What, Where and How: fMRI Evidence for Three Processing Streams in Human Visual Cortex

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10 Feb 04

Ruppe, M.D. & Beauchamp, M.S.

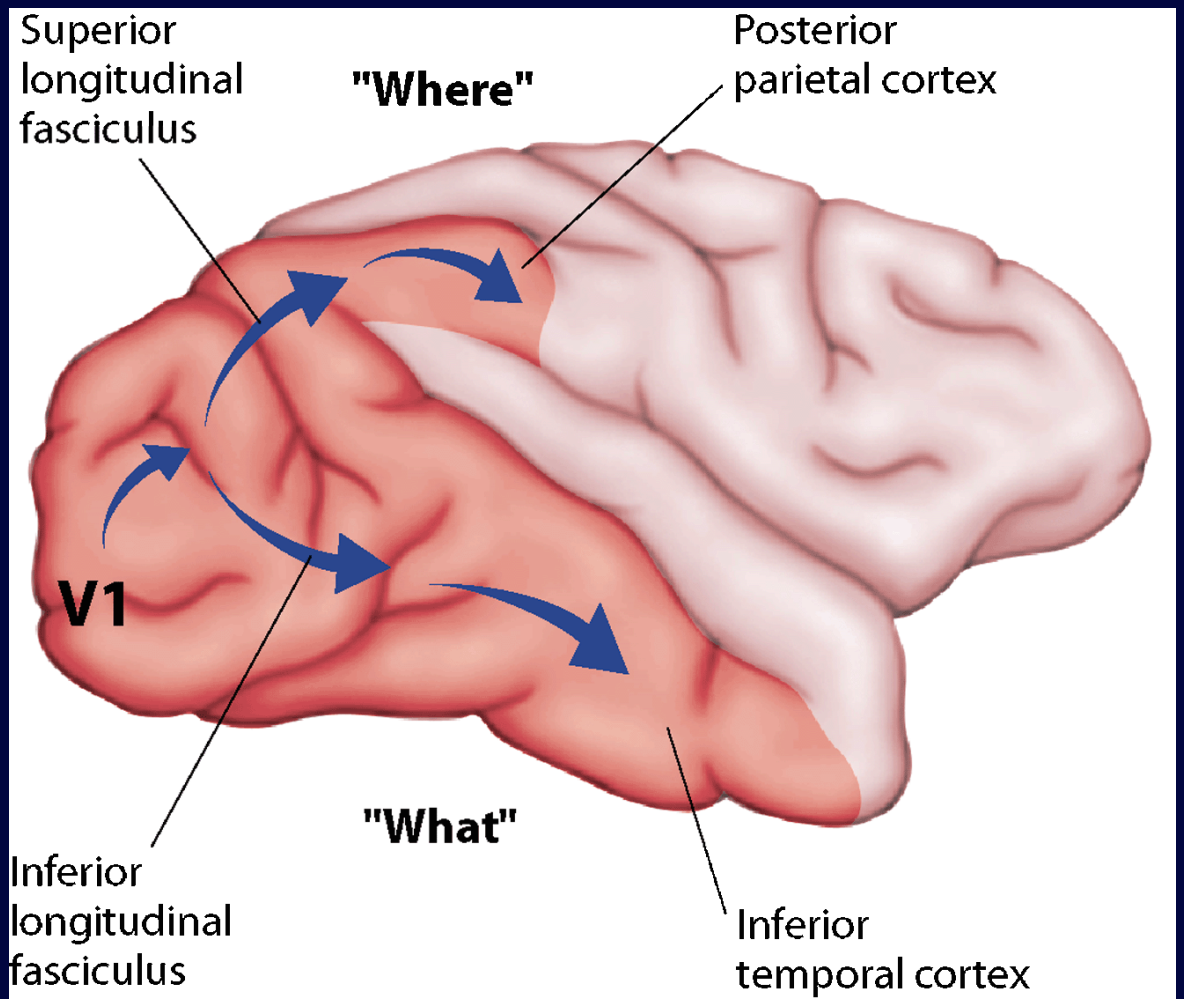
Rhys Aaron Beauchamp. Johns Hopkins Department of Maternal and Fetal Medicine. Aug 6, 2003: 8 lbs, 14 oz.

PEAK

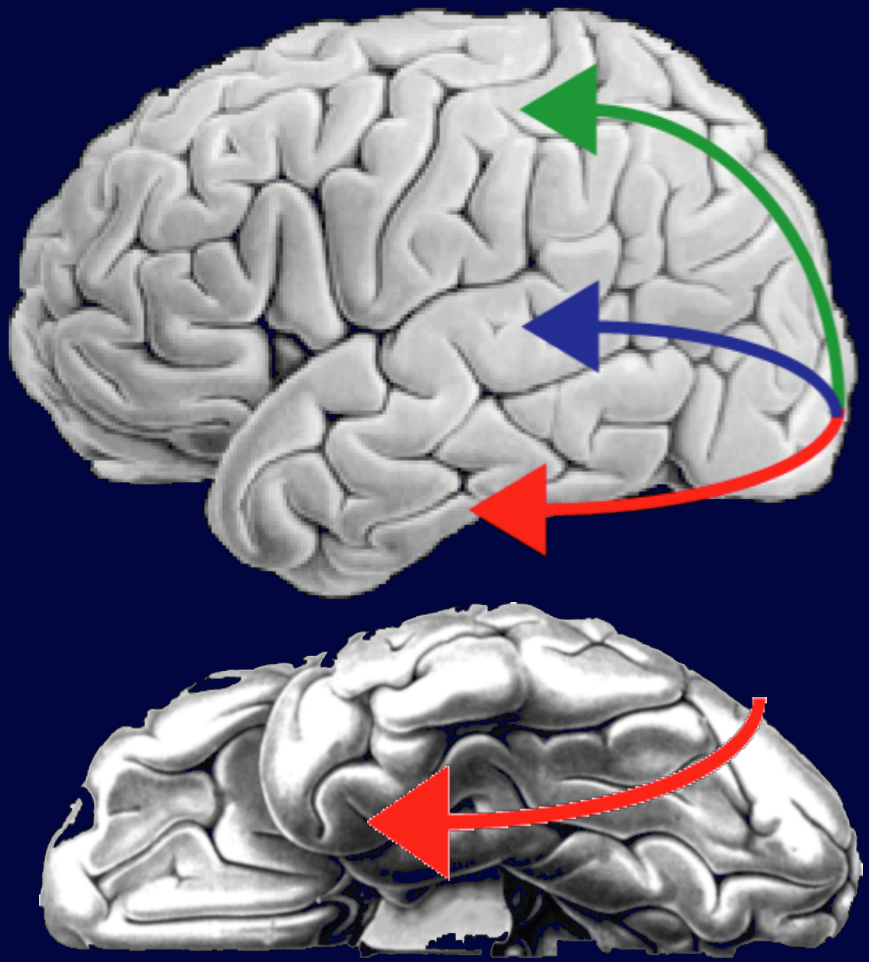
18 Two Cortical Visual Systems

Leslie G. Ungerleider
Mortimer Mishkin

In D.J. Ingle, M.A. Goodale and R.J.W. Mansfield (Eds.)
Analysis of Visual Behavior, The MIT Press, Cambridge, MA.
© The Massachusetts Institute of Technology 1982



Three Processing Streams



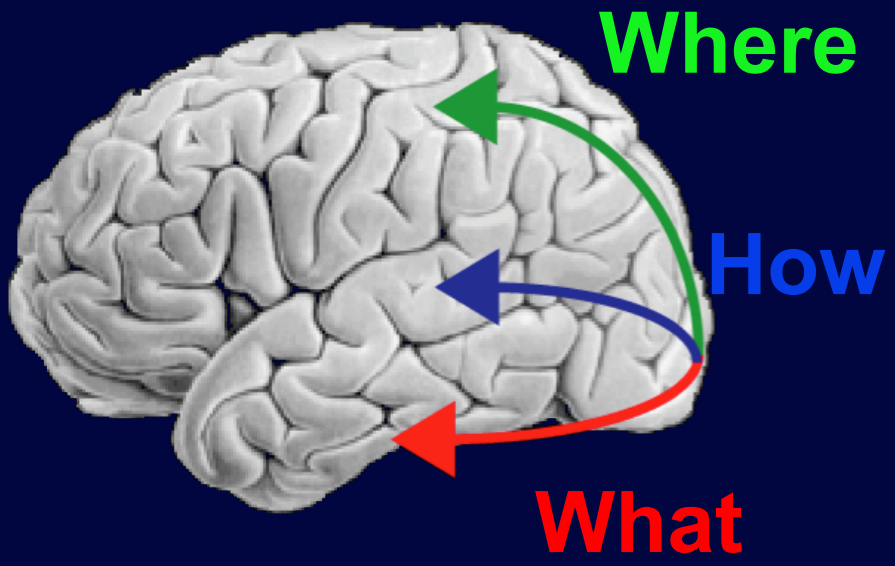
Where (action)

(Goodale & Milner)

How

What (perception)

Three Processing Streams

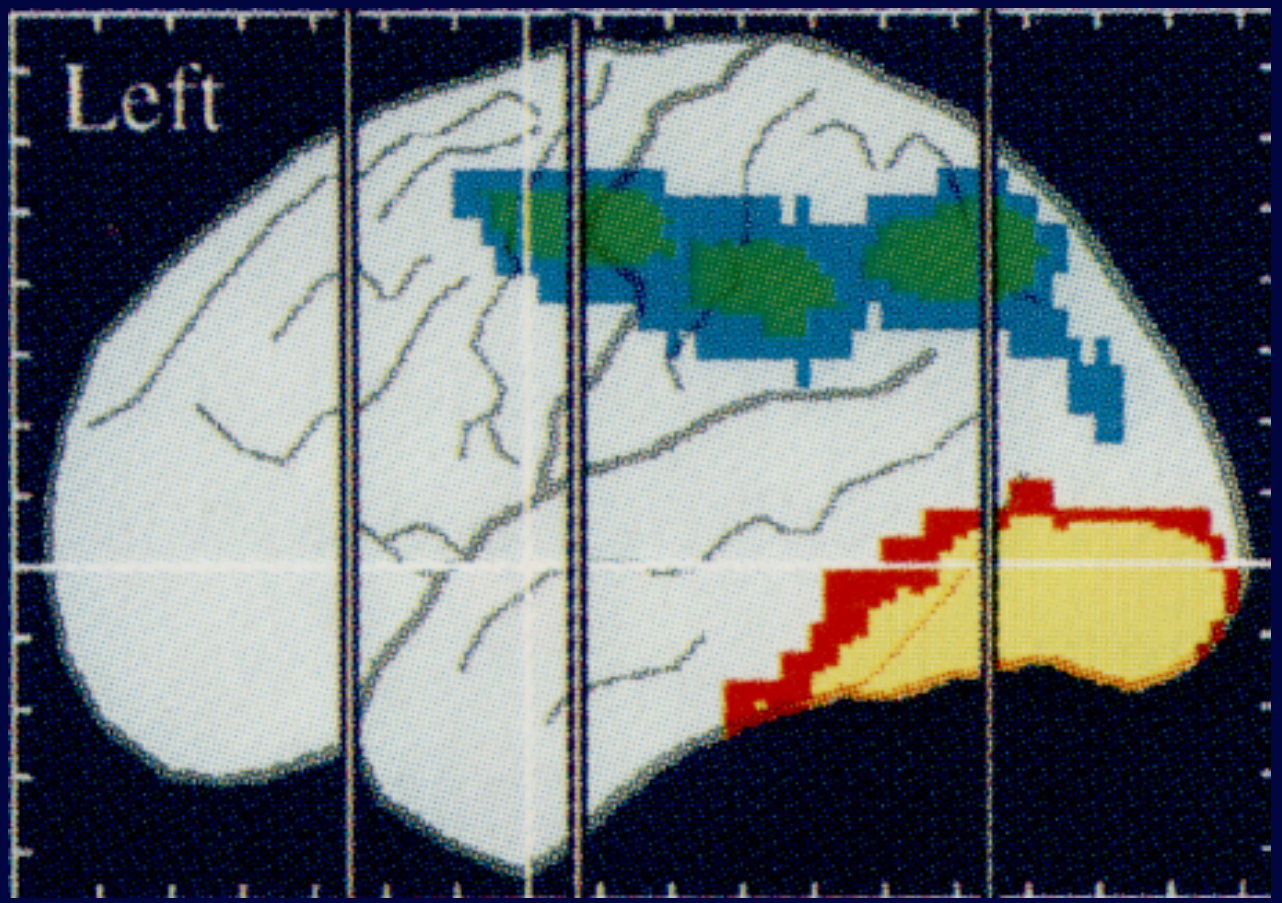


Beauchamp MS *et al. Neuroimage* 14:310-321.
Beauchamp, MS *Magnetic Resonance in Medicine* 49:376-380.
Petit L & Beauchamp, MS *Journal of Neurophysiology*, 89: 2516-2527.

Beauchamp MS *et al. Neuron* 34(1):149-159.
Beauchamp MS *et al. Journal of Cognitive Neuroscience.* 15(7) 991-1001.
Beauchamp MS *et al. Neuron (in press).*

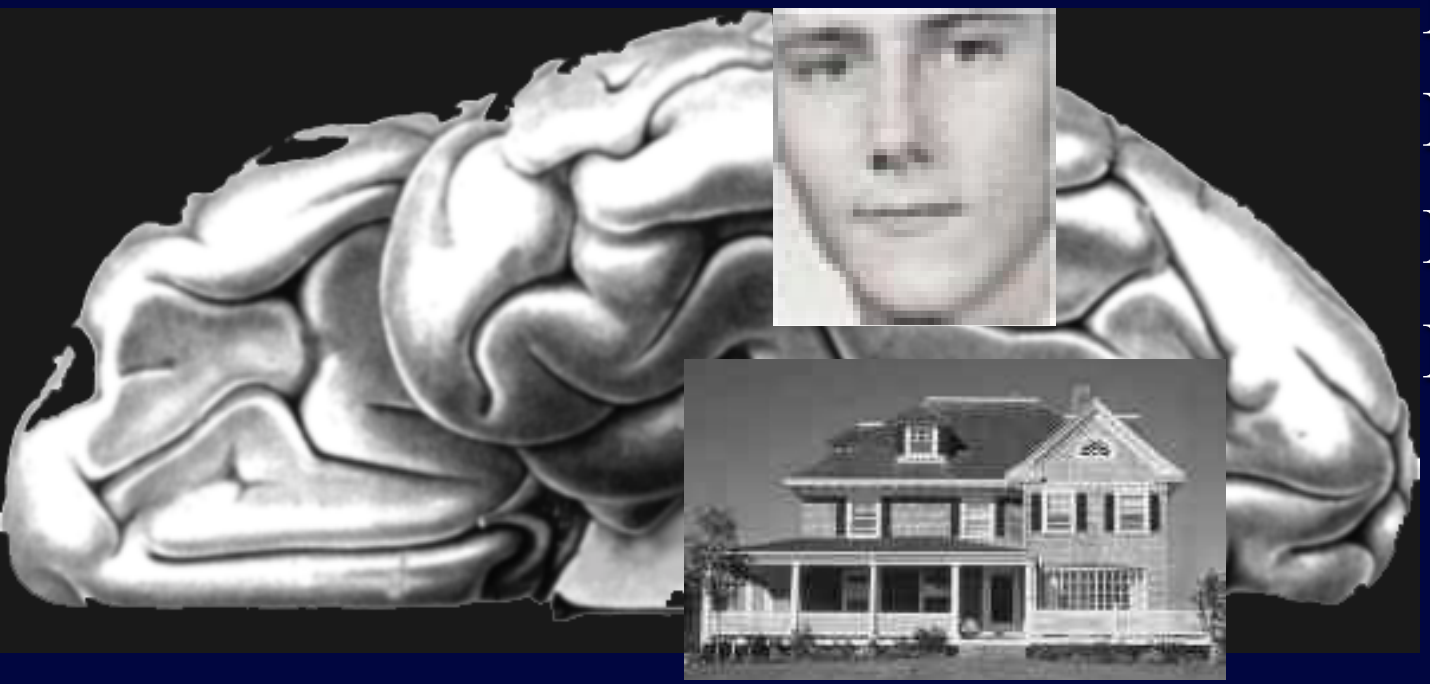
Beauchamp MS *et al. Cerebral Cortex* 9(3) 257-264.
Beauchamp MS *et al. Neuropsychologia* 38(8): 1170-9.

Two Visual Streams: What and Where



Haxby et al., 1997

Category-related activity in the what stream



Kanwisher

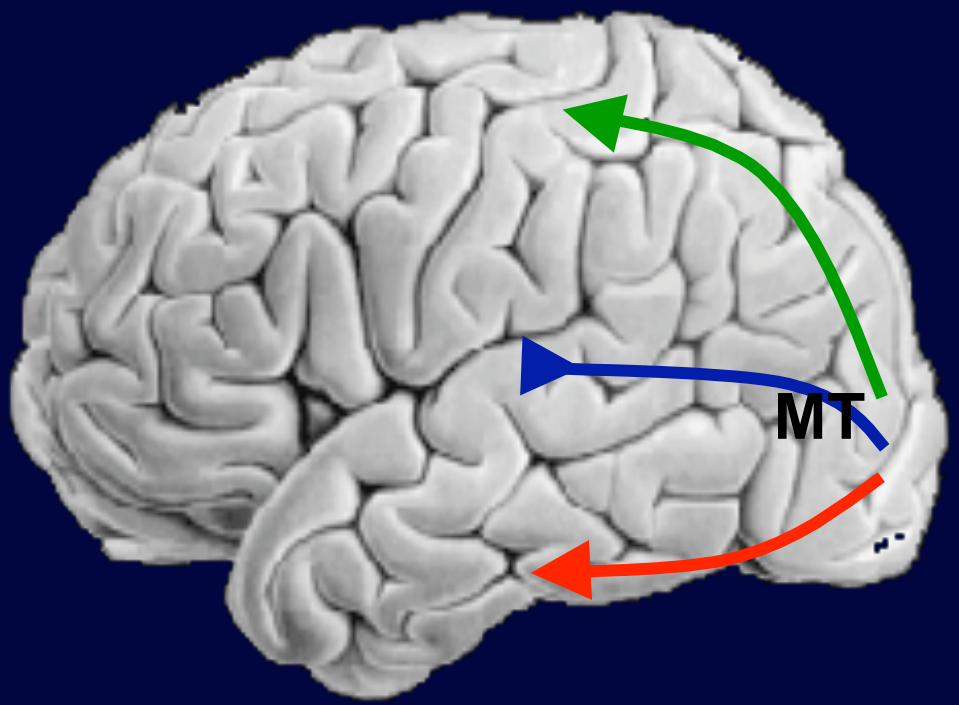
Malach

D' Esposito

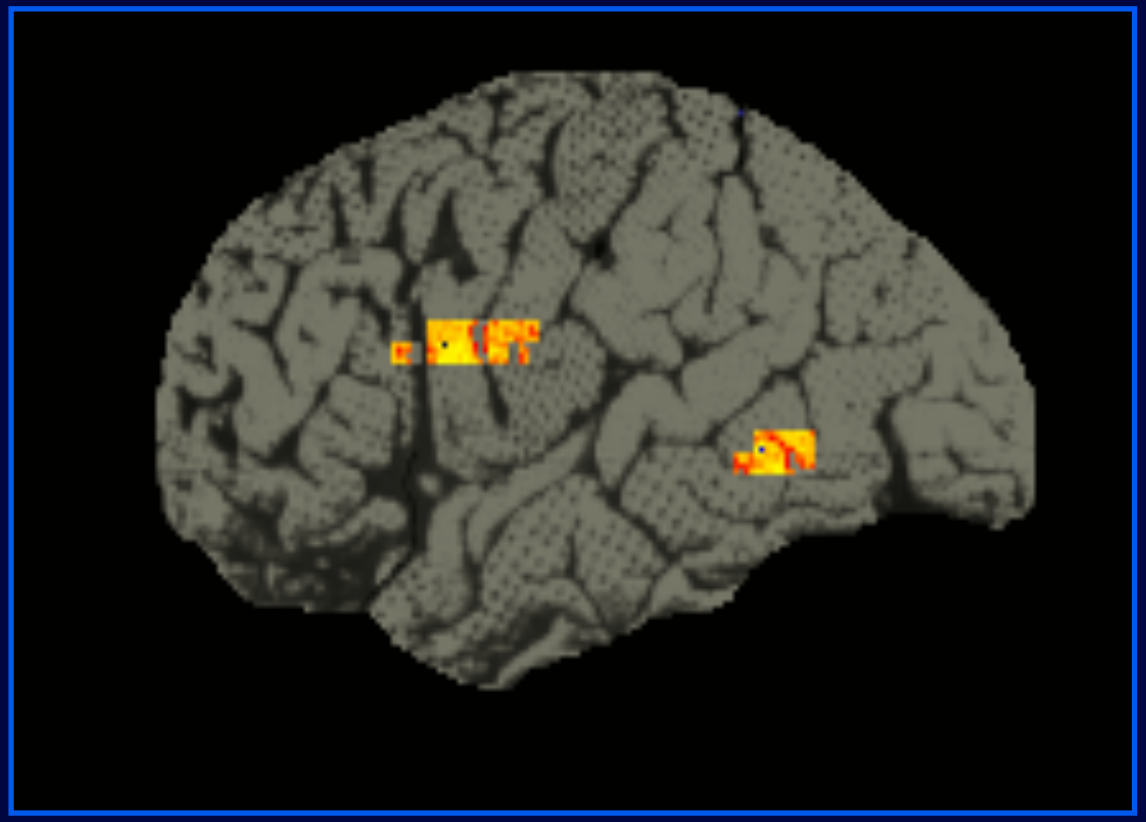
Haxby

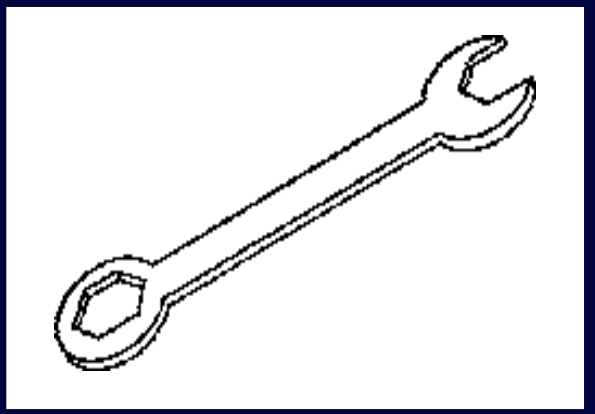
The “How” Stream: How it moves

Beauchamp *et al.*, Parallel Visual Motion Processing Streams for Manipulable Objects and Human Movements. *Neuron* Vol. 34, 149-159, Mar 28, 2002.



