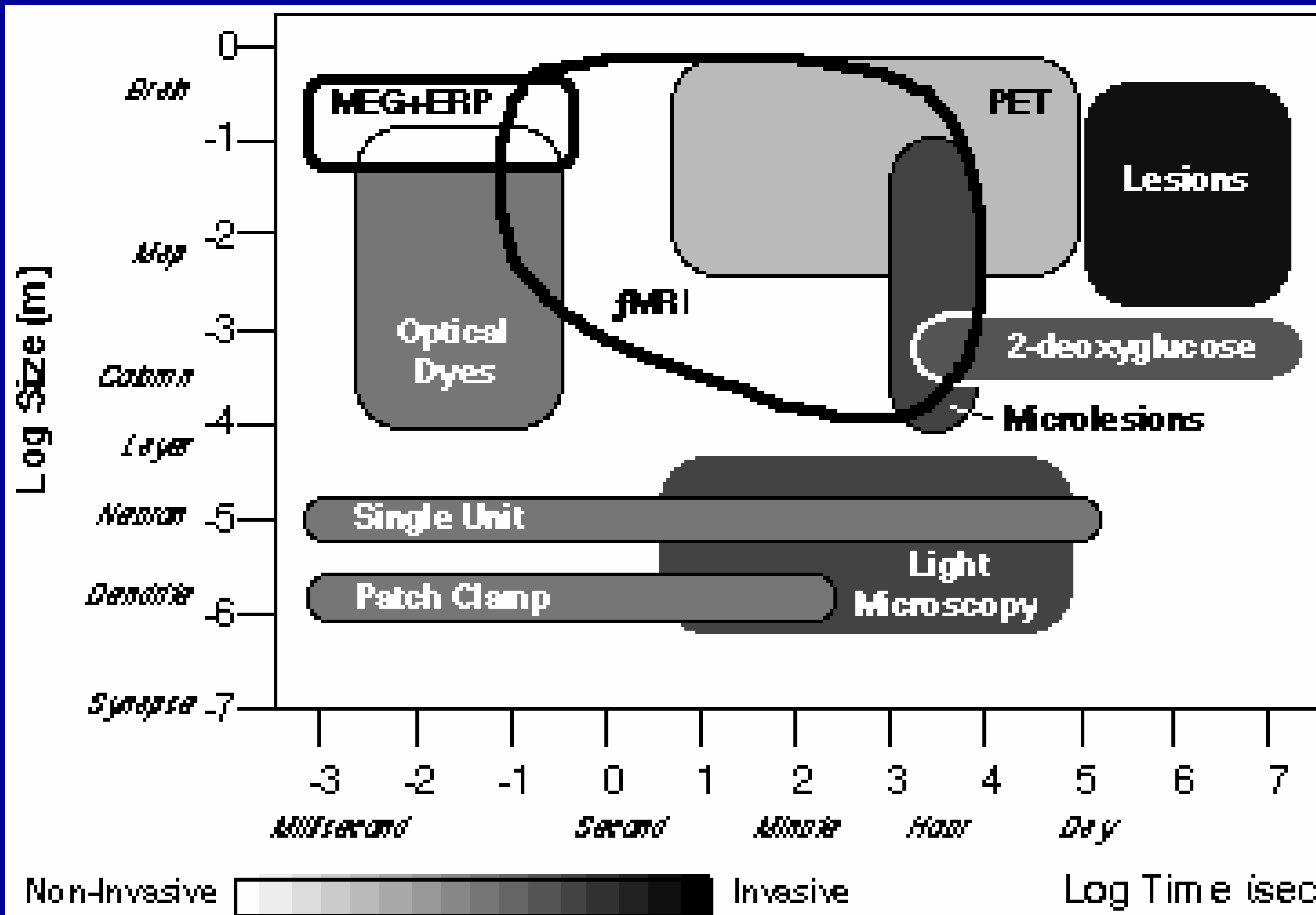
Methods to examine brain activity associated with emotional states and traits

- Brain electrical activity methods
  - – description and explanation of method
  - – state effects
  - – trait effects
- Positron emission tomography (PET)
  - – description and explanation of method
  - – state effects
  - – trait effects

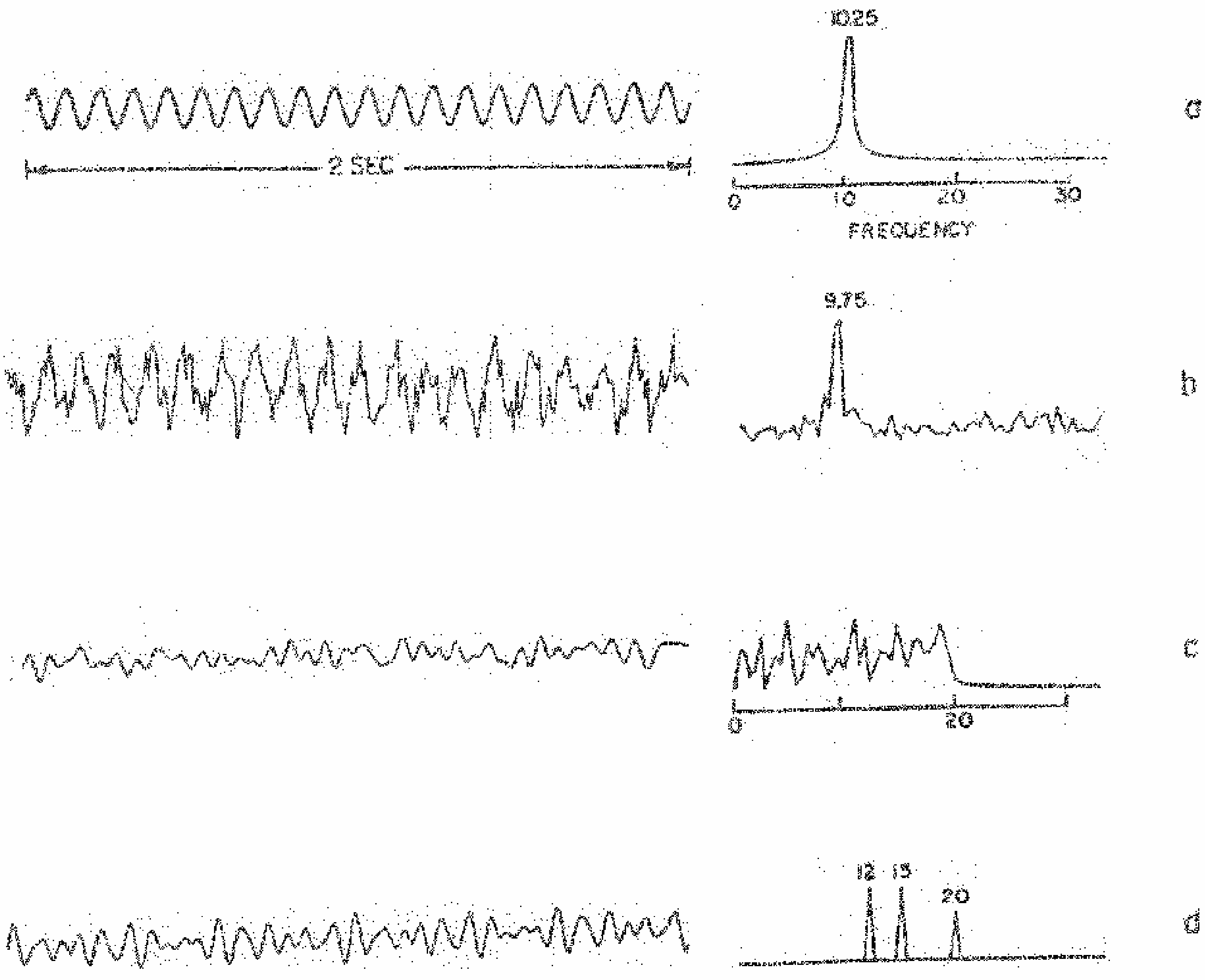
Methods to examine brain activity associated with emotional states and traits

- Functional magnetic resonance imaging (MRI) methods
  - description and explanation of method
  - state effects
  - trait effects
- Structural MRI

Spatial and temporal resolution of modern methods to study brain function



Brain electrical activity methods



10.25
2 SEC
0
10
20
30
FREQUENCY
a
9.75
b
0
20
c
12
15
20
d

Electrical and magnetic signals have excellent time resolution

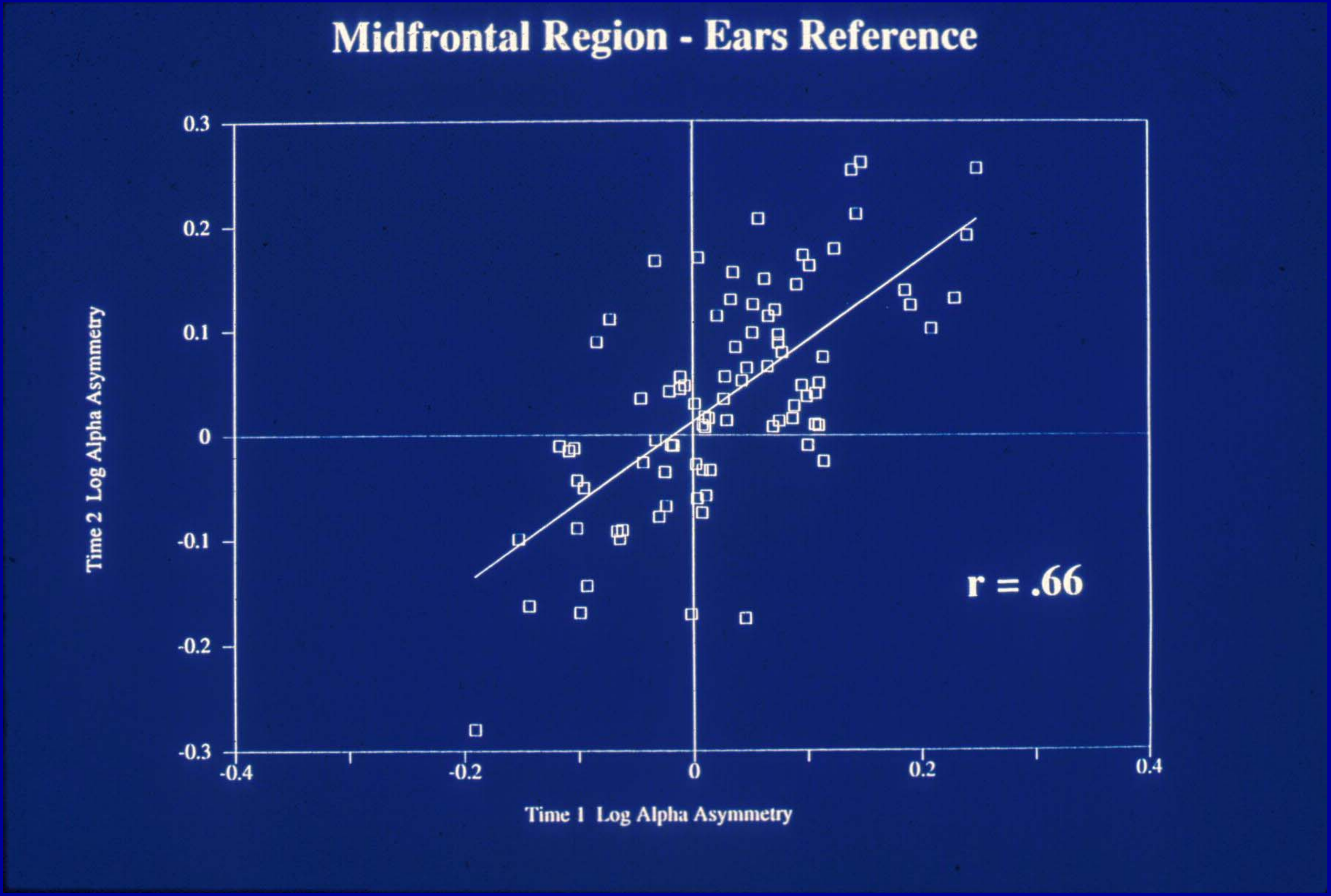
- Ideal for studying transient states
- Brain activity can be extracted during the spontaneous expression of particular facial signs of emotions, even fleeting expressions that last just a few seconds

Activation in response to faces that elicit emotional reactions, detected by electrical signals in fusiform gyrus approximately 160-170 ms following the face

Trait measures of brain electrical activity

- Aggregating across many epochs of brain activity produces reliable measures that reflect traits
- Asymmetric activation in the prefrontal cortex is one such measure

Asymmetric activation is stable over time



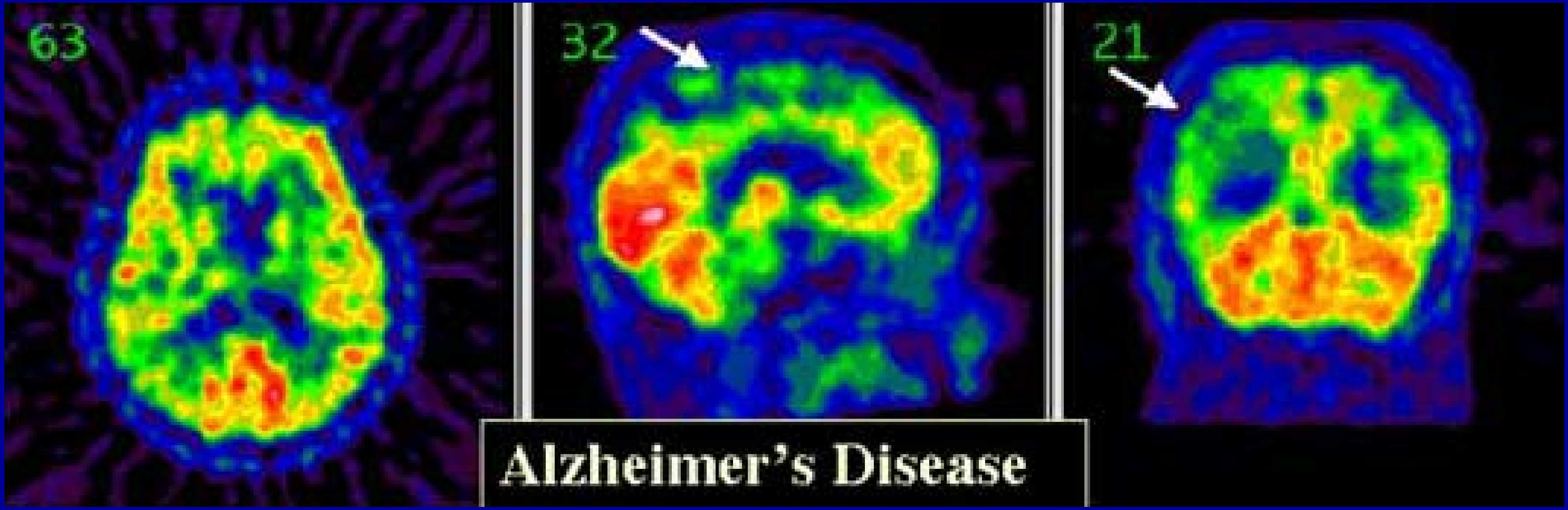
Positron emission tomography (PET)

