Applications of functional MRI

Quantitative and Functional Imaging

BME 4420/7450

Fall 2022

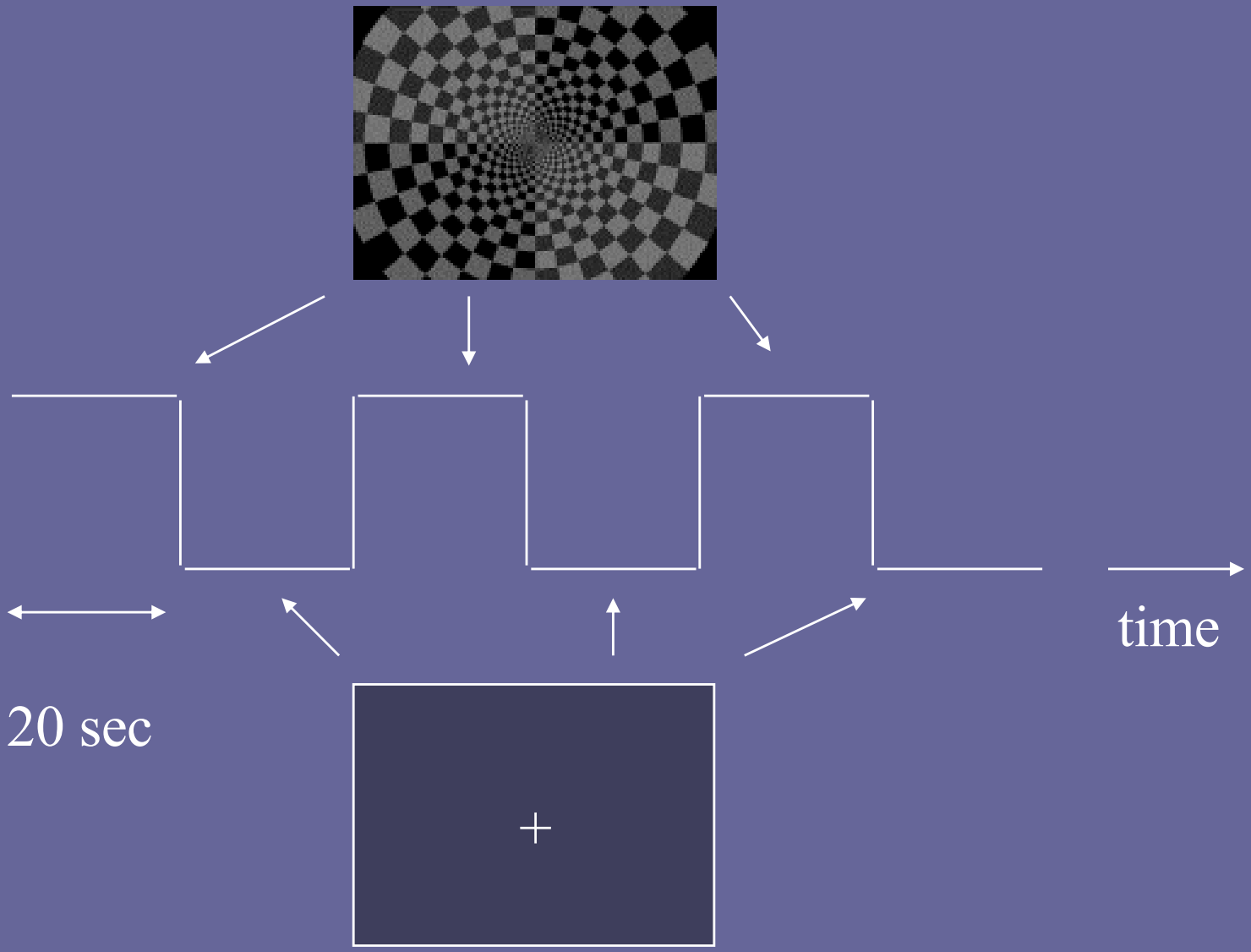
Topics

- Mapping basic functions
  - Brain physiology
  - Brain development
- Mapping higher-order cognitive functions
  - Attention
  - Memory
    - Schizophrenia
  - Learning
    - Autism

Brain activation

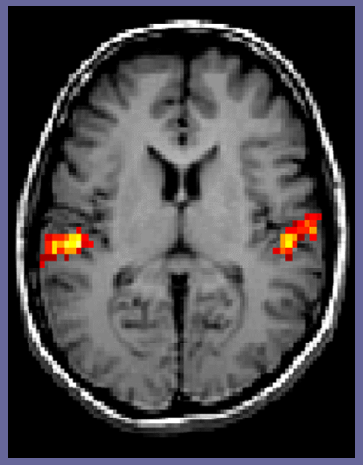
- Sensory systems
  - Visual
  - Auditory
  - Tactile
  - Olfactory
  - Gustatory
- Active tasks
  - Motor
  - Cognitive

Basic blocked design experiment

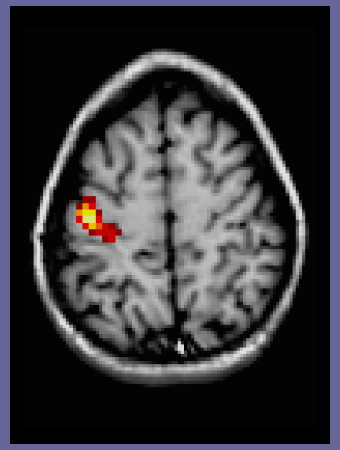


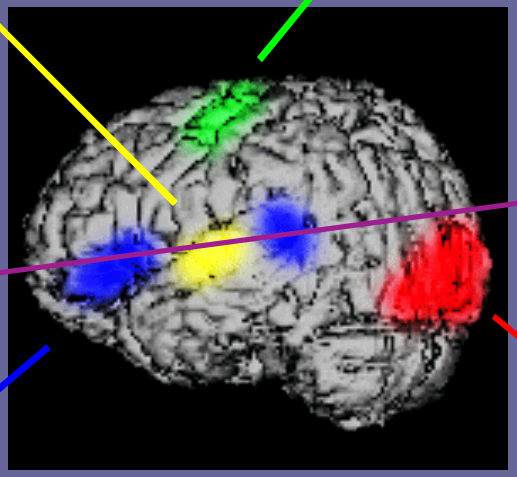
- Mapping basic sensory/motor and language areas of the brain is useful e.g. in neurosurgery