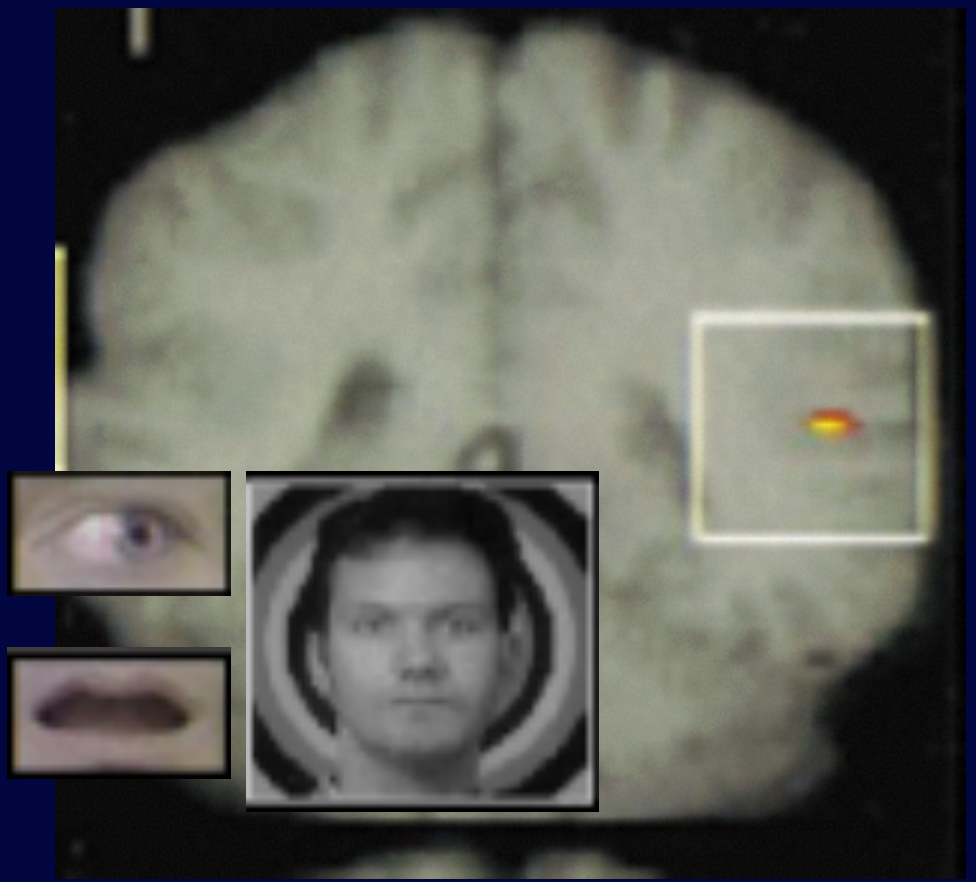
Background: Responses to Tool Pictures in MTG/ITS





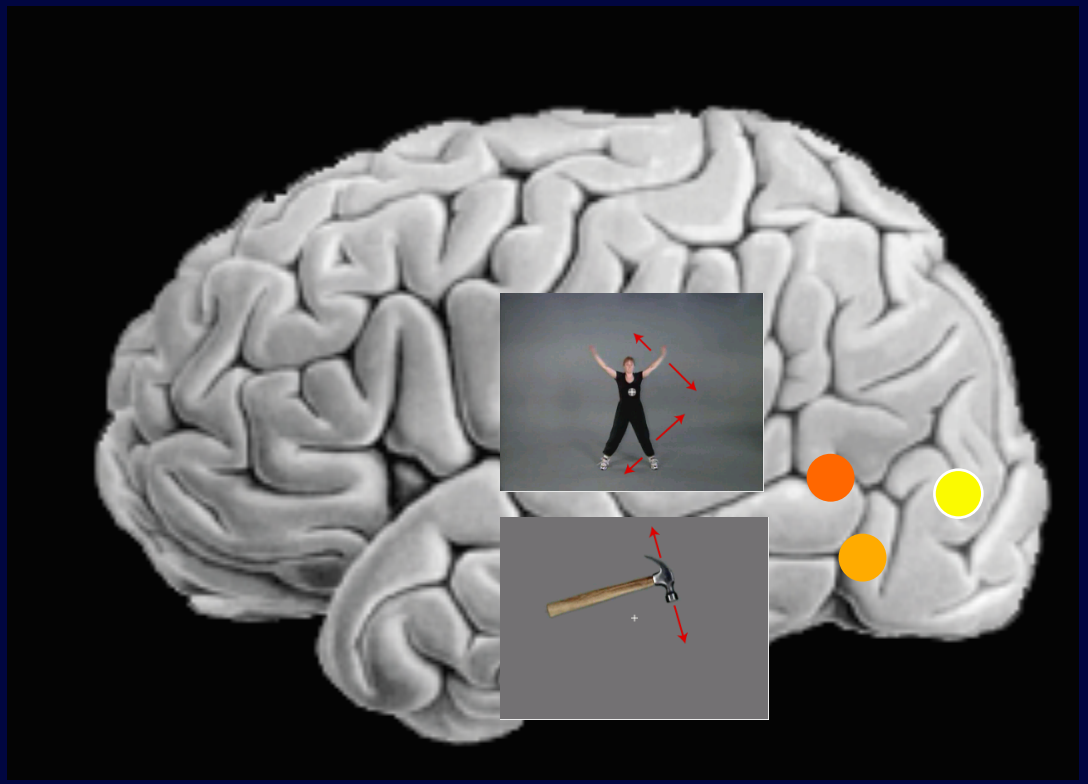
Martin *et al.*, *Nature*, 1996

Background: STG/STS

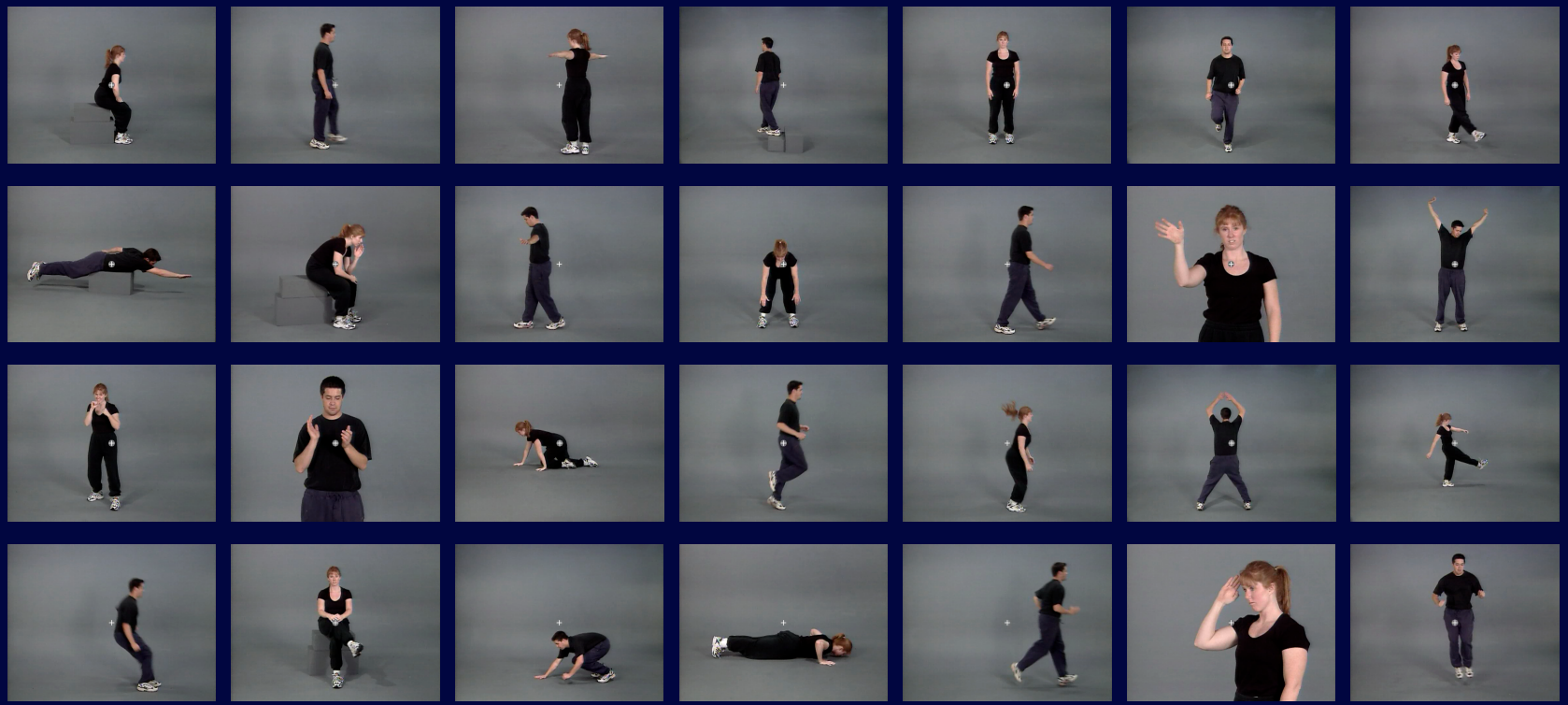


Puce et al., *J Neurosci.,* 1998

Experimental Hypothesis

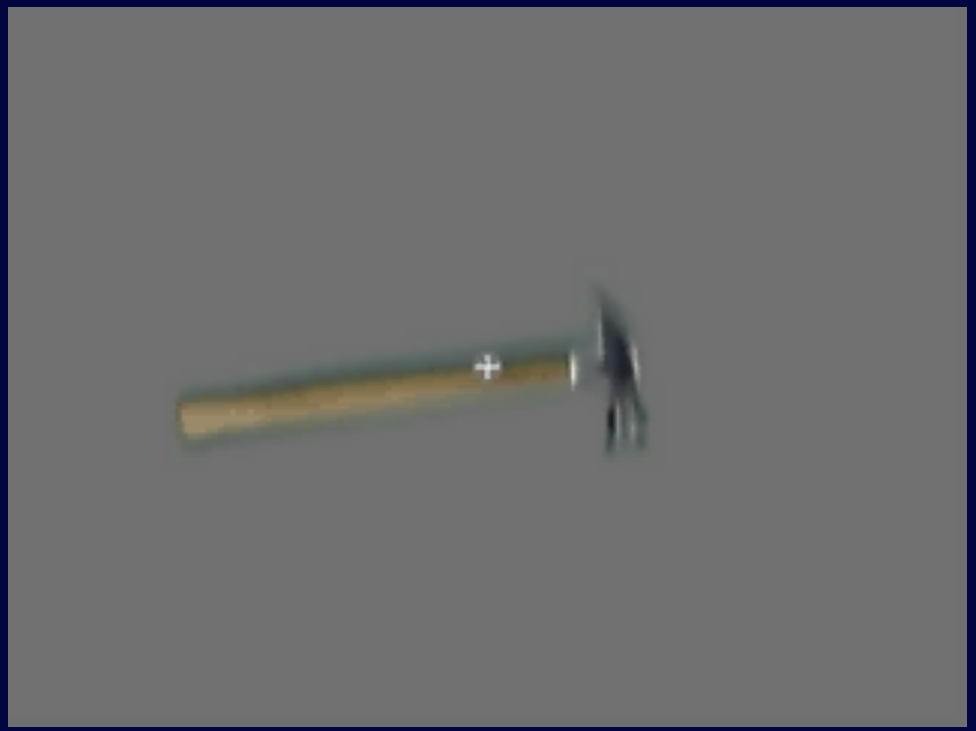


28 Complex Human Motions

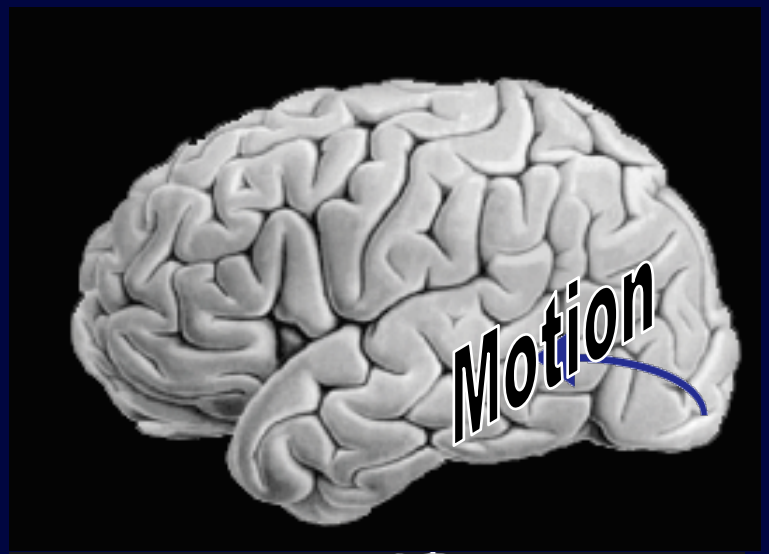


28 Complex Tool Motions

Sample Clips



Experimental Hypothesis



Methods Interlude

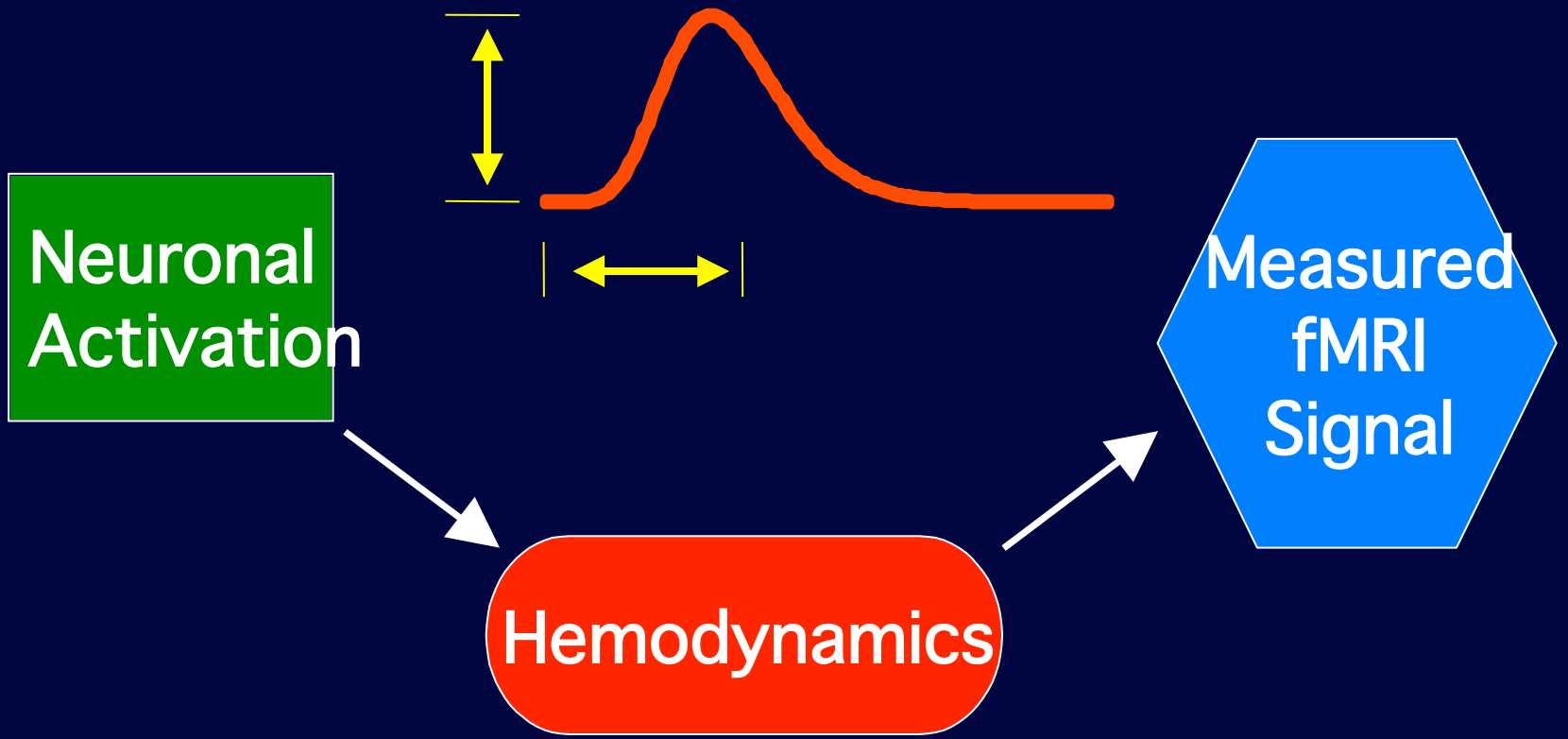
BOLD Basics

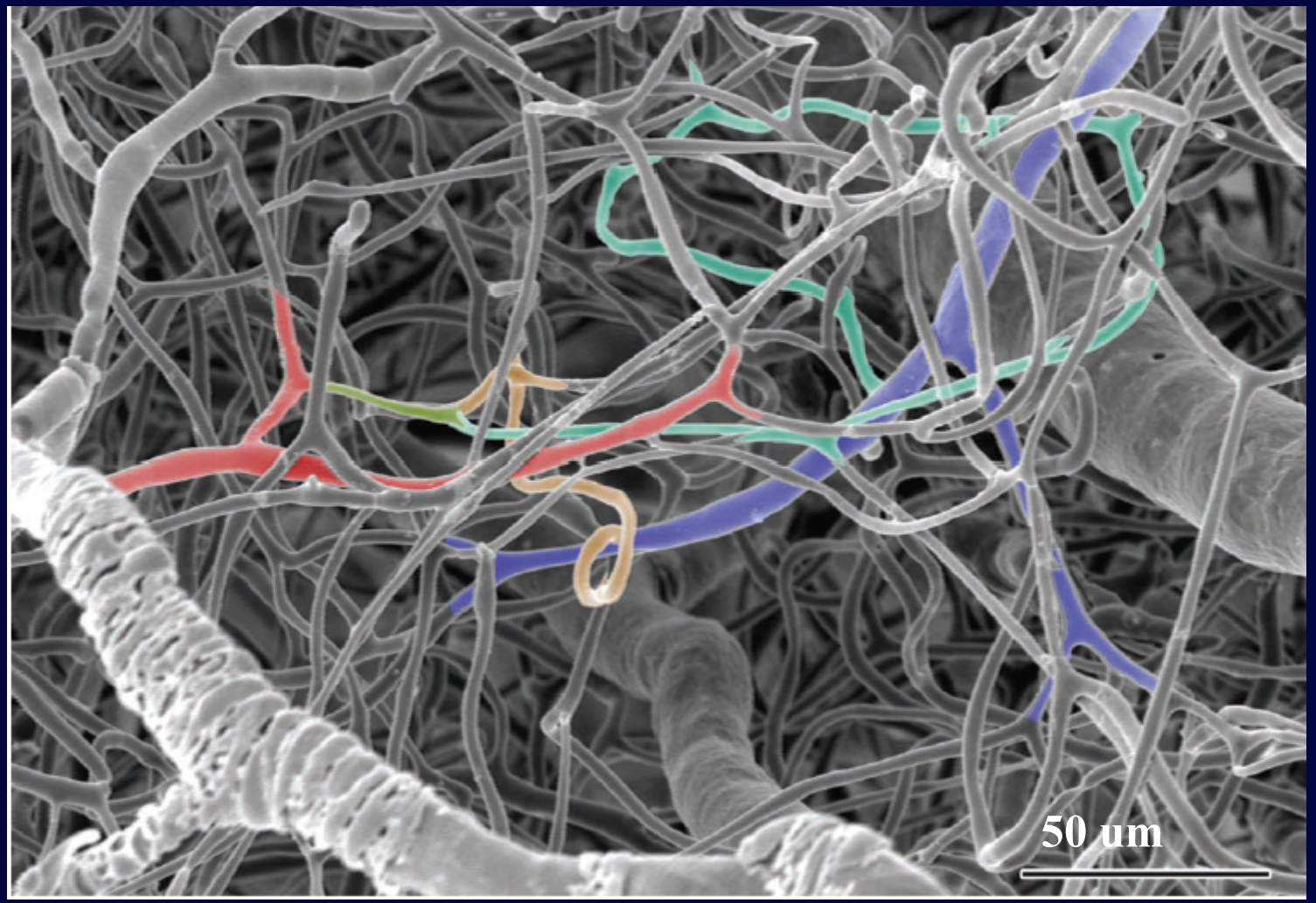
Rapid Event-Related Designs

Cortical Surface Models

The BOLD Signal

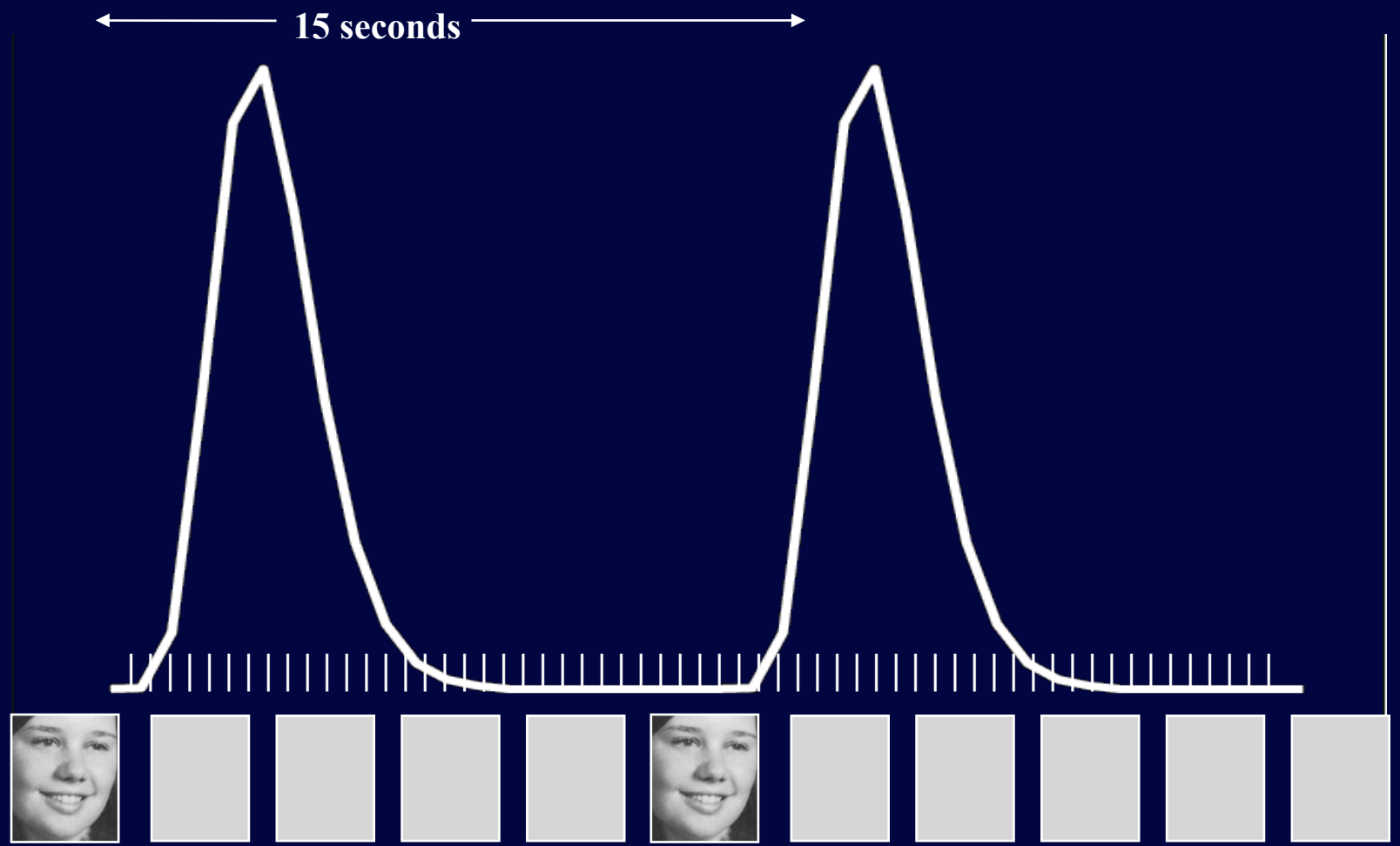
Chapter 2 (p. 38-63) of Jezzard et al.





Harrison et al. *Cerebral Cortex* (2002) 12: 255-233

Hemodynamic Response to Single Stimulus



Rapid Event-Related Design

Data Acquisition

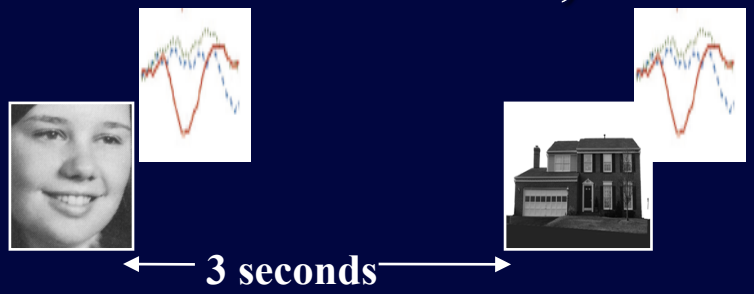
1 – 4 seconds per time point

Stimulus Presentation

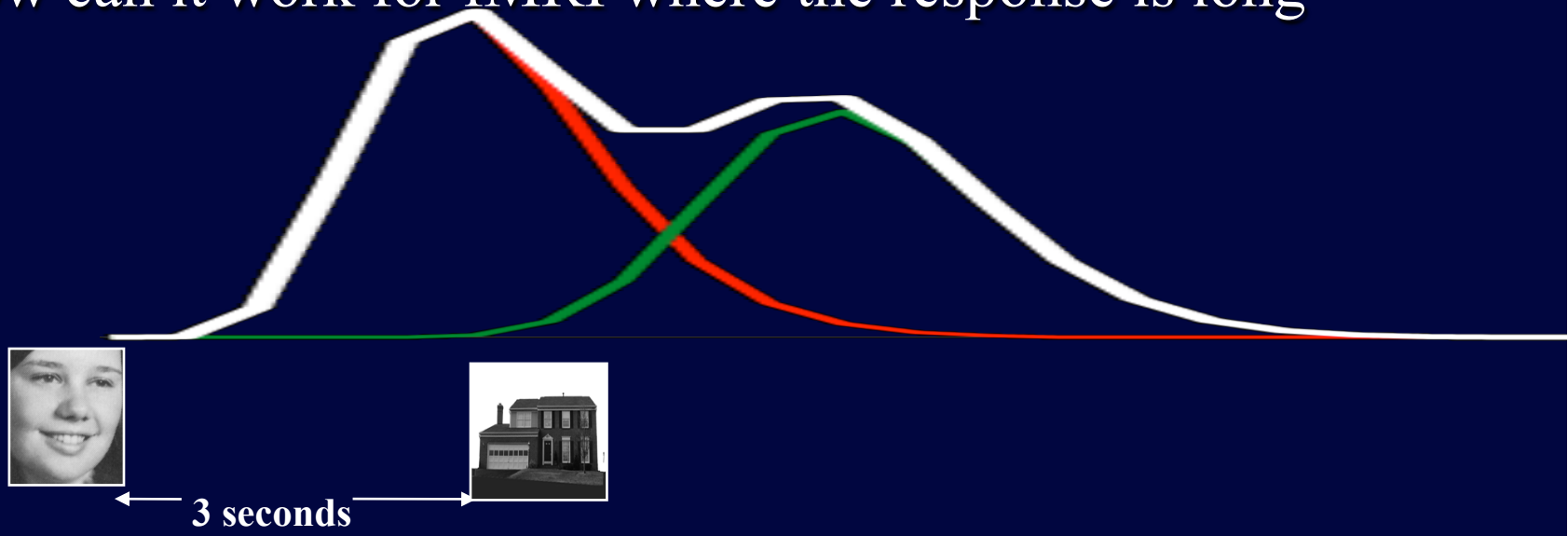
Single stimuli, 1 – 4 seconds interstimulus interval

Isn't the hemodynamic response too slow?

It works for EEG/MEG, where the response is short

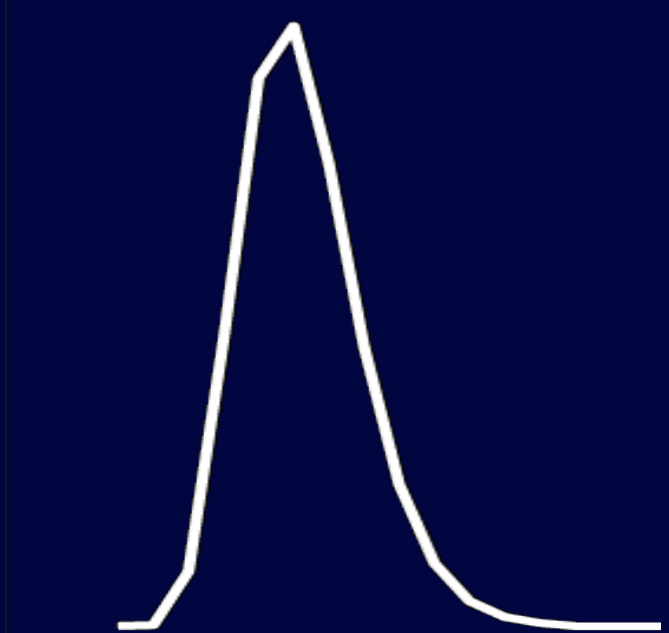


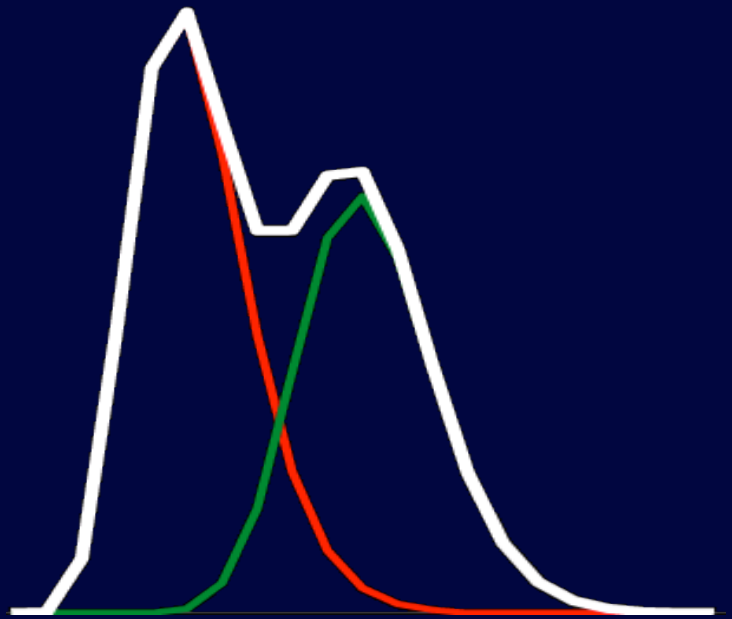
How can it work for fMRI where the response is long



How Can It Work?