- Reveals the biochemistry of the brain
- Different tracers can be used to label different chemical systems
- Glucose metabolism in the brain was one of the first processes to be studied
- Neurotransmitter systems can now be examined and new methods are coming on line for molecular imaging

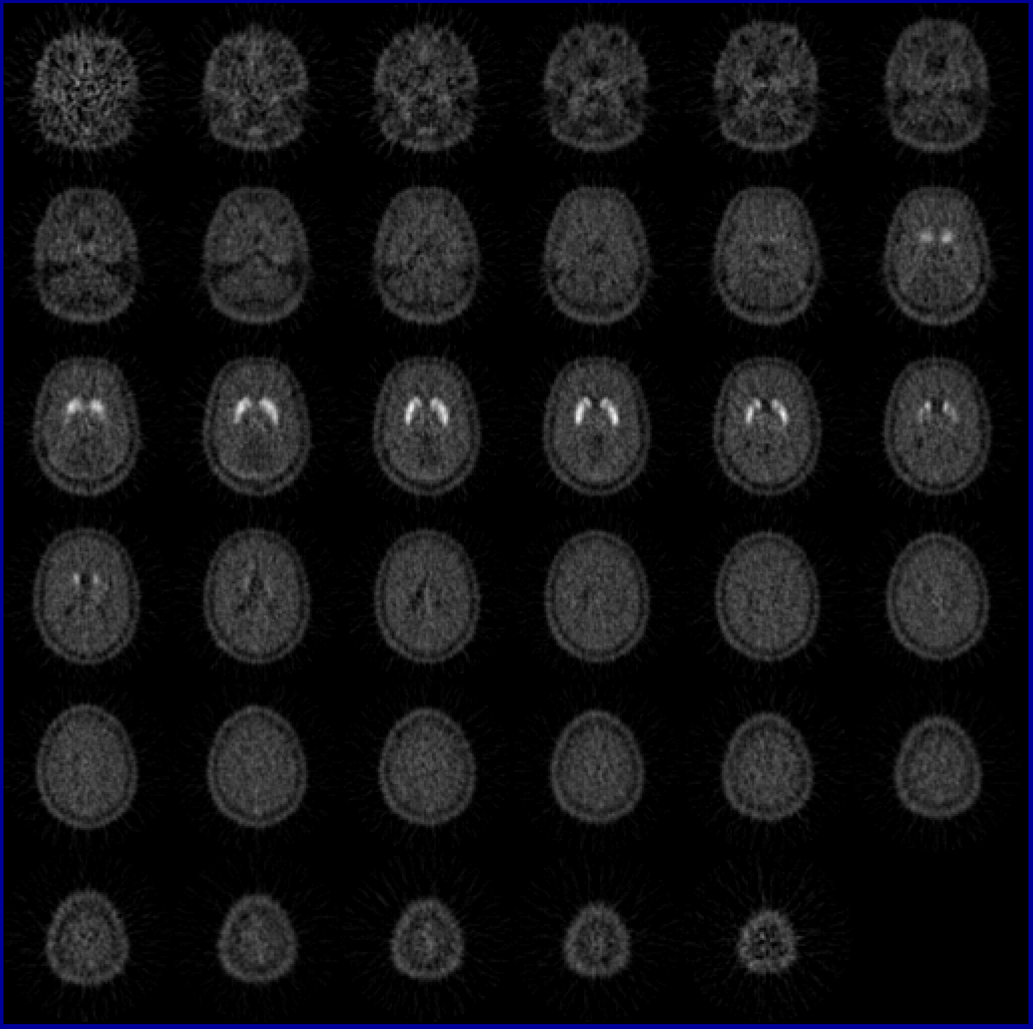
Positron emission tomography (PET), cont.

- State changes in neurotransmitter function--e.g., behaviorally-induced changes in dopamine
- Trait changes in both tonic activation and transmitter (e.g., receptor) function can be measured

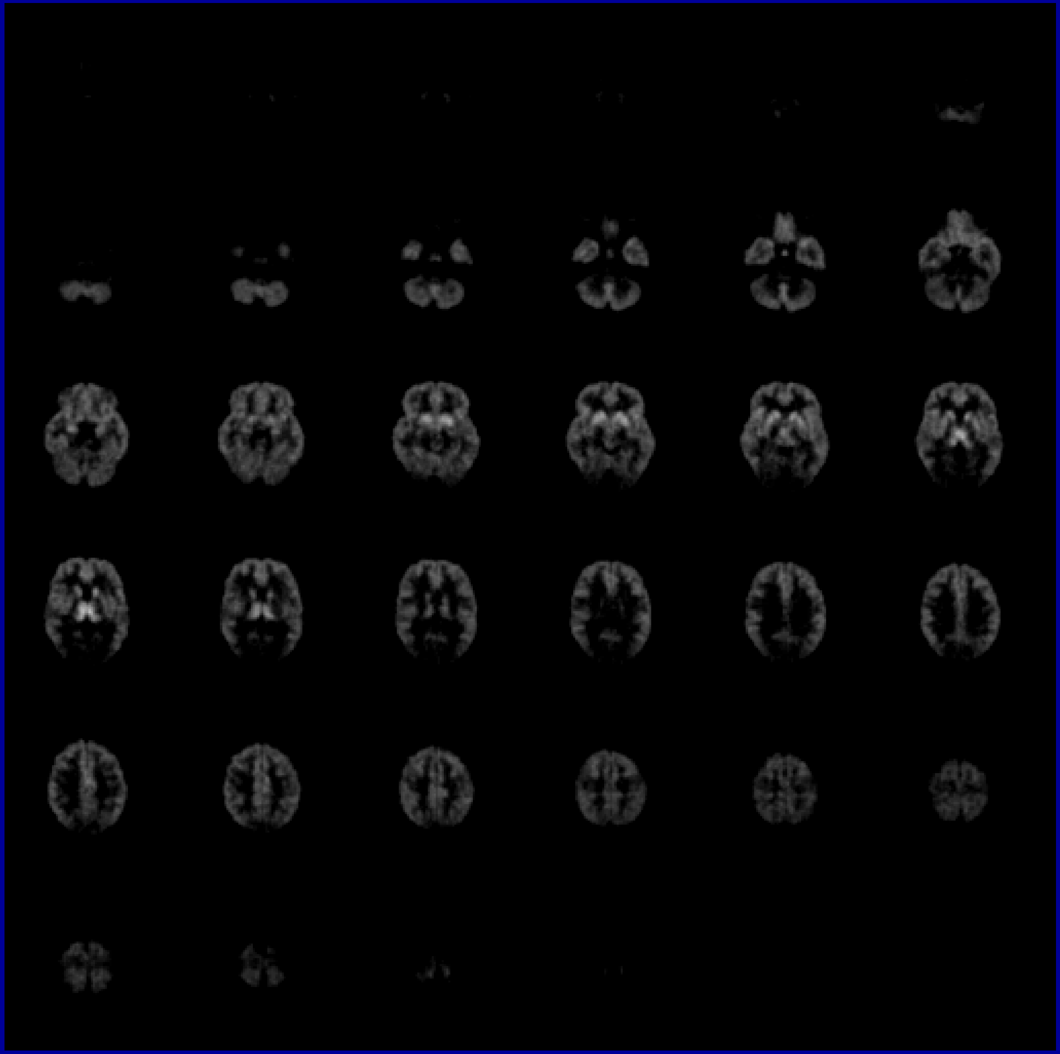
Hypometabolism in the parietal cortex in Alzheimer’s disease



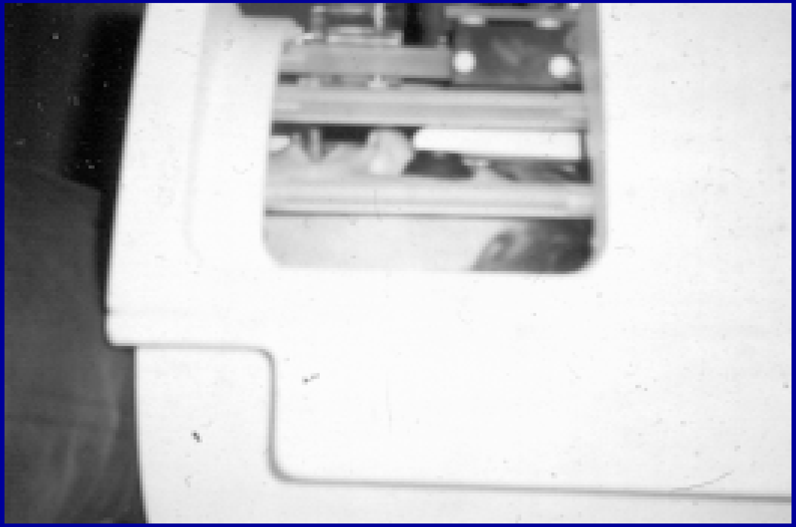
Dopamine (D_2) receptors in basal ganglia

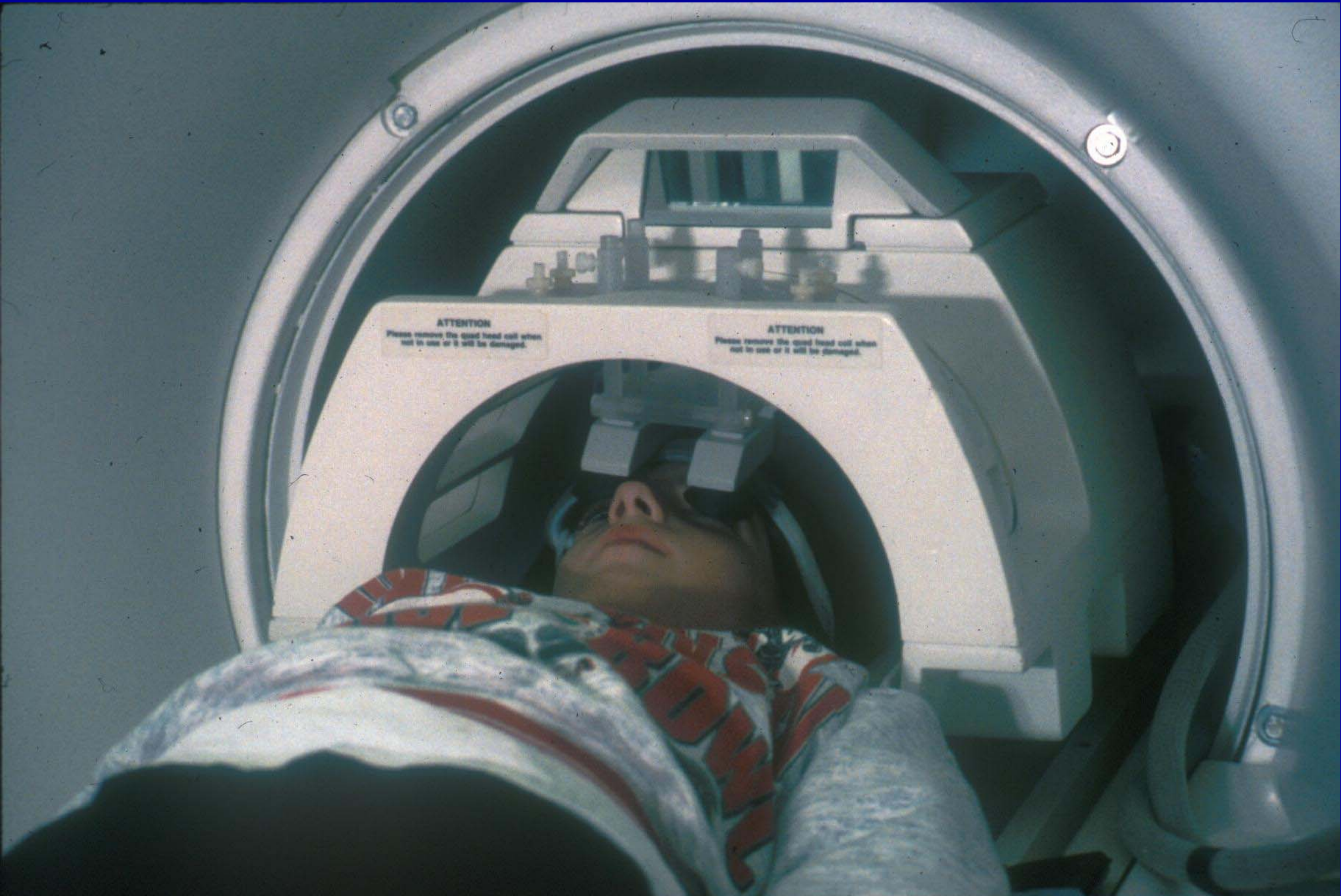


Opiate receptors in basal ganglia, amygdala and thalamus



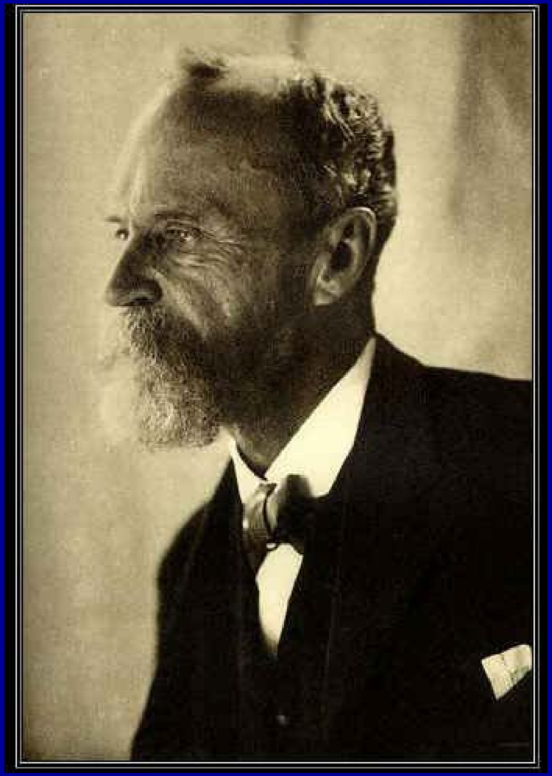
Magnetic resonance imaging (MRI) methods




ATTENTION
ATTENTION

Basic principles of MR imaging

- Used to image the distribution of hydrogen atoms which are abundant in biological tissue
- There are differences in the distribution of hydrogen atoms in, and in the magnetic properties of different tissues; we can take advantage of these facts to image hemodynamic changes in the brain that reveal function