Auditory Activation

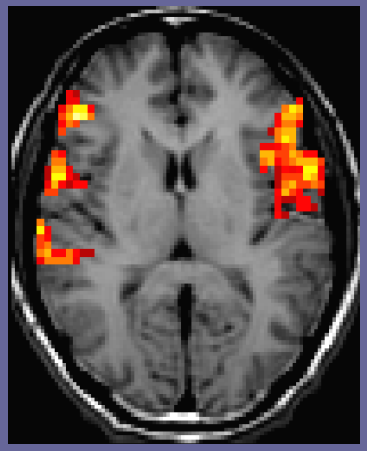


Motor Activation

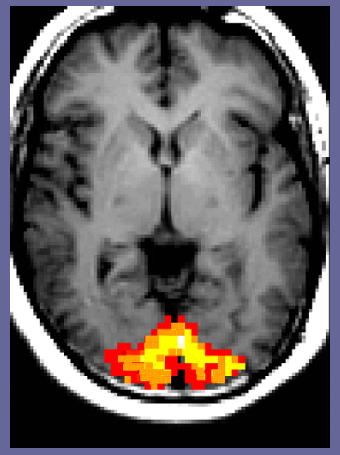




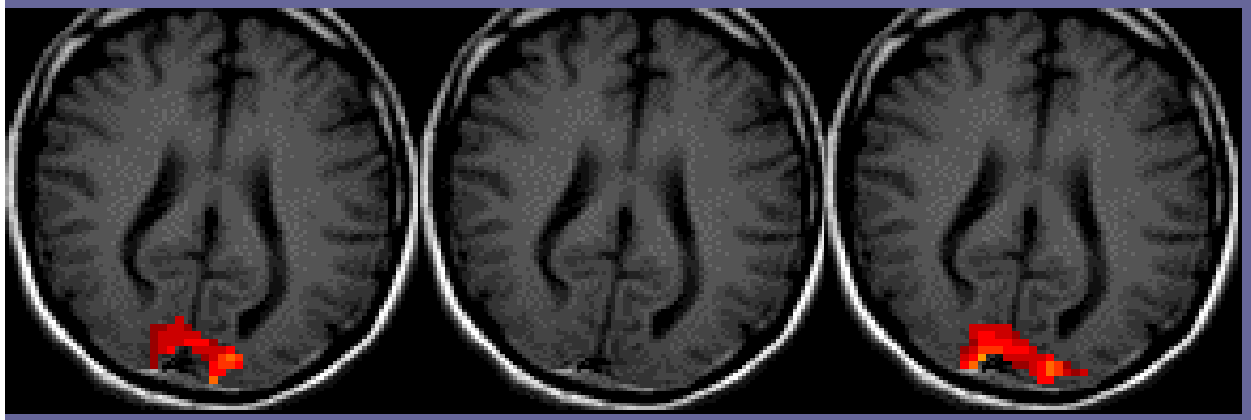
Language Activation



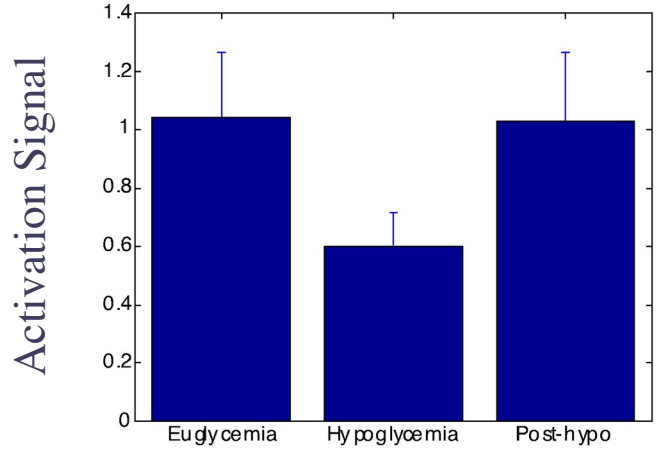
Visual Activation



Using the BOLD signal to study physiology



Visual stimulation at different blood glucose levels



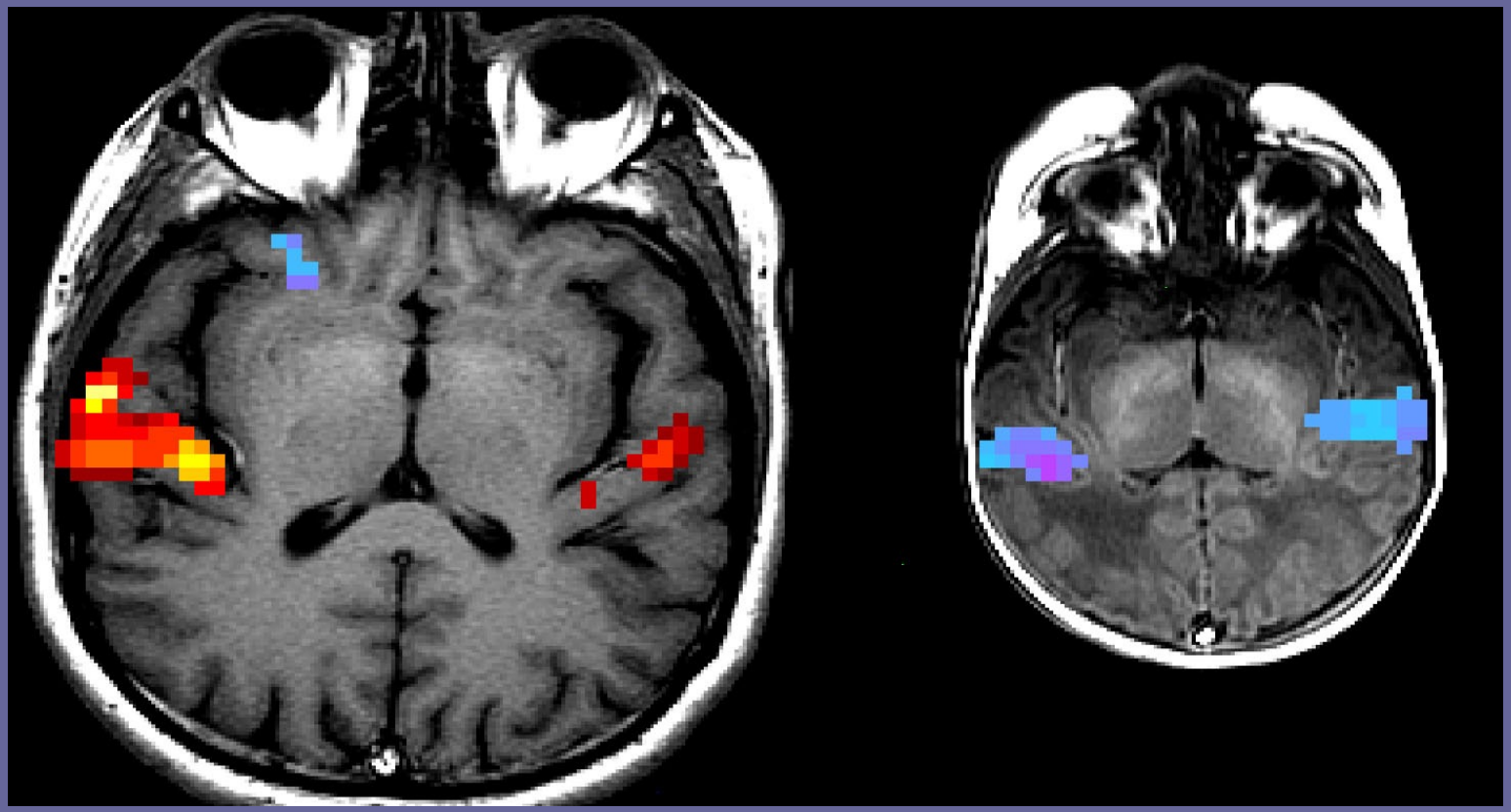
BOLD signal in V1 drops to 60% during mild hypoglycemia even though flow does not increase

Origin of BOLD signal changes

- Neurons need energy (glucose+O_2) to do work
- Cerebral blood flow (CBF) increases locally
- Oxygen saturation increases locally
- Oxygen makes iron in Hb less magnetic
- Magnetic field around vessels becomes more uniform
  - Measure signal change

Brain development

Auditory stimulation



Adult
positive BOLD signal

Newborn
negative BOLD signal

Origin of BOLD signal changes

- Neurons need energy (glucose+O_2) to do work
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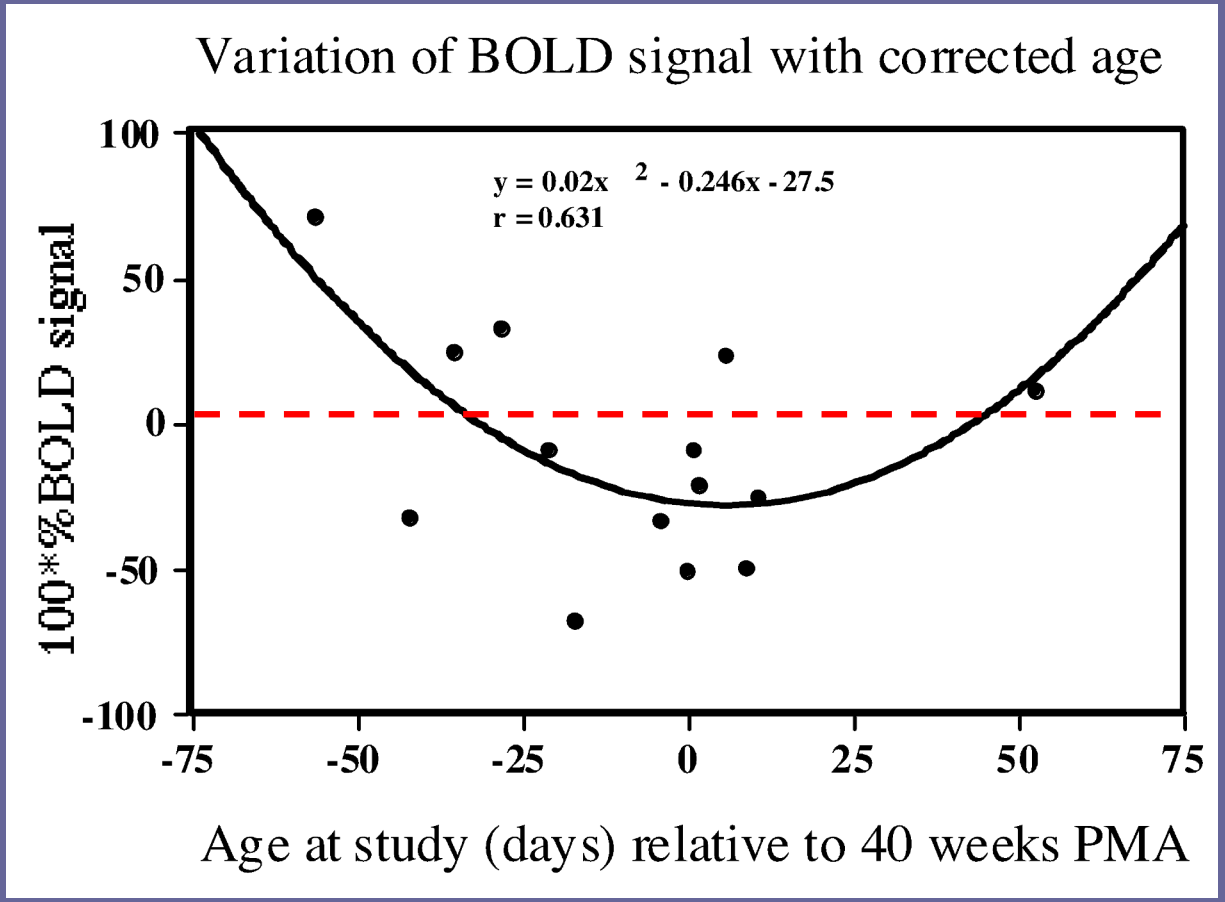
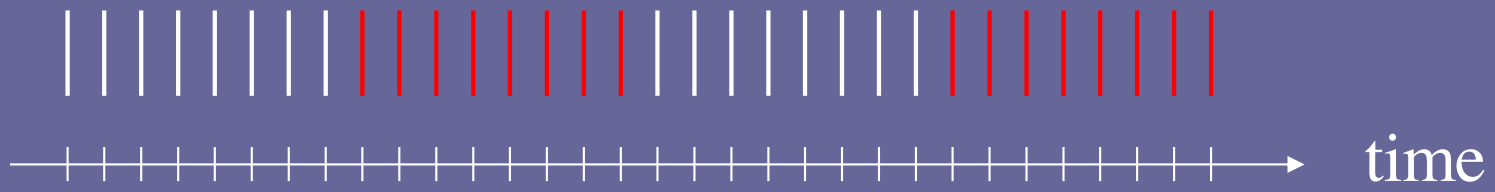


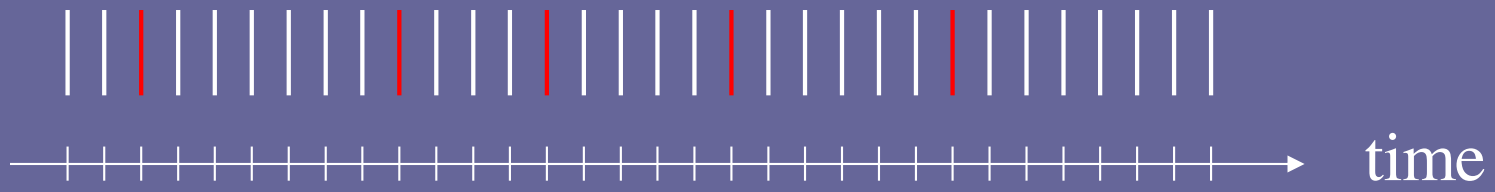
Flow / metabolism balance is different in newborns
Reflects maturity of brain