Short Answer: Linear; Time Invariant





Rapid Event-Related Deconvolution, Two Event Types

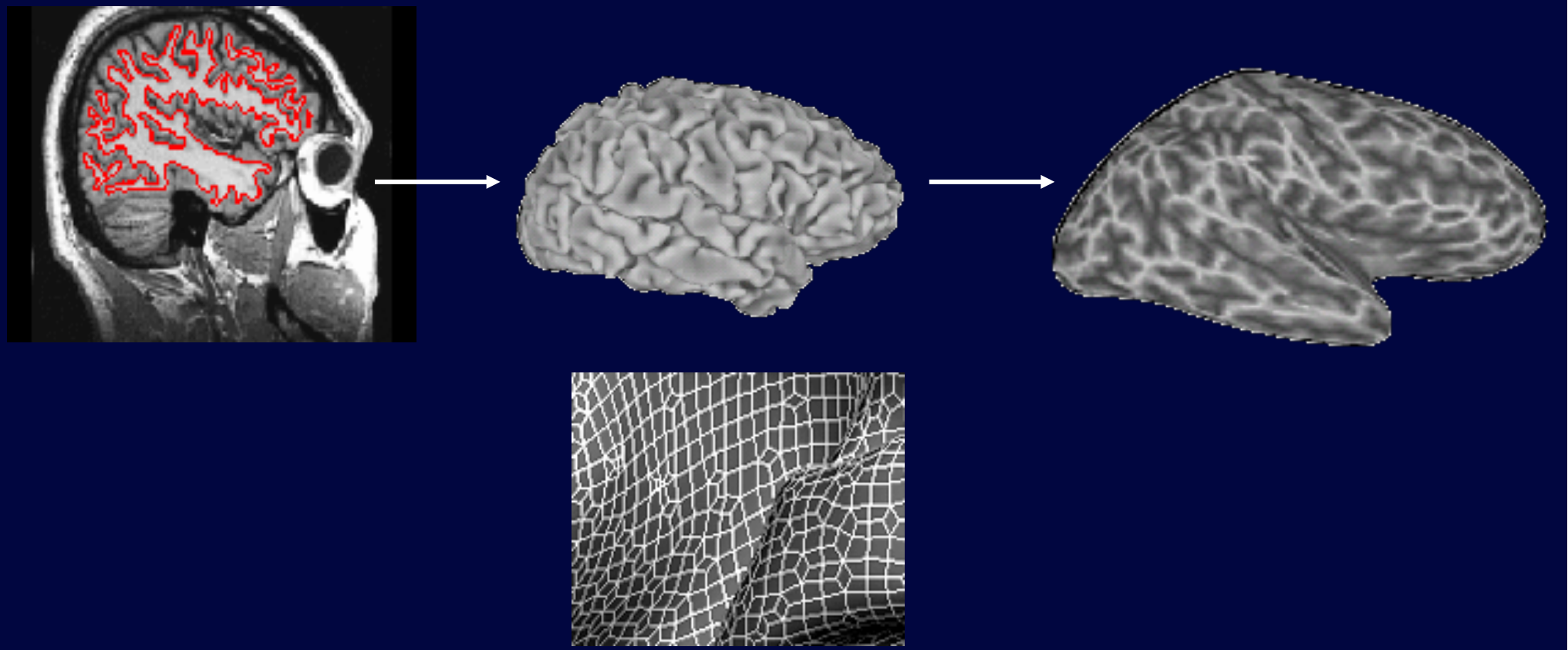
Stimulus A
Peristimulus Time

3
4
5
6
7

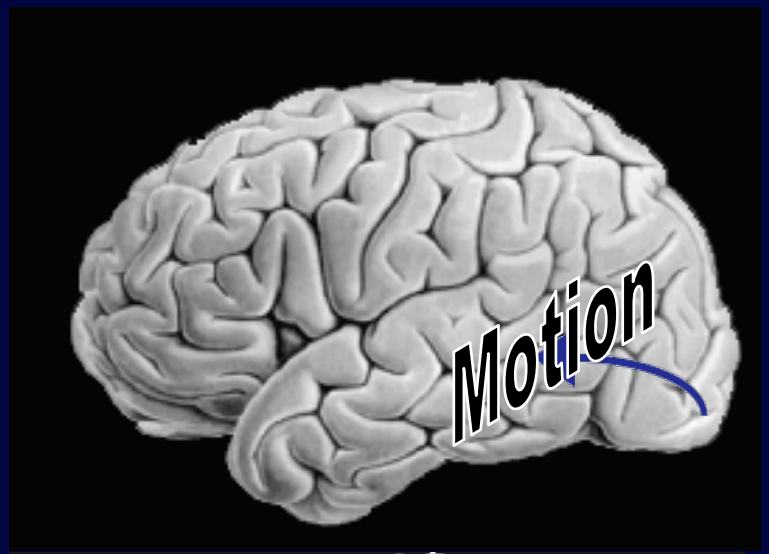
Stimulus B
Peristimulus Time

3
4
5
6
7

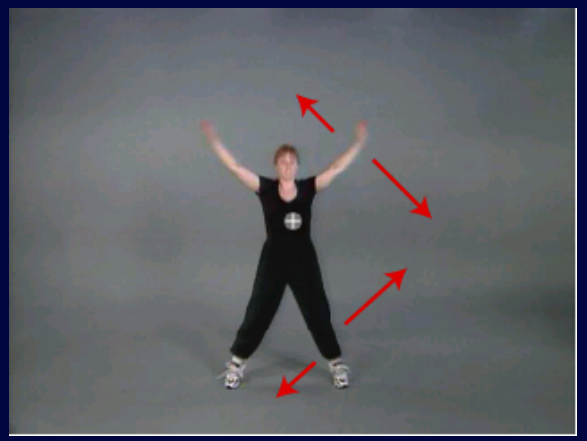
Cortical Surface Models

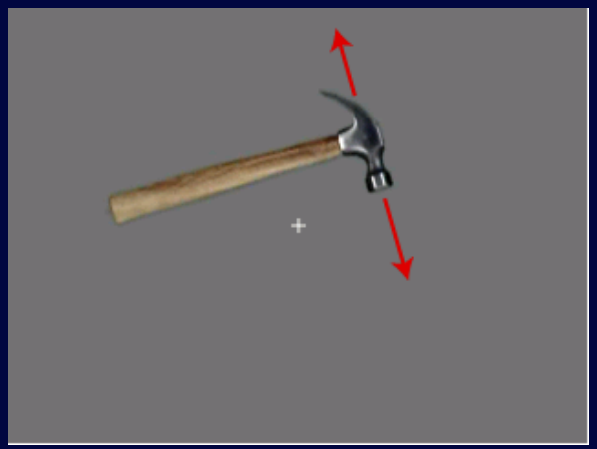


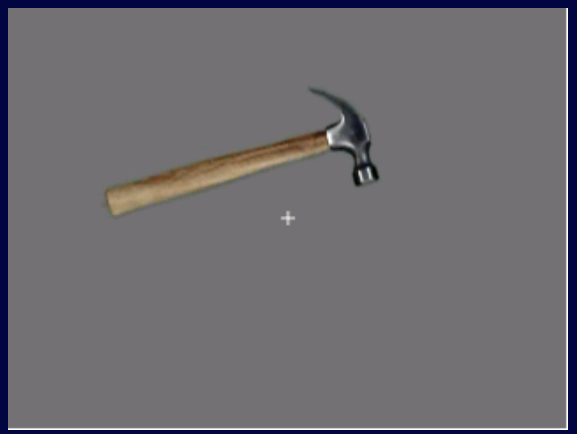
Experimental Hypothesis



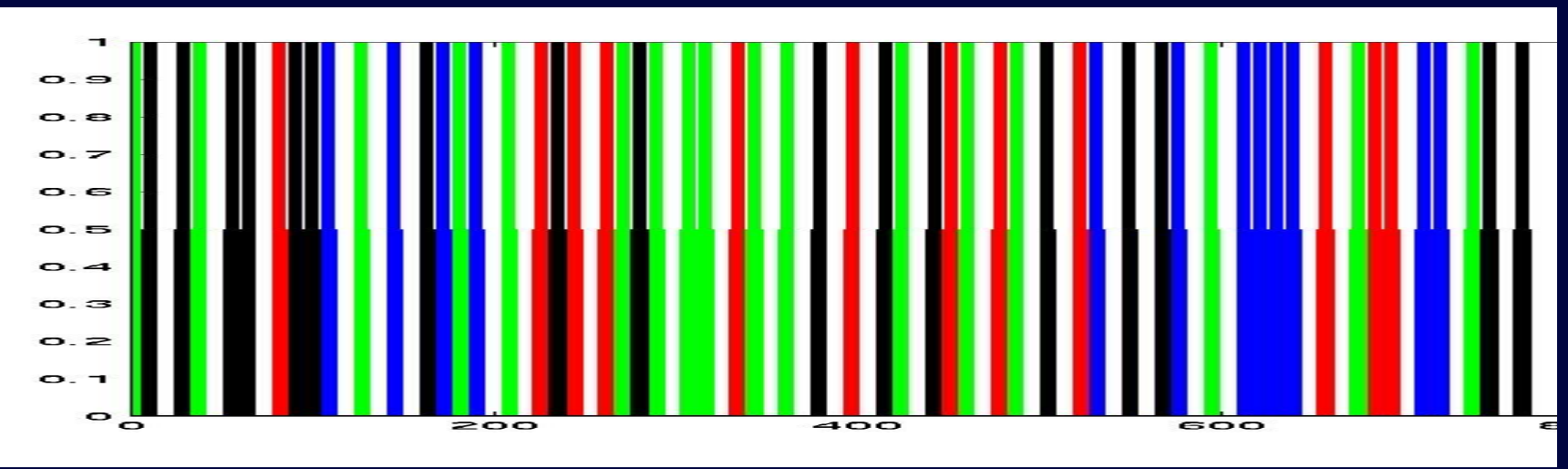
Static and Moving Humans and Tools







Rapid Event-Related Design



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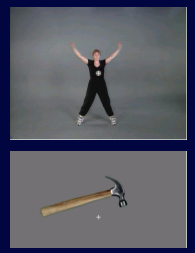
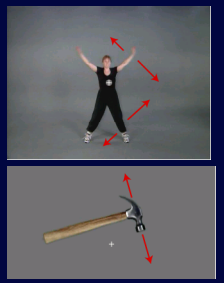
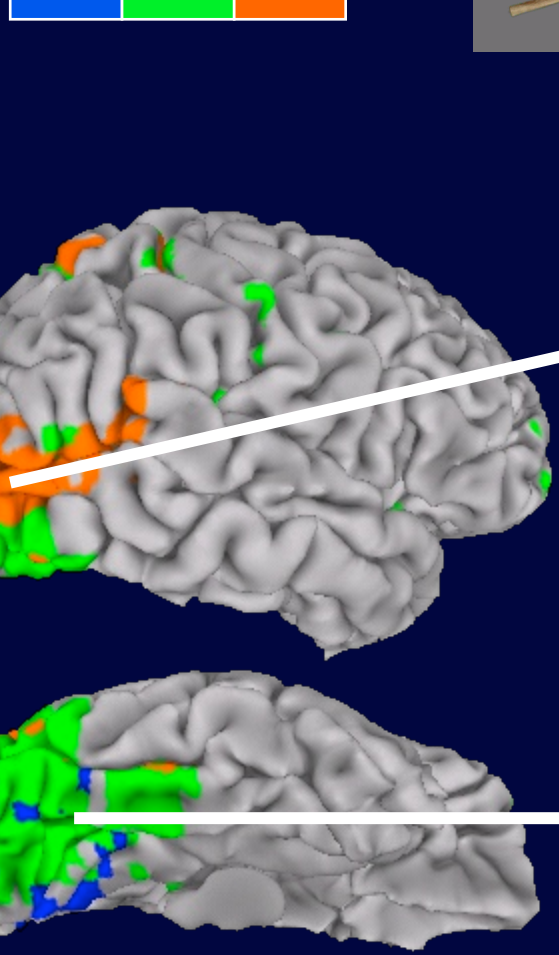
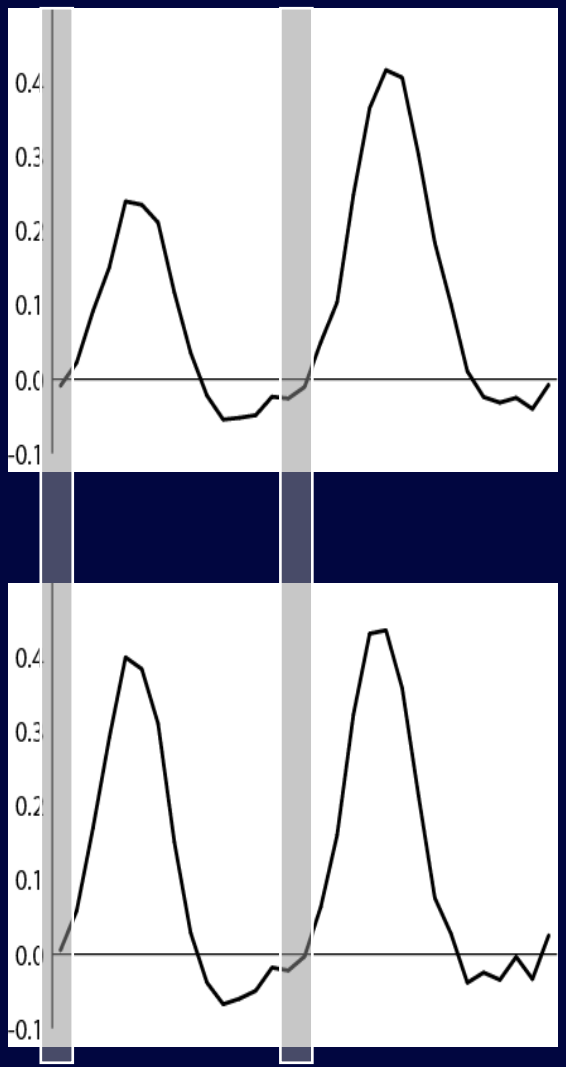




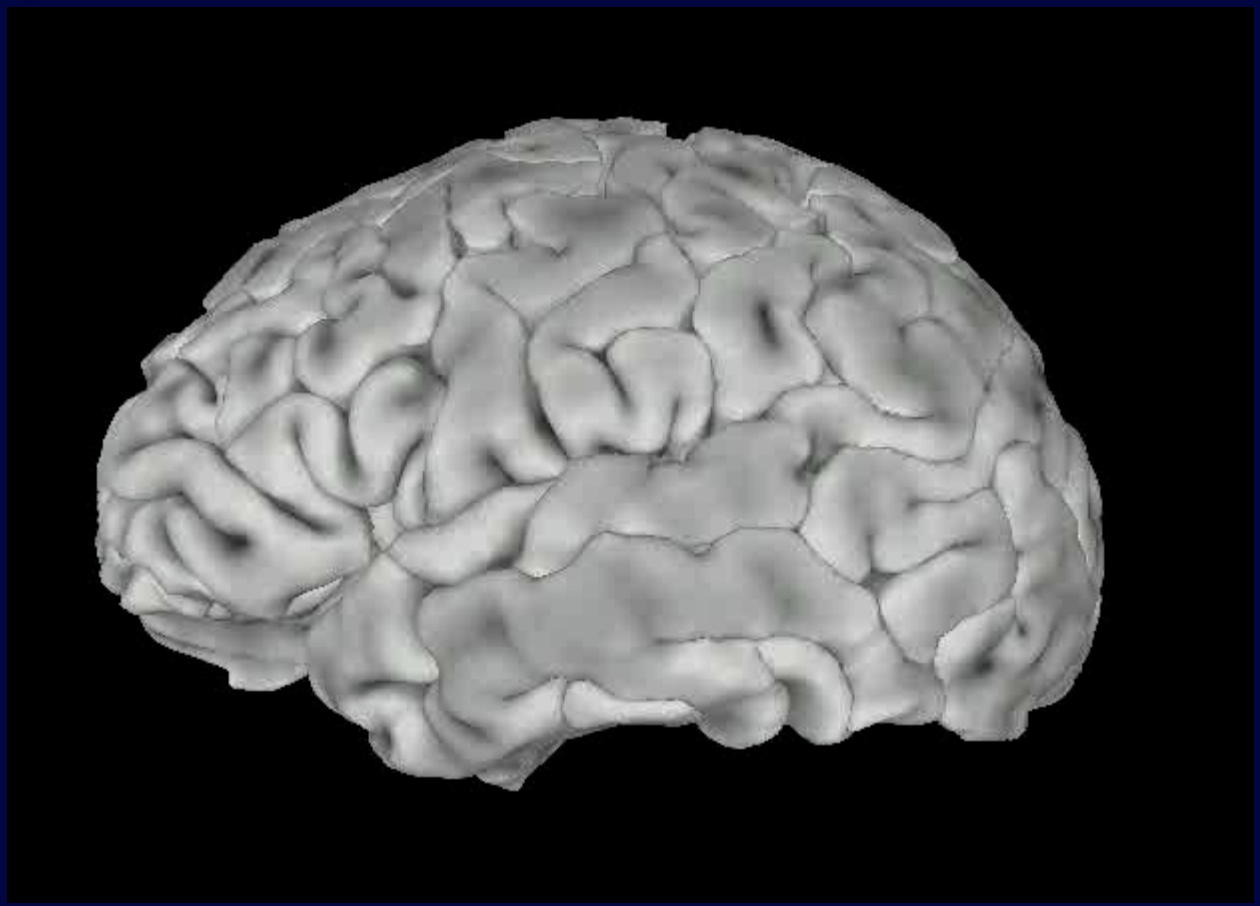
static moving

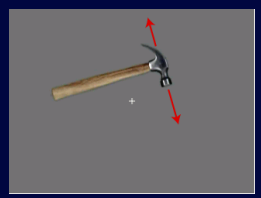


static moving

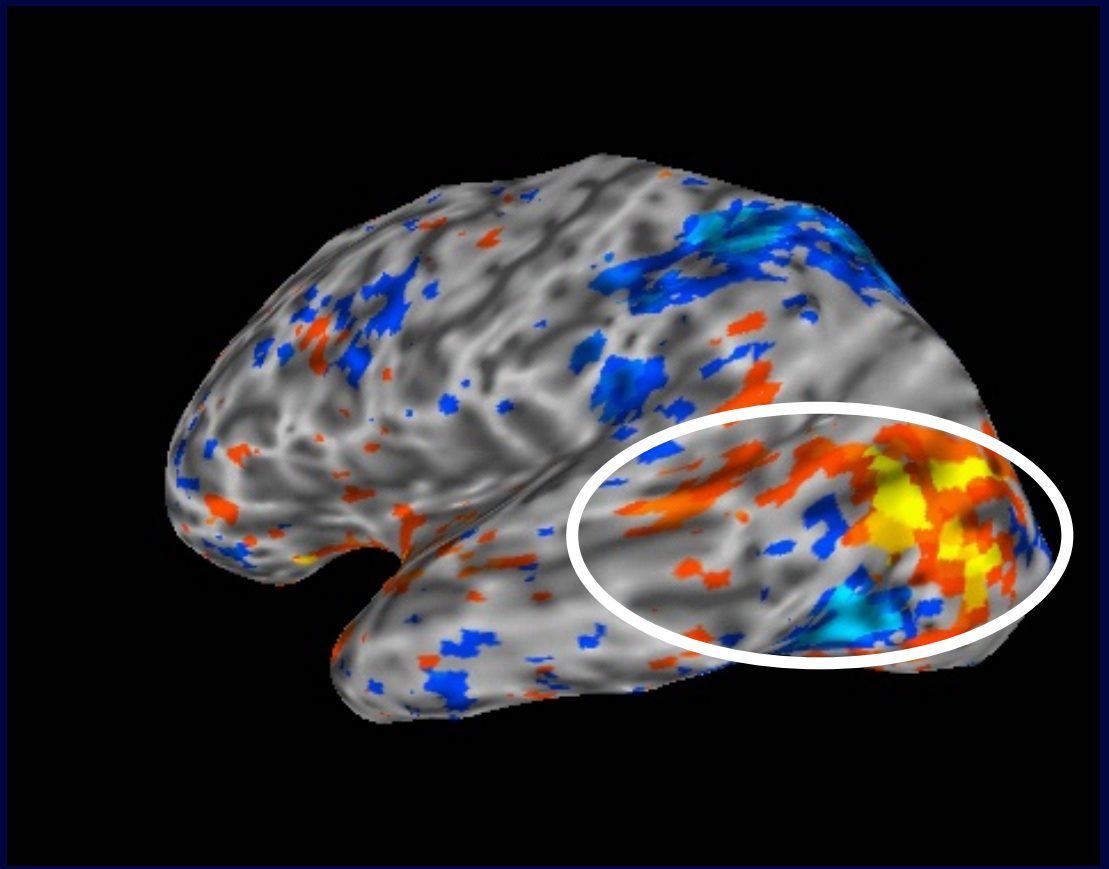


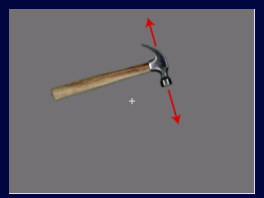
Contrast: People vs. Tools Single Subject Surface Model



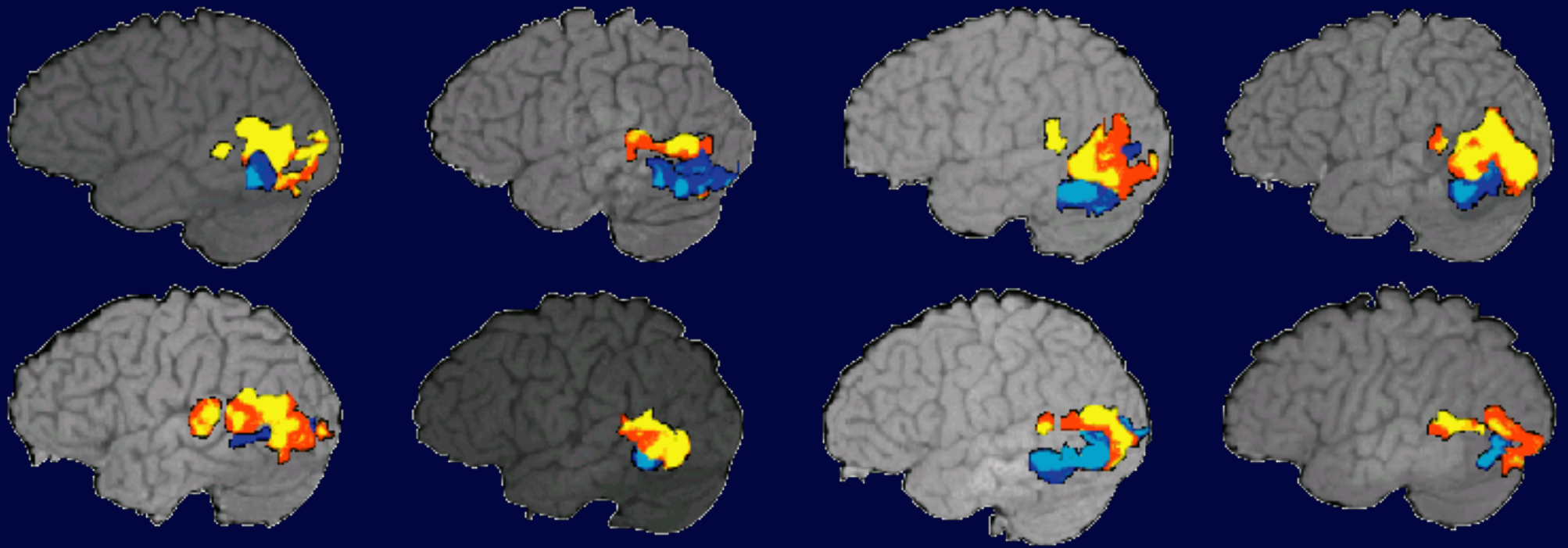


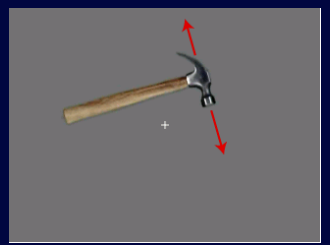
Contrast: People vs. Tools Single Subject Surface Model

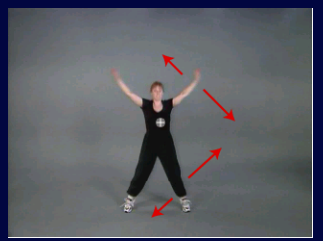




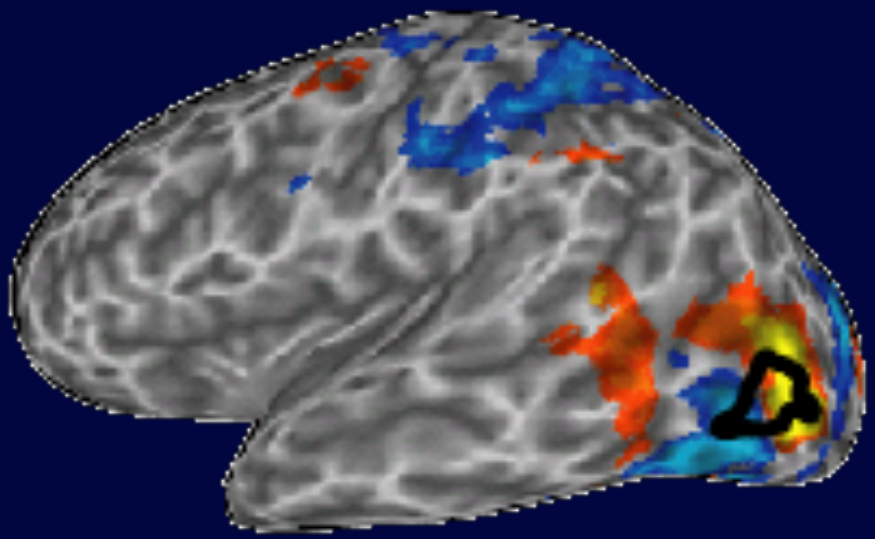
Preferences for Different Categories of Complex Motion: Single Subjects