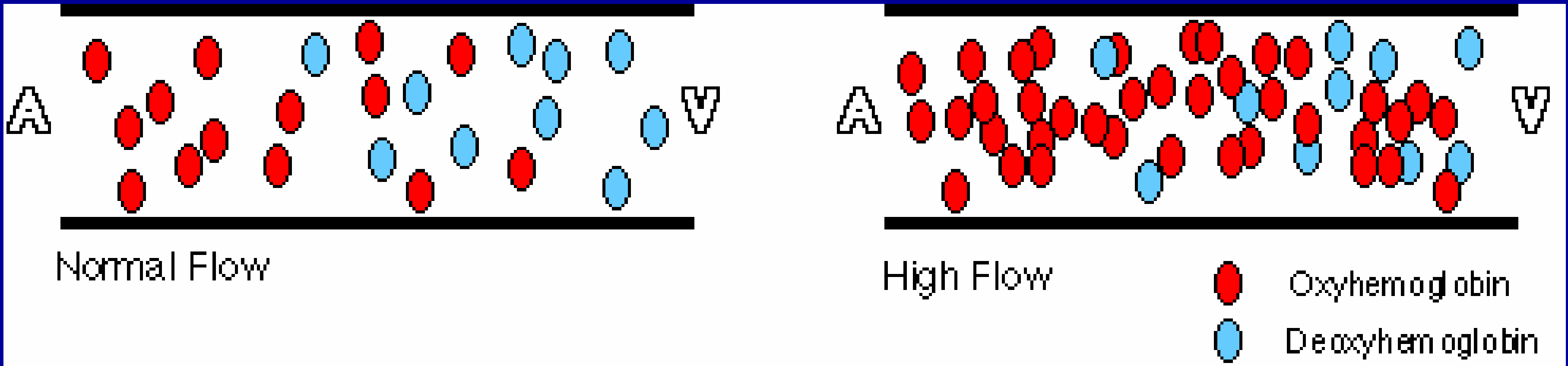


“We must suppose a very delicate adjustment whereby the circulation follows the needs of the cerebral activity. Blood very likely may rush to each region of the cortex according it is most active, *but of this we know nothing”* (William James, 1890, italics added)

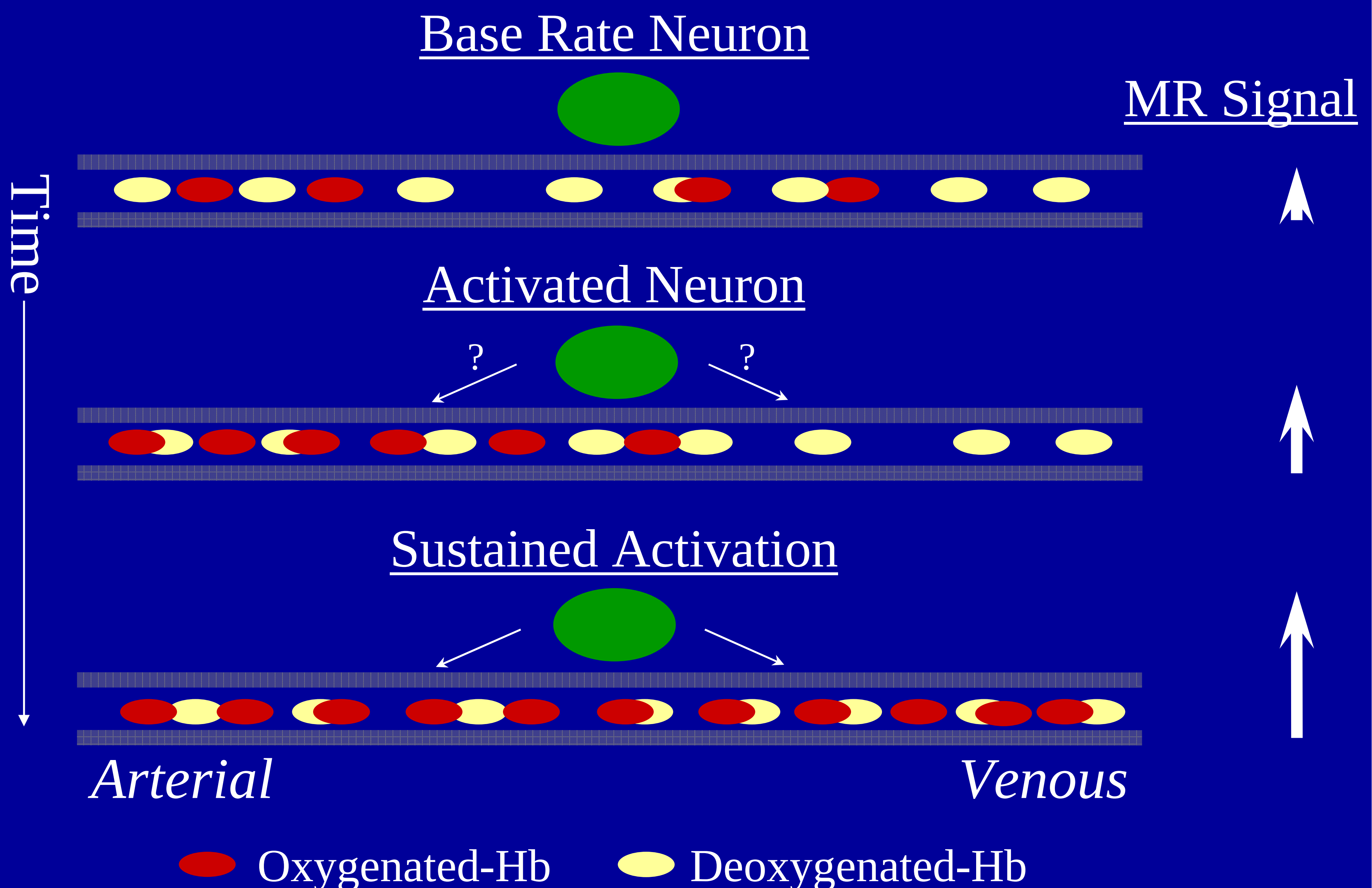
Basic principles of MR imaging, cont.

- As early as 1936, Linus Pauling first reported that the magnetic susceptibility of hemoglobin and deoxyhemoglobin differed slightly
- Most functional MRI today is based upon this original observation and detects local changes in the relative amounts of hemoglobin in the brain

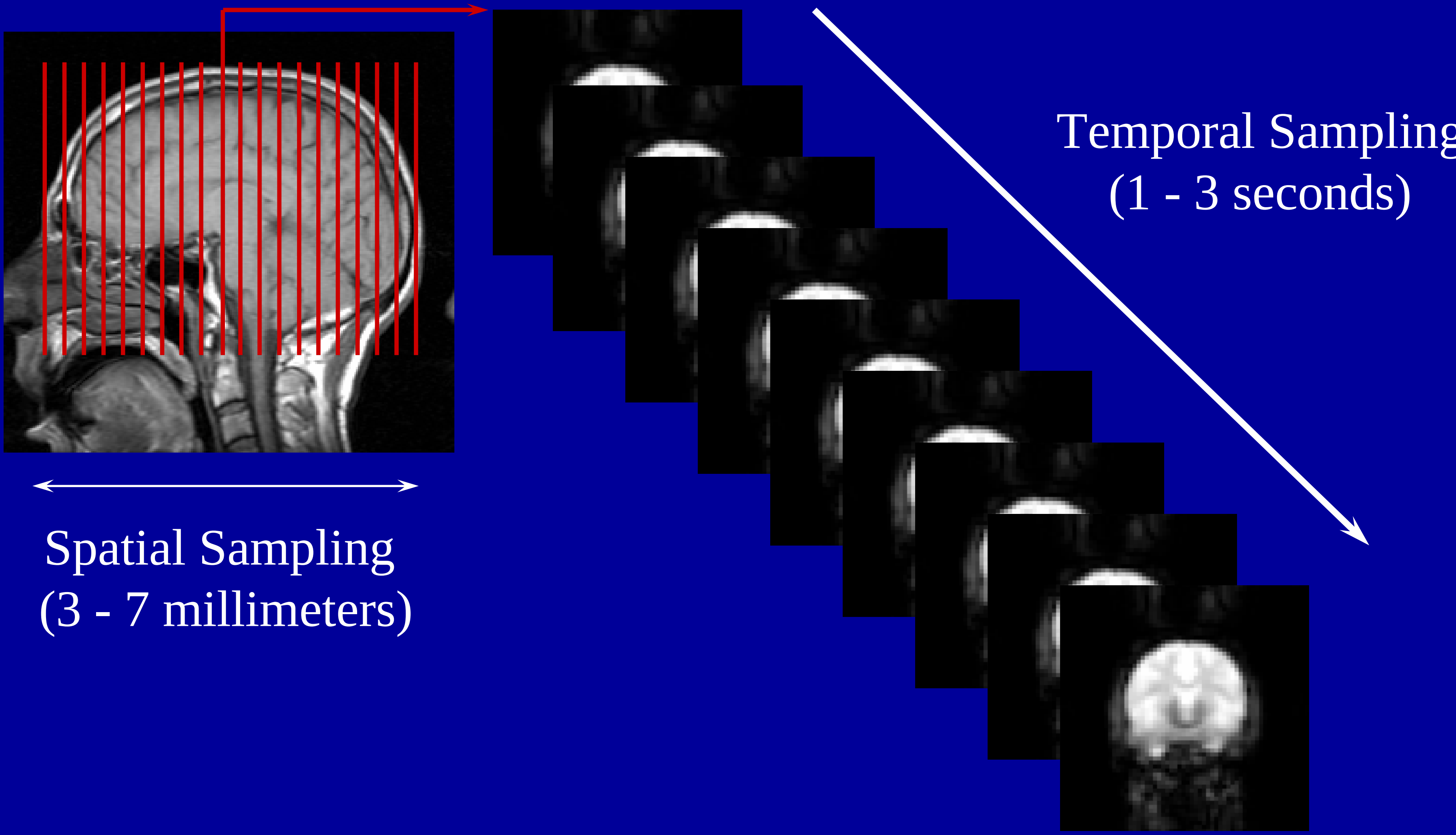
Increased neuronal activity is associated with an increase in local blood flow



Hemodynamic Response

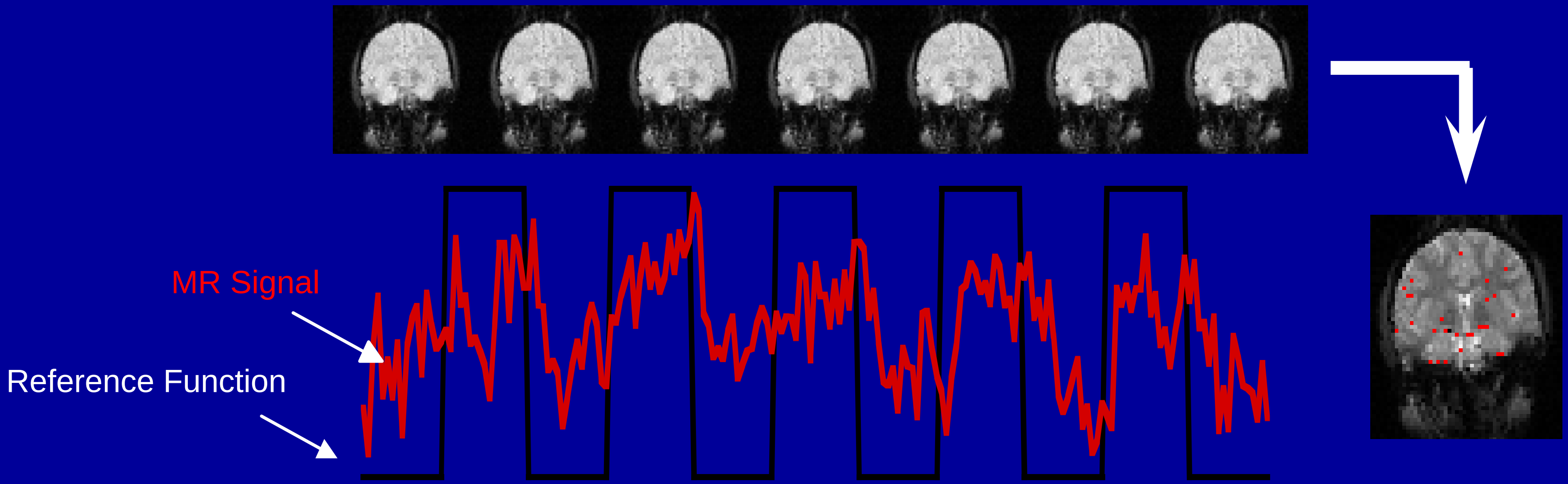


Echo Planar Imaging (EPI)



Time Series Analyses

- Least-squares fit between MR signal and a reference function
- Fit yields statistical parameters (i.e., Student's *t*)
- Paradigm-correlated signal changes are visualized in a "functional map"



Visualizing Brain Function: Basic Principles

Stimulation
(multi-modal;
active, passive)

↓

Increased Neuronal Activity
(local input processing)

↓

Increased Neuronal Metabolic Rate
(glucose &
hemodynamic changes)

→

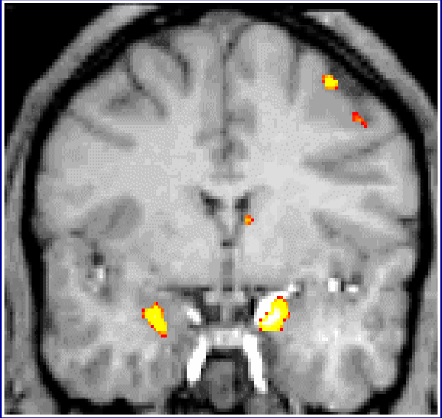
Acquire Image Data
Condition 1 & Condition 2
(distribution of glucose/hemodynamic change)

↑

Statistical Assessment of Change
Condition 1 - Condition 2
(Student's *t*, correlation, etc..)