Study design

- Blocked design



- Event related design



Event Related fMRI

Condition

A

B

The transient change in MRI signal produced by ‘A’ is detected

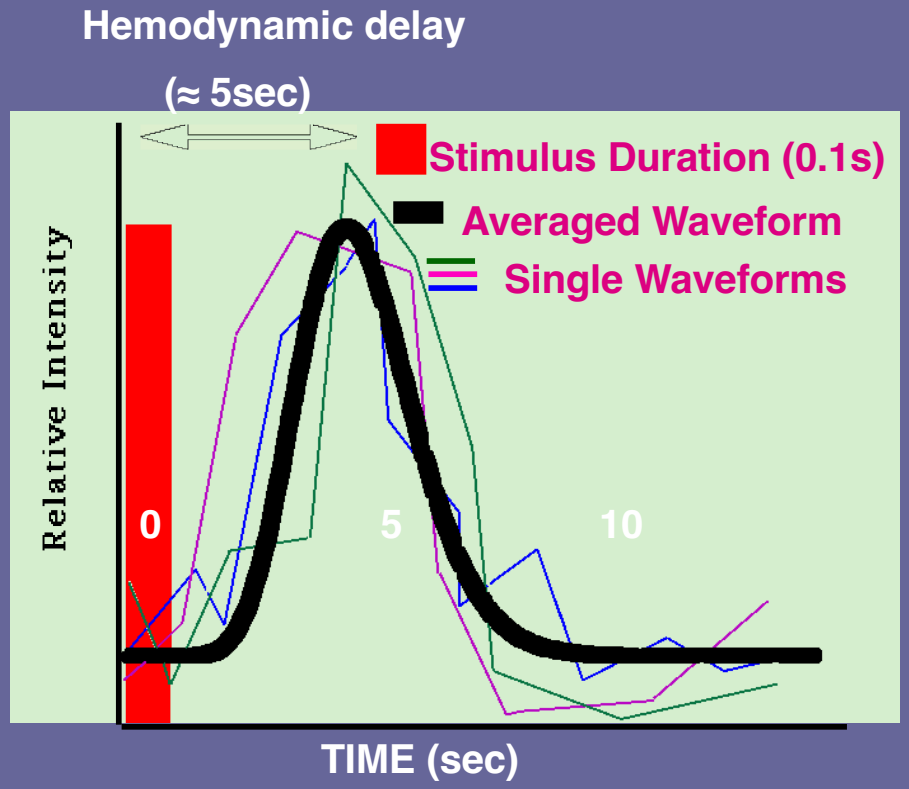
MRI signal

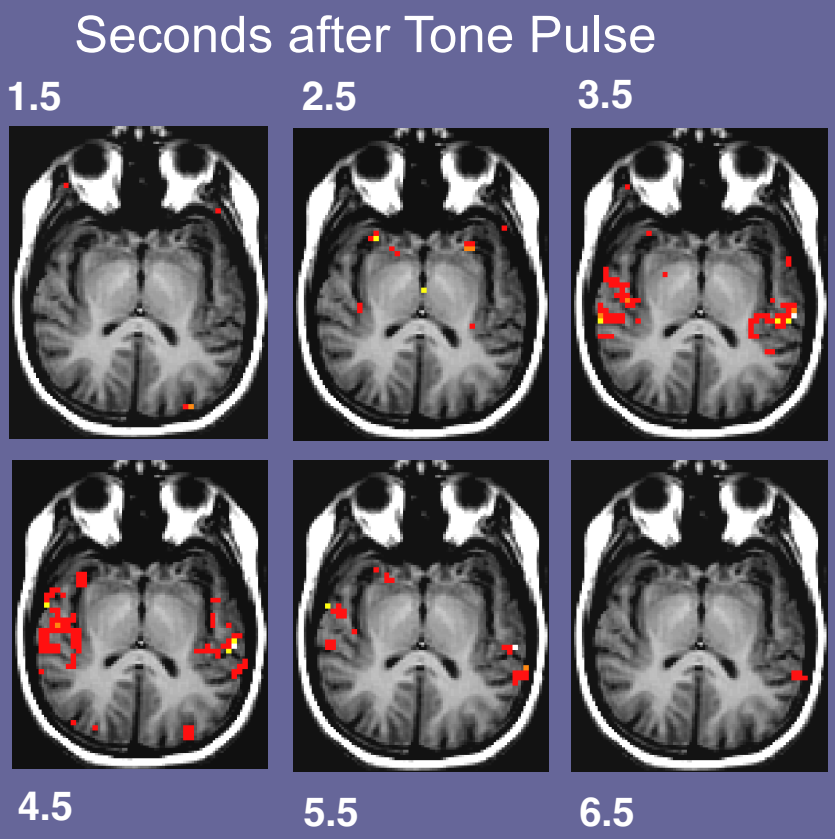
= The hemodynamic response

Event related fMRI

- Measure response after transient stimulus
- Allows other types of experiment, e.g. “oddball” studies (no adaptation to repeated stimuli)
- Provides some temporal information of response
- Is less affected by some types of noise and drift

Effects of a short audio tone





The hemodynamic response is slow and delayed - it takes seconds to wash out the deoxyHb

Testing Attention

- The Stroop task
- Name the COLOR of the letters
  - Do not read the word!
- For example,

Hello = GREEN
Goodbye = RED

Name the color - do not read

blue

green

red

yellow

red

blue

yellow

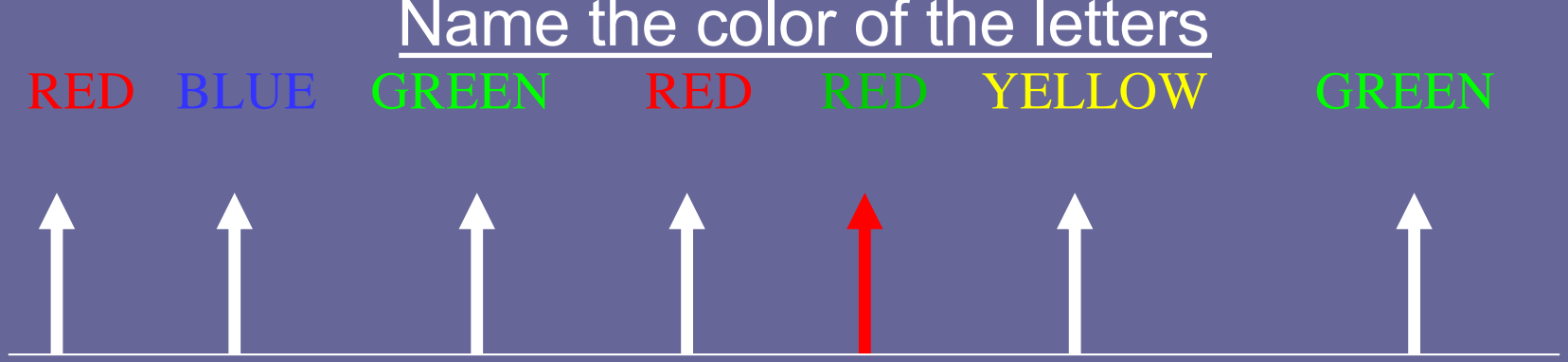
green

red

Event Related fMRI

Transient stimuli produce a transient flow change

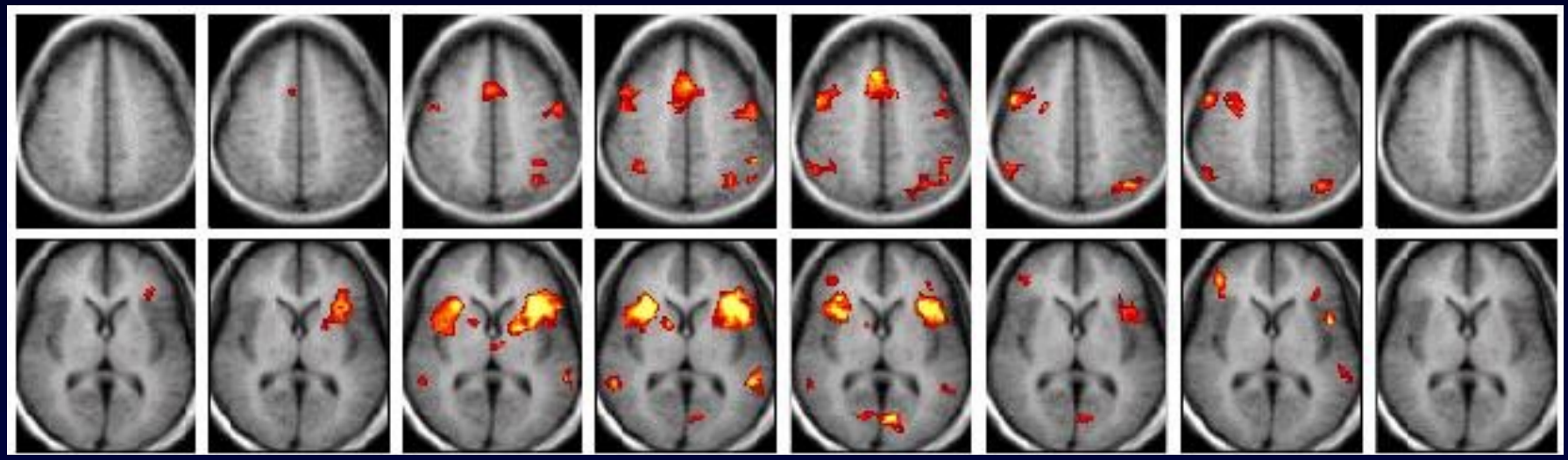
Event-related Stroop test - insert incongruent "color words" into a string of congruent "color words"



Event related Stroop effect

- Appearance of incongruent color-word pair triggers response in brain
- Conflict between attention to task and automatic reading response
- Transient change in attentional network as error correction and task monitoring occur

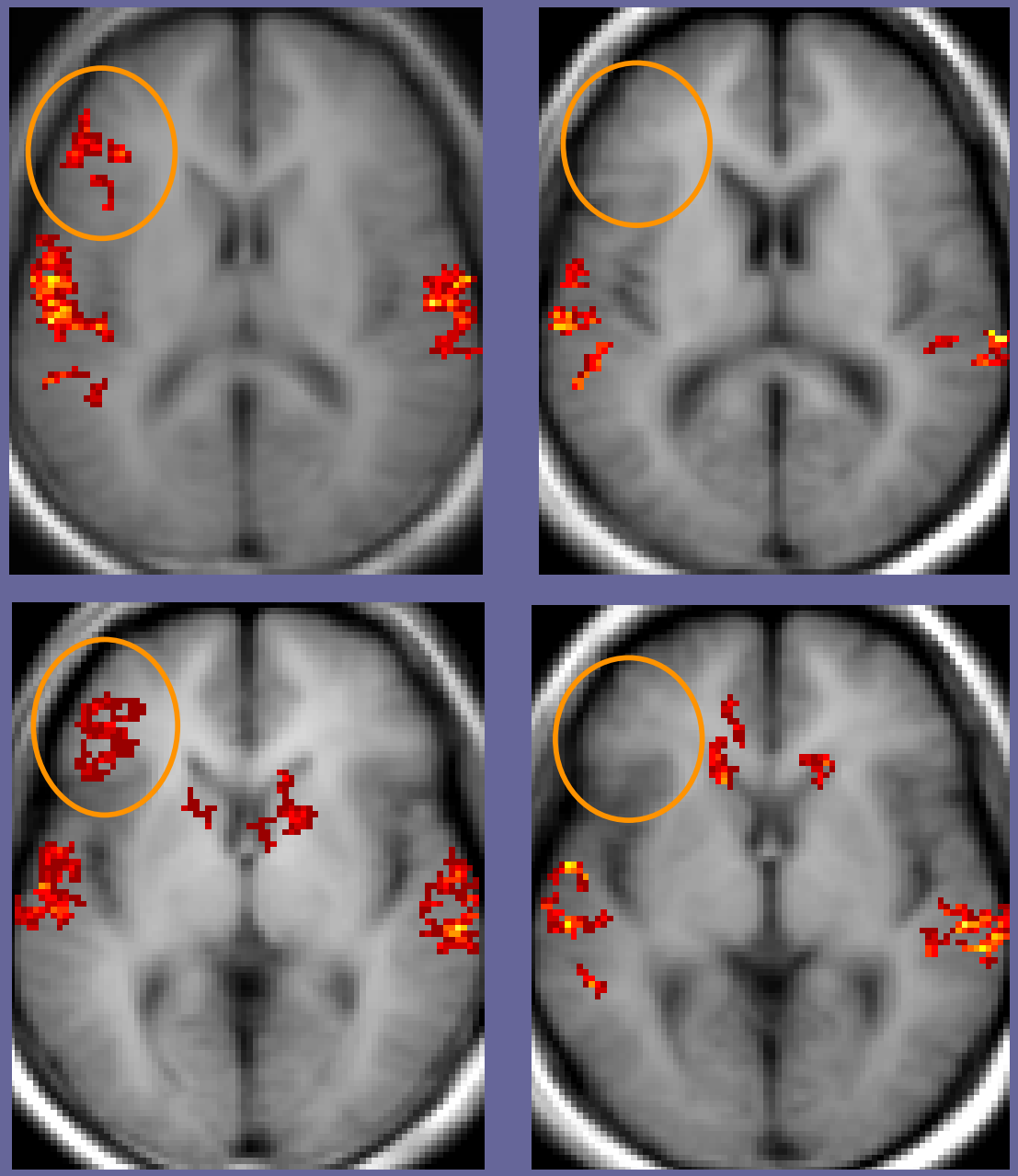
Event-related Stroop test



Time after incongruent word

Verbal Working Memory

- Subject hears words - “...foot…grass…pole…horse…”
- Rehearse and remember serial positions
- Hear one word
- Respond with position (1 - 4)
- Compare to non-word sounds