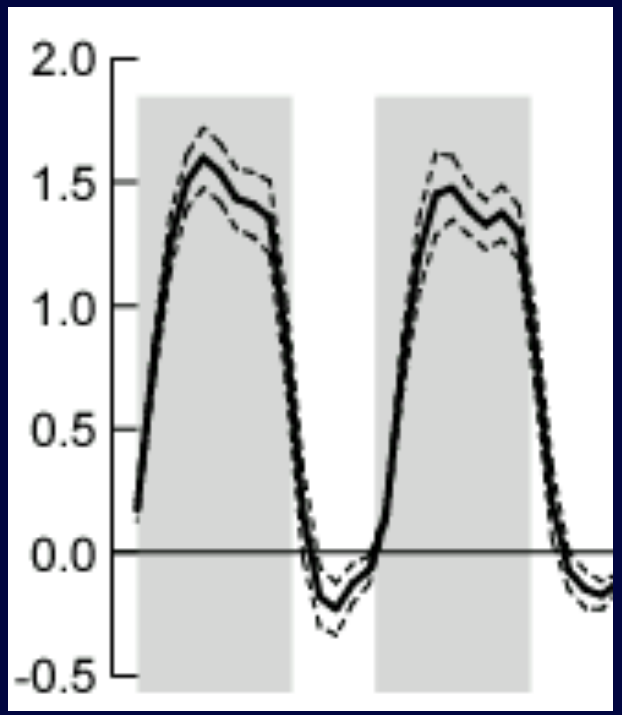


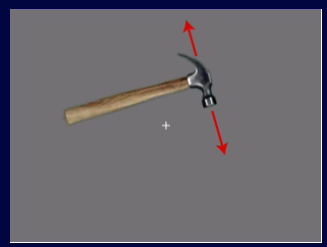




Relationship to Area MT

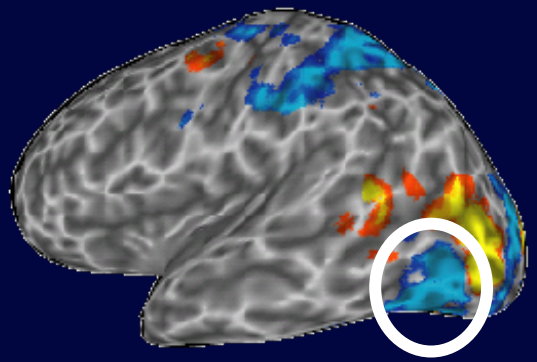


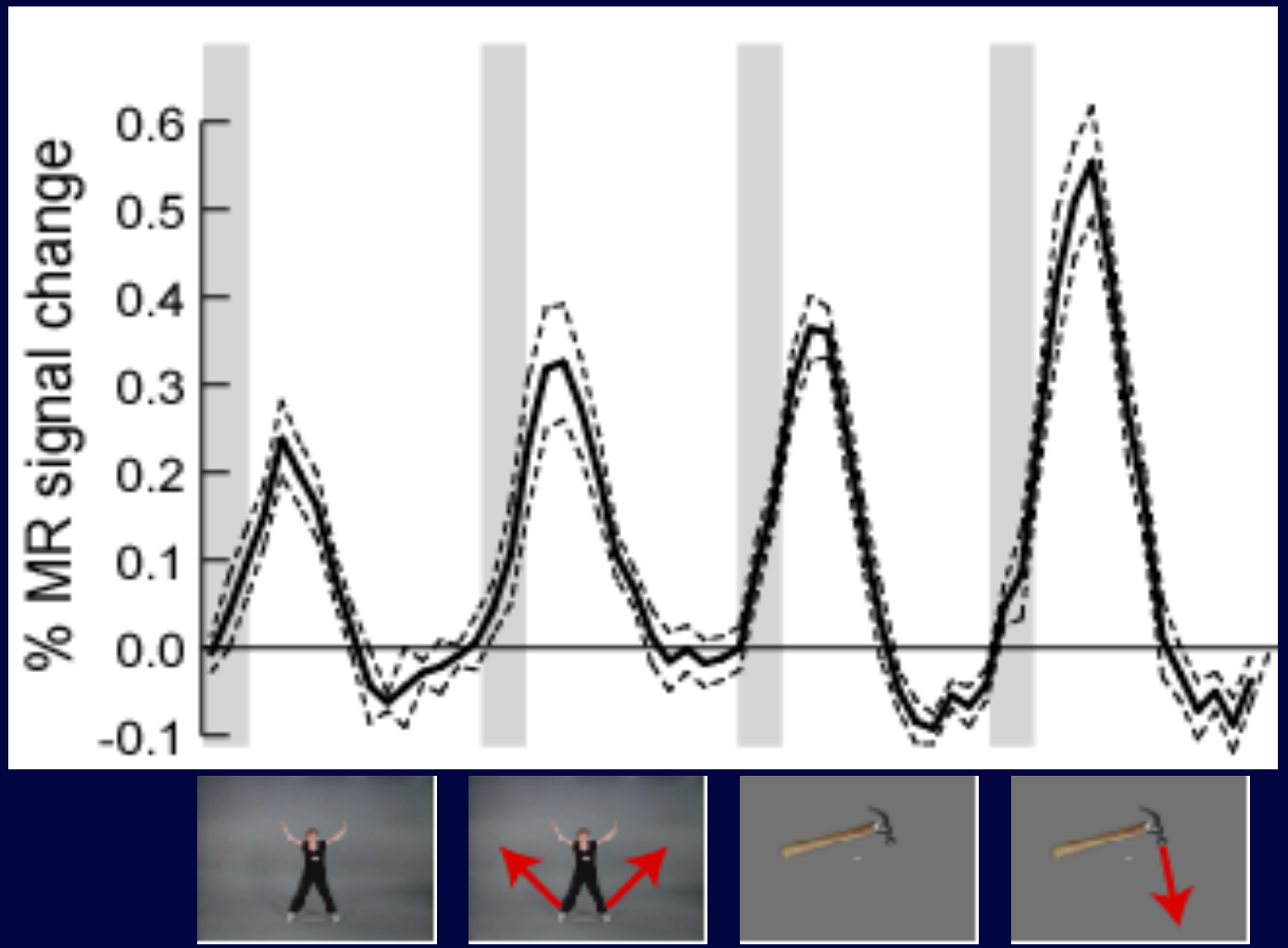




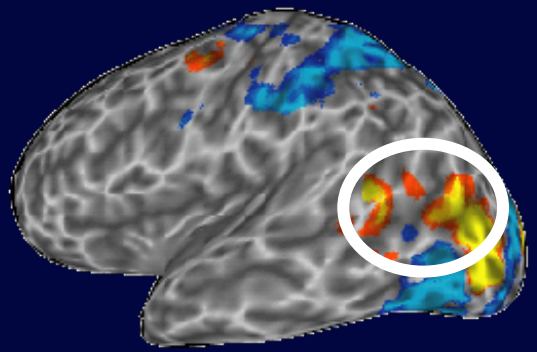
Average Response in MTG

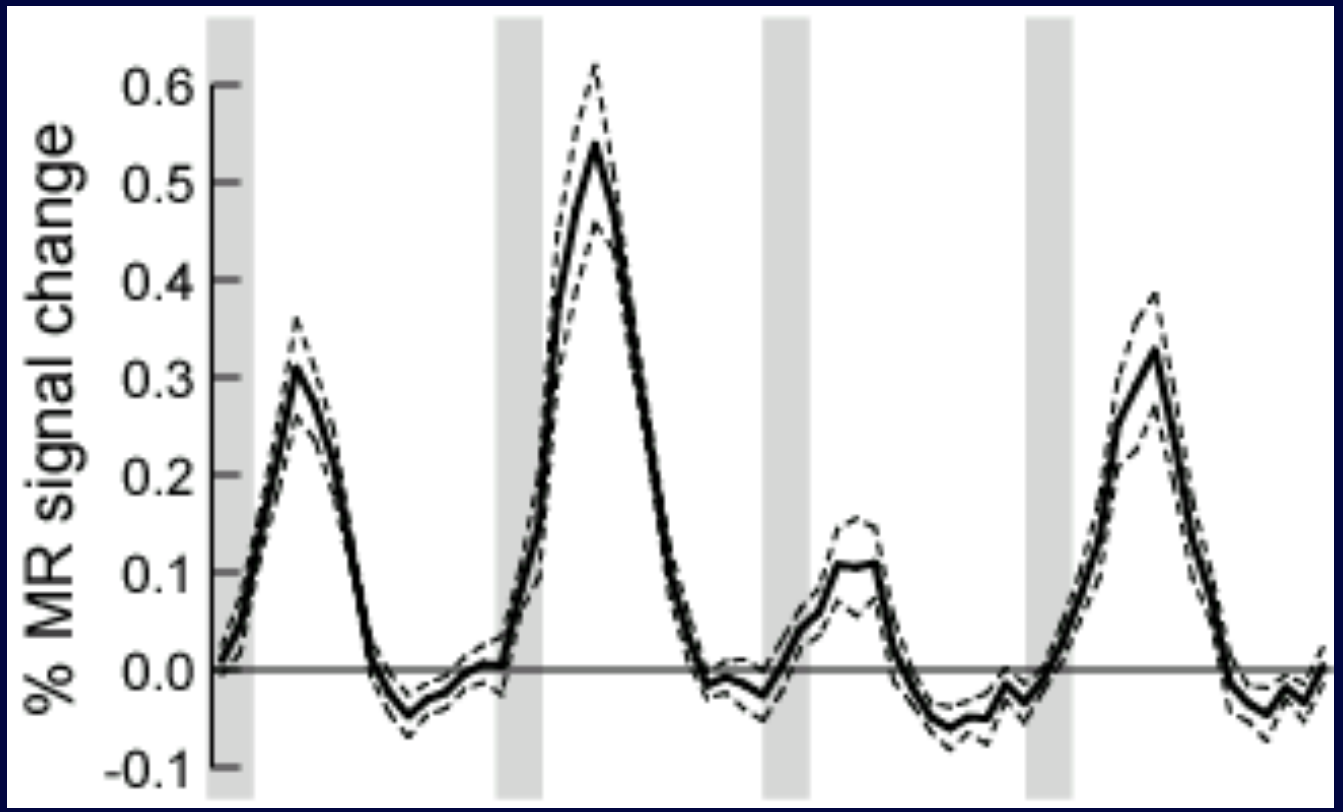
n=6



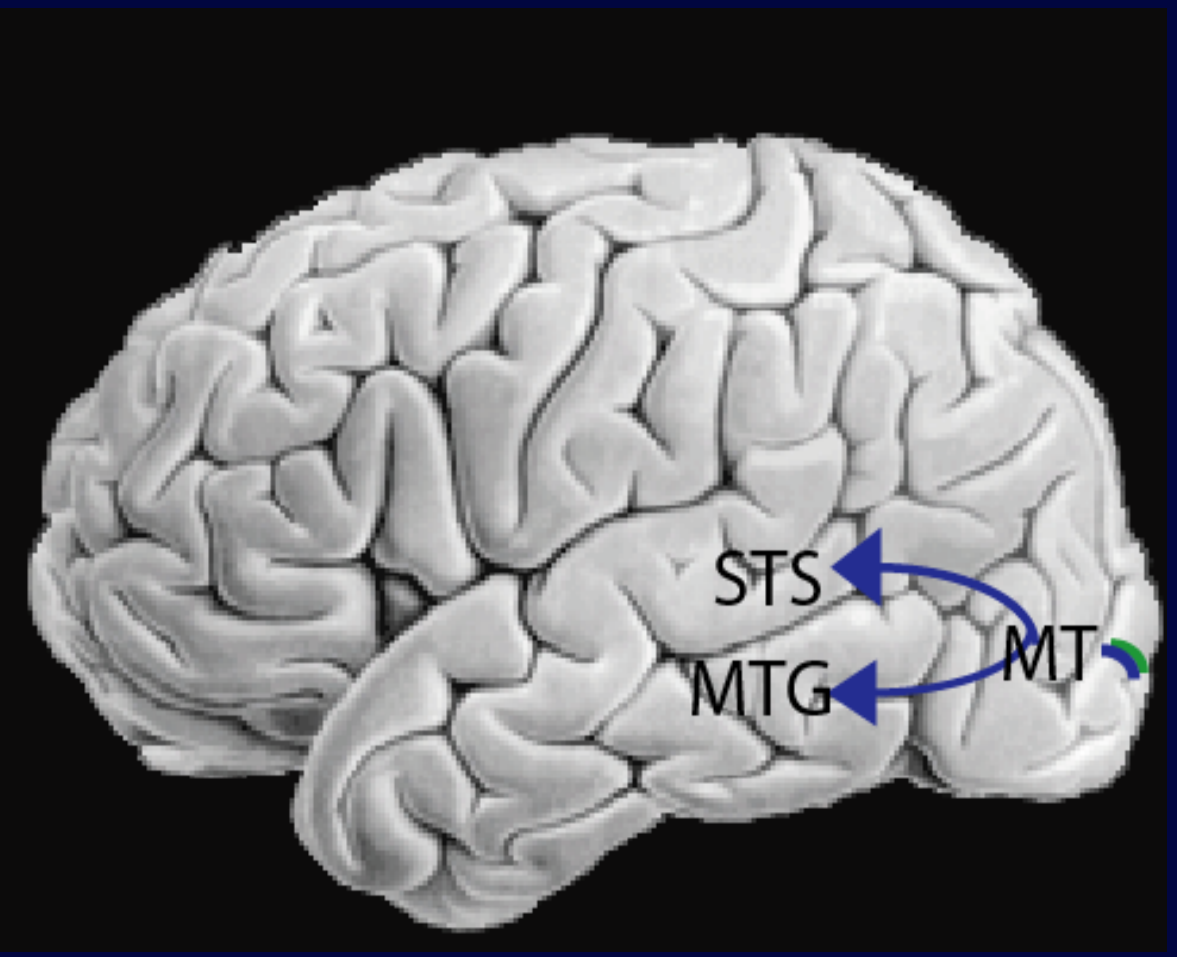


Average Responses in STS





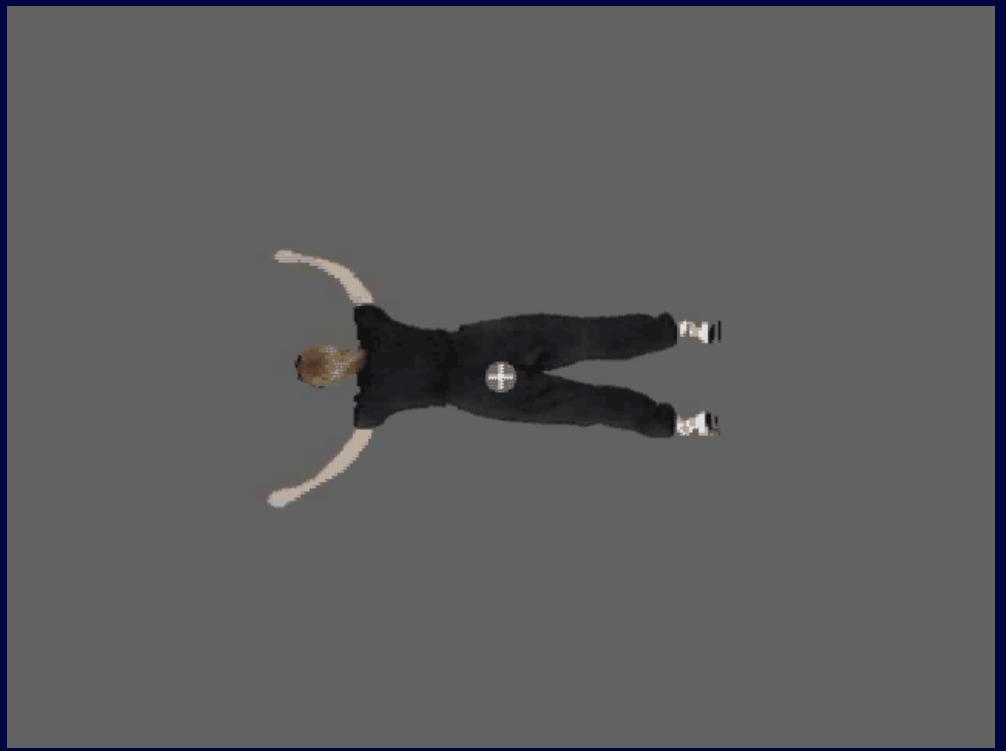
“How” stream details



Biological Motion
articulated; non-rigid

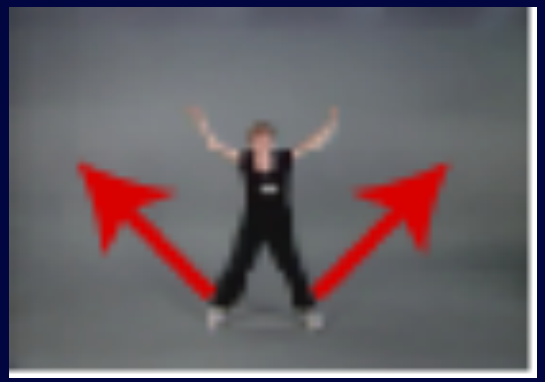
Tool motion
unarticulated; rigid body

Tool/Biological stimuli with identical unarticulated motion vectors



Hypothesis

STS

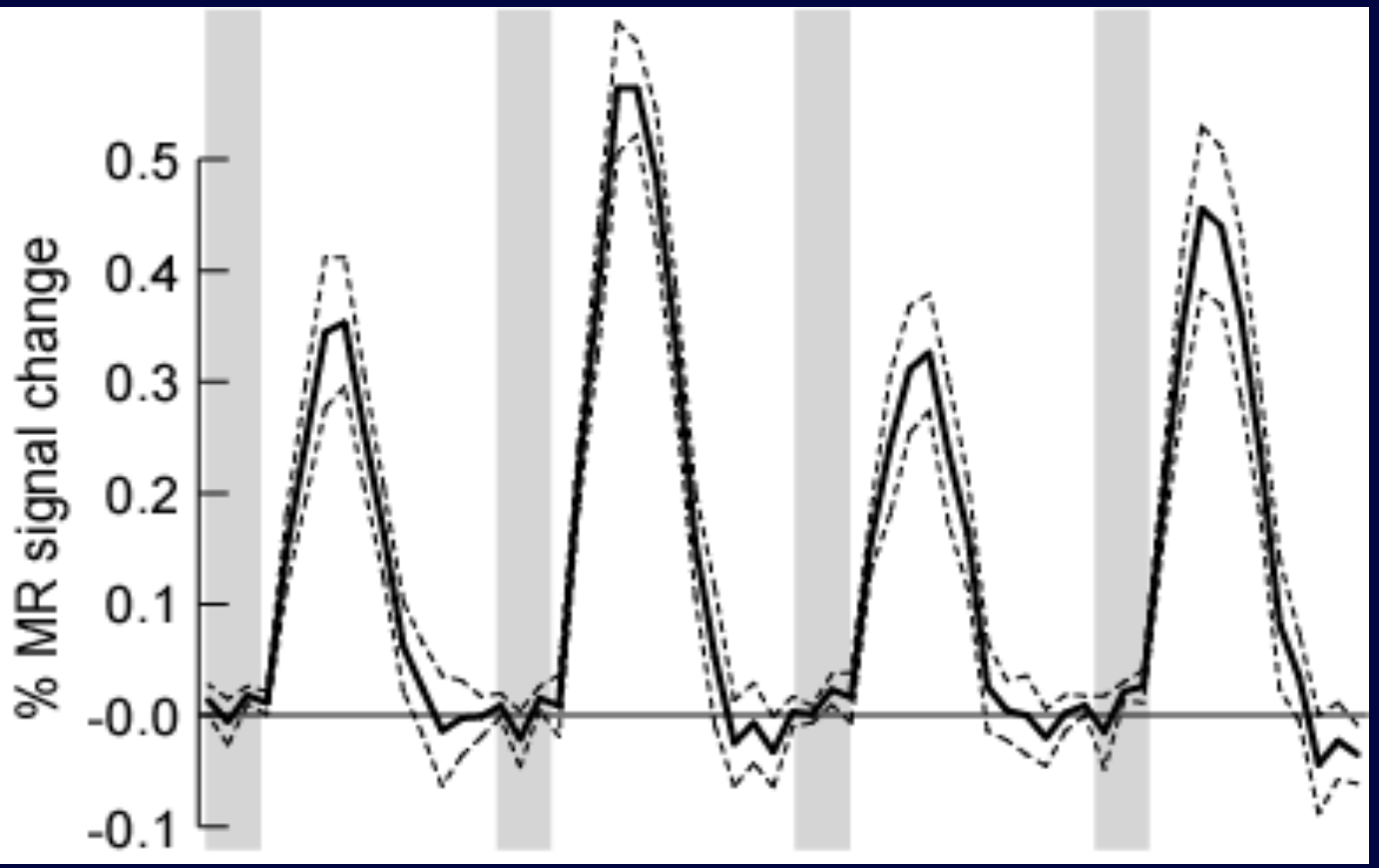


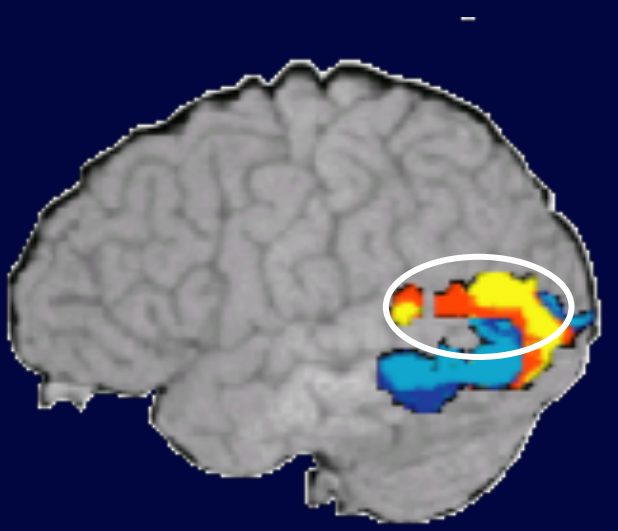
>

MTG

=

STS Response





MTG Response

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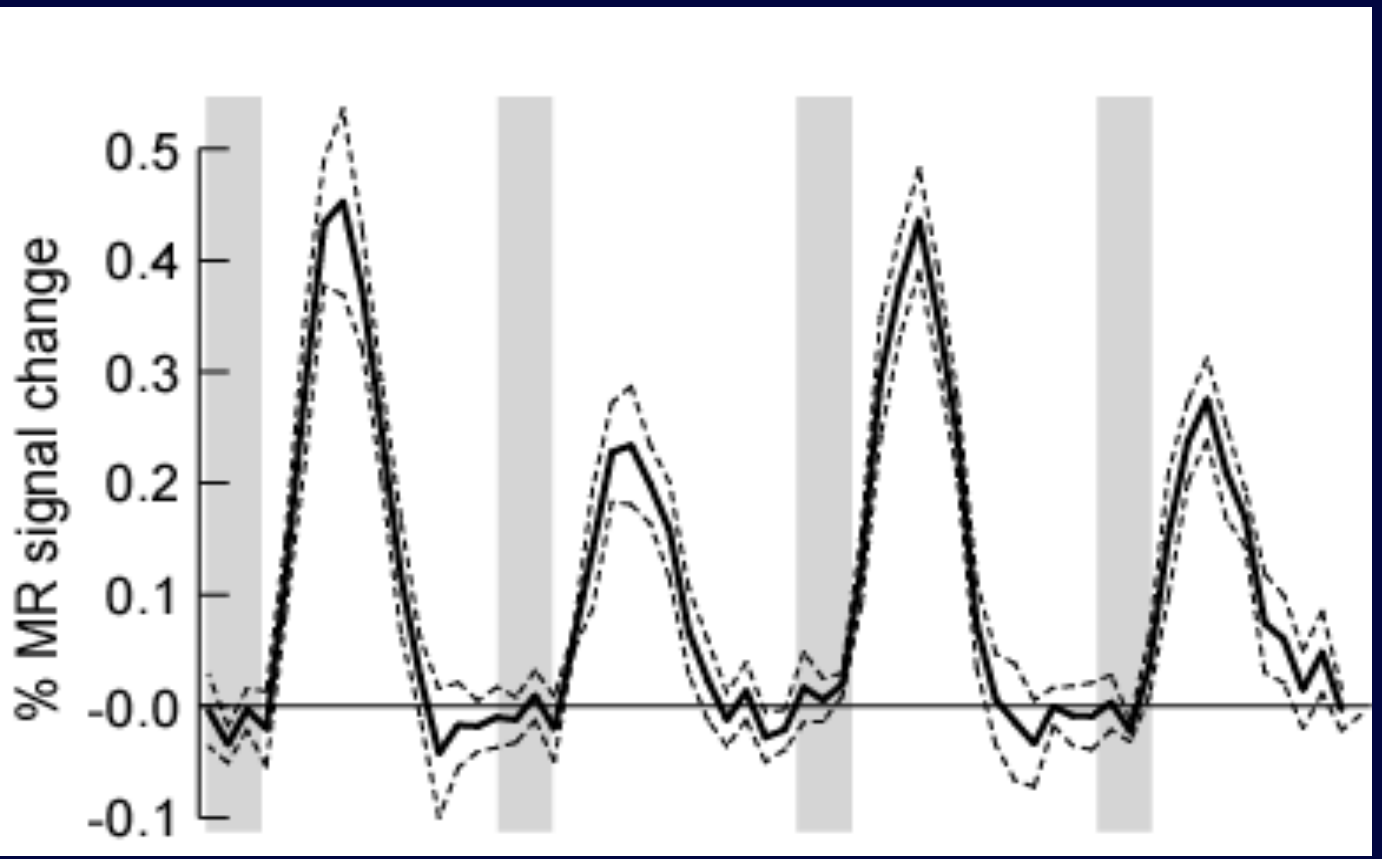