↖ ↗

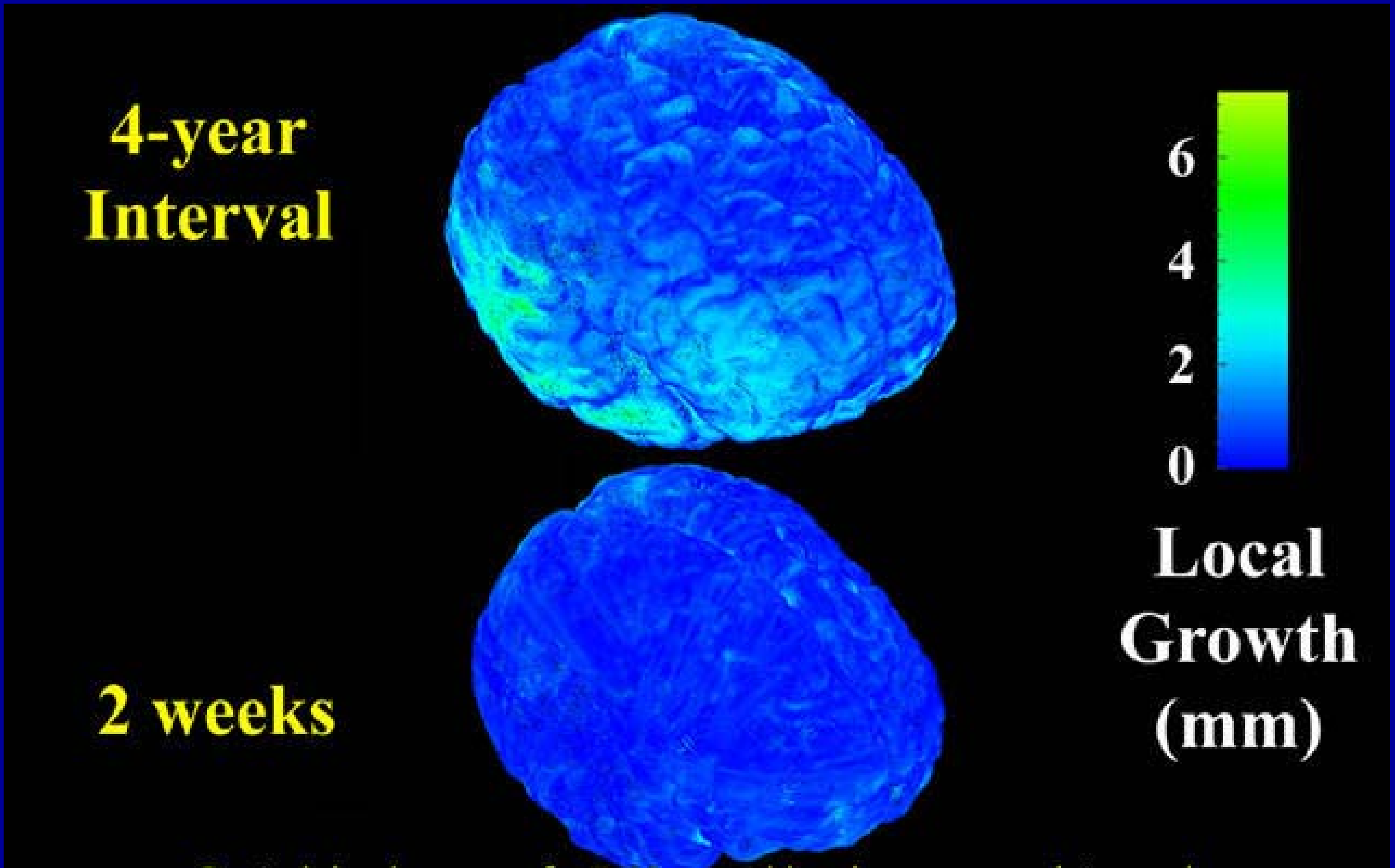
Statistical Parametric Map
(false color)



MRI can also be used to reveal anatomical differences

- Longitudinal changes within individuals over time
- Differences between individuals

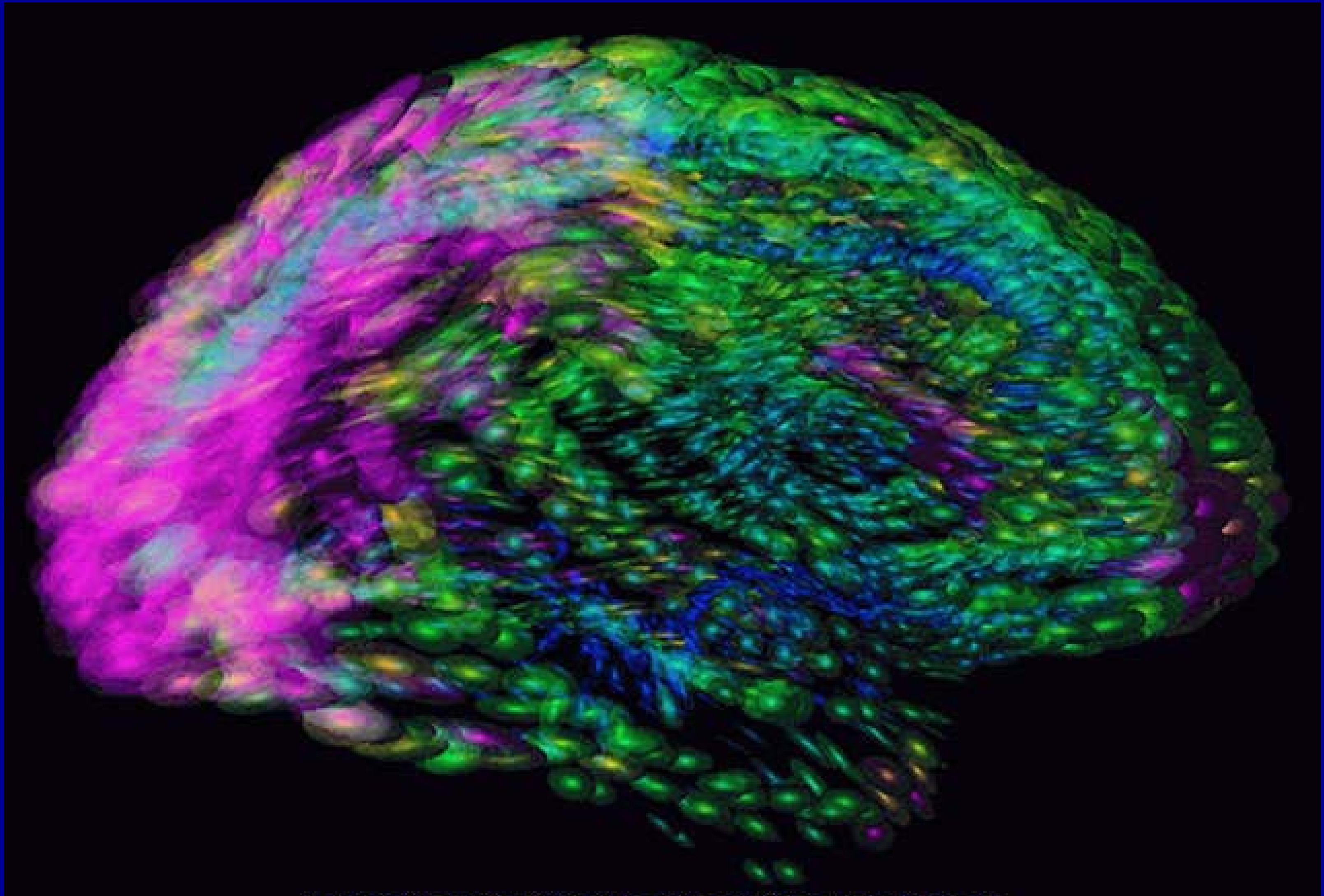
Longitudinal changes in brain anatomy



Cortical development of a 7–11 year old and at a two week interval

A complex pattern of growth is detected in the corpus callosum of a young normal subject. This map illustrates structural change occurring in the 4–year period from 7 to 11 years of age. The effects of the transformation are shown on a regular grid ruled over the reference anatomy and passively carried along in the transformation which matches it with the target. The color code shows values of the local Jacobian of the warping field, which indicates local volume loss or gain. Vector field operators have been applied to emphasize patterns of contractions and dilations, revealing their regional character.

Variability across people in brain anatomy



Composite variability elipsoids of 20 normal subjects

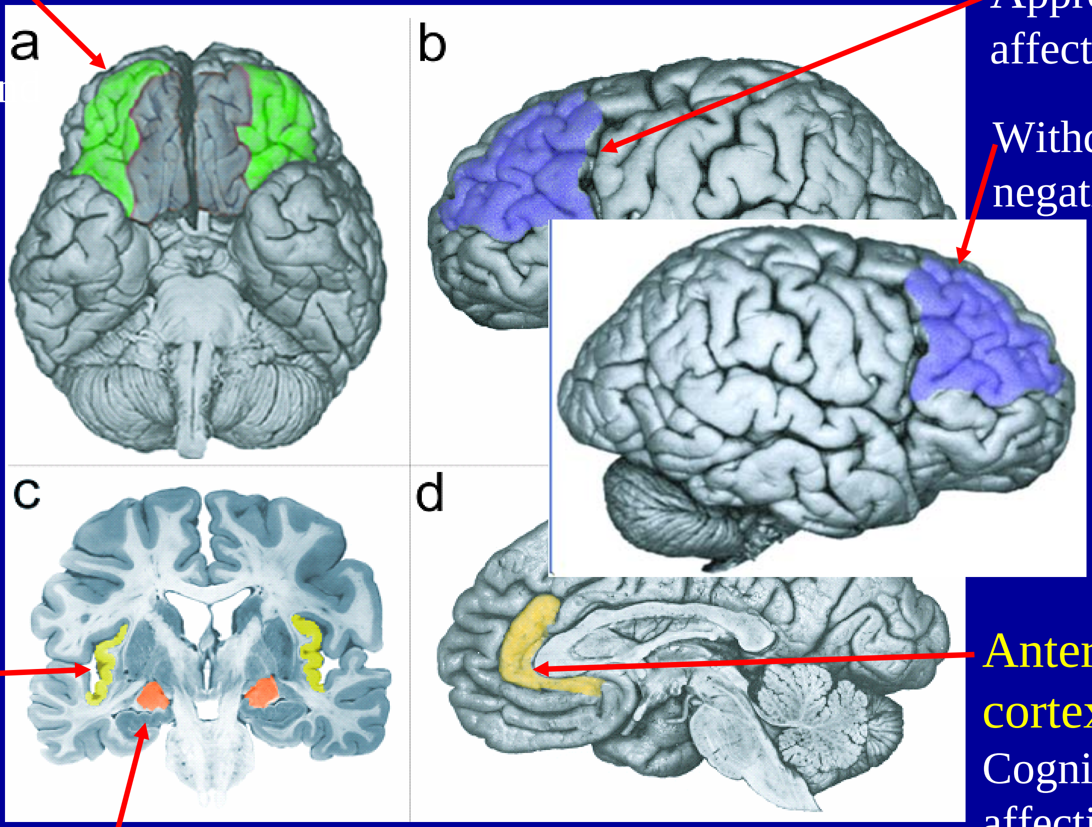
Purple blur represents highest variability from subject to subject in high-level regions such as the "personality centers," blue elipsoids represent lowest variability in low-level functions.

The circuitry of affect and affect regulation

Orbitofrontal cortex:
Affective evaluation (decoding punishment and reward value)

Dorsolateral PFC:
Approach-related positive affect

Withdrawal-related negative affect; threat-related vigilance



Insula:
Autonomic monitoring/control

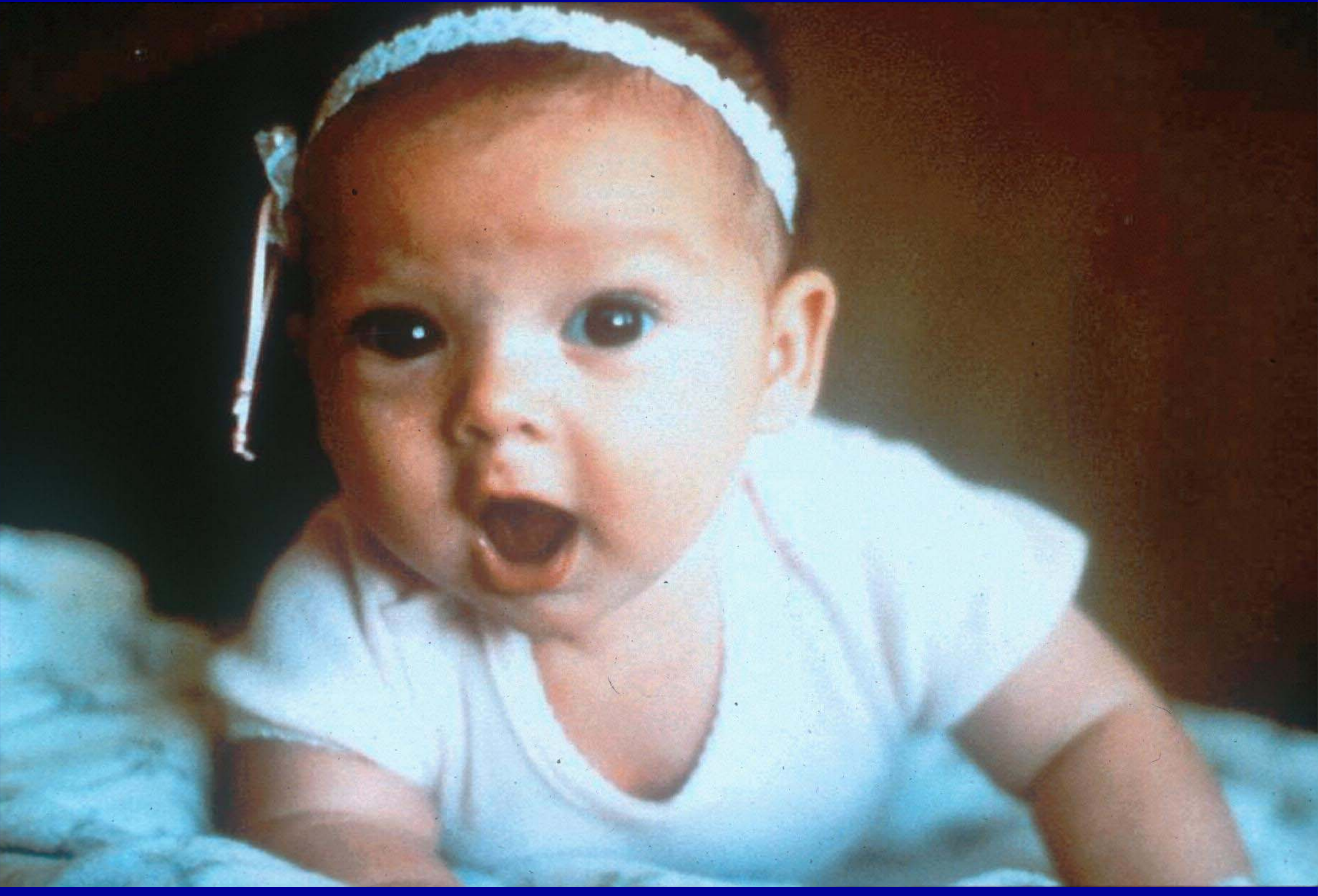
Anterior cingulate cortex:
Cognitive (dorsal) and affective (ventral) conflict monitoring

Amygdala:
Vigilance associative emotional for motivationally salient events; threat detection; learning