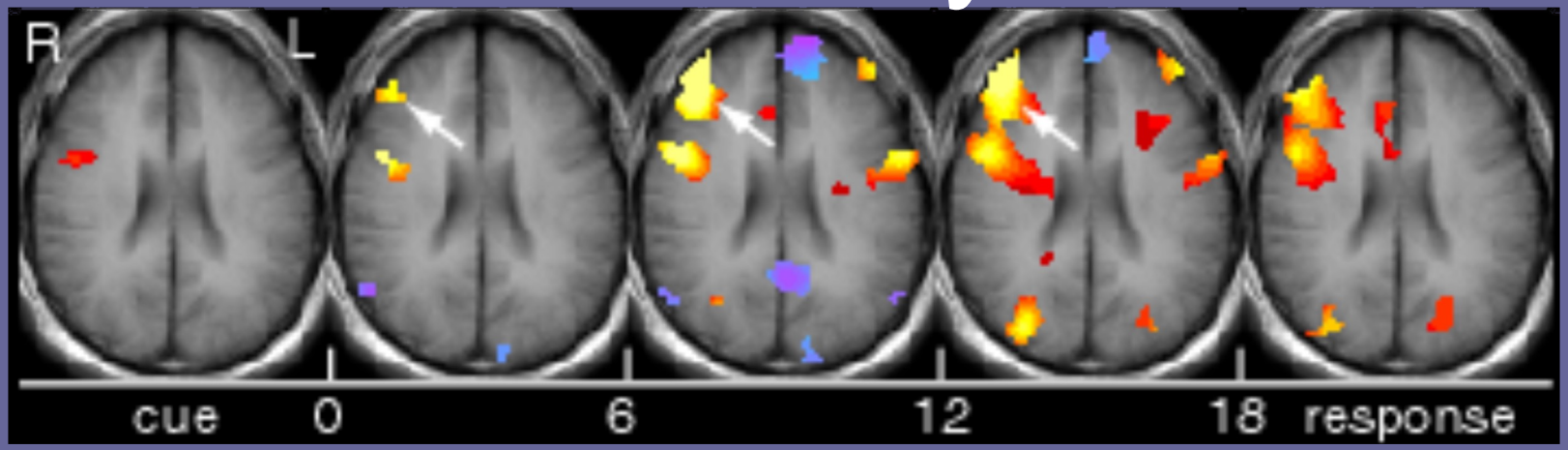


Verbal Working Memory Task

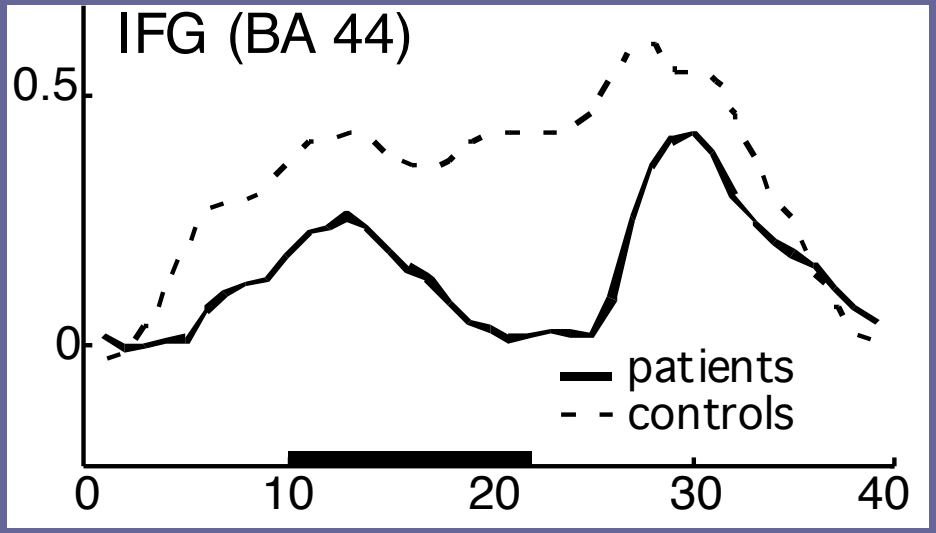
Controls

Schizophrenia patients

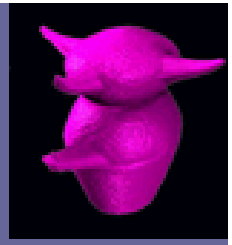
Event related verbal working memory



Time

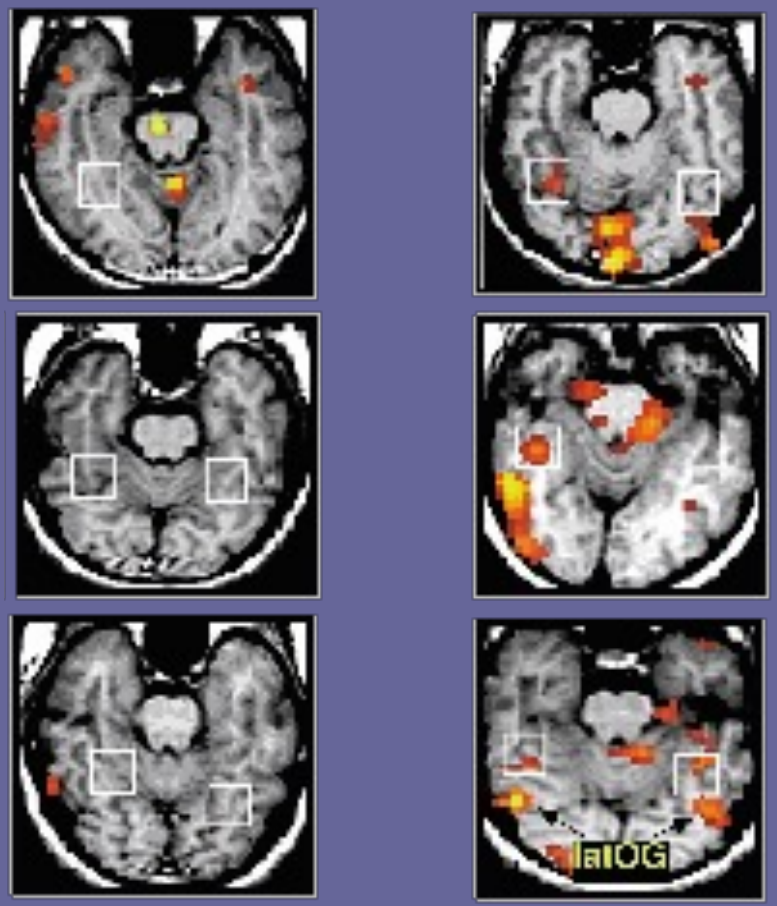


Schizophrenic subjects do not maintain activity in IFG



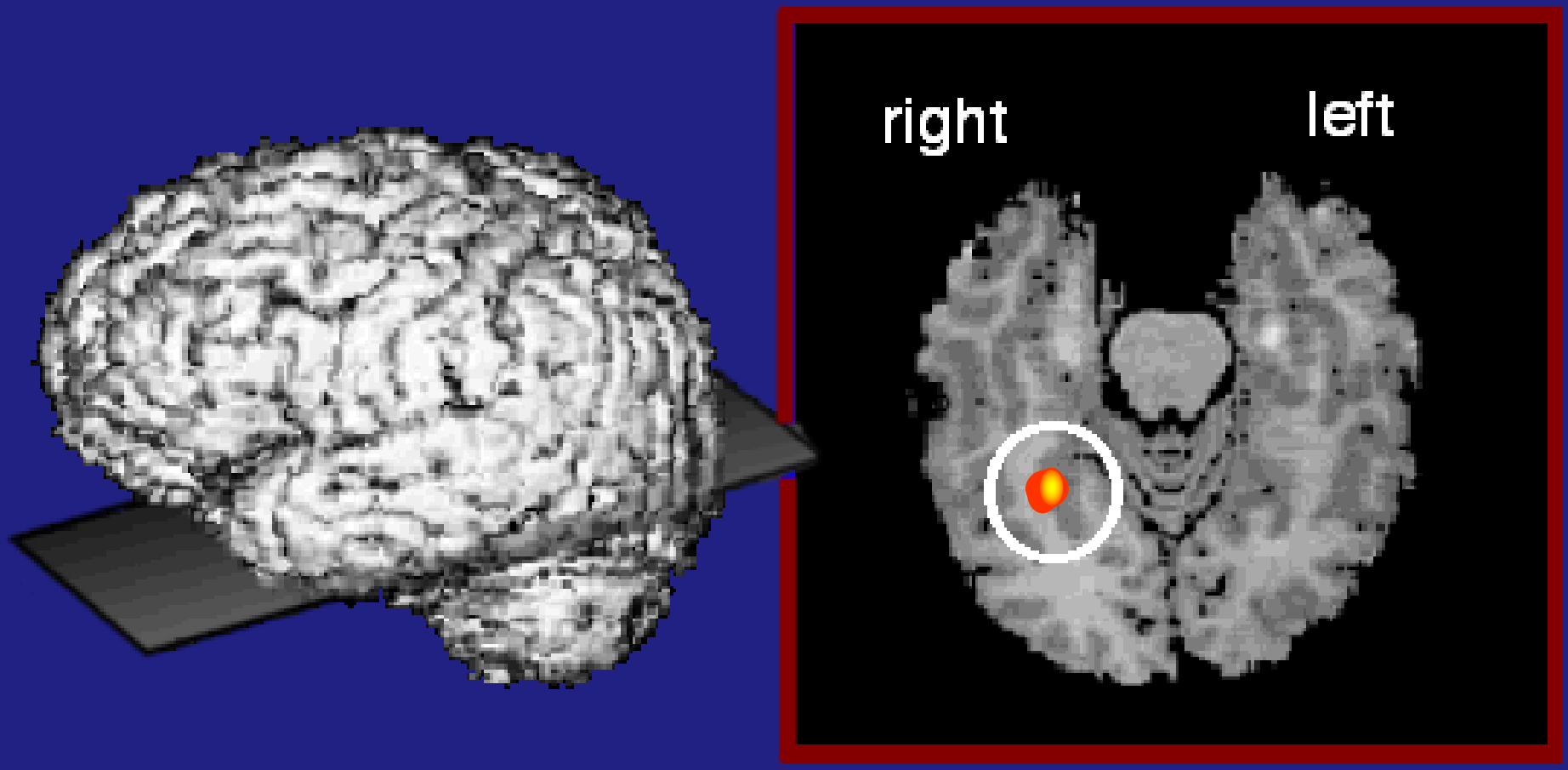
Learning: Using fMRI to study visual object recognition

novices experts

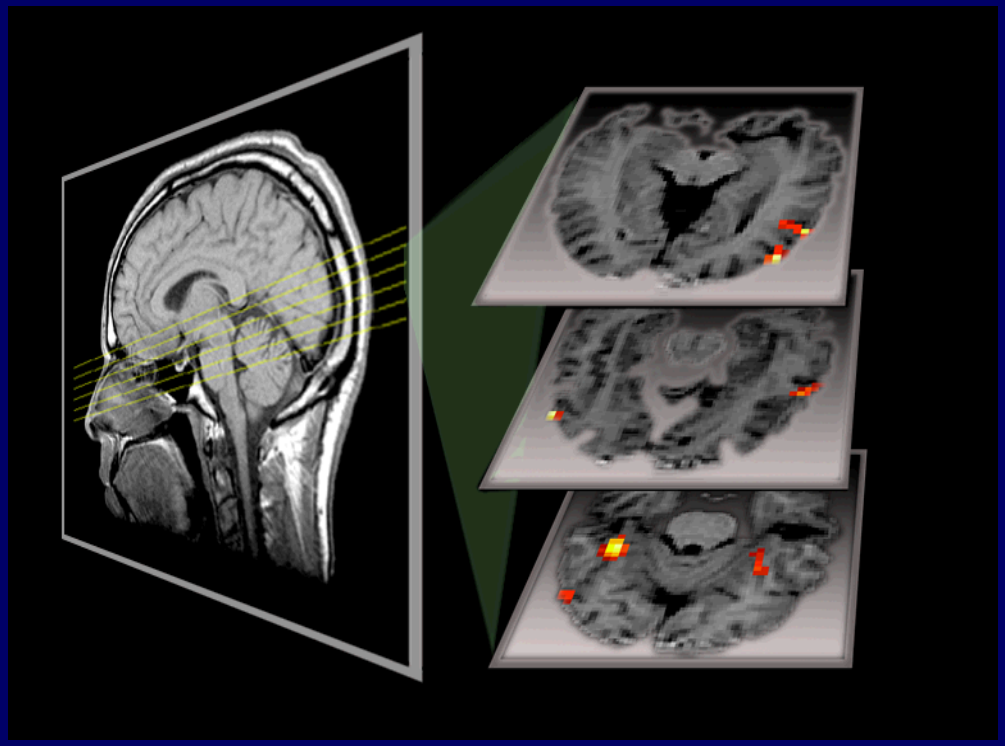


Gauthier et al, 1999

The fusiform "face area"