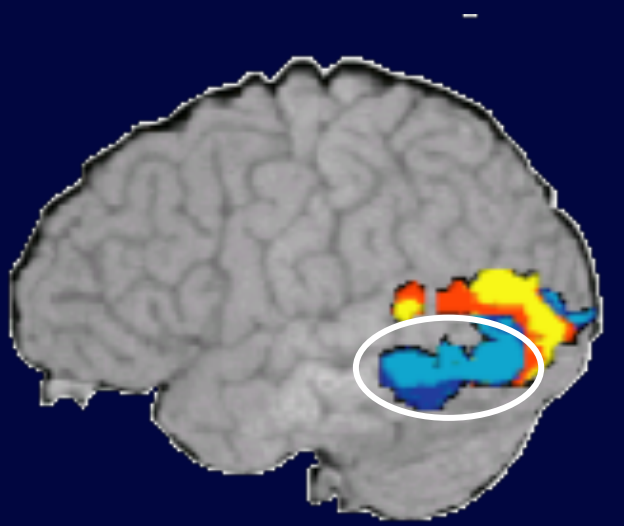
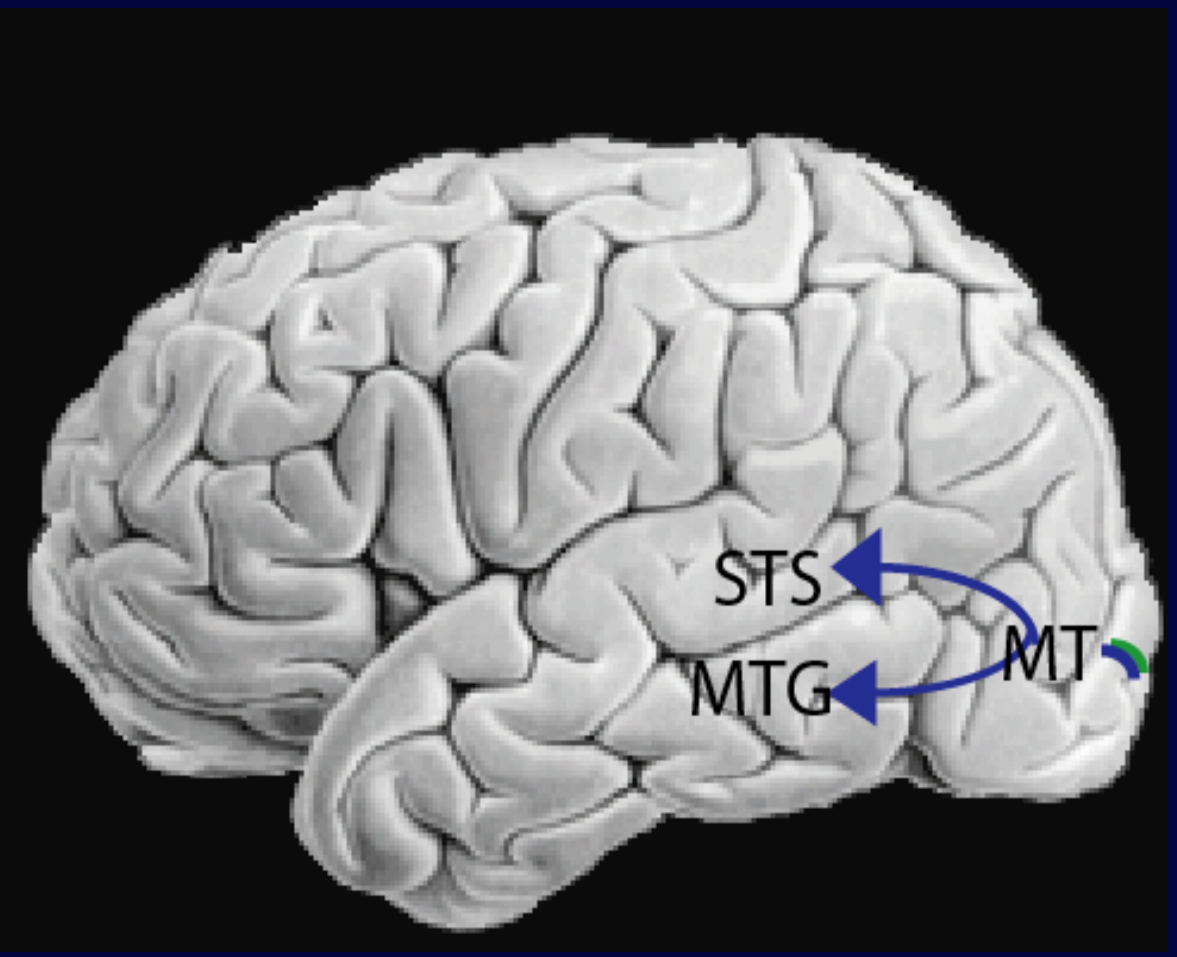




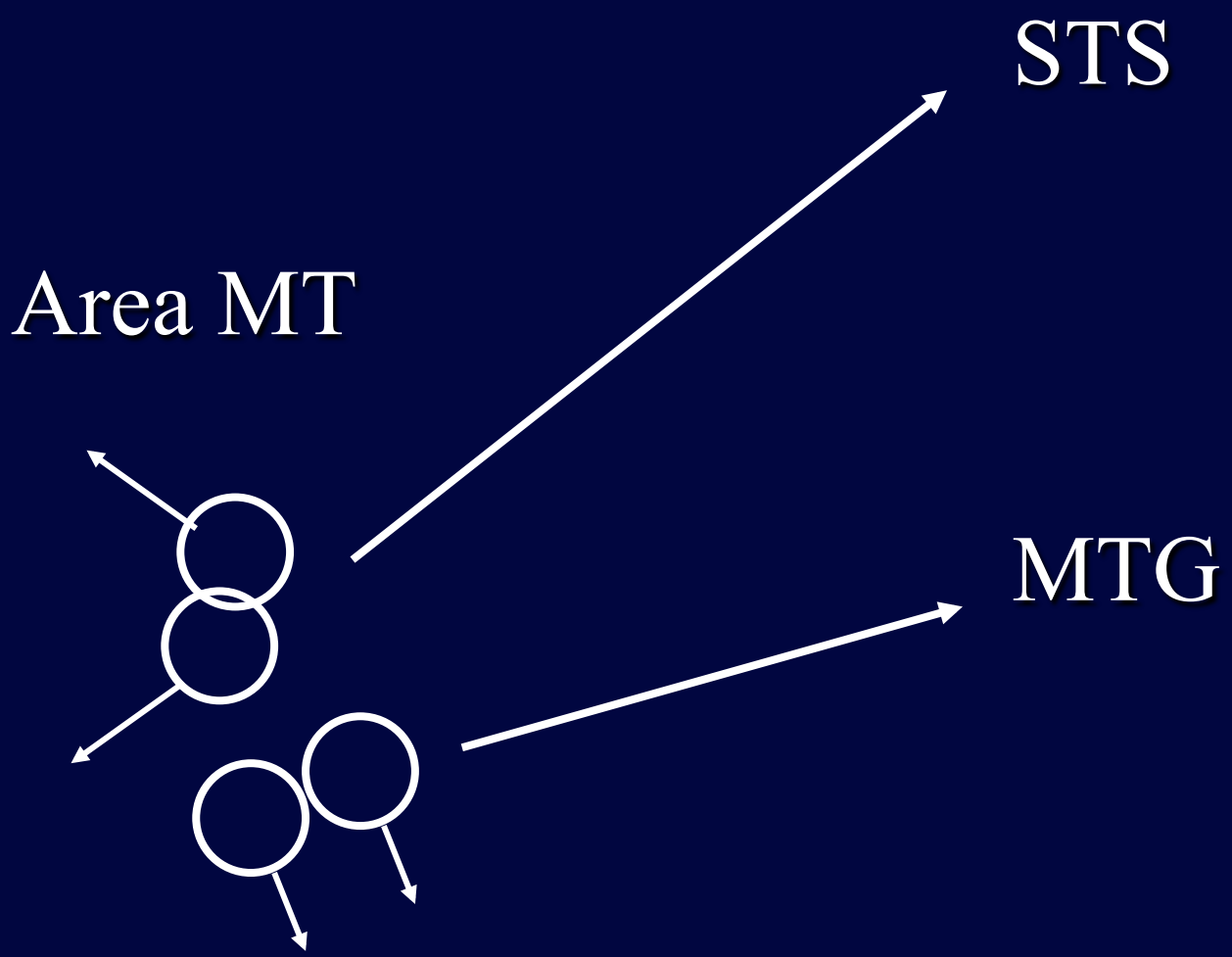
“How” stream details



Biological Motion
articulated; non-rigid

Tool motion
unarticulated; rigid body

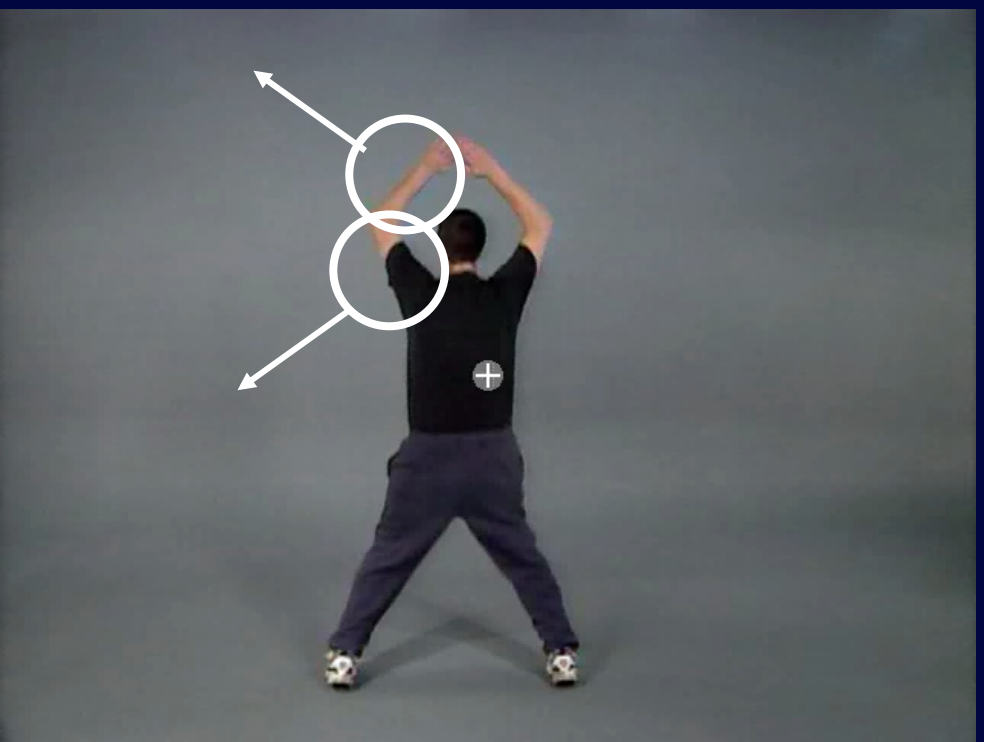
Model



Model

STS

Area MT

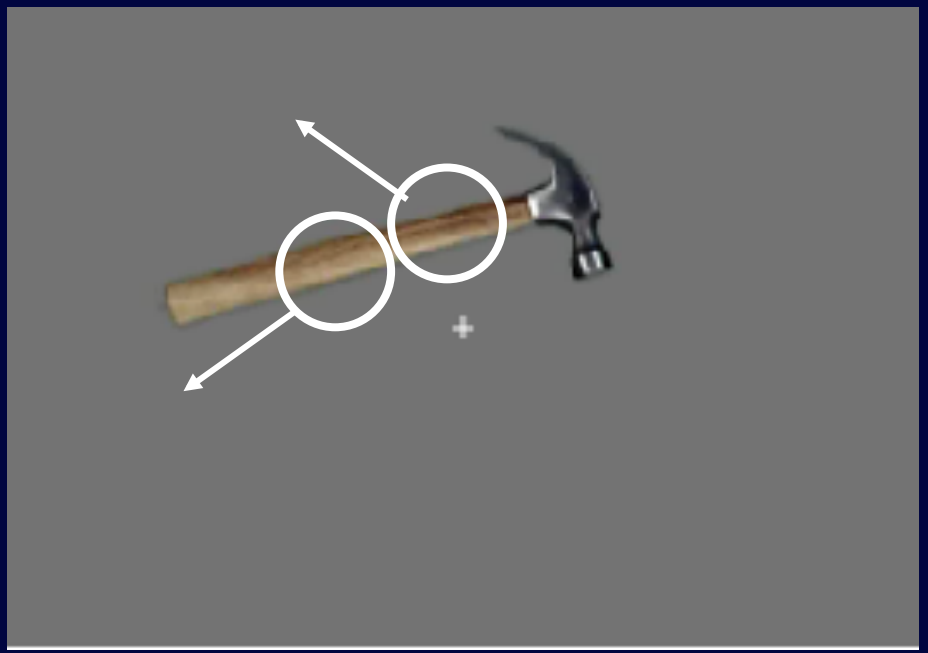


MTG

Model

STS

Area MT

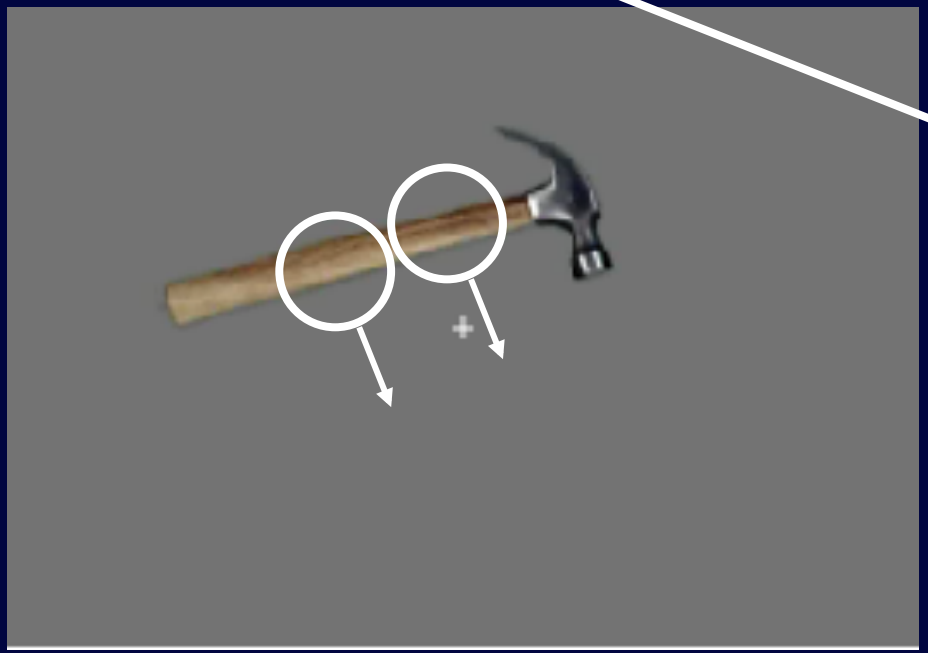


MTG

Model

STS

Area MT

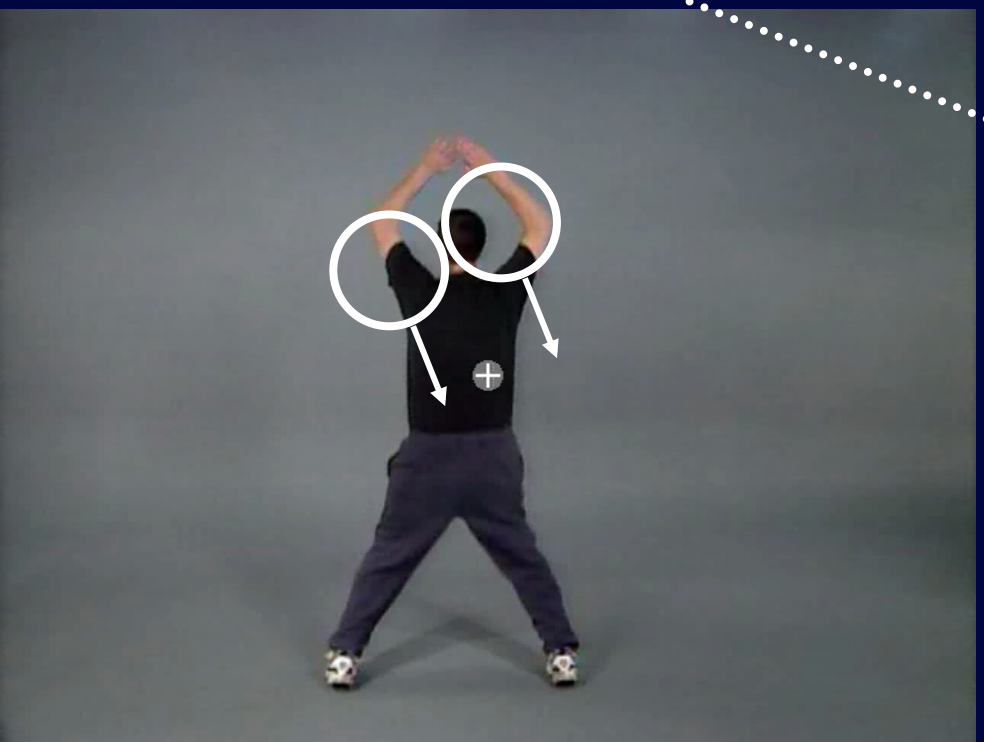


MTG

Model

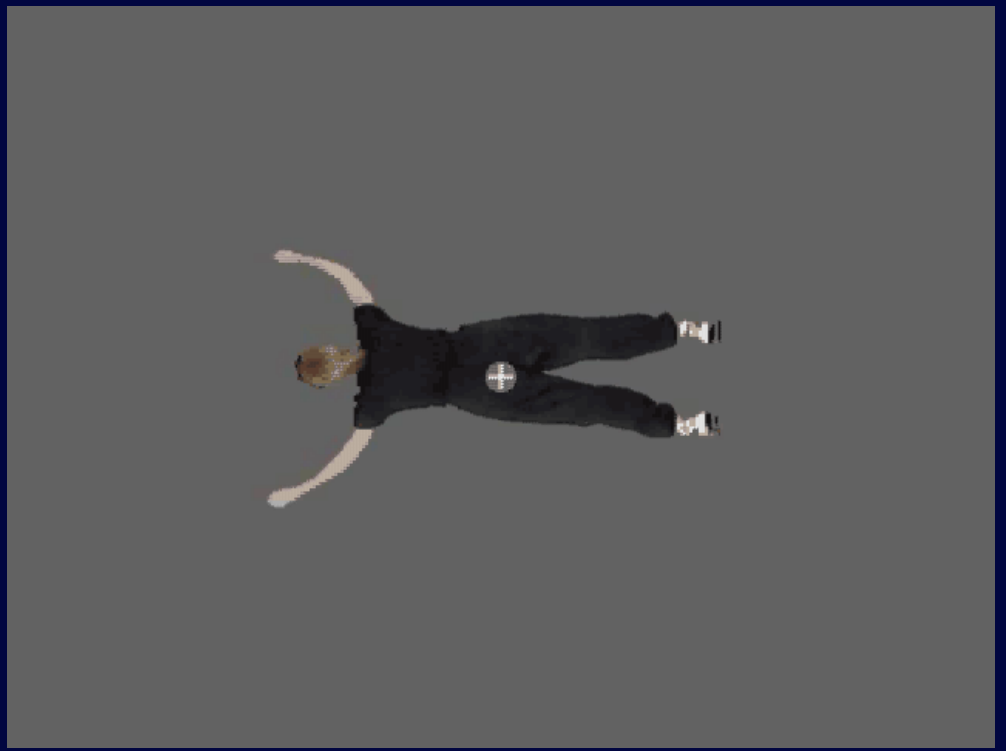
STS

Area MT



MTG

Problem: form, color information remain



Point-light study

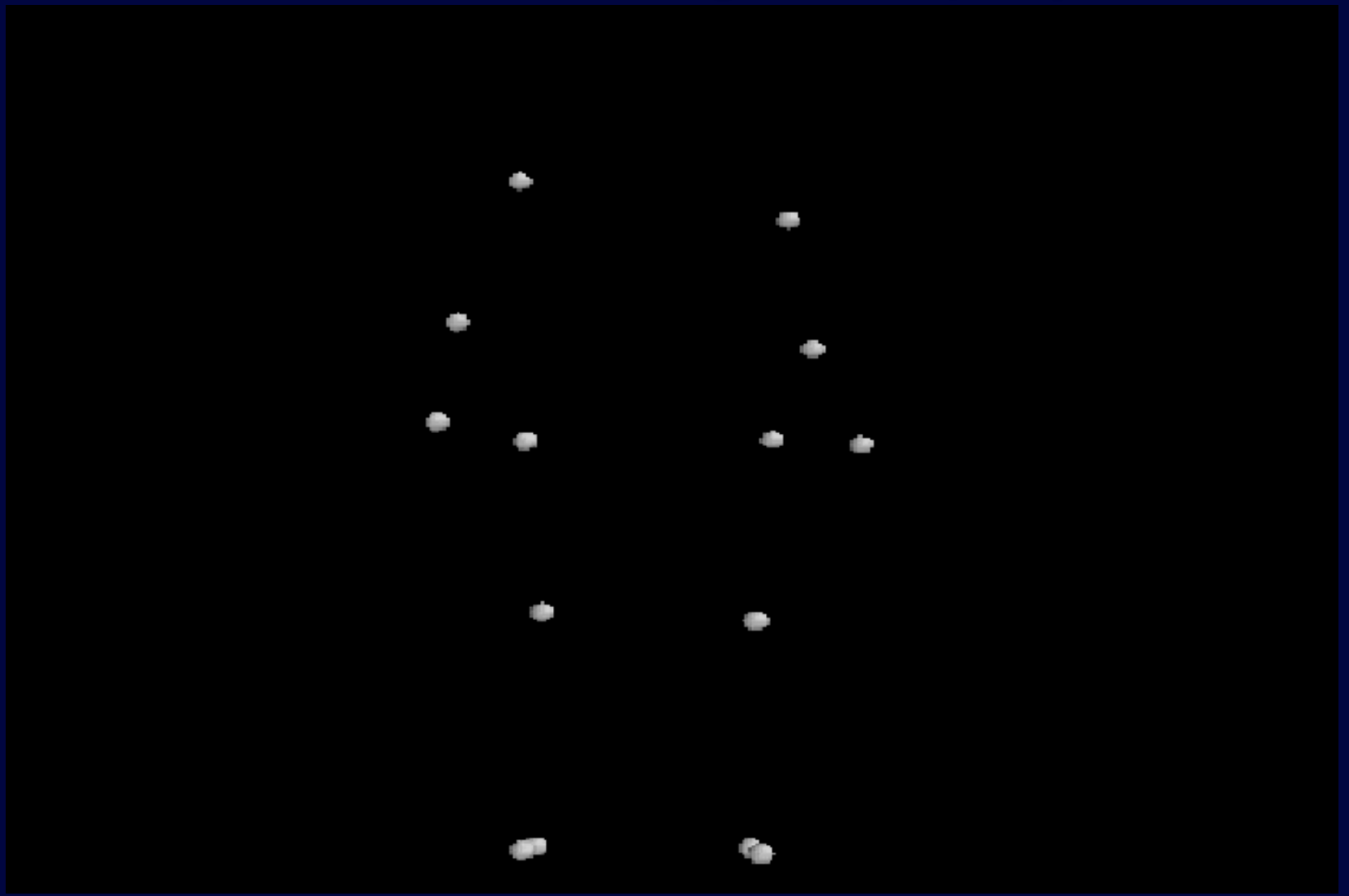
Beauchamp MS, Lee K, Haxby JV, Martin A (2003). fMRI Responses to Video and Point-Light Displays of Moving Humans and Manipulable Objects. *Journal of Cognitive Neuroscience 15(7).*

Servos et al.

