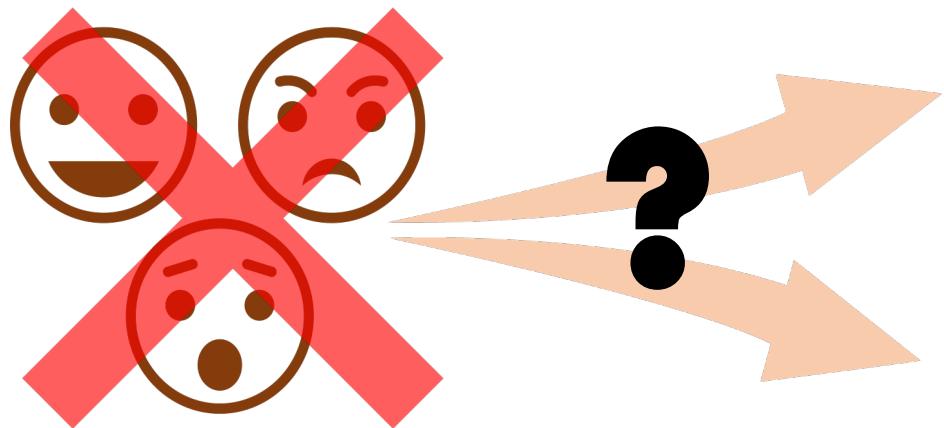




Jess Jordan

WHY STUDY EMOTION PROCESSING IN MOS?

Moebius Syndrome



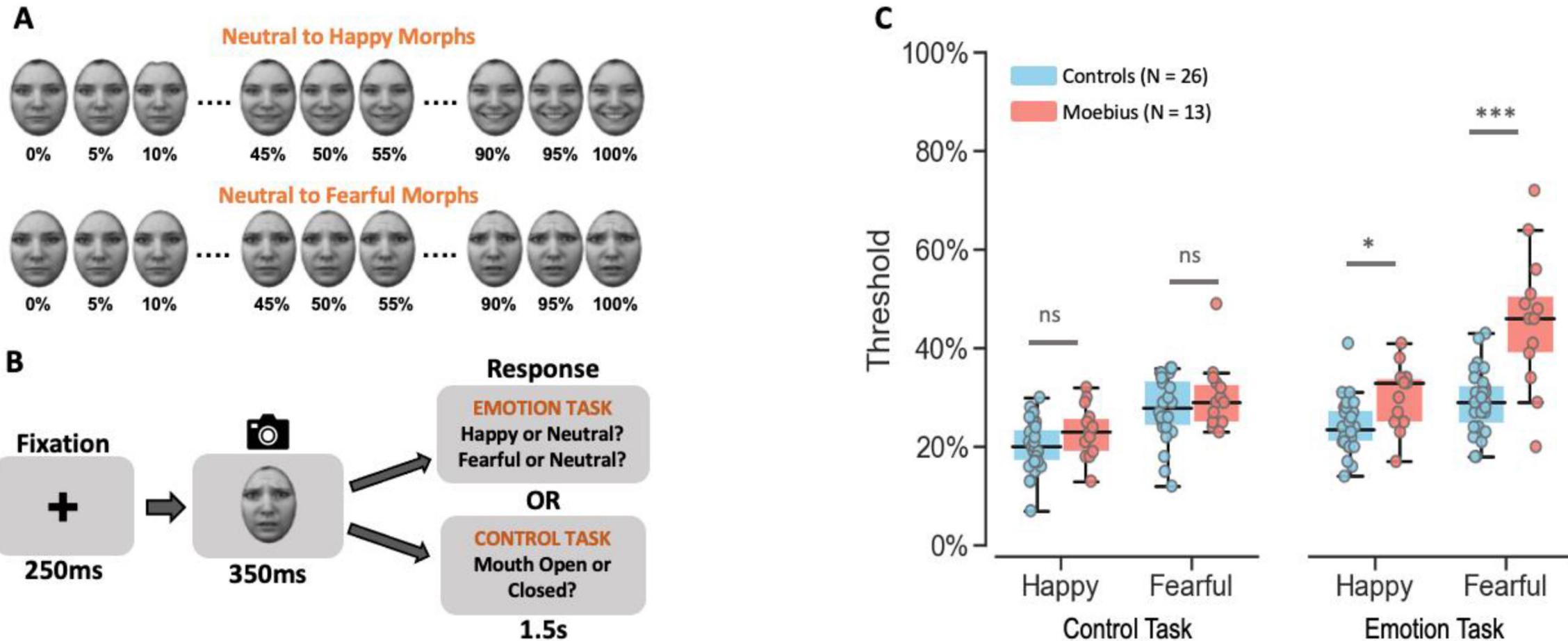
Facial expression
processing

Task-based fMRI

How does inability to make facial expressions affect the ability to recognize others' expressions?