Davidson et al., *Science*, 2000

PFC and affective style

Transient changes in the brain during induced emotional states

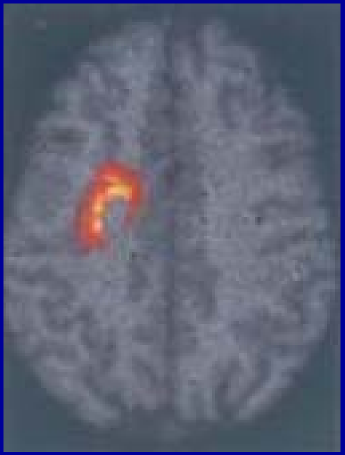


Activations in response to positive pictures

-16 mm

-12 mm

-8mm



36 mm

48 mm

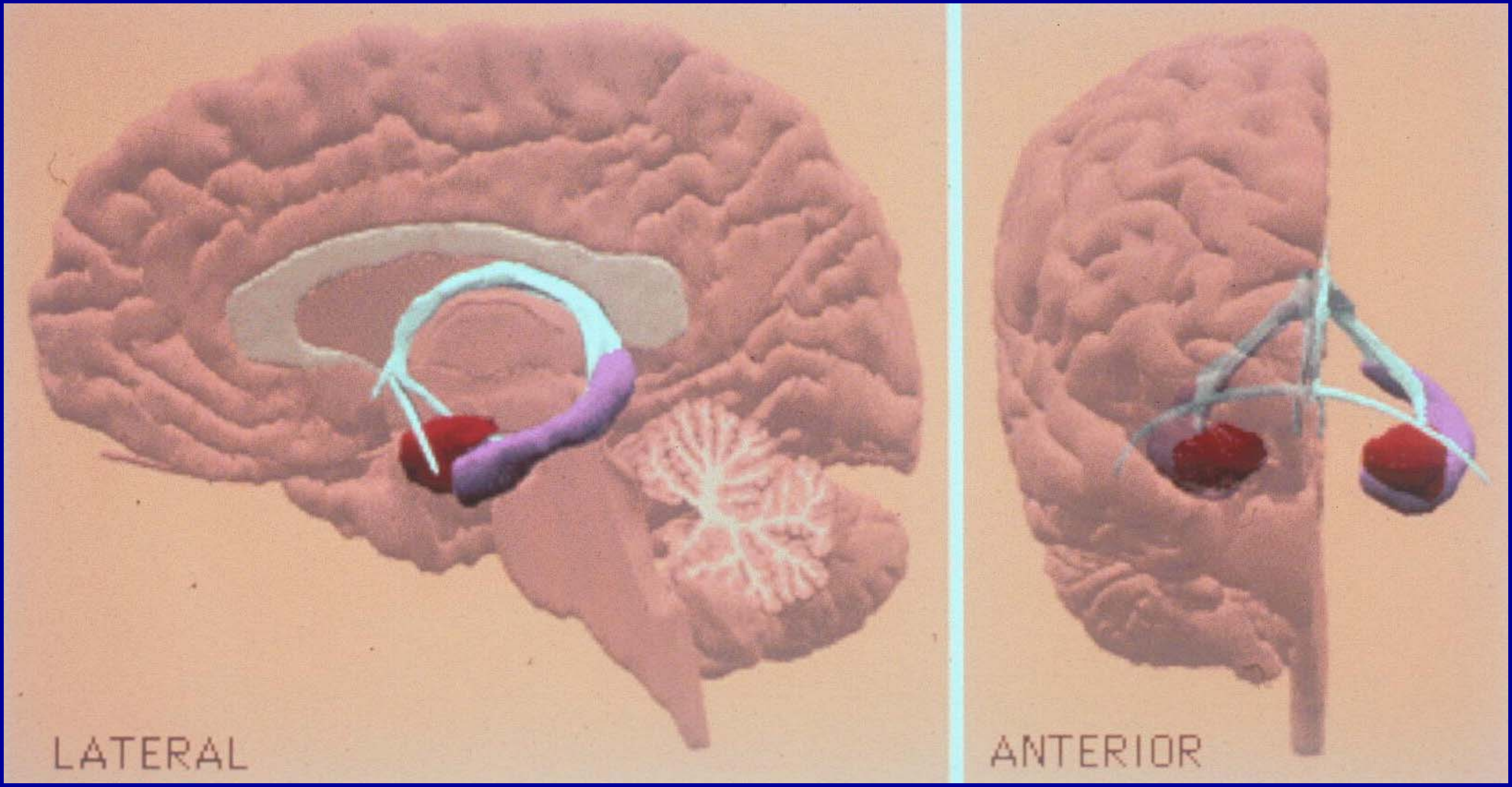
52 mm

Activations in response to negative pictures

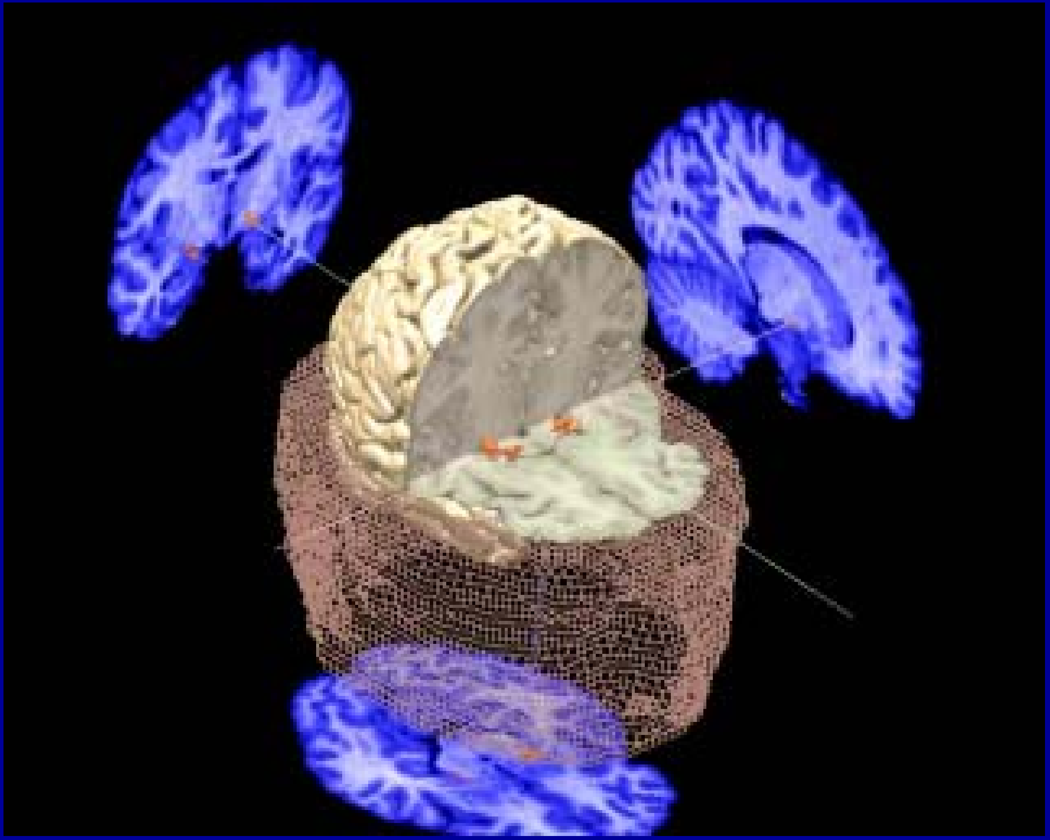
28 mm

32 mm

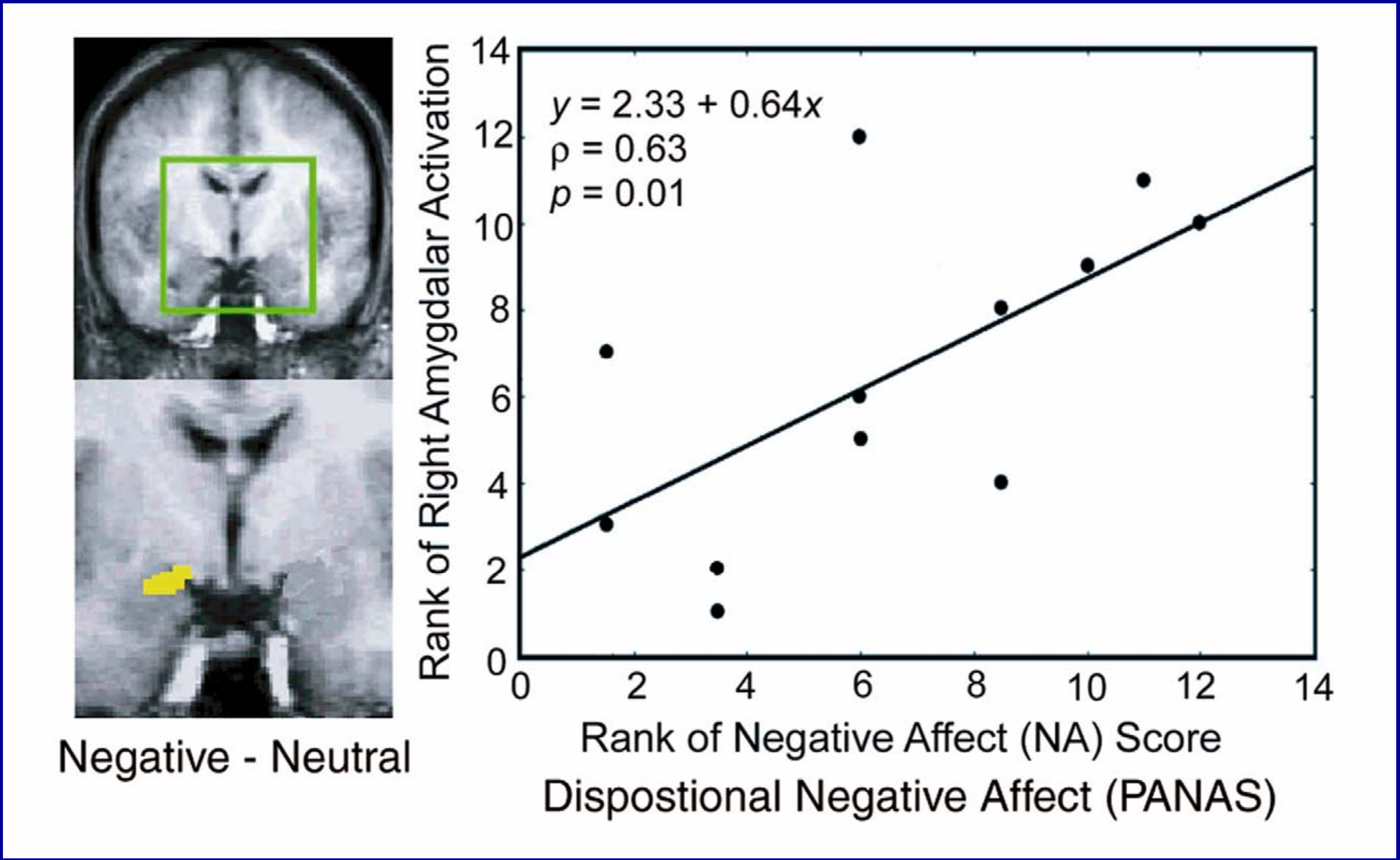
36 mm


LATERAL
ANTERIOR

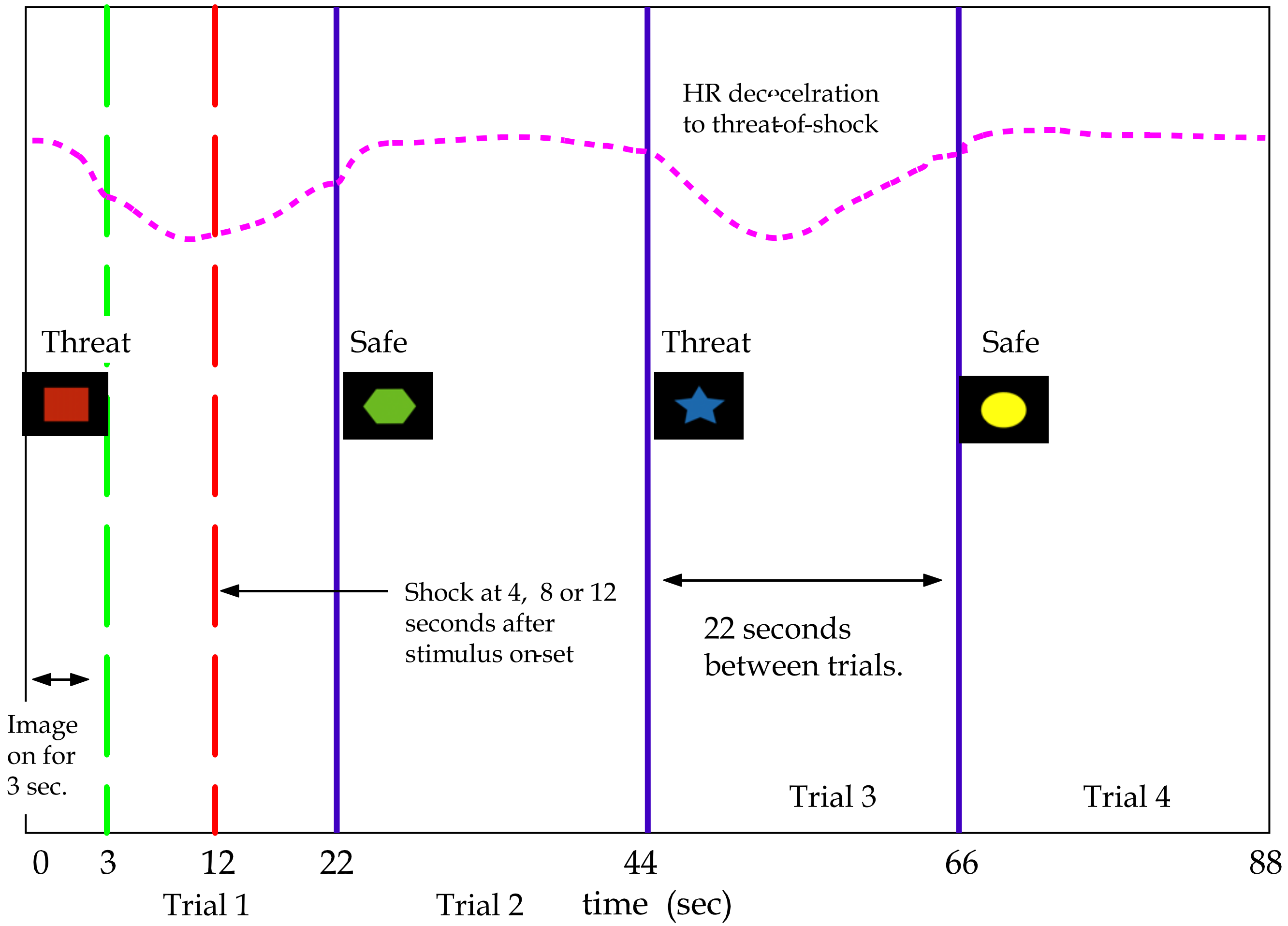
Amygdala activation in response to negative versus neutral pictures



Greater MR signal change to negative versus neutral pictures predicts dispositional NA