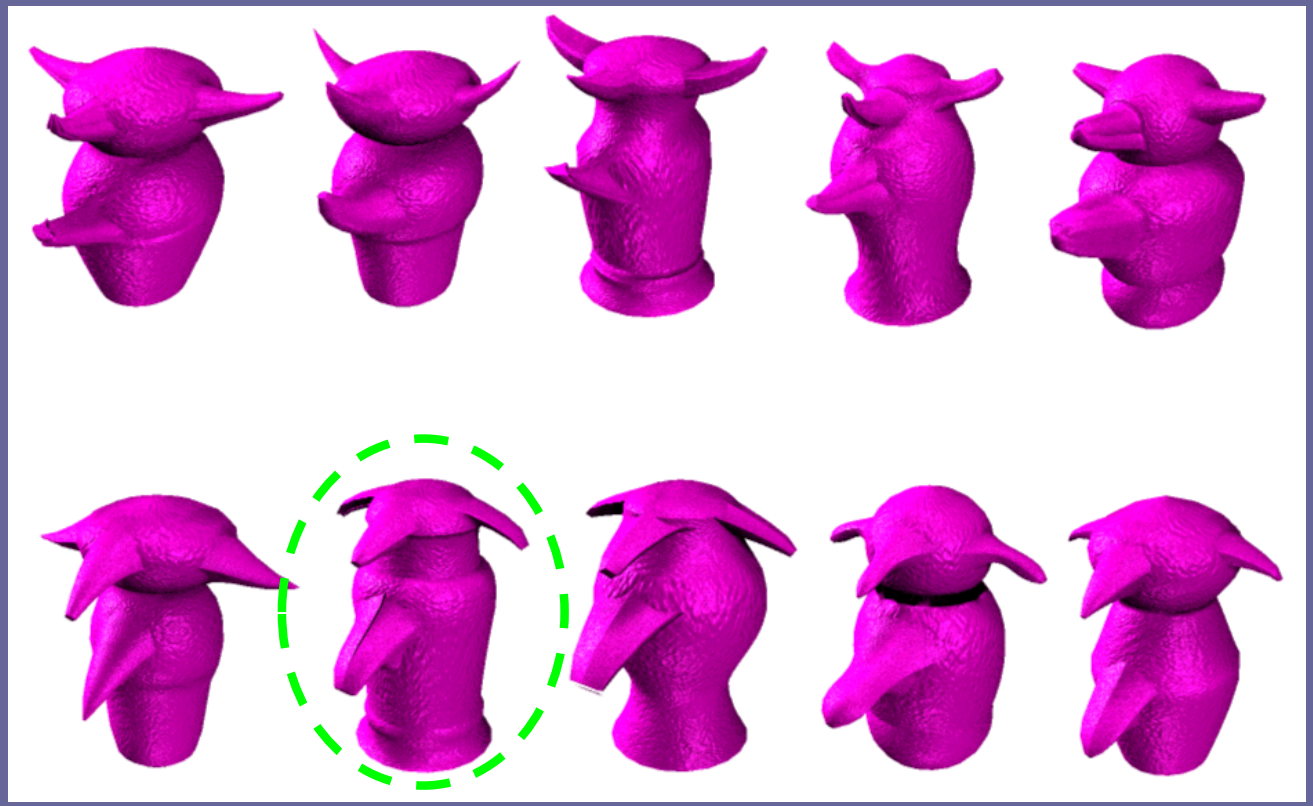


Functional definition of face-selective areas
(passive viewing localizer)



Learning

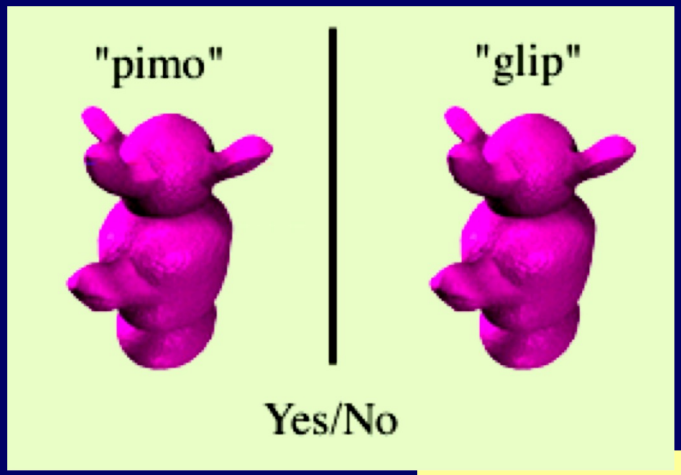
Novel stimuli: “Greebles”