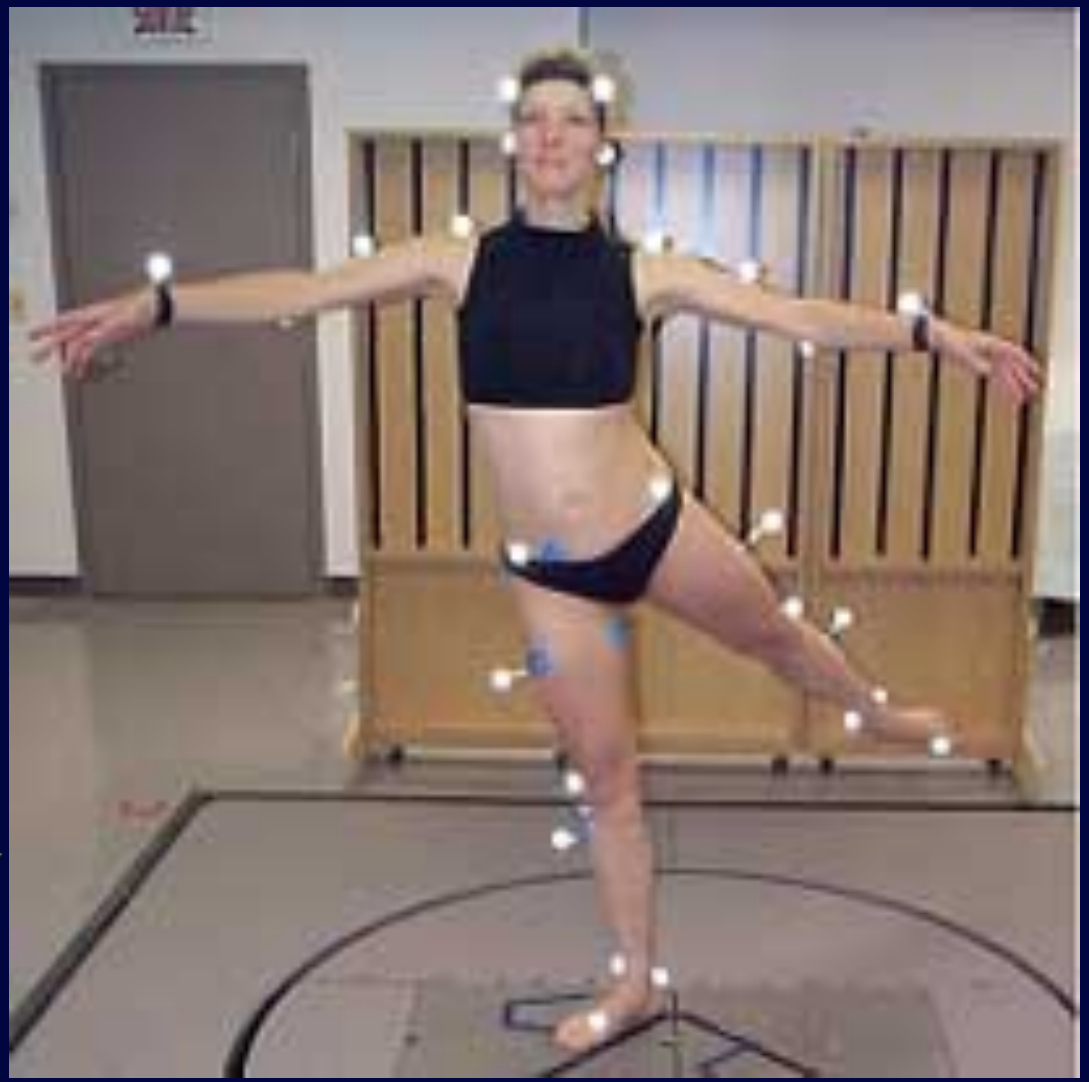
Decety

Grossman & Blake

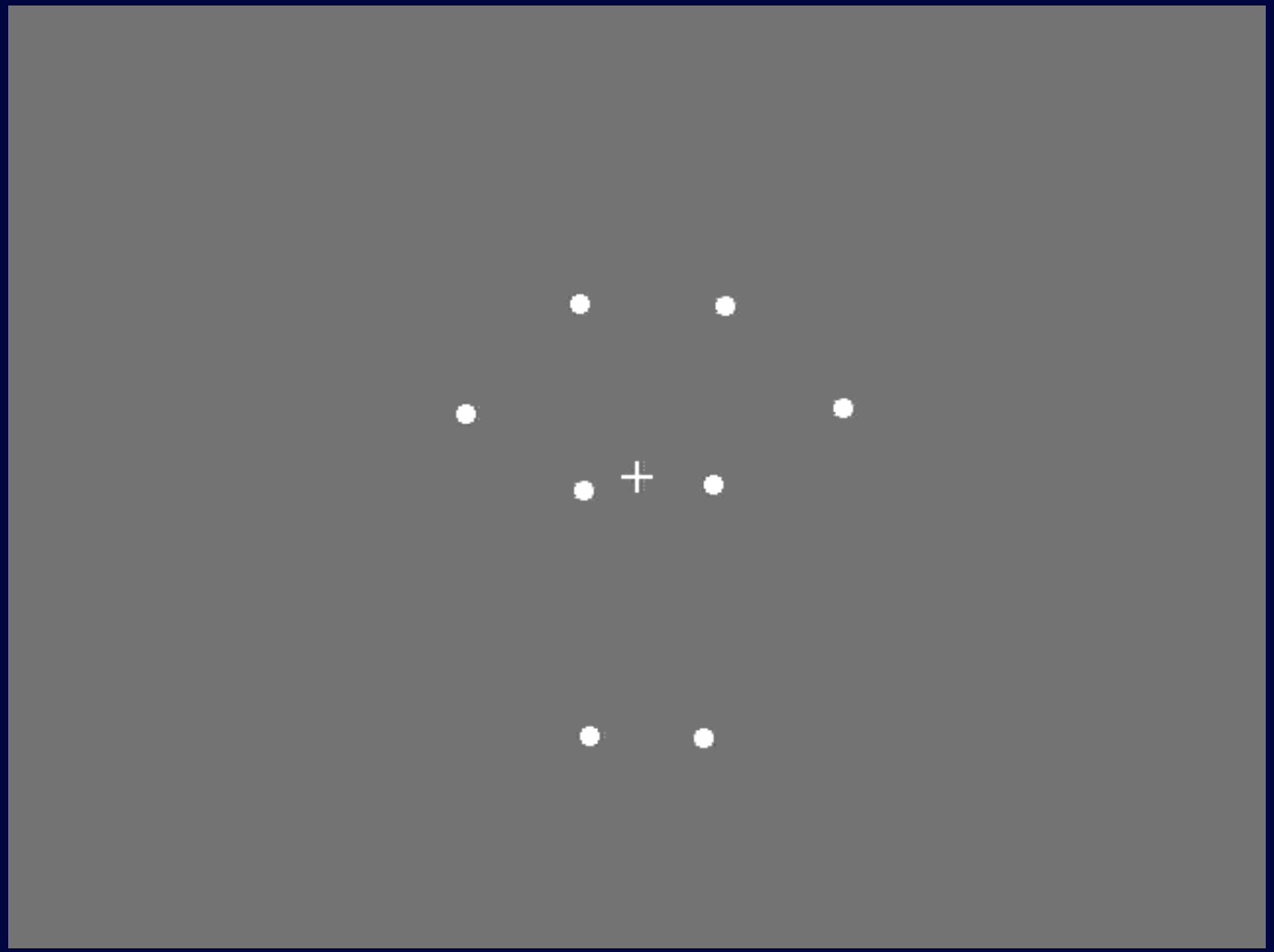
Johannson Point Light Displays



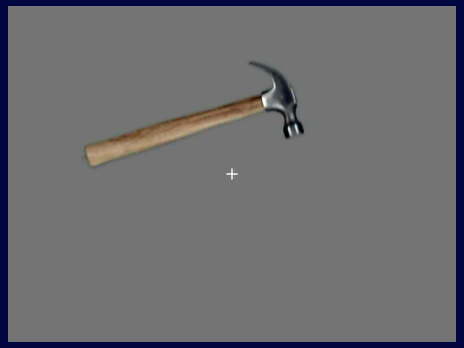
Stimulus Creation—Motion Capture

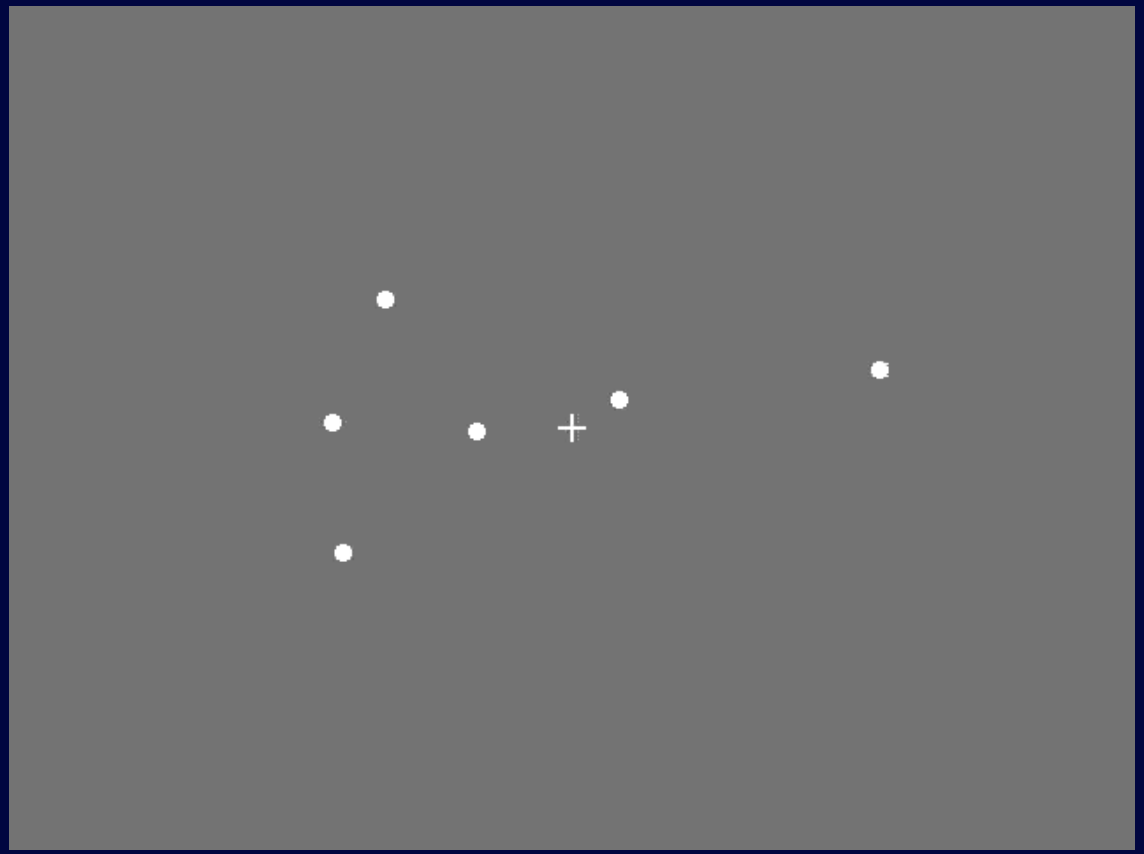


Controlled Stimulus

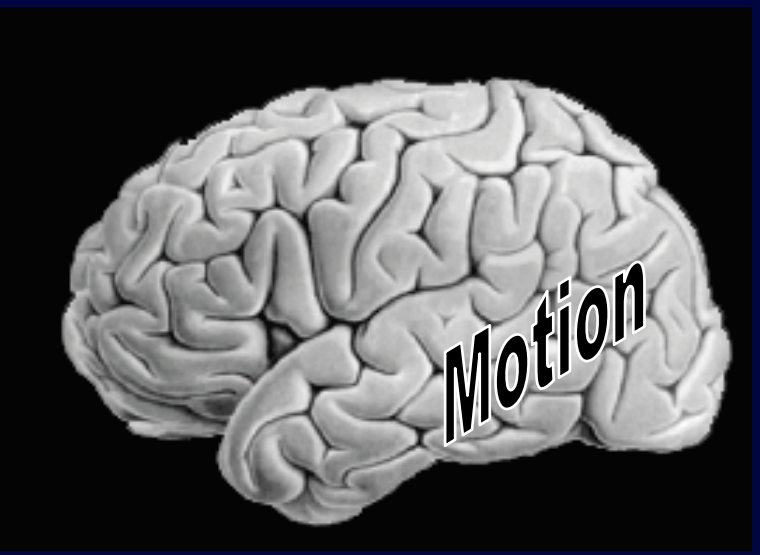


Sample Tool Stimulus





Motion properties hypothesis



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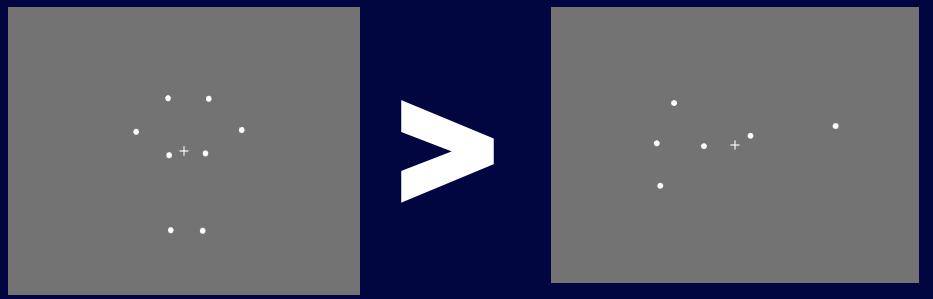
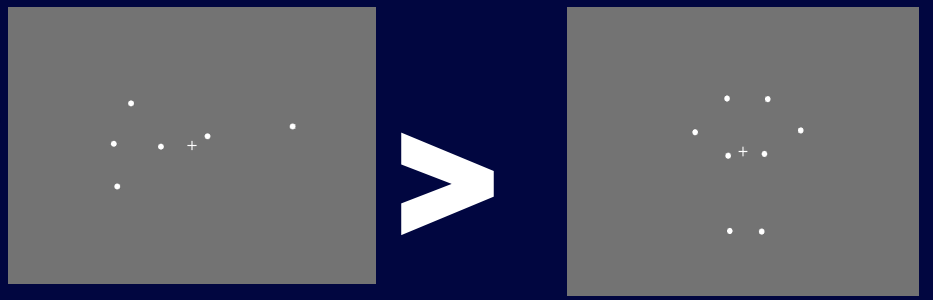


MTG



STS Response

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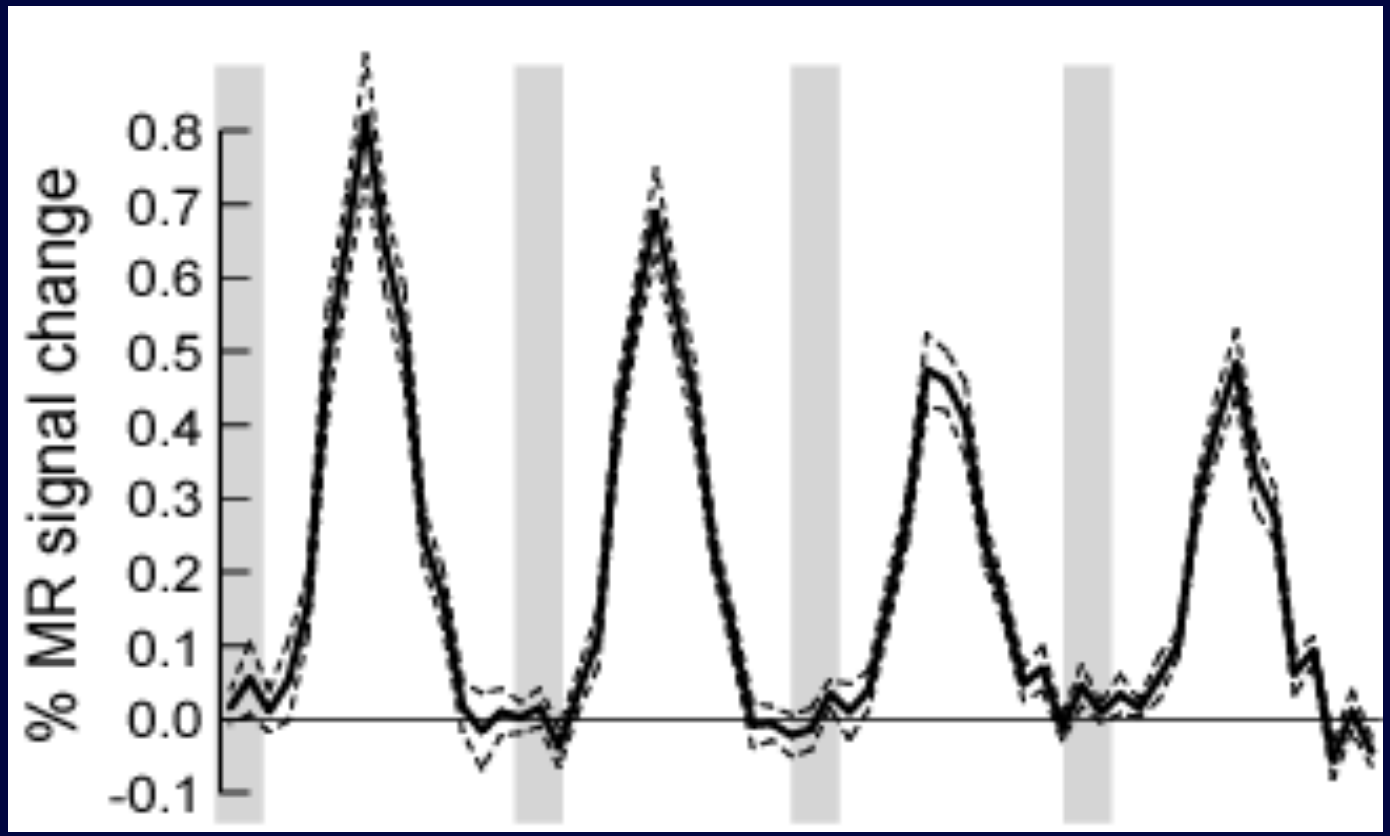
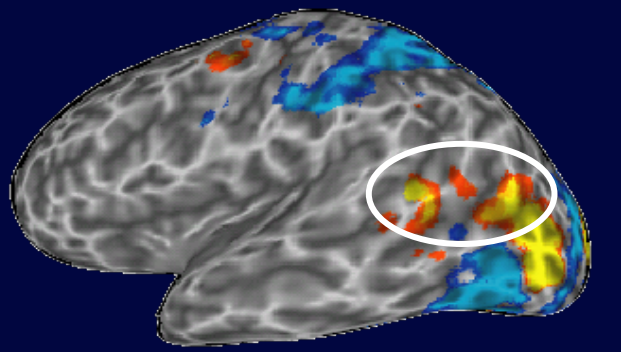
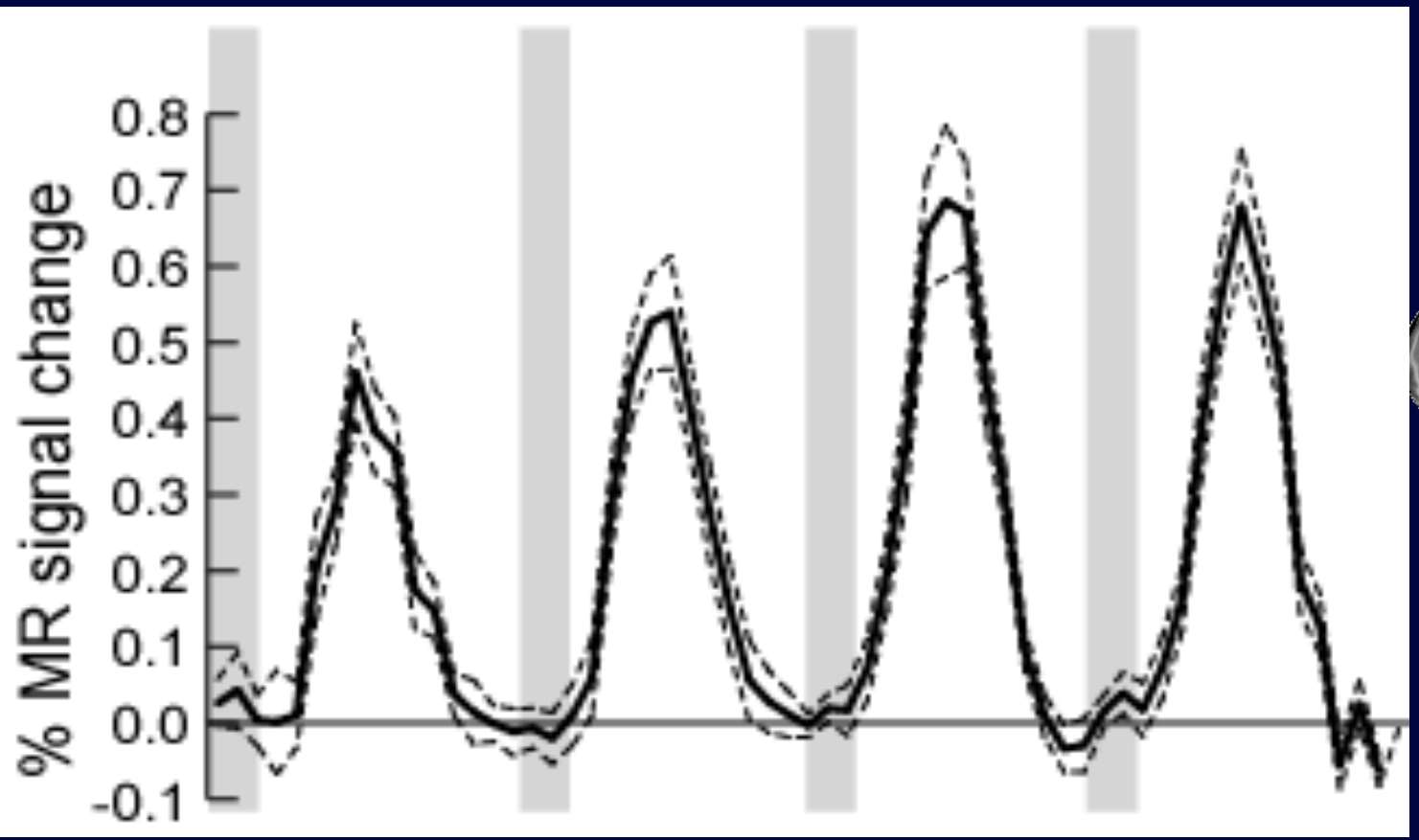
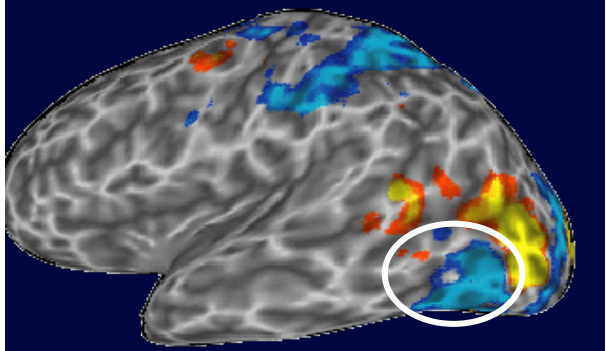


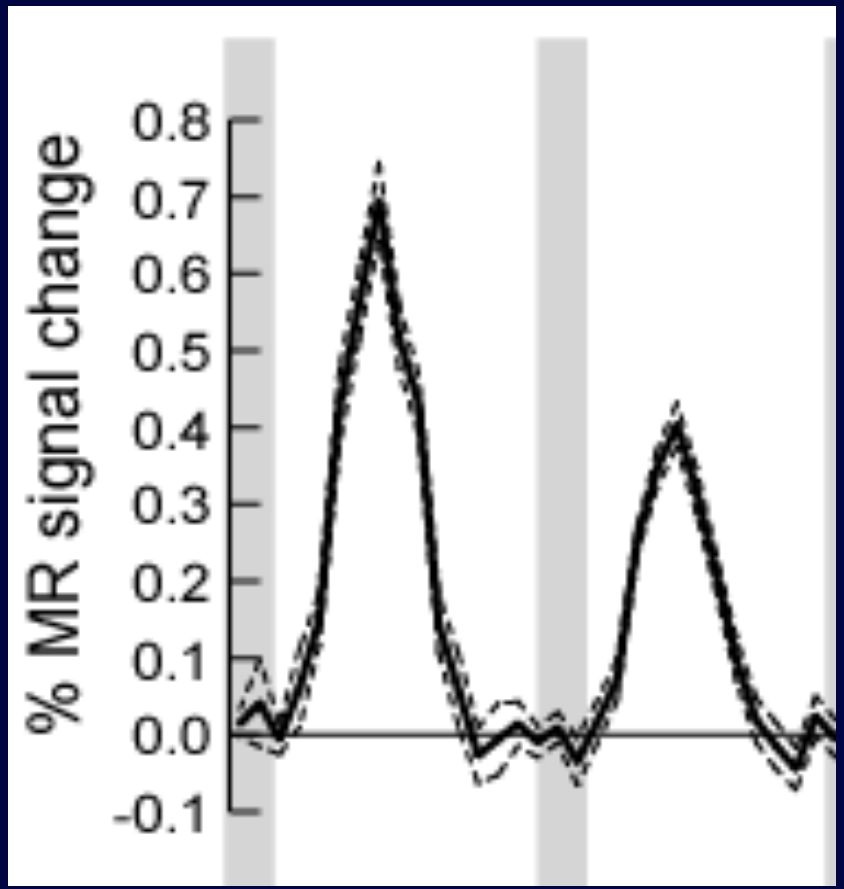


MTG Response





Ventral Temporal Response



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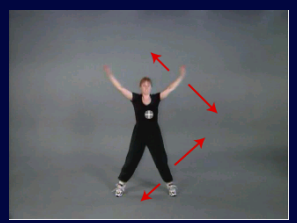
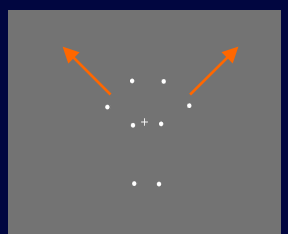
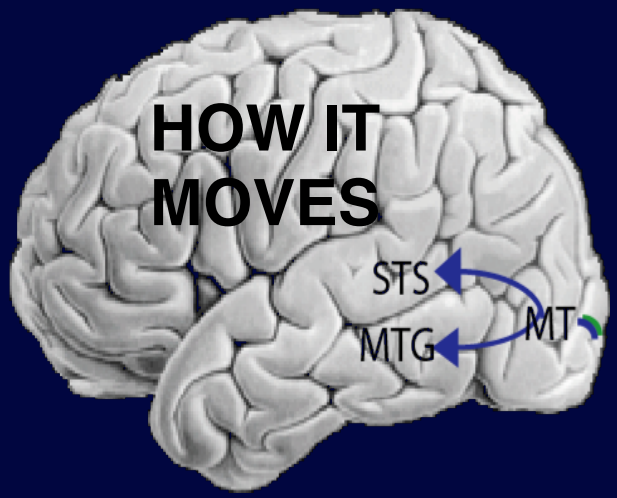
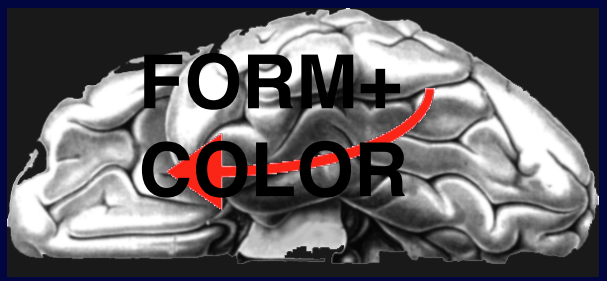
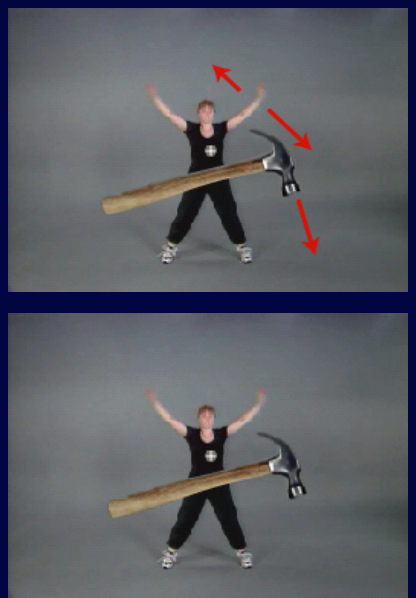
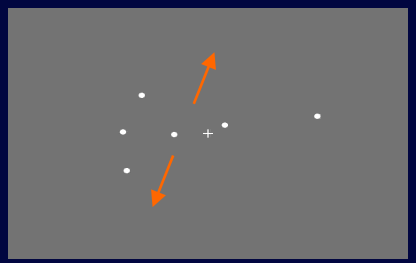