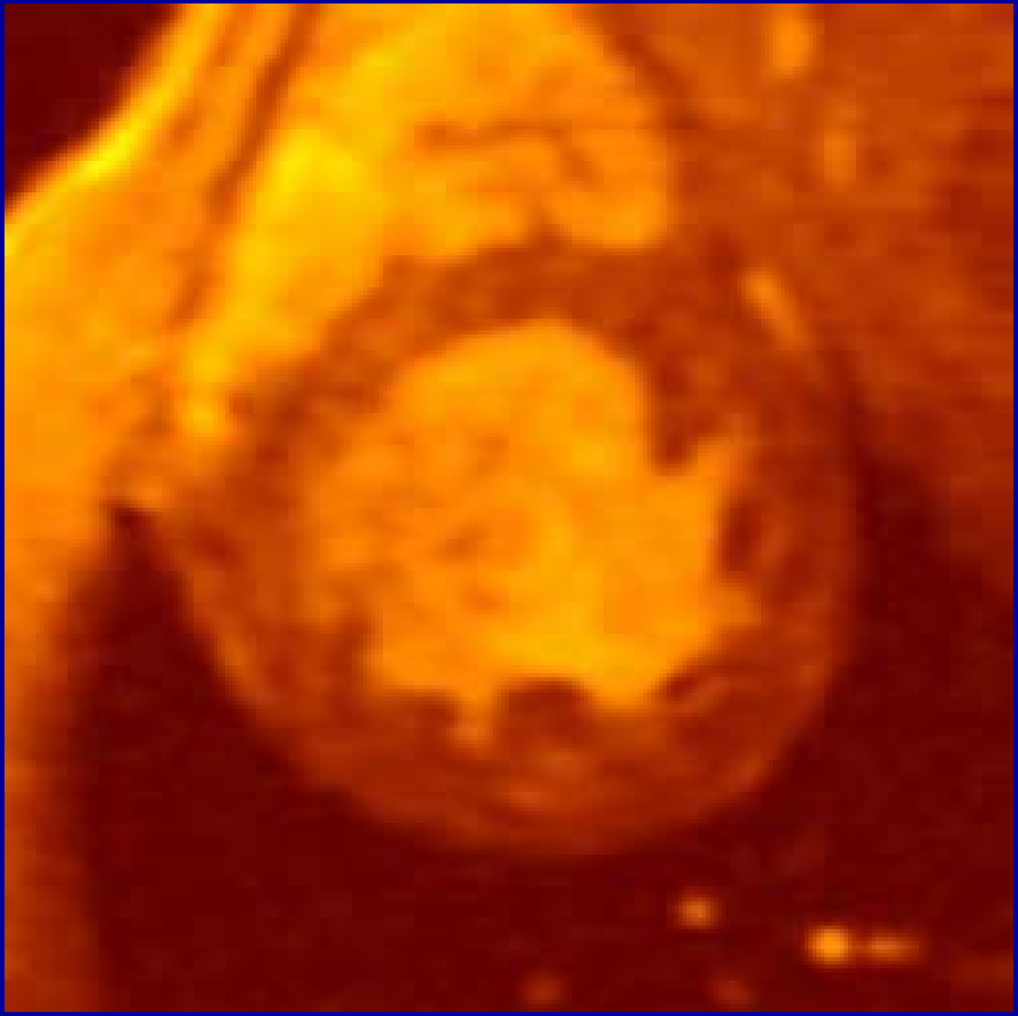


Threat-of-Shock Task for both the Brain & Cardiac MRI scans

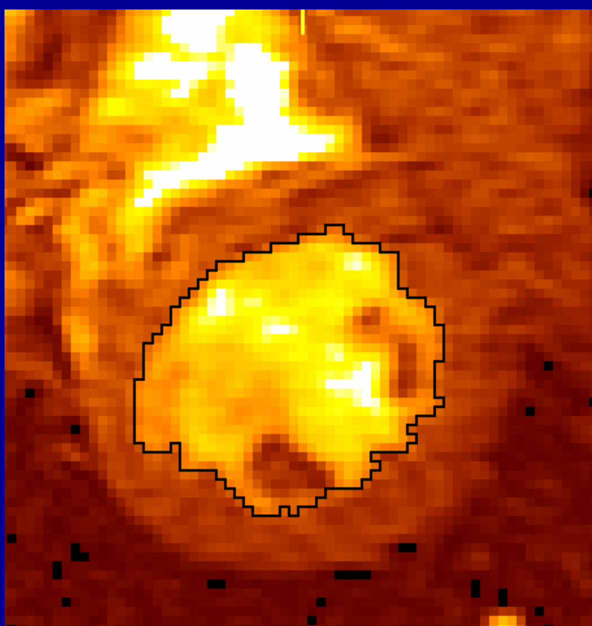


Dalton et al., J. Cog. Neuro, 2005

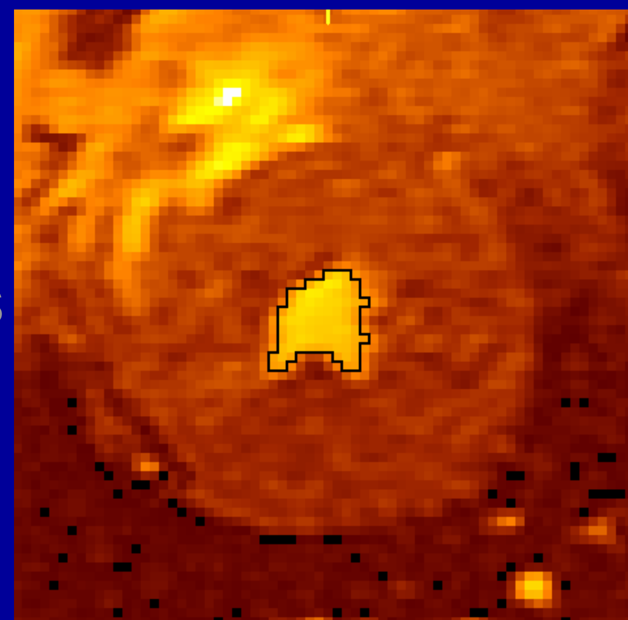
Functional MR of the heart



MRI measure of cardiac contractility



minus

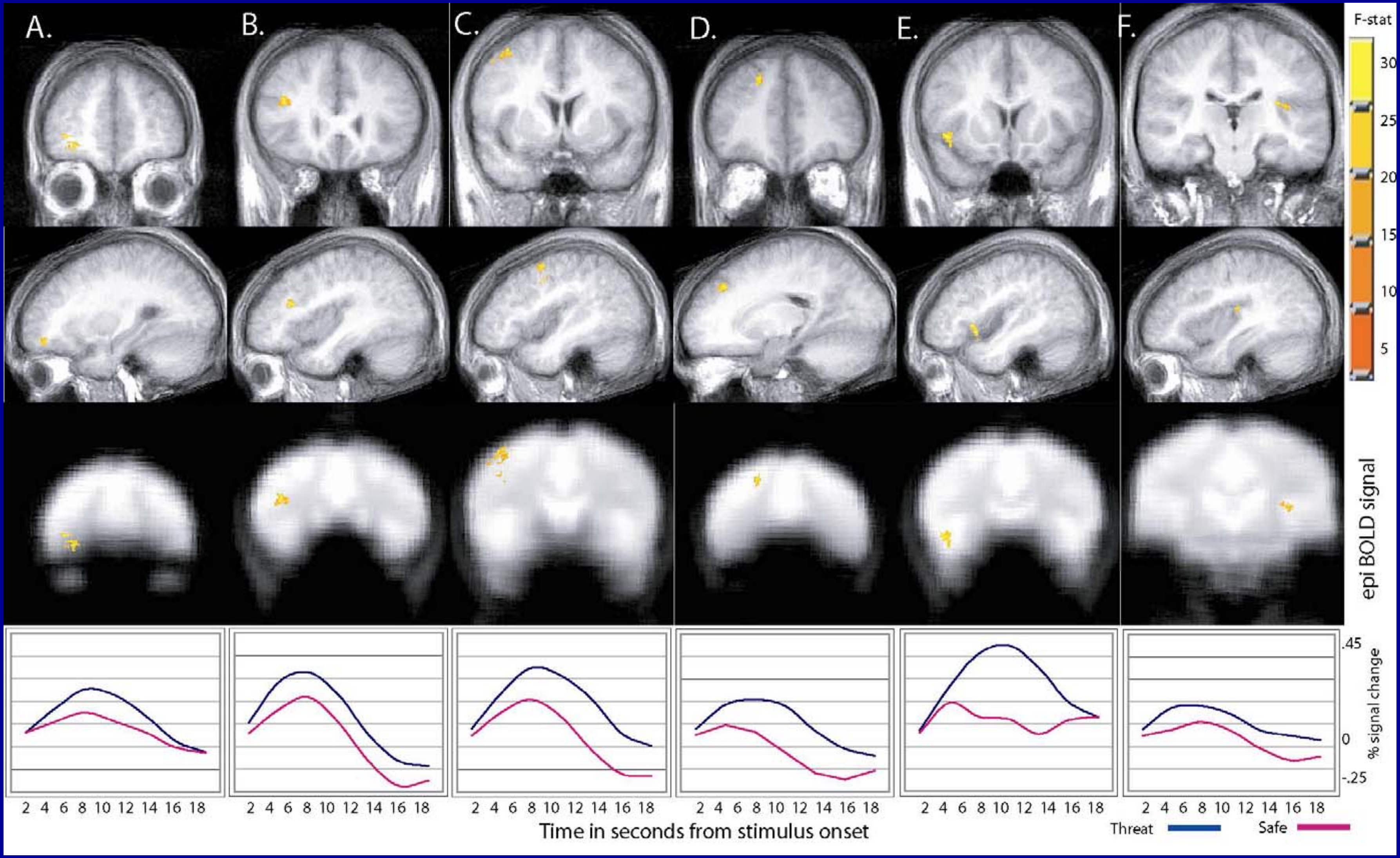


= contractility

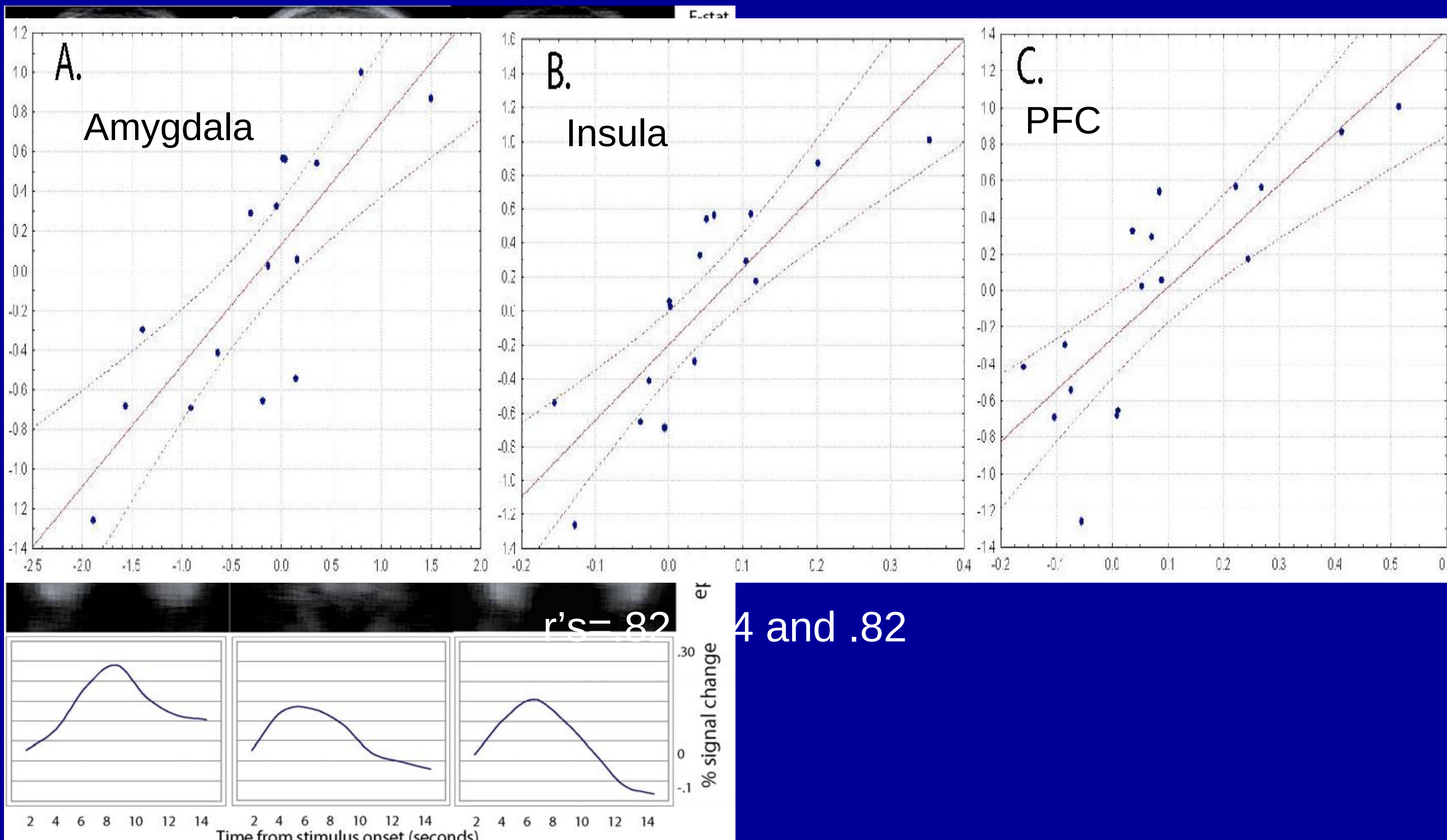
relaxed heart

contracted heart

Regions showing greater activation during threat versus safety



Relations between MR signal change and cardiac contractility



r's=.82 ...4 and .82

Facial emotion discrimination task

• 40 human faces: each face presented for 3 sec with 5, 6 or 7 sec in between faces (average = 6 sec).

• 24 emotional faces (8 each of happy, fear & anger) + 16 neutral faces.

•20 faces looking straight ahead + 20 quarter-turned (10 to right and 10 to left)

•Responses: press the first button if the face is neutral or “plain” (has no emotion) or press the second button if the face has any type of emotional expression (happy, fear or anger).