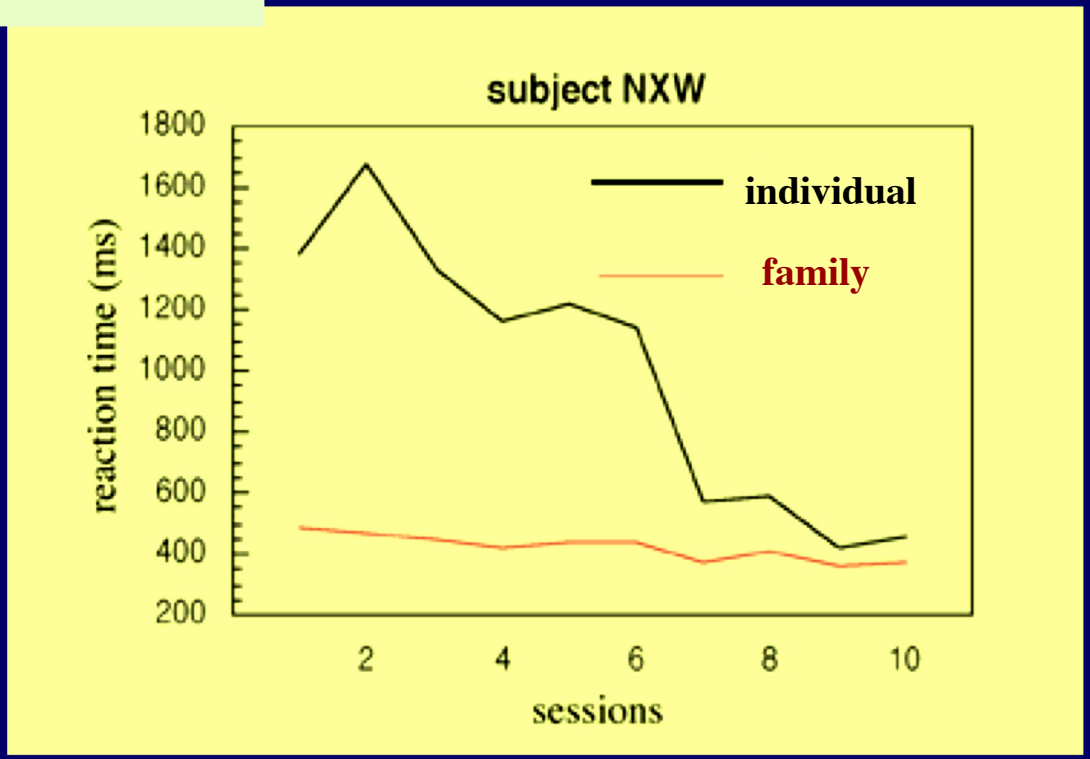


PLOKS

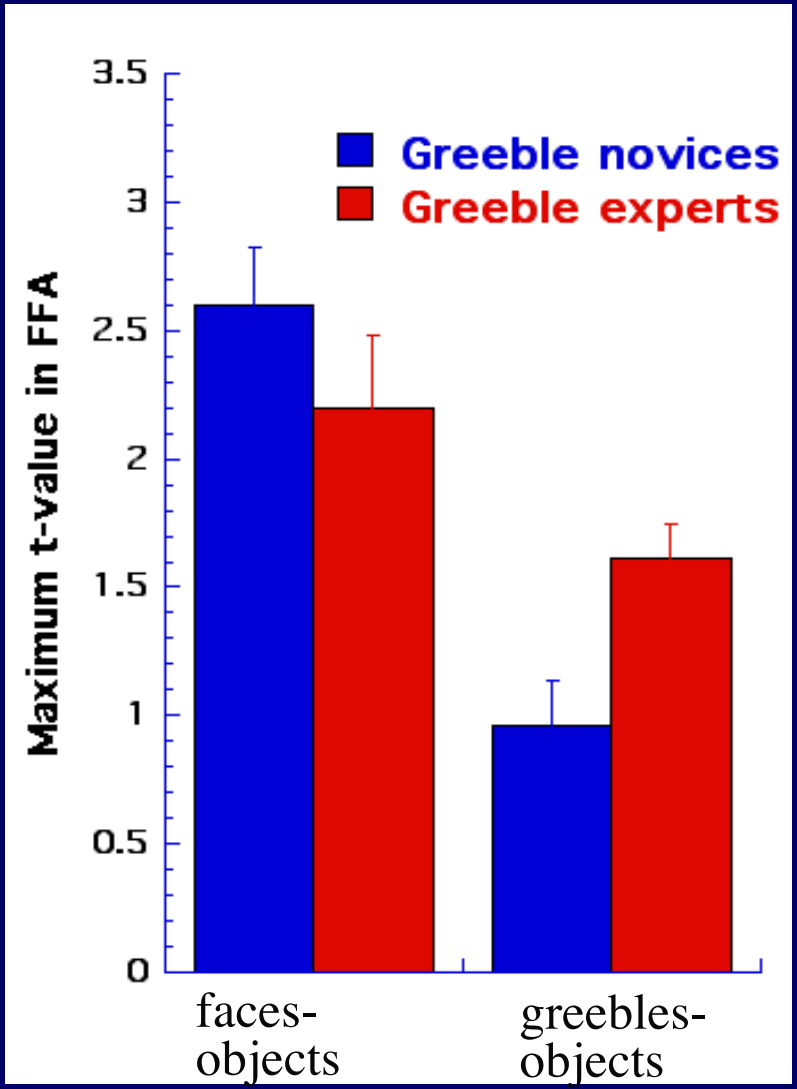
GLIPS

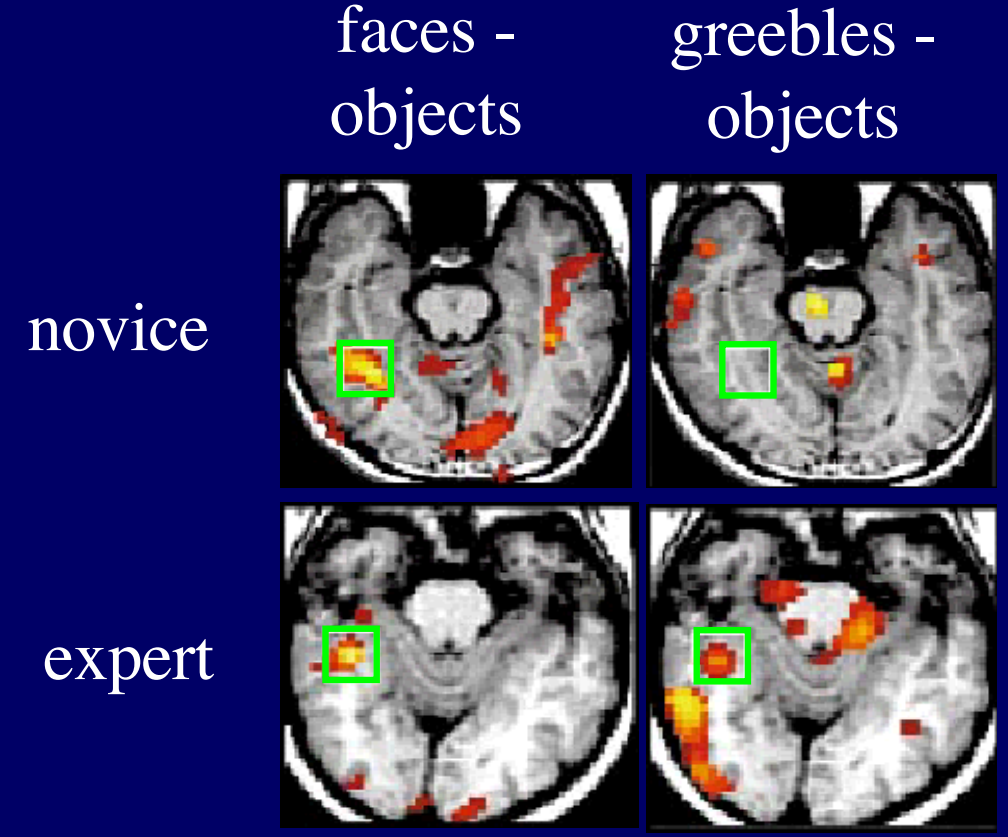
Learning to recognize greebles





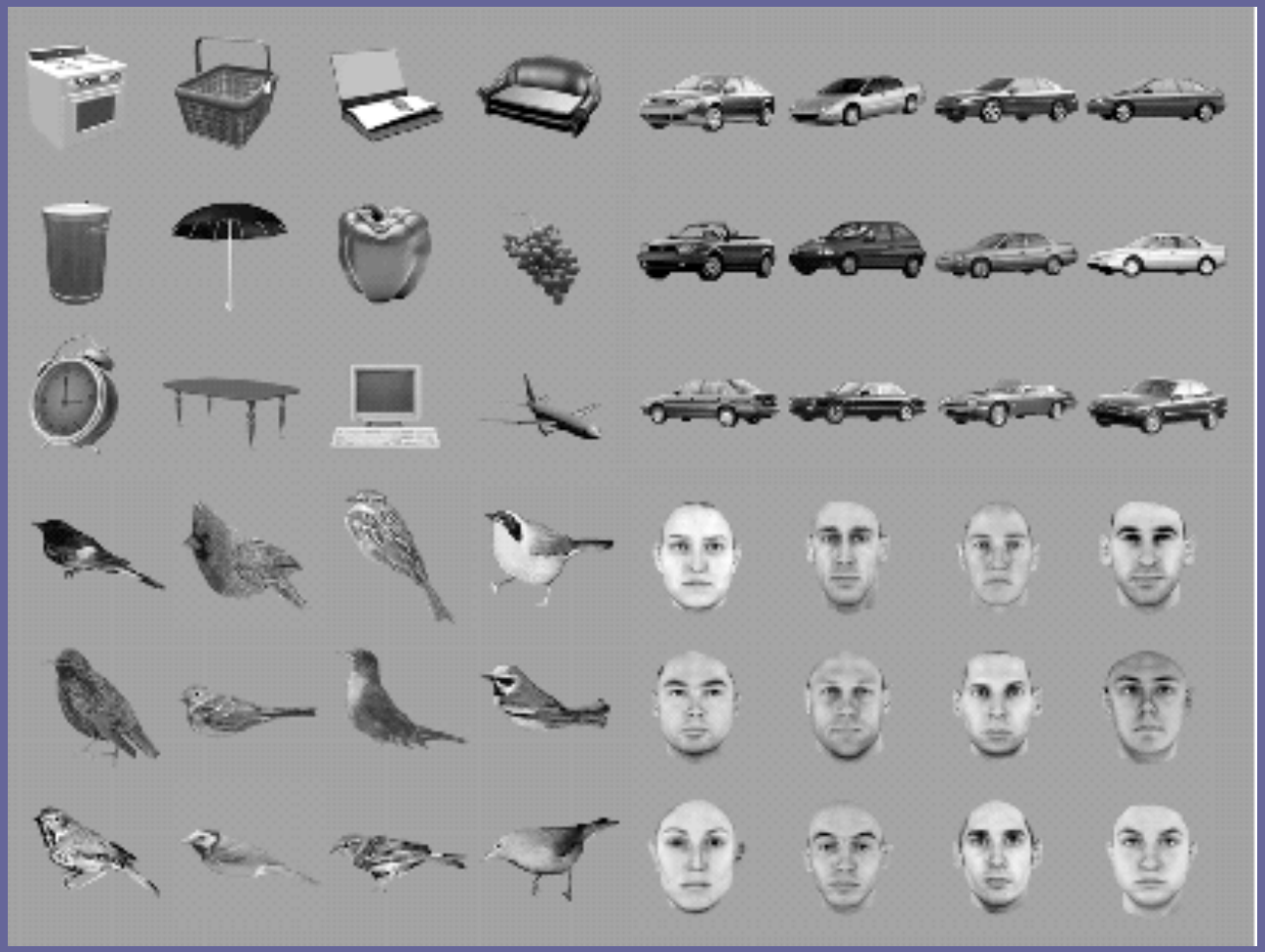
Greeble expertise is related to activity in the FFA





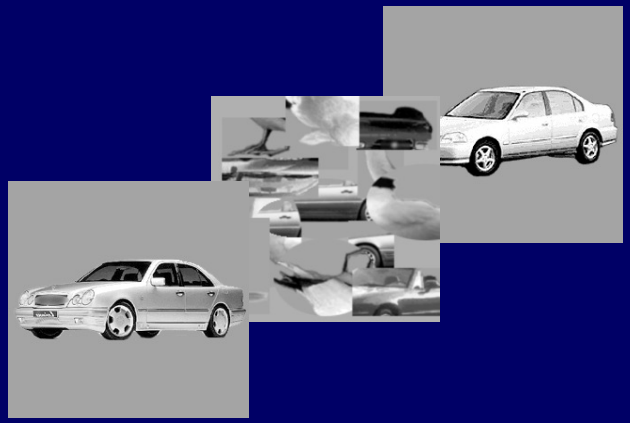
Gauthier et al., 1999

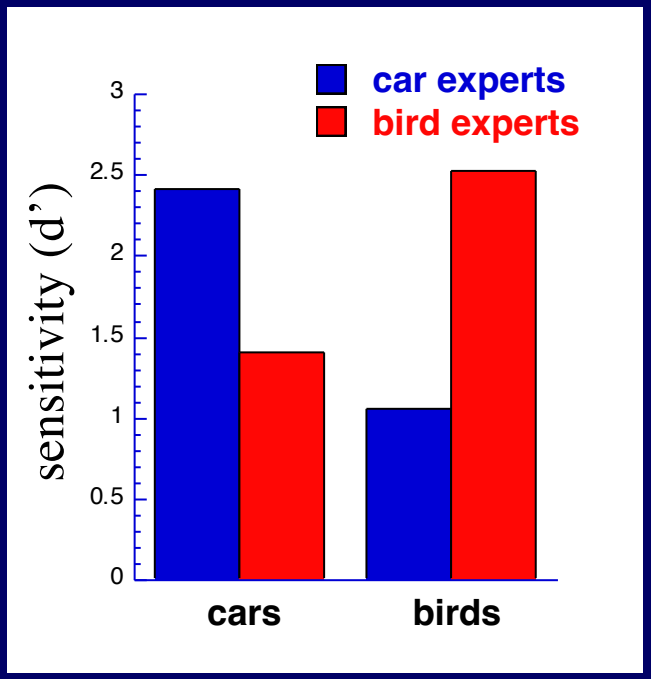
What about long-term learning?