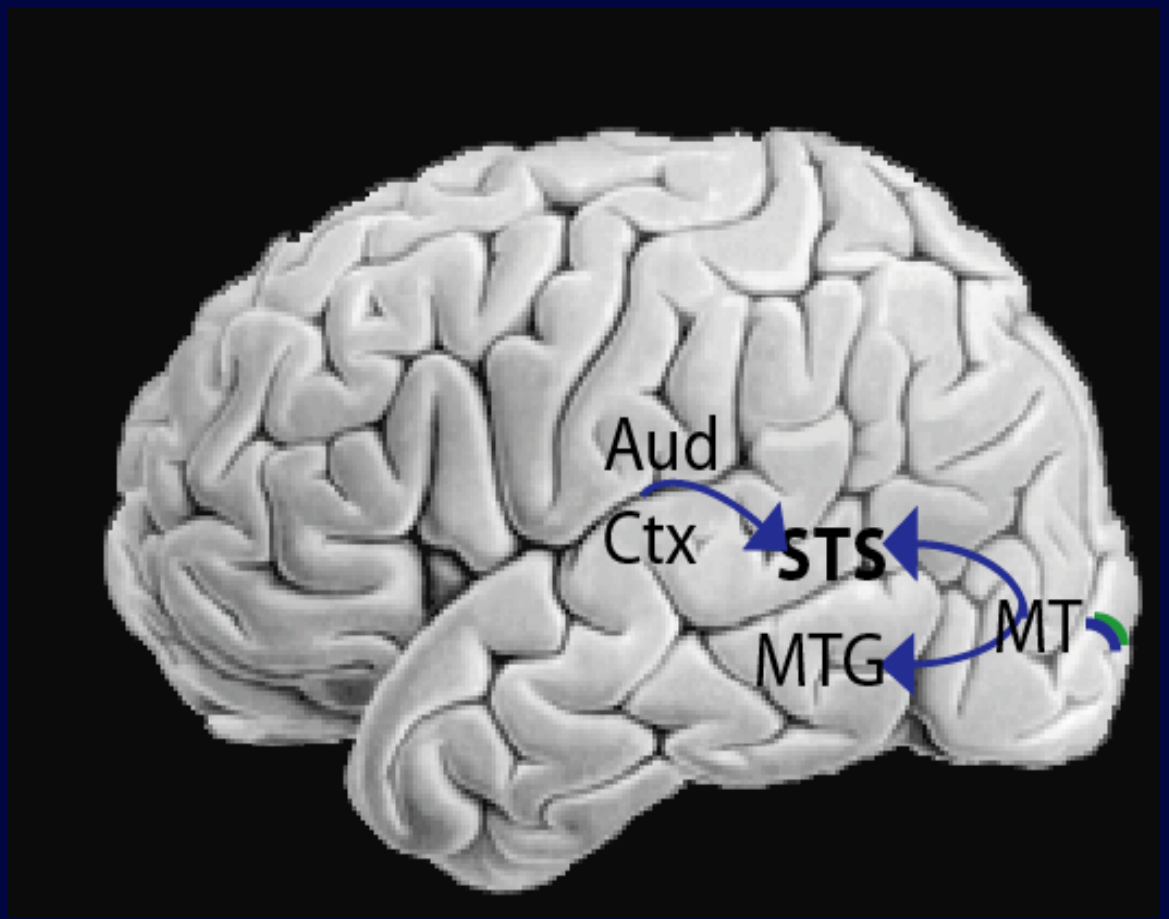

HOW IT
MOVES
STS
MT
MTG


FORM+
COLOR





The “How” Pathway: How it sounds

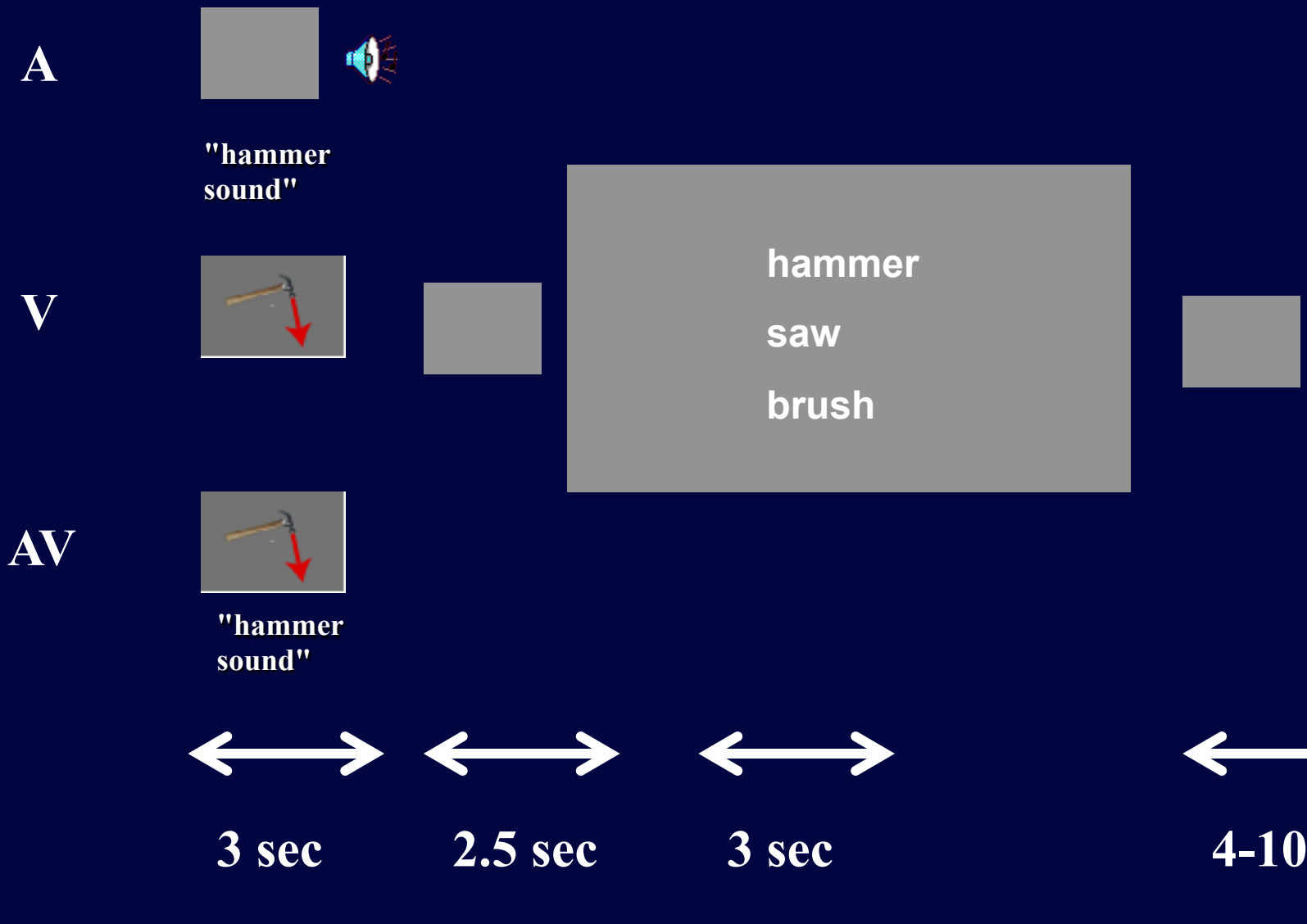


Beauchamp MS *et al. Neuron (in press).*
“Integration of Auditory and Visual Information about Objects in Superior Temporal Sulcus”

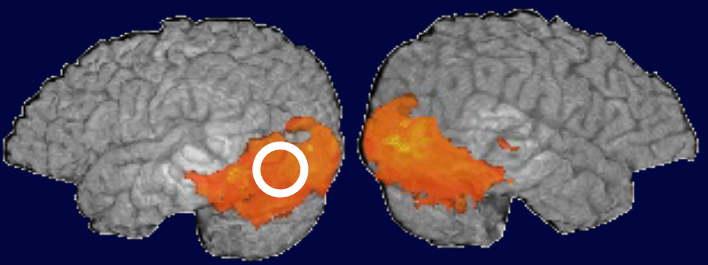
Multimodal responses in human STS: Calvert et al.

Multimodal responses in monkey STP/TPO: Bruce et al., Cusick et al.

Sub-trial design



Visual Activation



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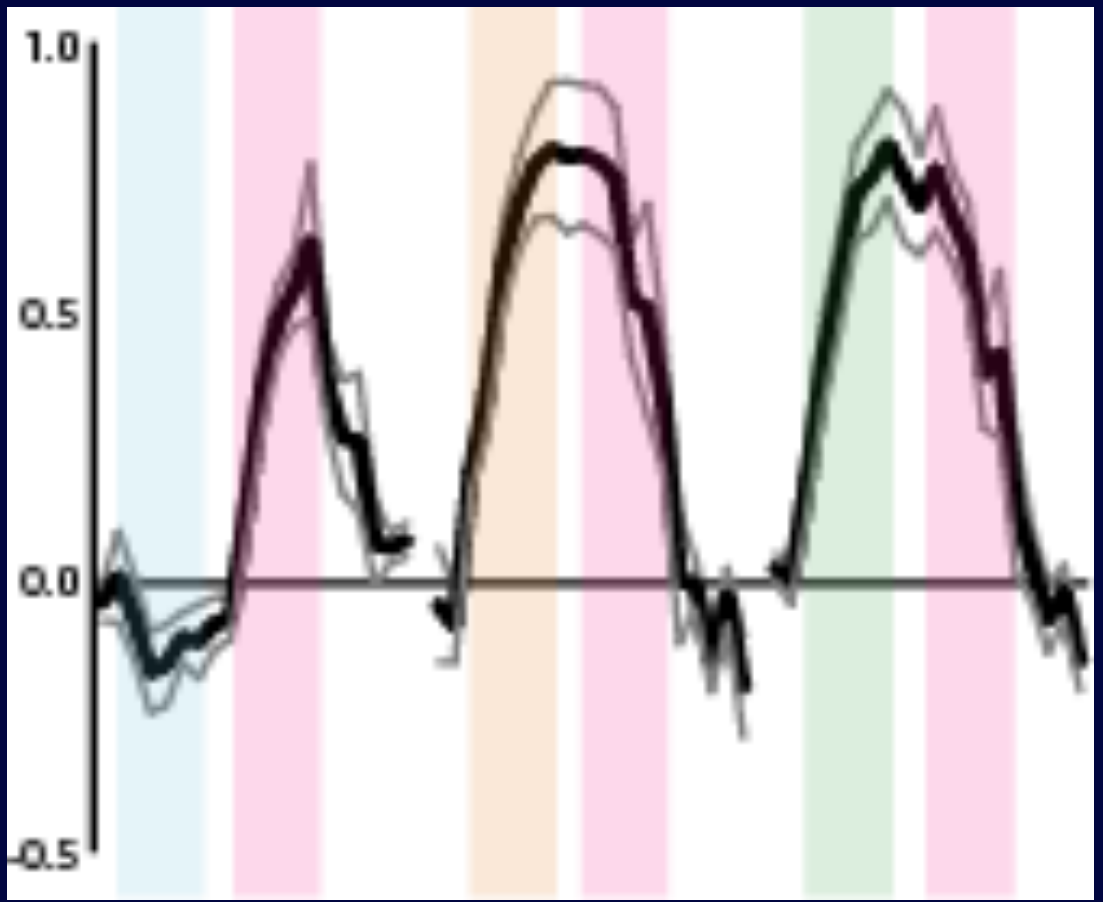
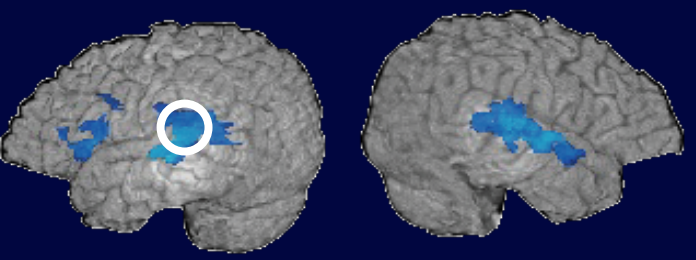


Visual
Auditory
Auditory+Visual
Response

"bang-bang" hammer saw clock

hammer saw clock **"bang-bang"** hammer saw clock

Auditory Activation



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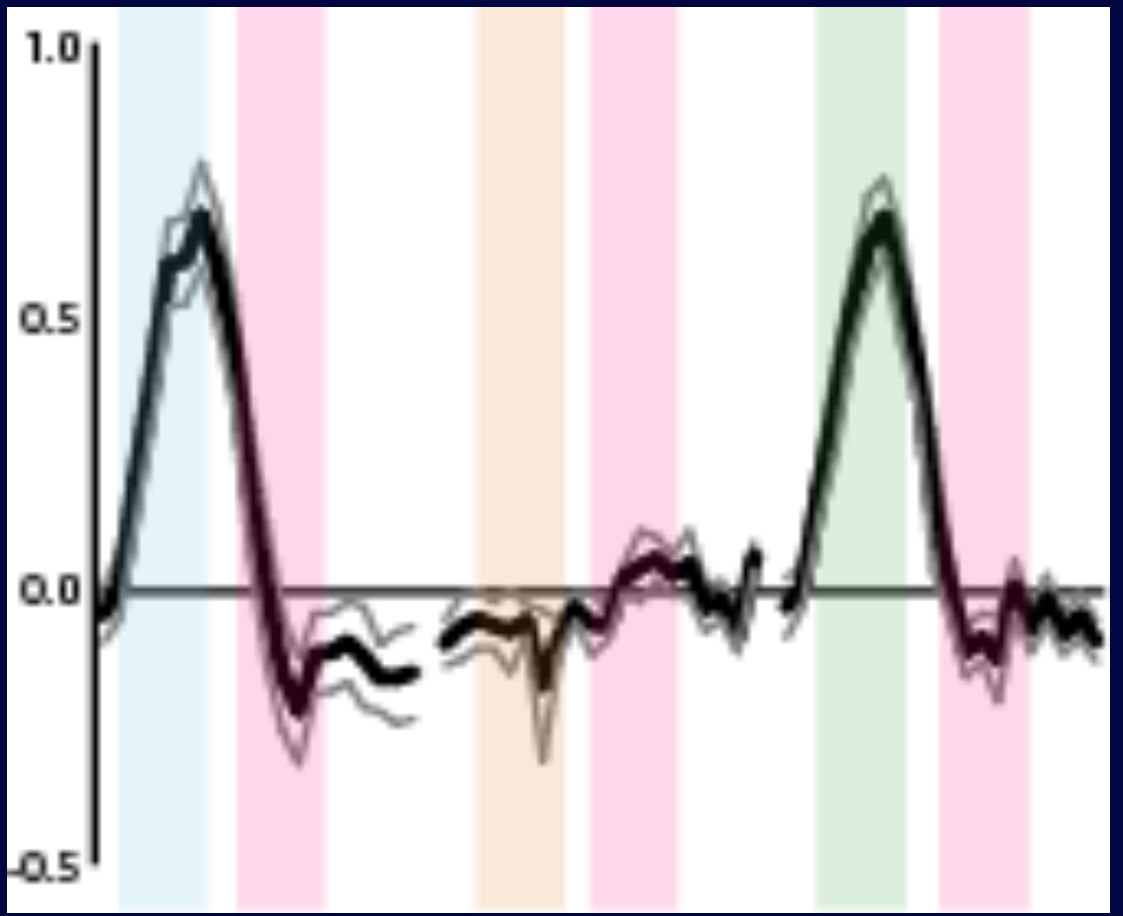


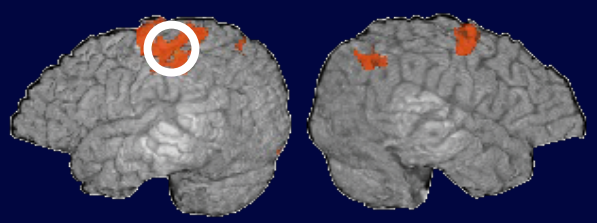
Auditory
Response
Visual
Auditory+Visual

"bang-bang" hammer saw clock

hammer saw clock

"bang-bang" hammer saw clock

Motor Activation



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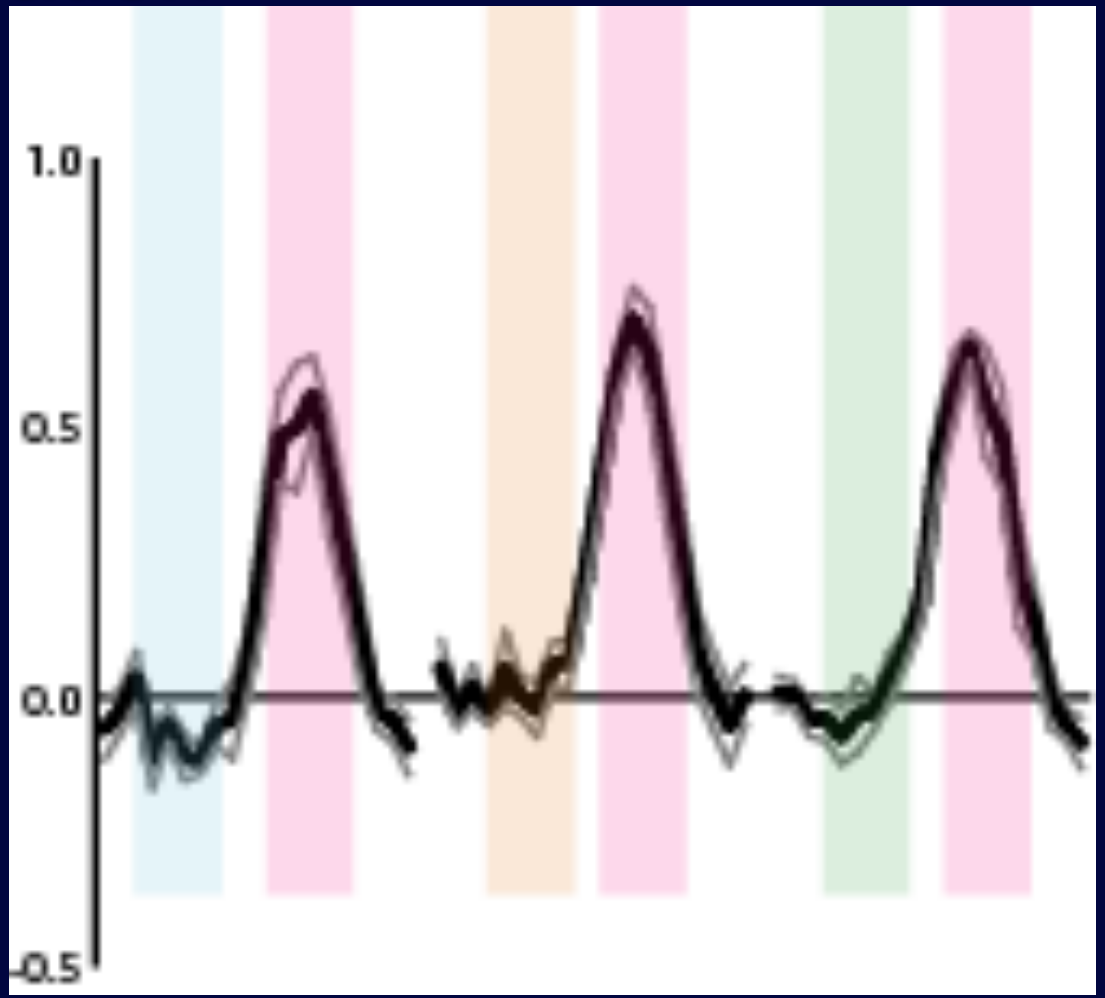


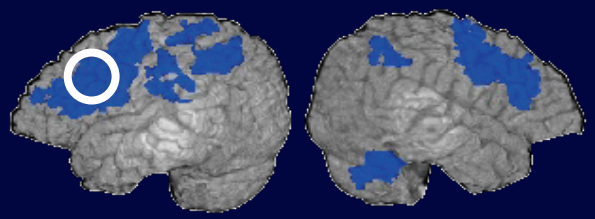
Auditory
Response
Visual
Auditory+Visual

"bang-bang" hammer saw clock

hammer saw clock

"bang-bang" hammer saw clock

General Task Activation



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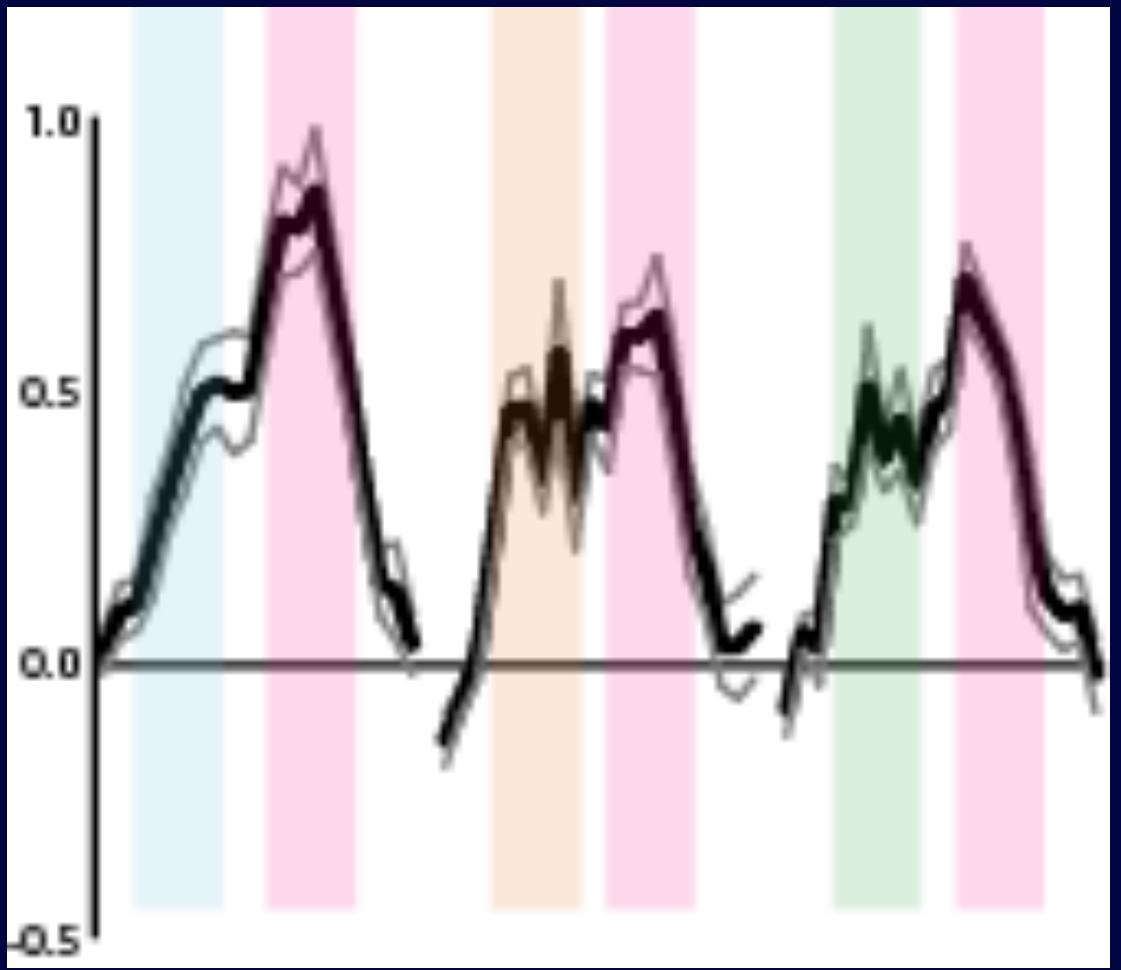


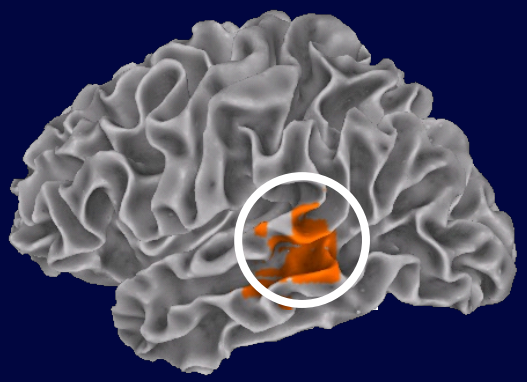
Auditory	
Response	
Visual	
Auditory+Visual	

"bang-bang" hammer saw clock

hammer saw clock

"bang-bang" hammer saw clock

STS Activation



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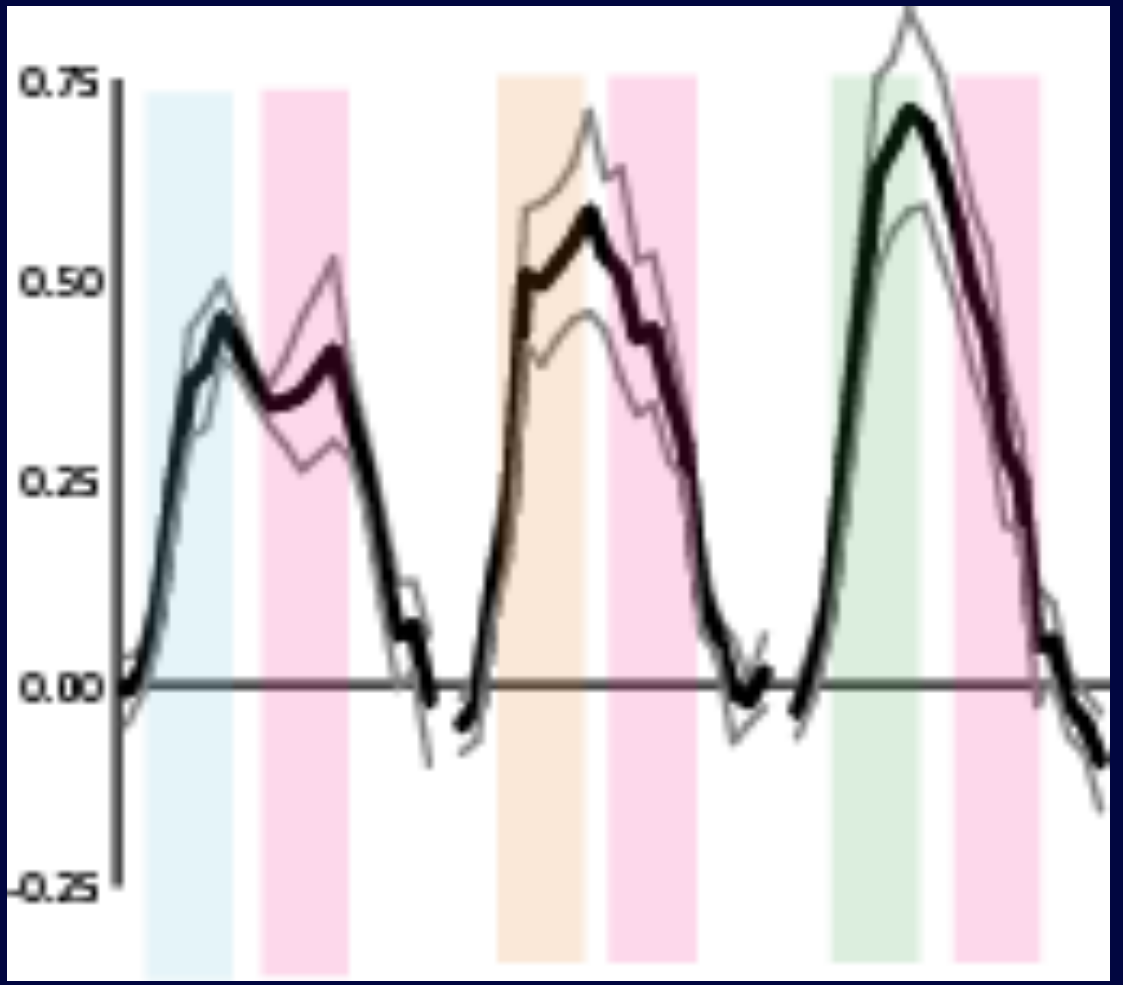