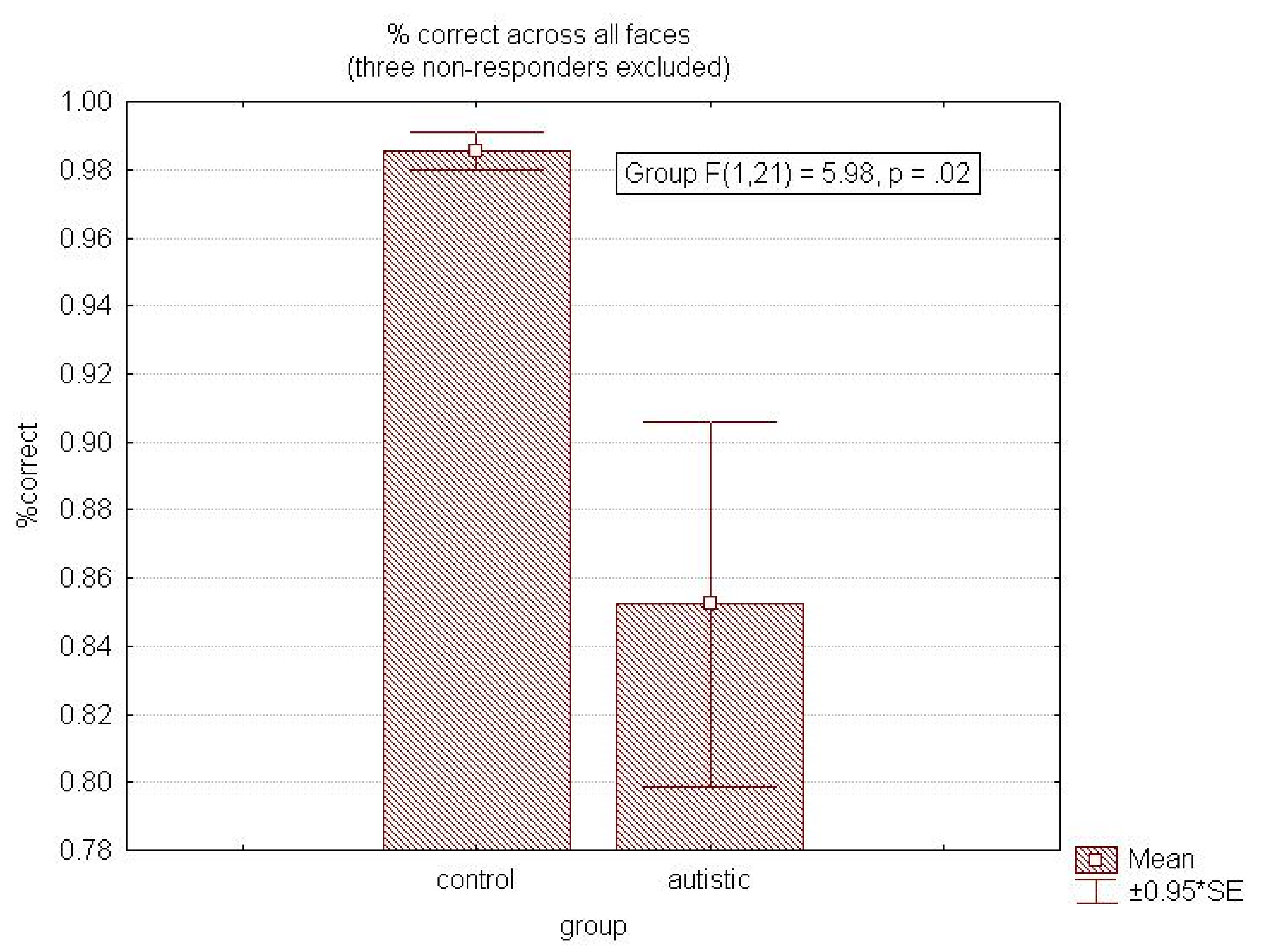
2 (Emotion) x 2 (Orientation) repeated measures task

Neutral Emotional

Straight Ahead

Quarter -turned

Accuracy



% correct across all faces
(three non-responders excluded)
Group F(1,21) = 5.98, p = .02
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0.78
%correct
control
autistic
group
Mean
±0.95*SE