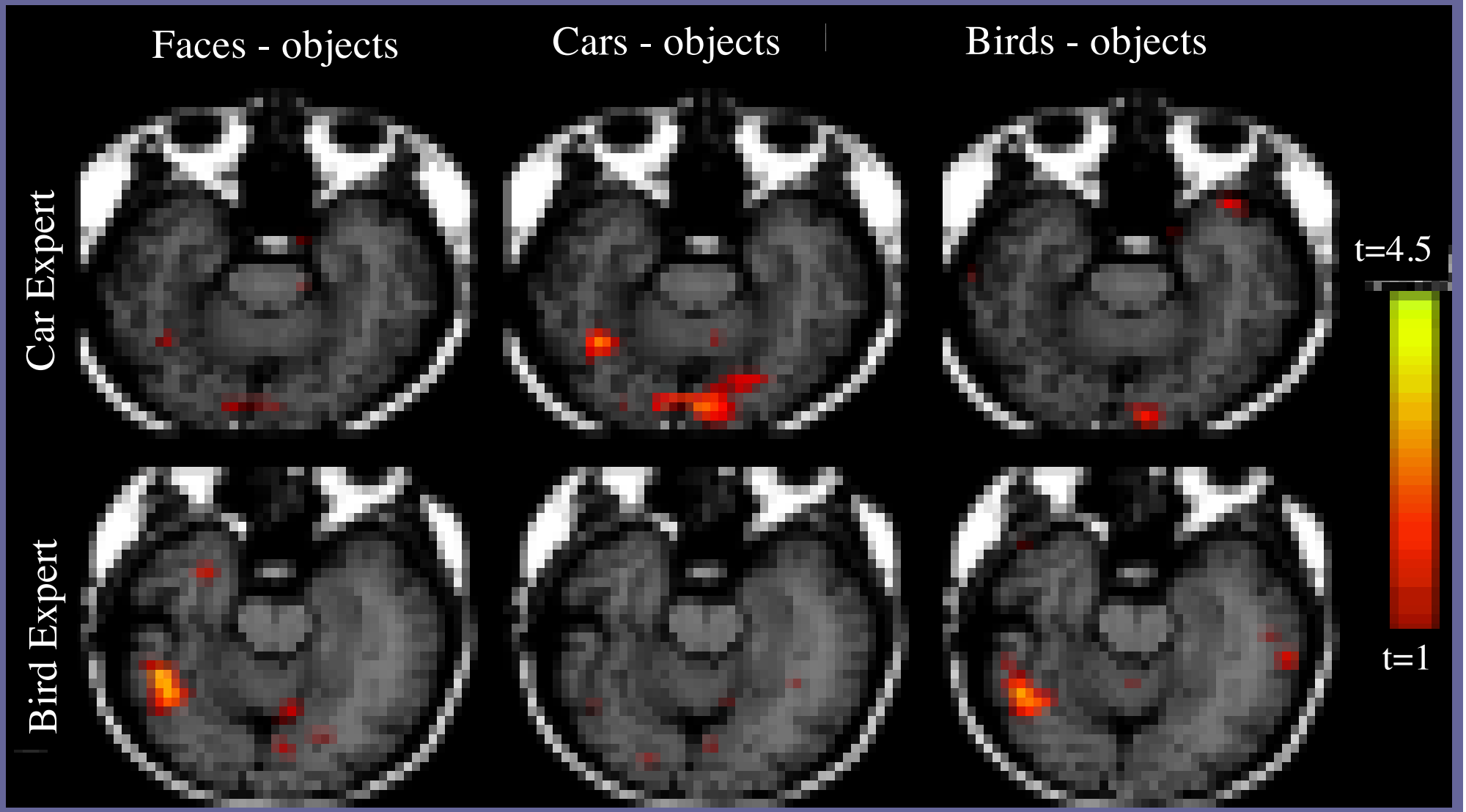


Gauthier, Skudlarski, Gore & Anderson, 2000

Behavioral measure of expertise: matching task





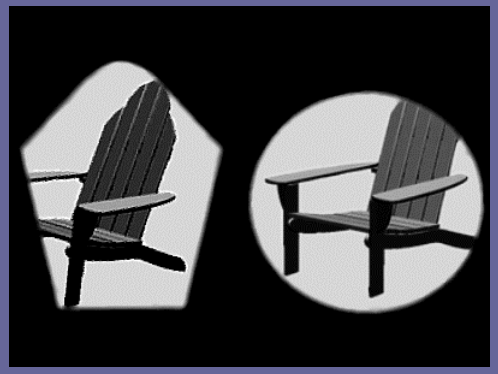
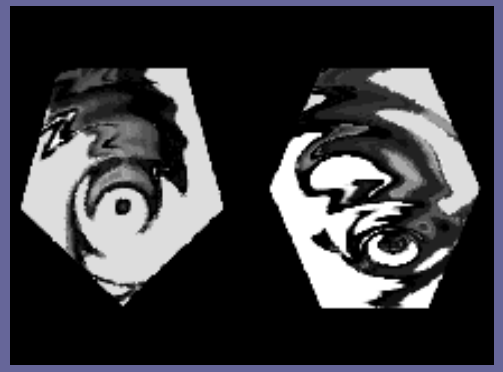
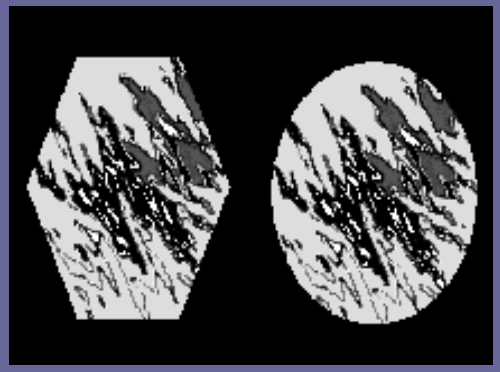


‘Face’ area is generally used for object recognition

fMRI Tasks

Same/different judgments for faces, objects, patterns



- 7 pairs per 41 sec block
- Stimulus duration 4 sec
- ISI 2 sec

2 runs:

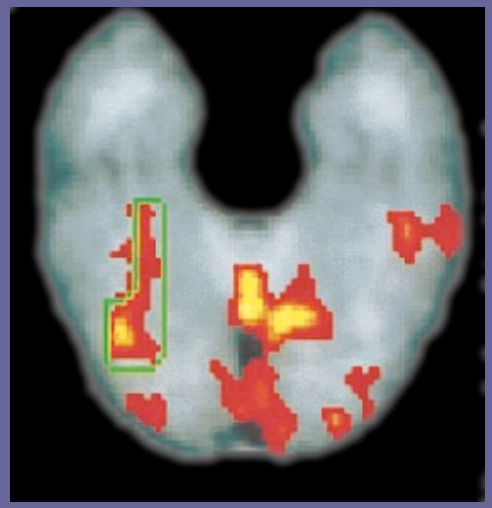
2 runs:

Region of interest (ROI) definition

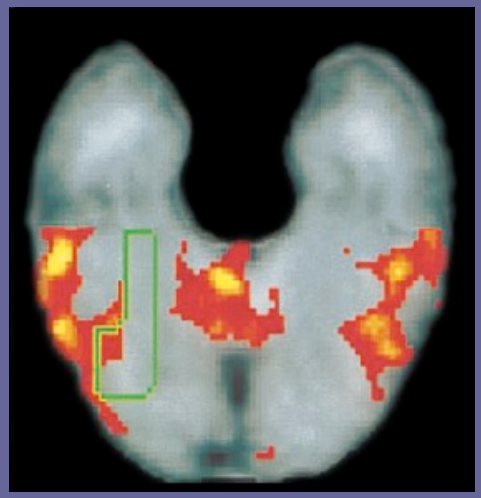
Results for faces

Autistism Ss show less activity in the normally face-selective right fusiform when viewing faces

Control group
Faces - patterns



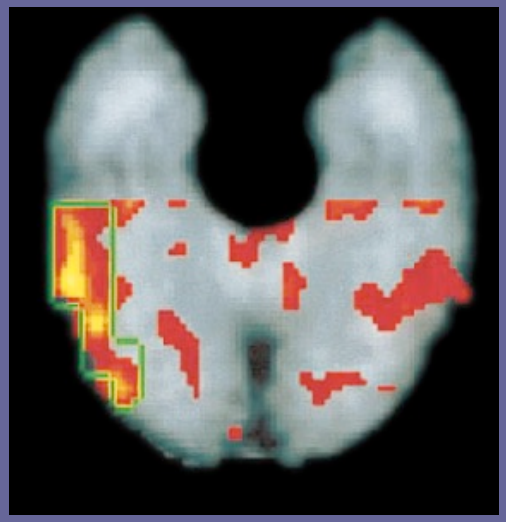
Autism group
Faces - patterns



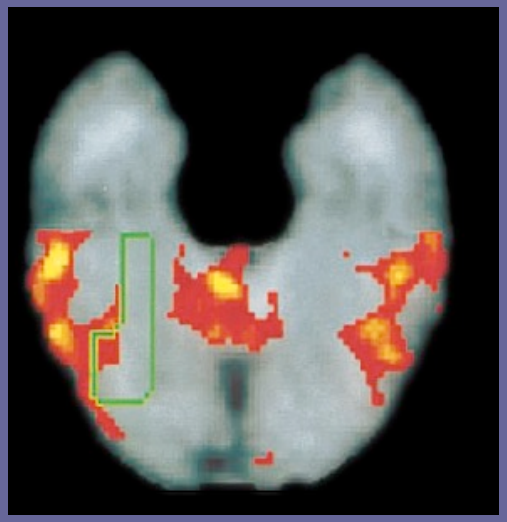
Activity in normally object-selective areas

Autistic Ss show more activity in the normally object-selective right temporal gyrus when viewing faces