BEHAVIORAL RESULTS FROM MOEBIUS STUDY

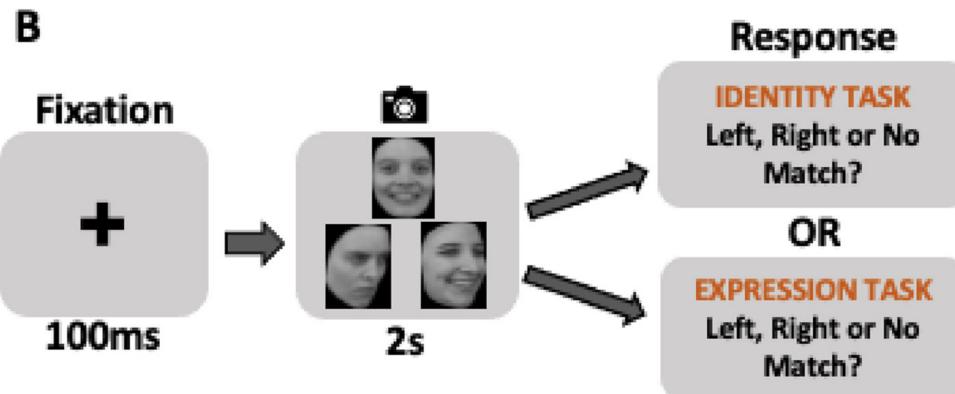
Detecting facial expressions



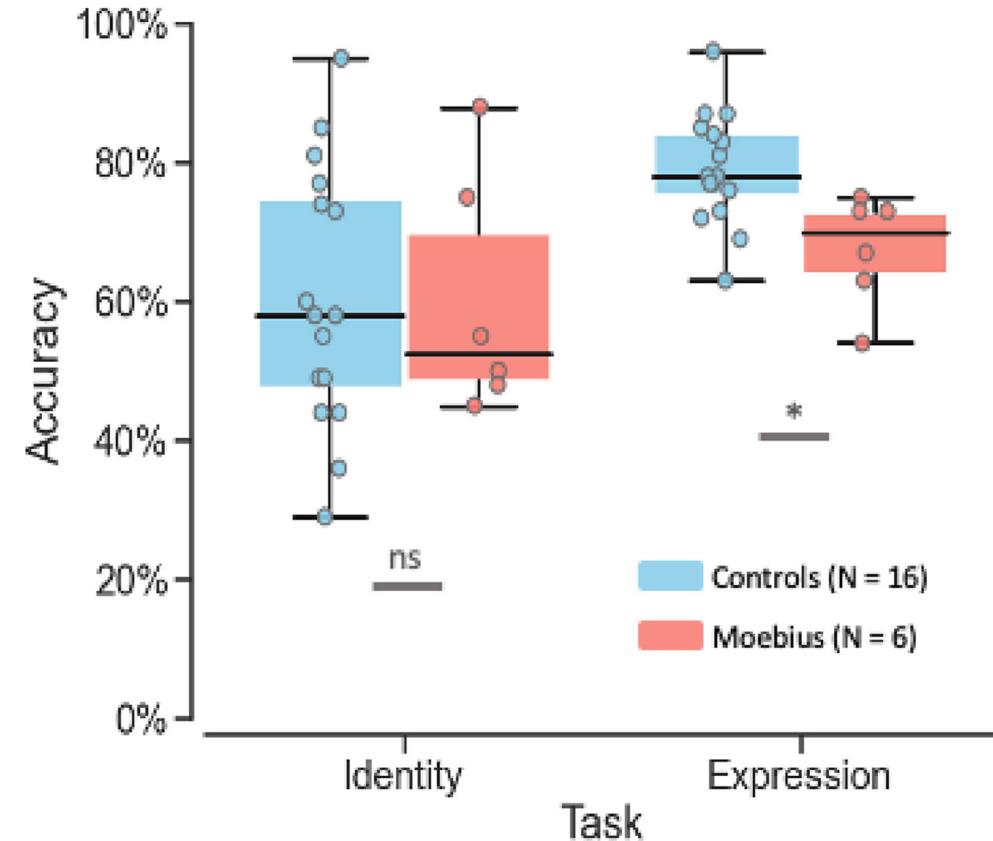
BEHAVIORAL RESULTS FROM MOEBIUS STUDY

Identity and Expression Matching

A Face images showing 8 identities, 4 expressions and 3 head orientations



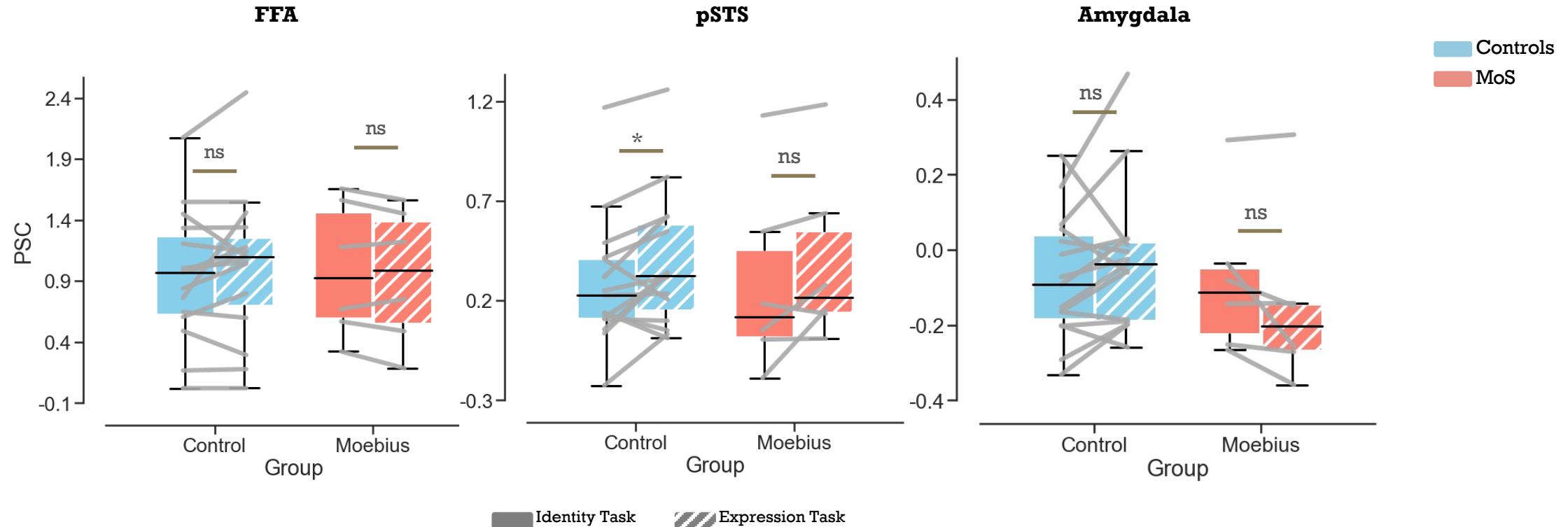
C



Moebius individuals are impaired at facial expression processing



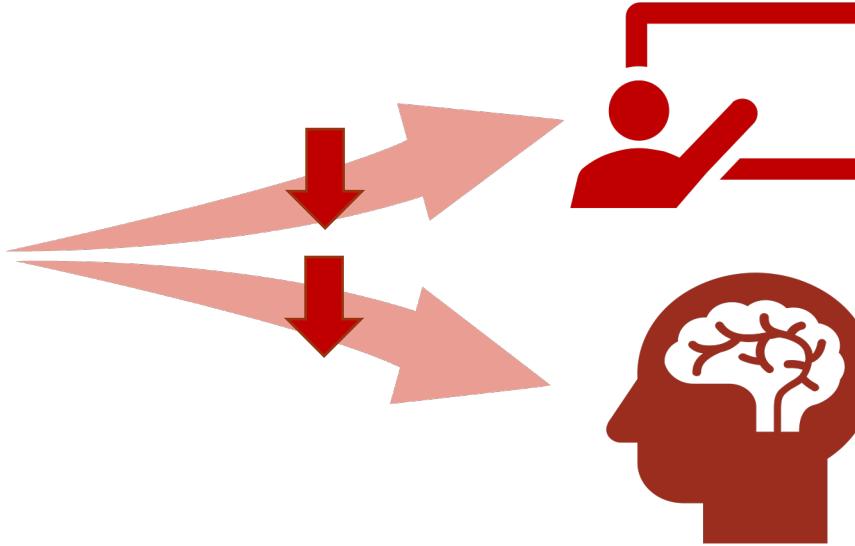
FMRI RESULTS FROM MOEBIUS STUDY



Moebius individuals show reduced pSTS activity and lack of amygdala engagement during expression processing



CONCLUSIONS FROM MOEBIUS STUDY



BEHAVIOR

BRAIN



General dampening of facial expression processing



Reduced engagement of expression regions

Facial paralysis affects expression perception



SUMMARY

- Face perception is supported by dedicated neural circuitry
- Different aspects of a face are preferentially processed by parts of the face processing network
 - Fixed and changeable aspects of a face are extracted by ventral and lateral regions, respectively
- Identity information is extracted early while expression detection evolves over time
- Inability to make facial expressions impacts their perception



THANKS TO

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- Kelsey Holiday

MENTORS

- Chris Baker
- Leslie G Ungerleider

SUPPORTED BY