Example Face Scanning Patterns

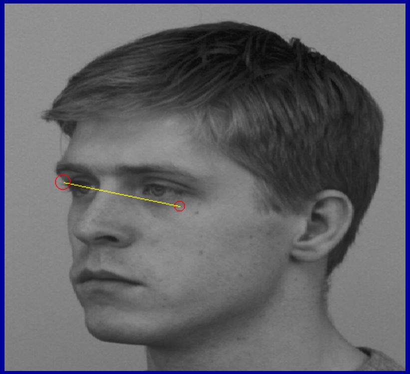
Control Individual

Individual with Autism

Face scanning patterns using iView eye-tracking

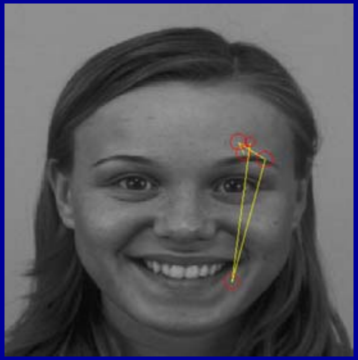
Control Examples

Fixating on both eyes
& sides of face



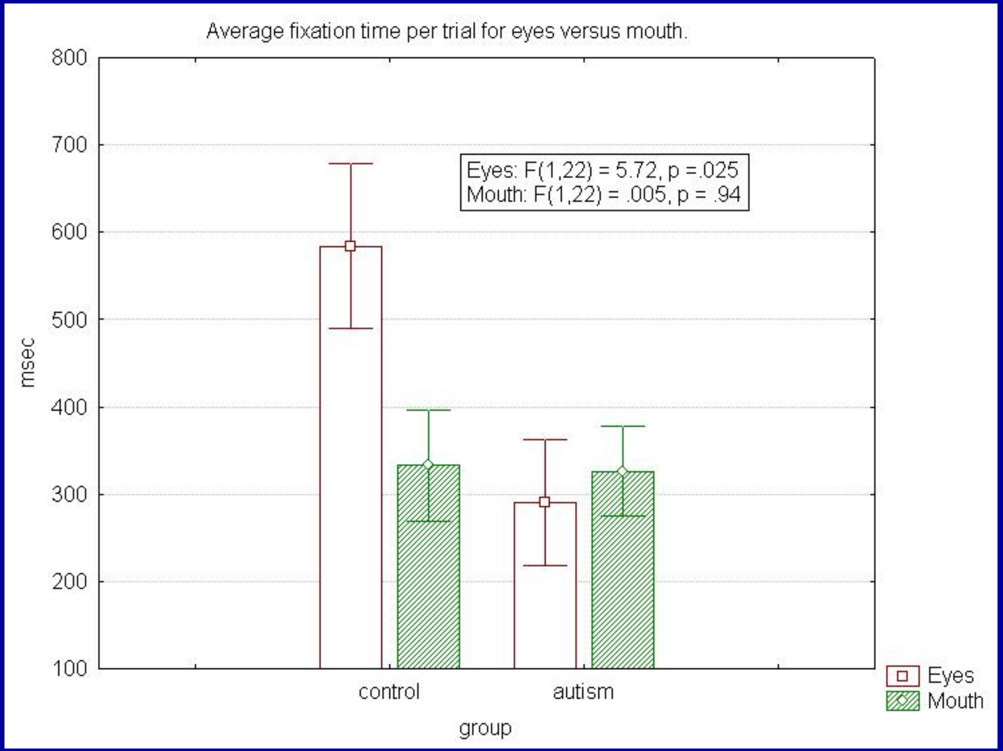
Fixating on both eyes

Autism Examples



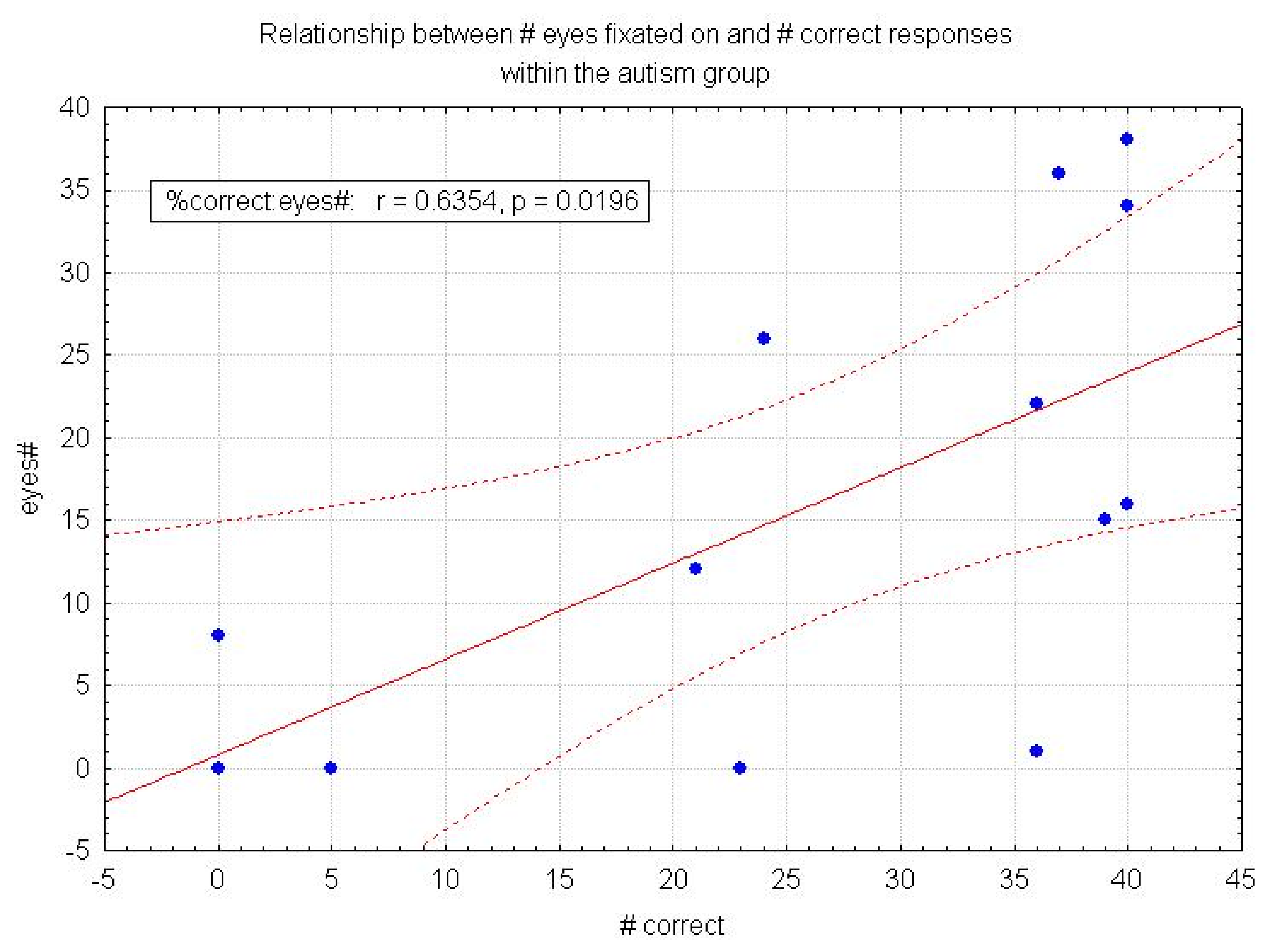
Fixating on one side of
face and mouth

Fixating on side of
face and off face

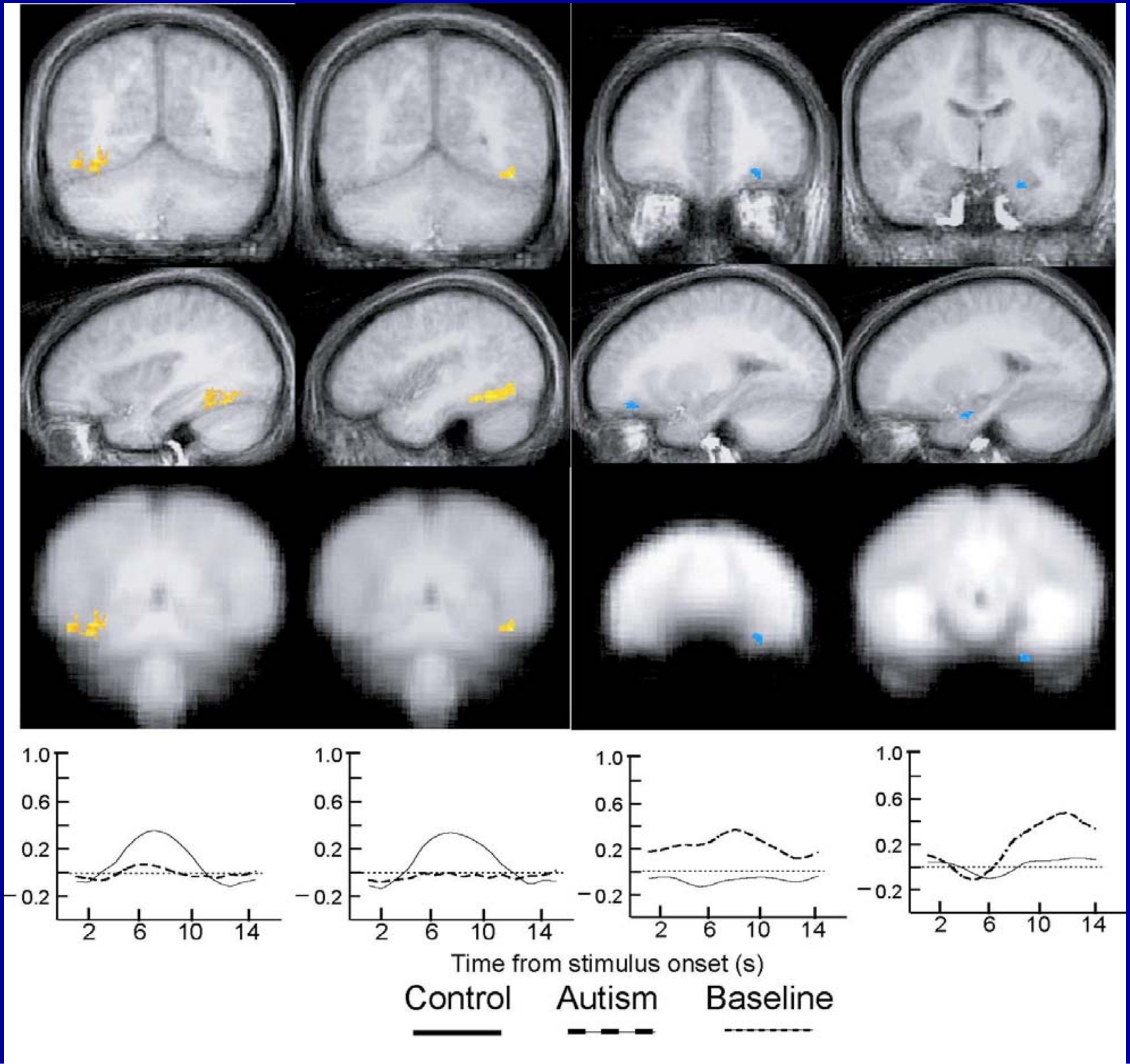


Dalton et al., (2005), *Nature Neuroscience*

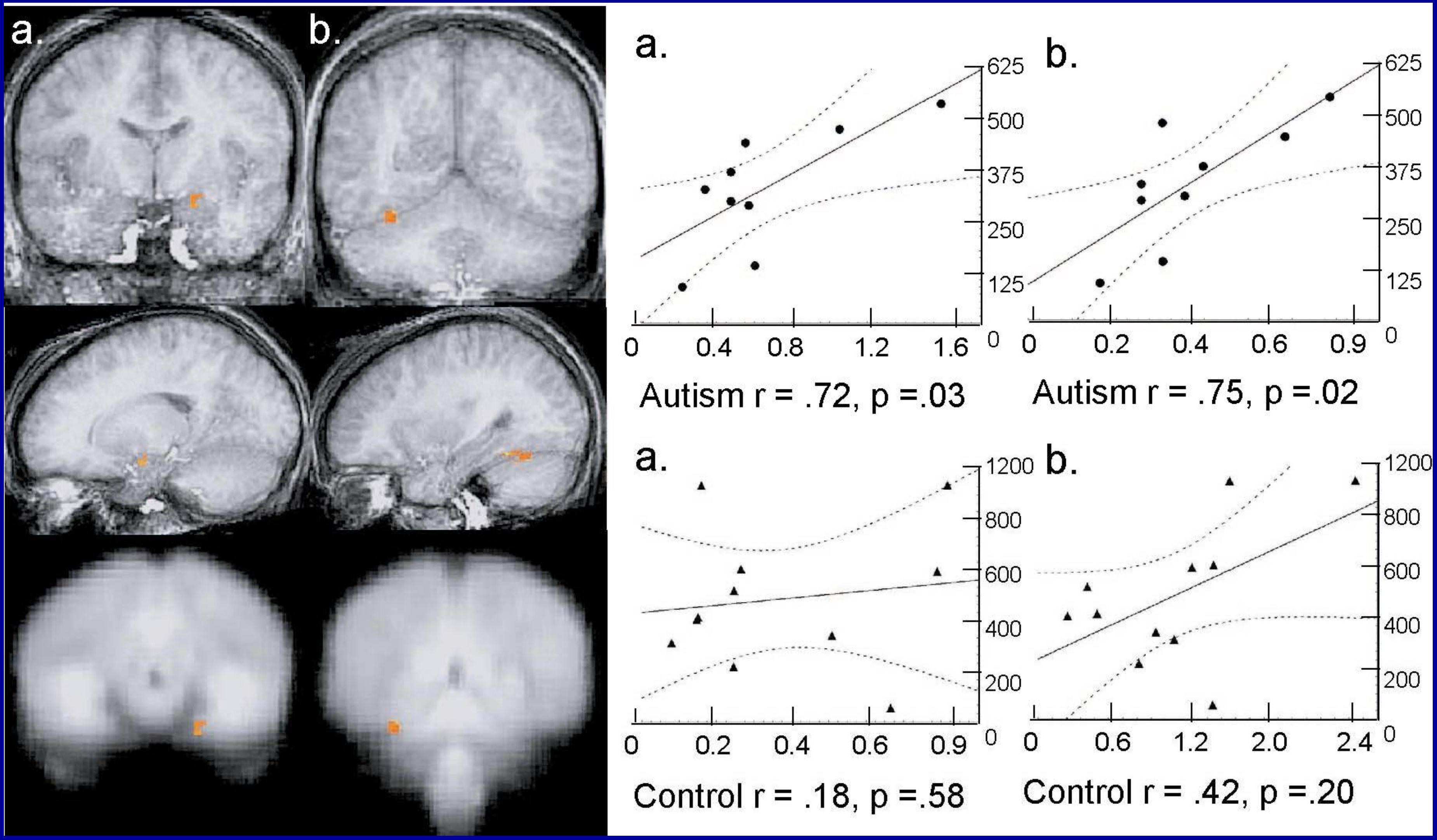
Number of eyes fixated predicts task performance in the autism group



Subjects with autism fail to activate fusiform but show increased activation in OFC and amygdala



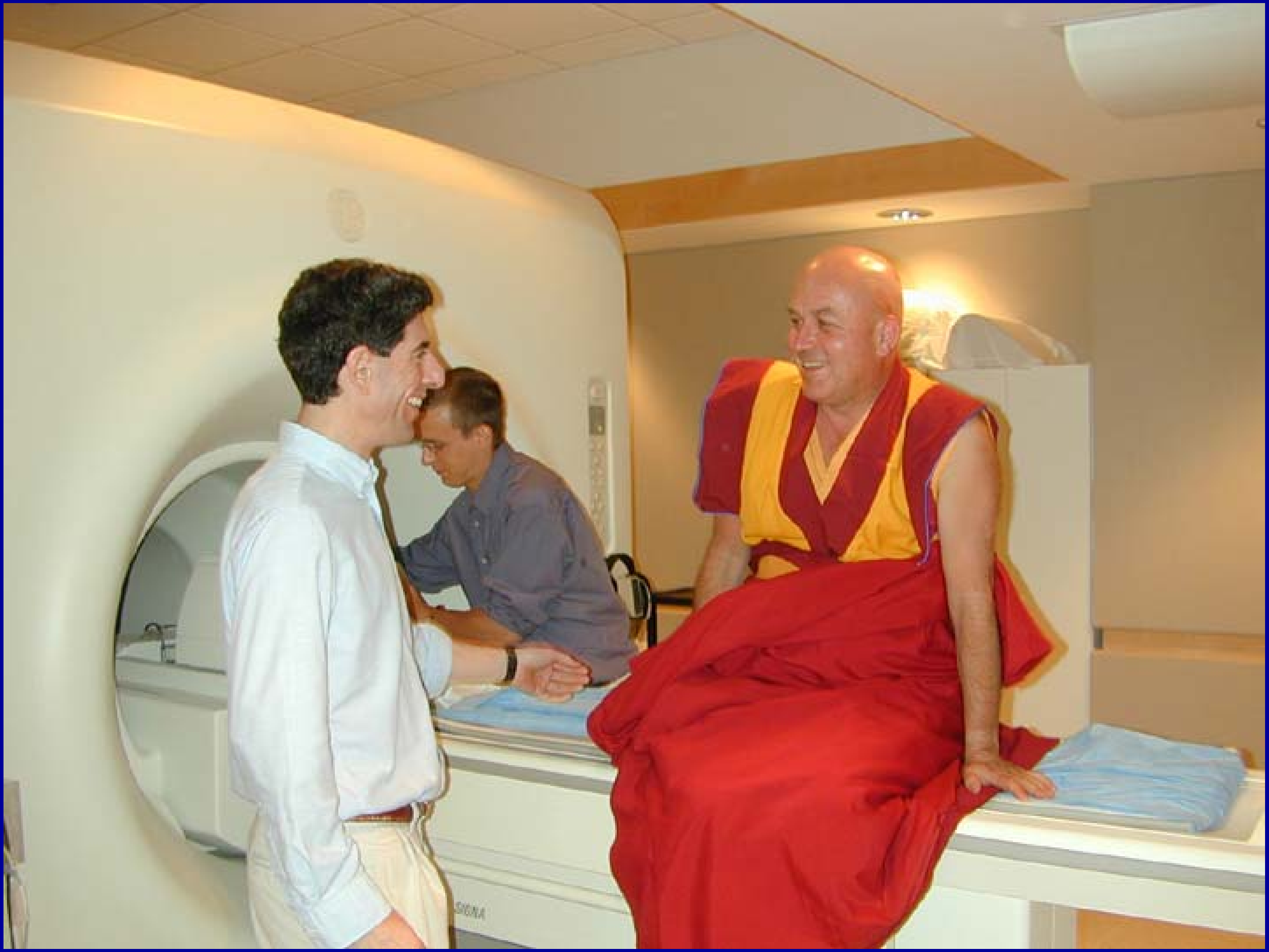
Study I: Brain activation clusters associated with average eye-fixation time for the autism versus control group

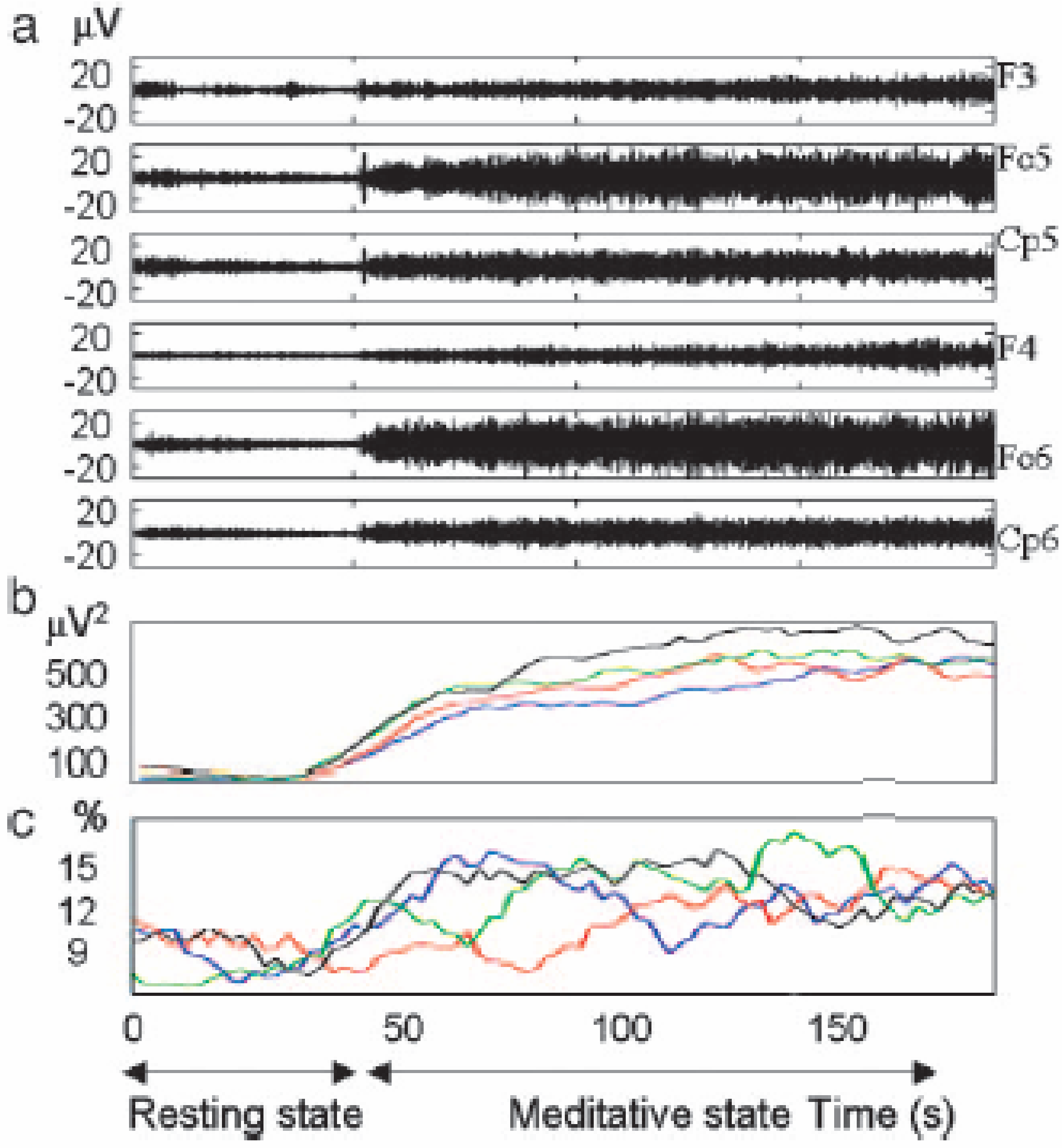


Dalton et al., (2005), *Nature Neuroscience*

"It is painful for me to look at people's faces… I don't even like to look at myself in the mirror." M.W.

What is the impact of training the mind on brain signals that are associated with emotion?




a
μV
20
-20
F3
Fc5
Cp5
F4
Fc6
Cp6
b
μV²
500
300
100
c
%
15
12
9
0
50
100
150
Resting state
Meditative state
Time (s)

Neural signature of objectless compassion

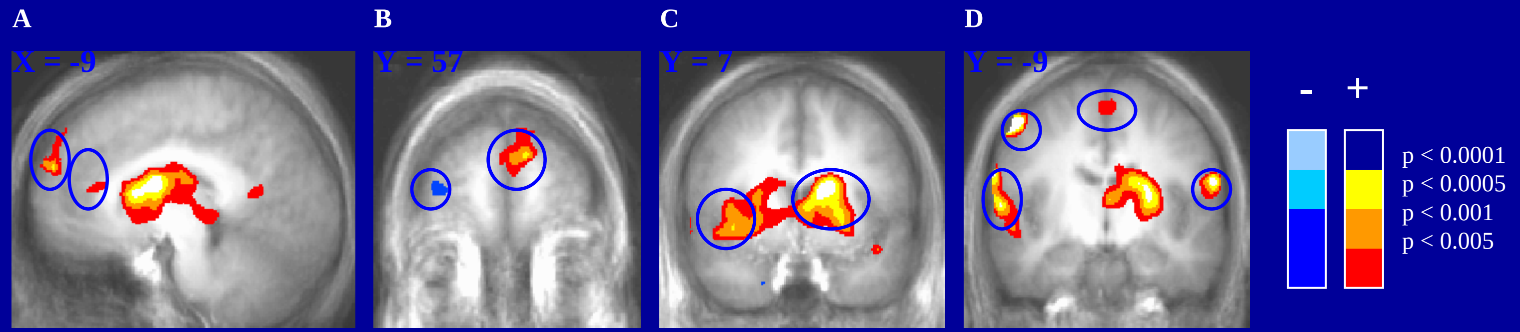


Figure 1. Shared network exhibiting differences in activity during loving-kindness-compassion meditation compared to resting state for both long-term practitioners and novices. Statistical map (ttests, corrected, $p<0.005$) are overlayed on the mean structural scan. Brodmann's Areas and Talaraich (ref) coordinates (x,y,z) in mm refer to peak variation in each area and are as follow: (**A-B**) Activation in left superior frontal gyrus, BA9 (-9, 57, 25) and anterior cingulate cortex BA32/24 (-9, 33, 15), deactivation in right middle frontal gyrus BA10 (32, 58, 11) (**C**) Activations in caudate (-13, 7, 16), thalamus (-12, -20, 17), putamen (-21, 7, 3) and anterior insula (36, 7, -2). (**D**) Activations in the pre- and postcentral gyrus BA3/4 (50, -10, 48), (-61, -10, 20) and medial frontal gyrus BA6 (-2, -10, 57). The changes in these regions of interest are significant ($p< 0.05$) within each group. A complete list of activated and deactivated area is in table S1. Images are reversed left to right to follow radiologic convention.

“The systematic training of the mind—the cultivation of happiness, the genuine inner transformation by deliberately selecting and focusing on positive mental states and challenging negative mental states—is possible because of the very structure and function of the brain...But the wiring in our brains is not static, not irrevocably fixed. Our brains are also adaptable” (His Holiness the Dalai Lama, *The Art of Happiness,* pp. 44-45).