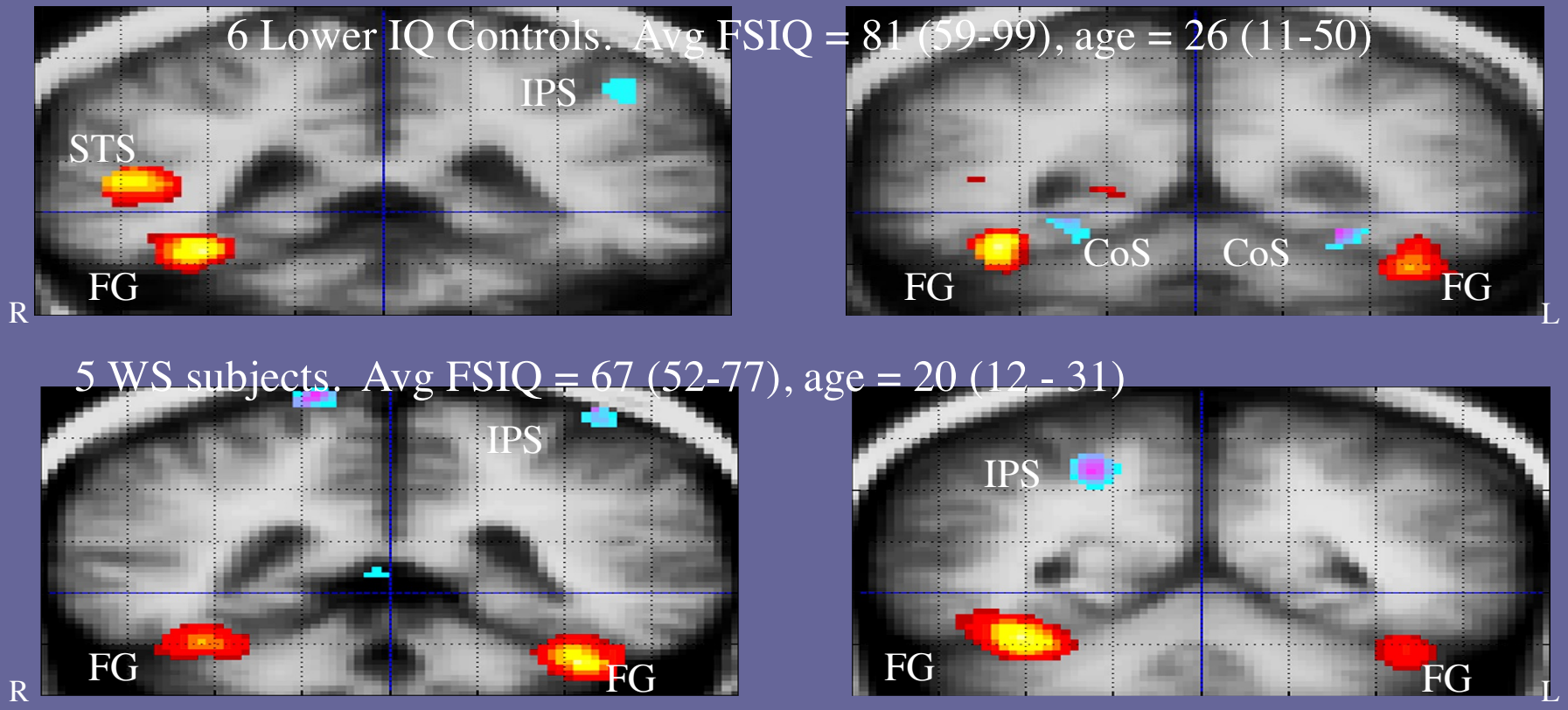
Control group
objects - patterns



Autism group
faces - patterns



Face vs. Object Discrimination Composite t Maps



t Threshold = 0.5

Face recognition in autism

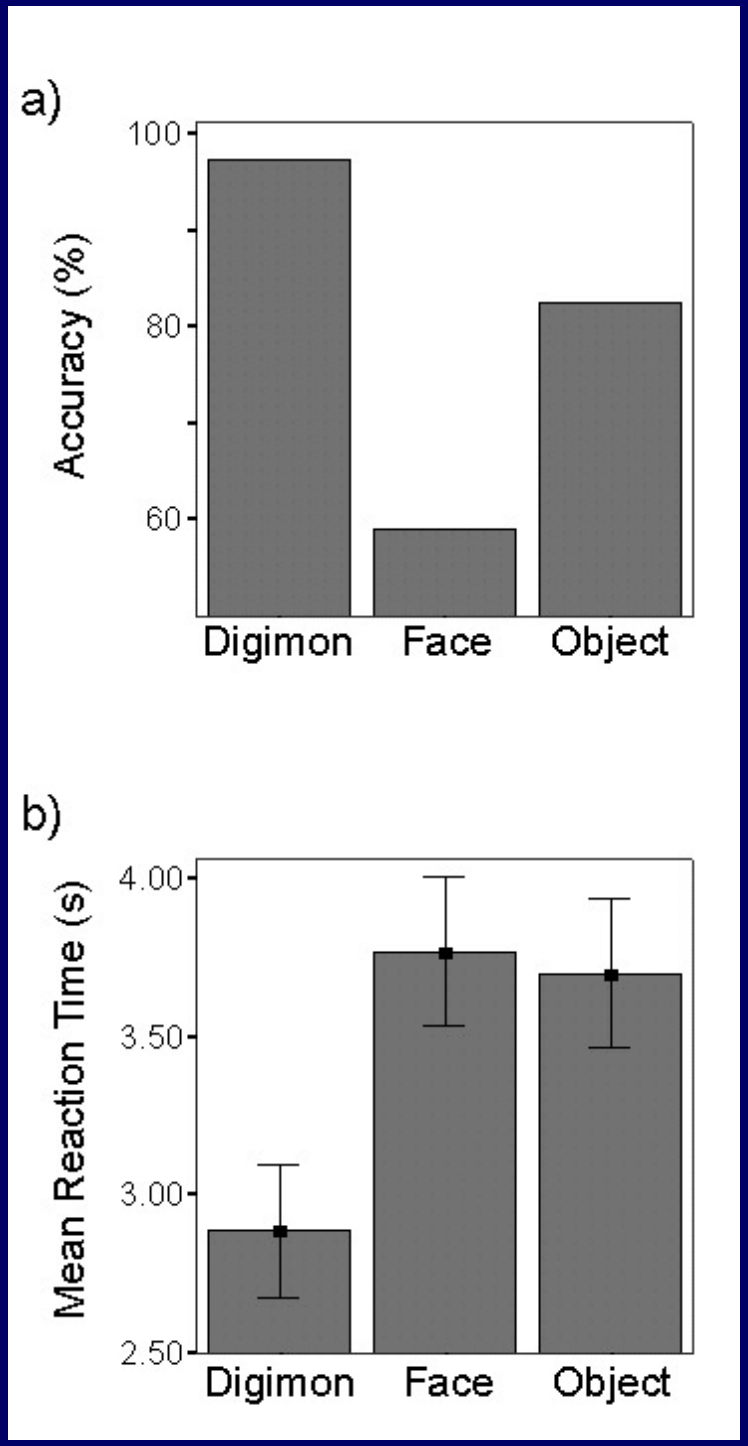
- No evidence of anatomical abnormality in fusiform gyrus in Autism
  -> normal response to objects

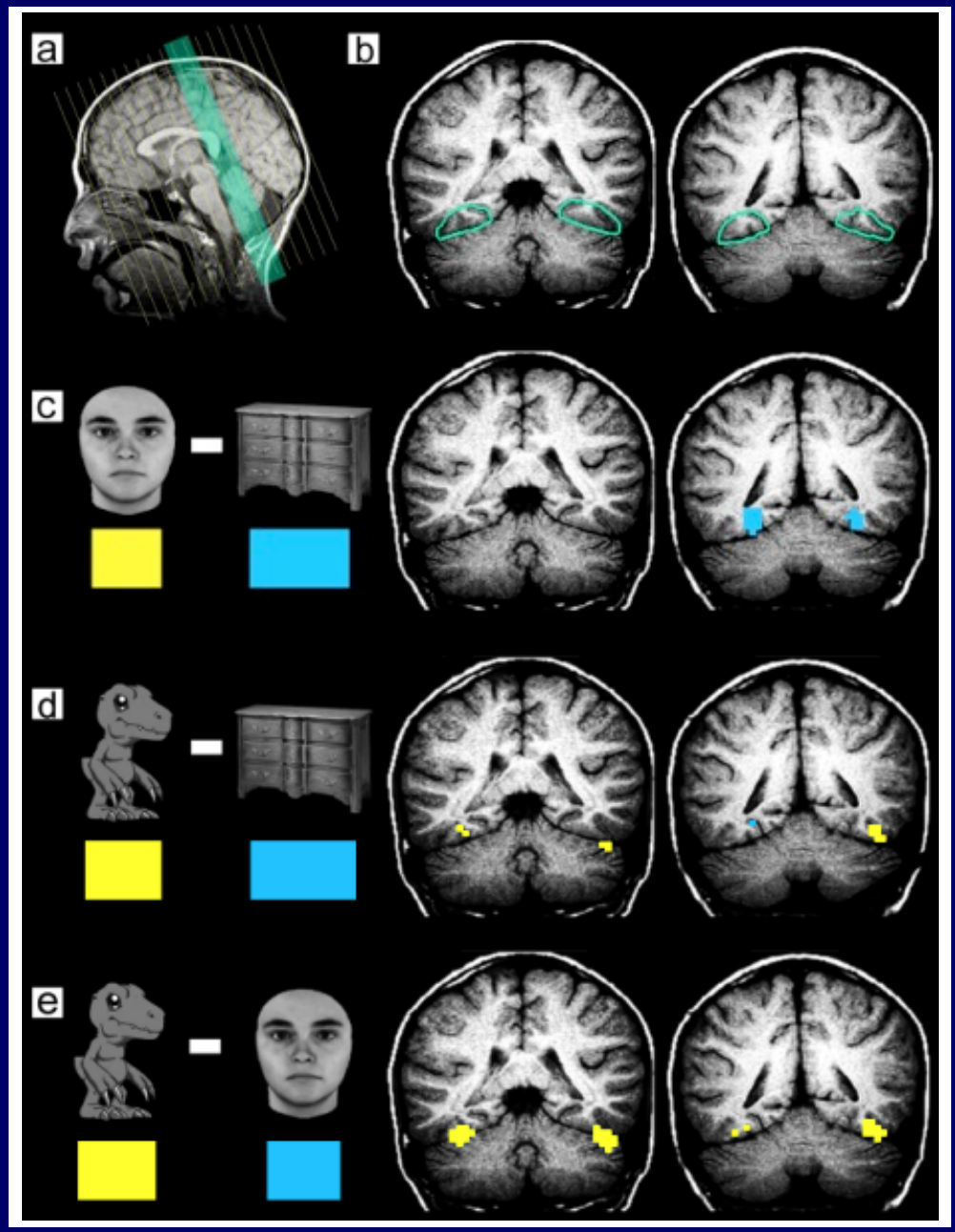
- Functional abnormality for face processing

- Is this part of the cause of autism or caused by developing with autism ?

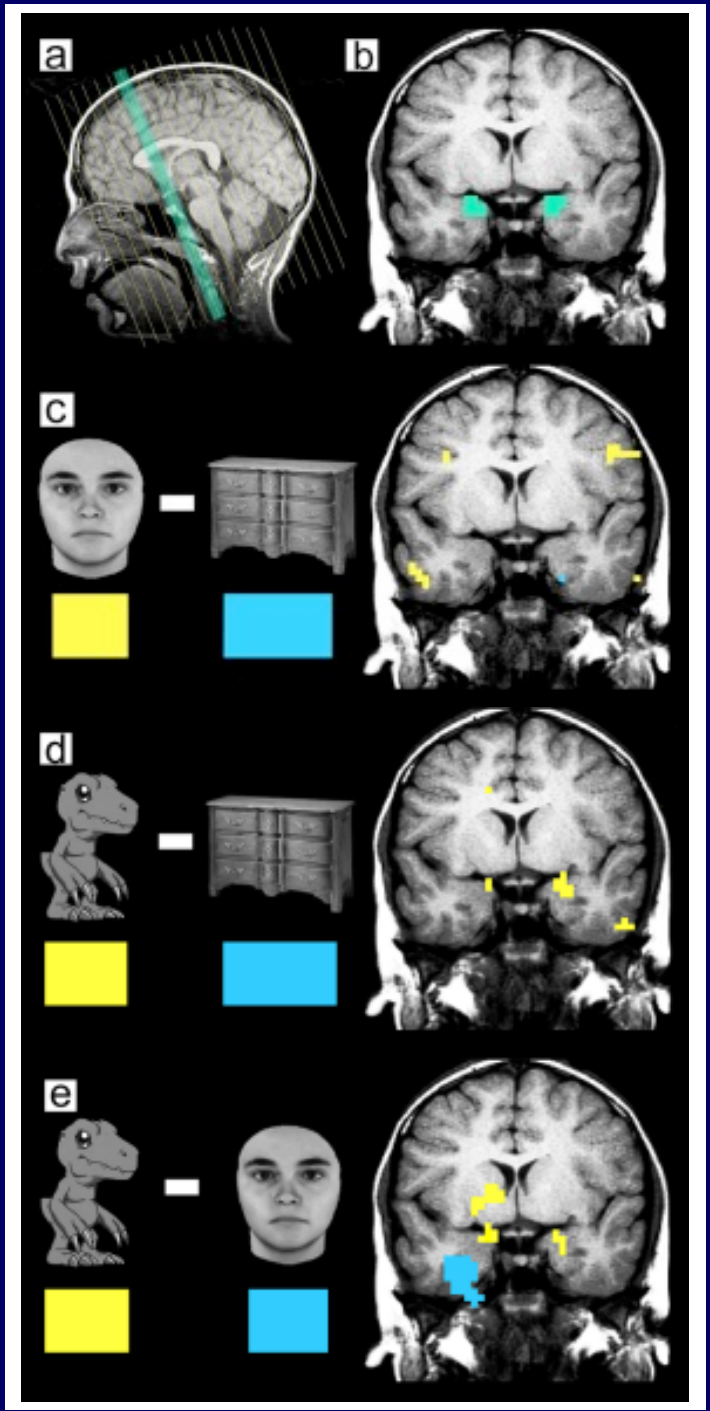
Case Report – Child with Autism

- Shows obsession with “Digimon” cartoon characters
- Behavioral testing reveals high expertise in recognizing Digimon
- Tested in magnet vs faces, objects





FFA is intact



Digimon elicits amygdala response: circuitry intact

Summary of fMRI applications

- Normal brain function and organization
- Treatment planning and patient assessment
  - Neurosurgery
  - Neurology
- Abnormal brain function: relationship to underlying neurobiology
  - Psychiatry
  - Developmental disorders
  - Degenerative disorders