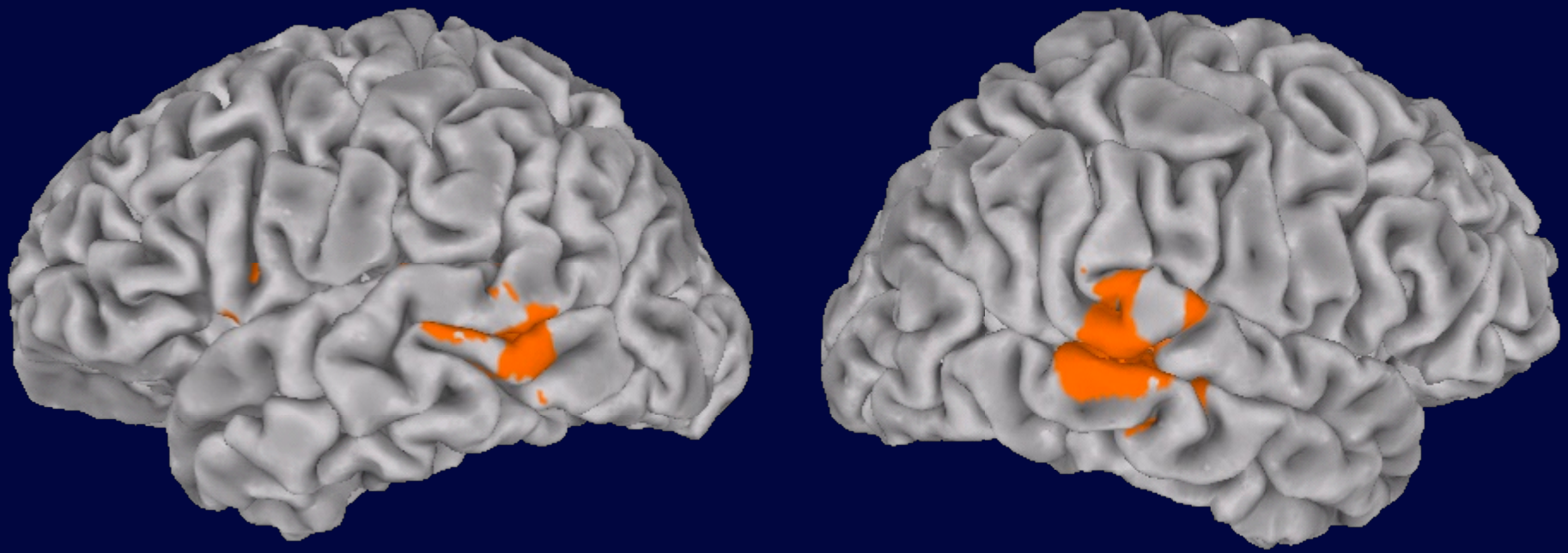
Auditory
Response
Visual
Auditory+Visual

"bang-bang" hammer saw clock

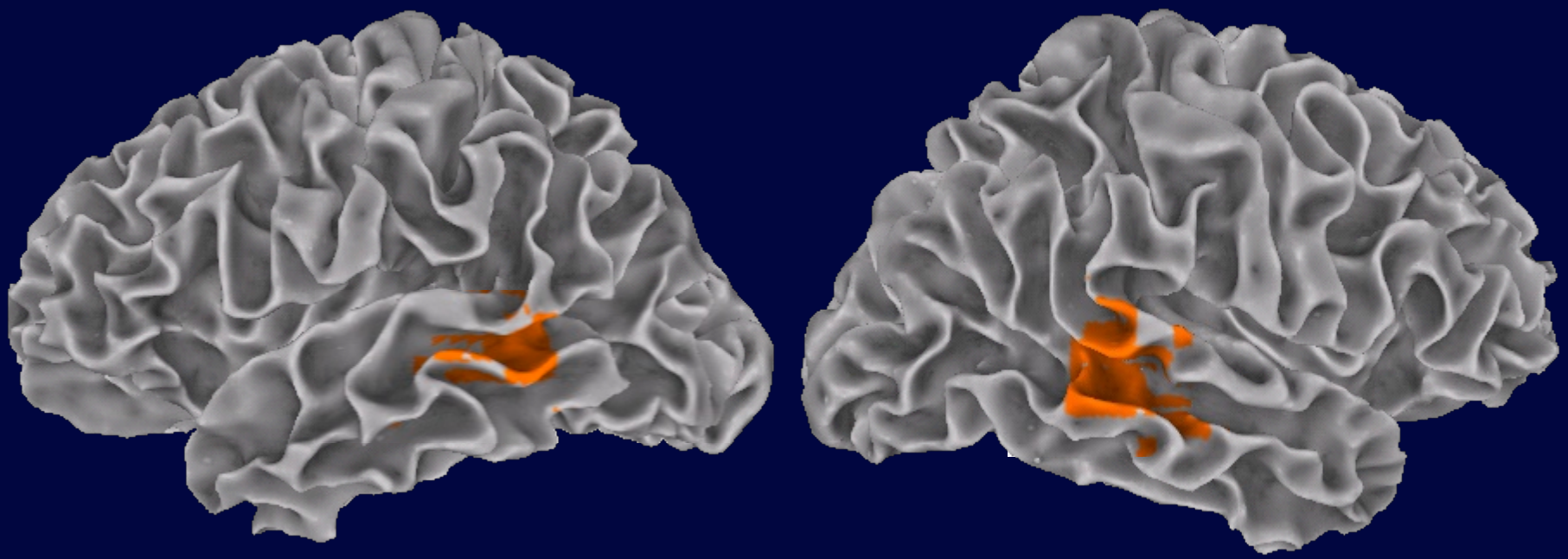
hammer saw clock

"bang-bang" hammer saw clock

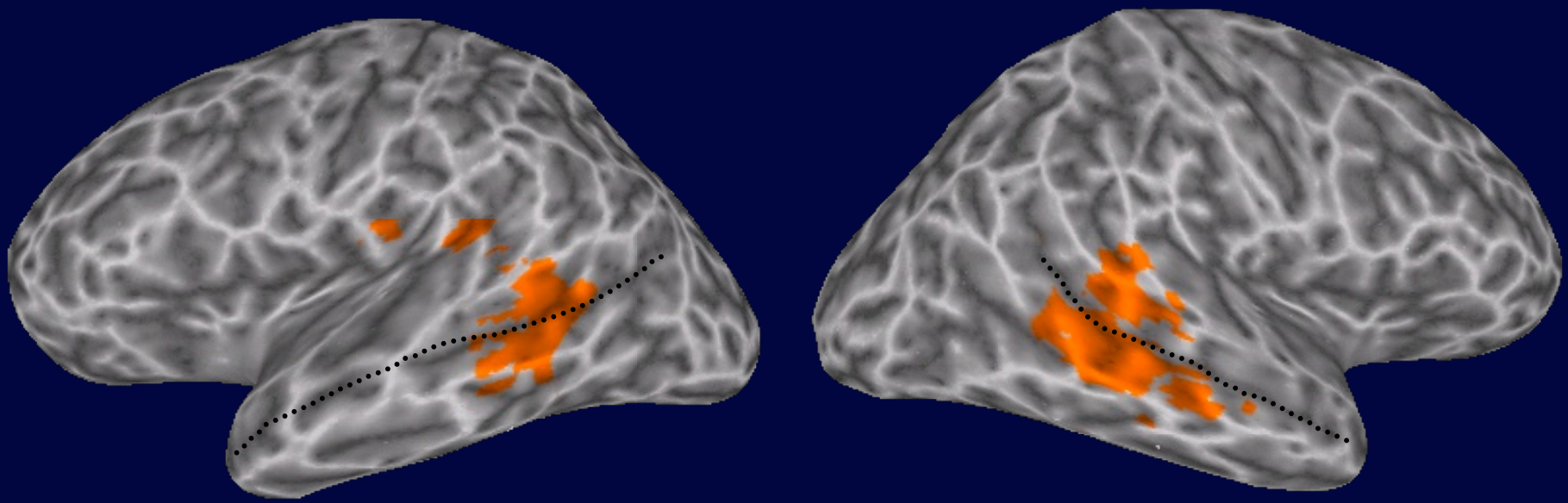
Location of pSTS/MTG Multimodal Region



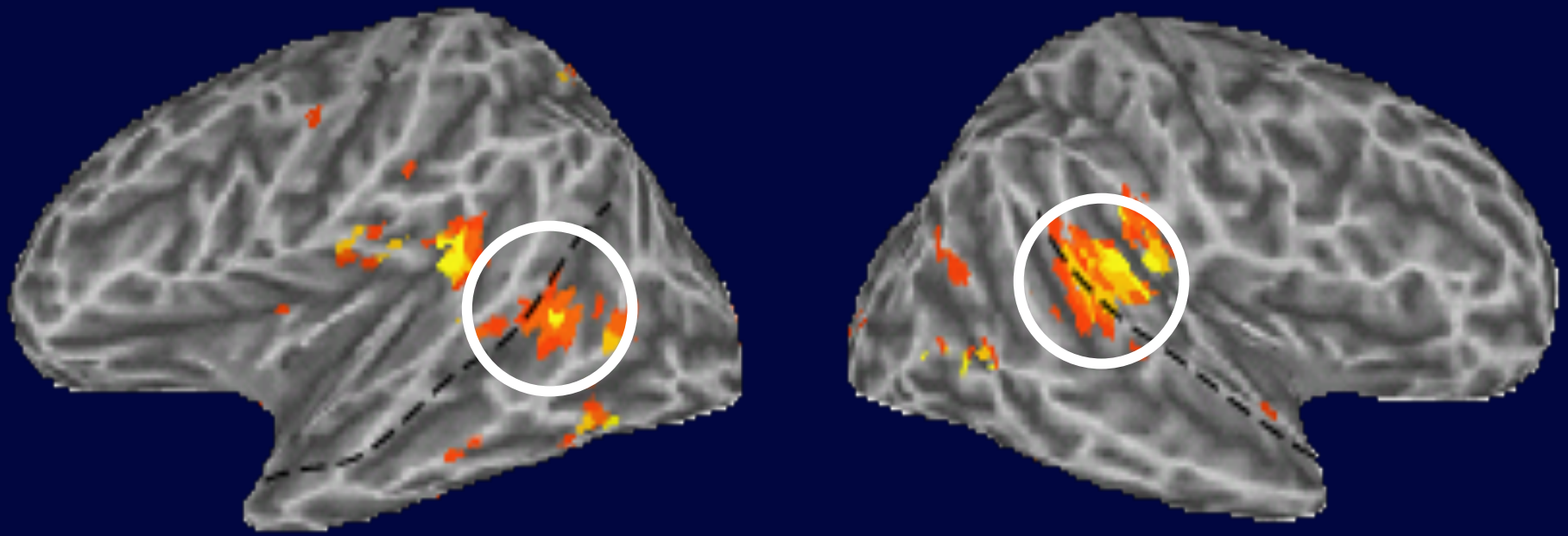
Location of pSTS/MTG Multimodal Region



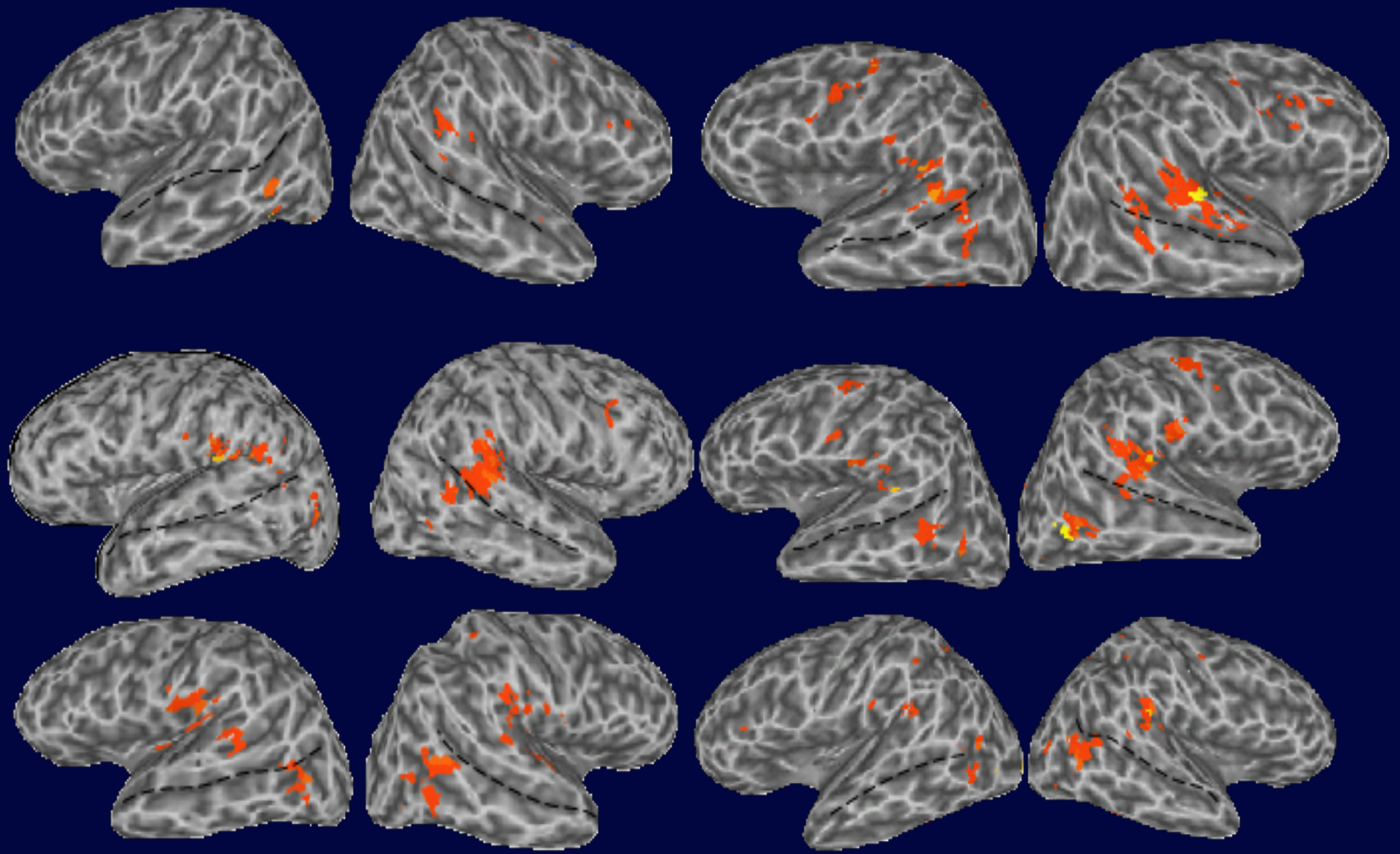
Location of pSTS/MTG Multimodal Region



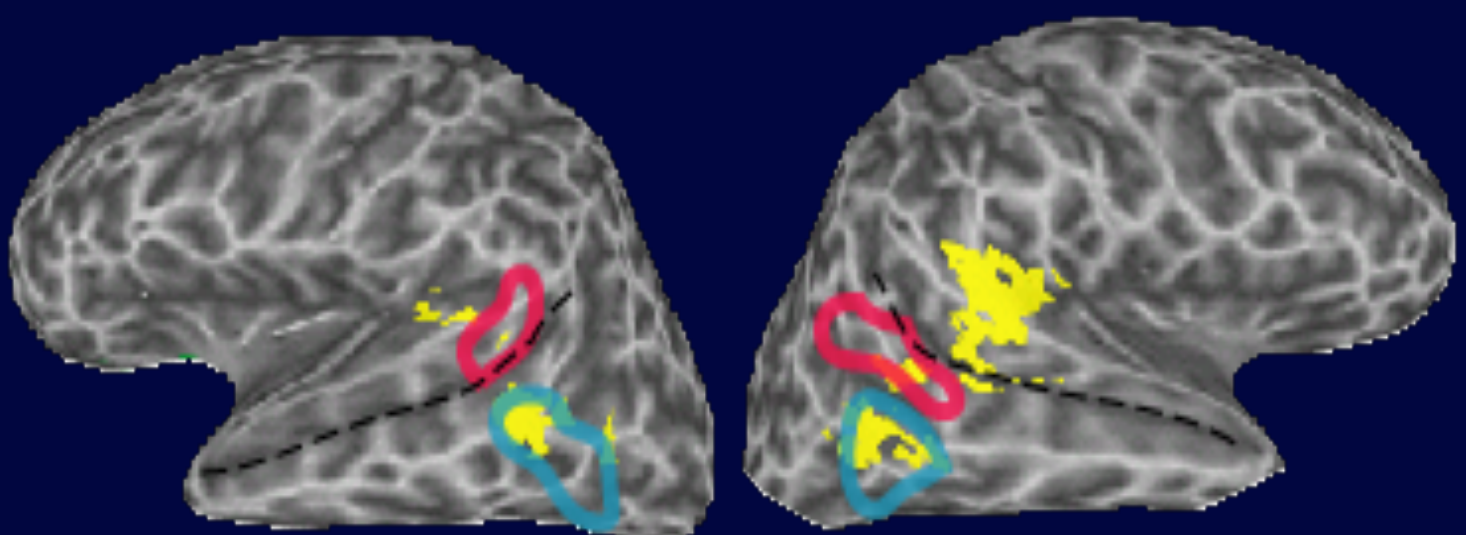
Location of pSTS/MTG Multimodal Region



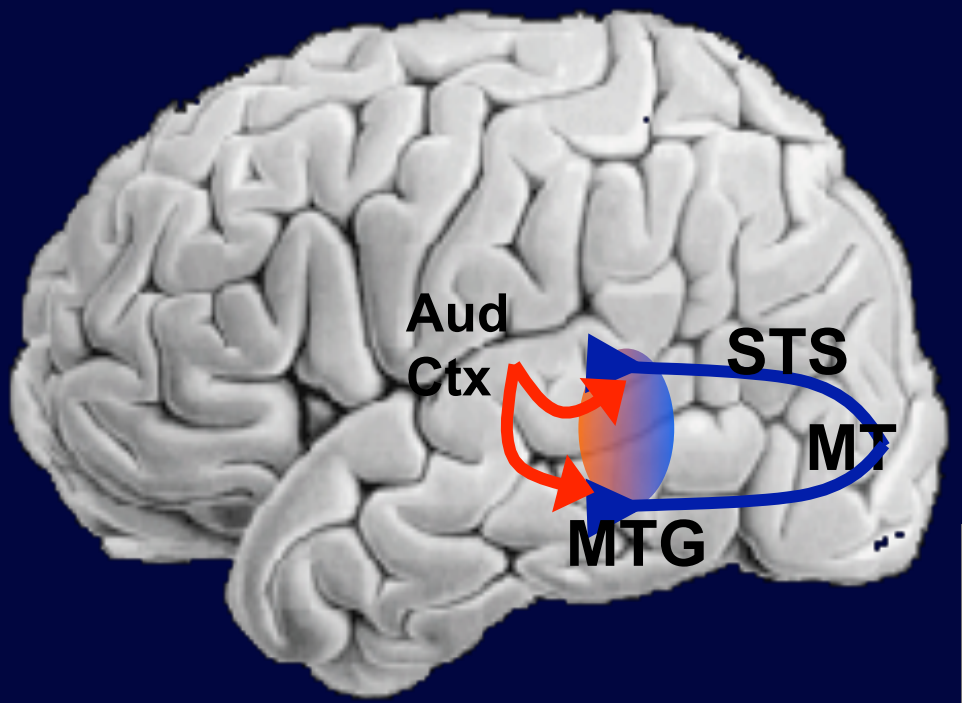
Location of pSTS/MTG Multimodal Region



Relationship to Action/Tool Regions

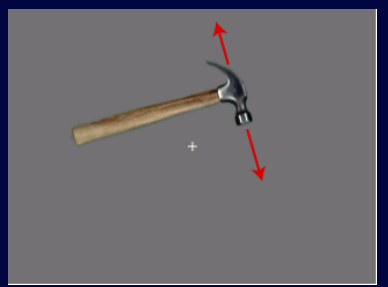


Summary



articulated

unarticulated

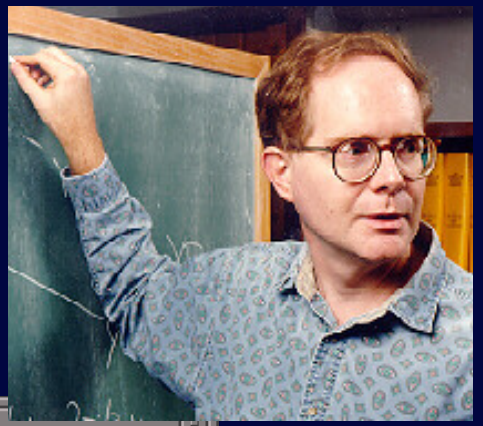


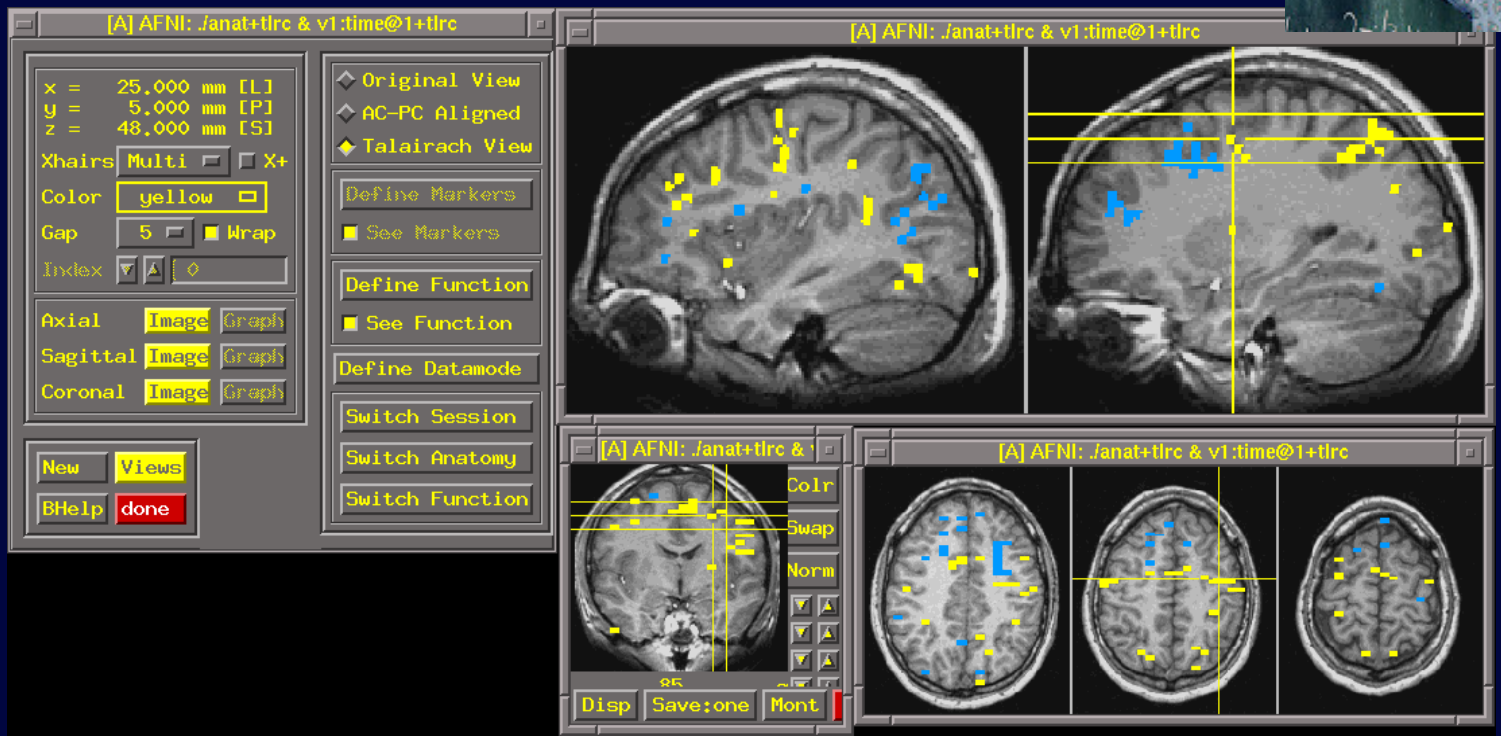
Summary

Data Analysis & Visualization I: AFNI

Analysis of Functional Neuroimages

Robert W. Cox, SSCC, NIMH

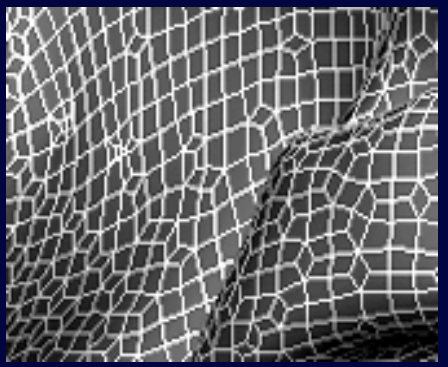


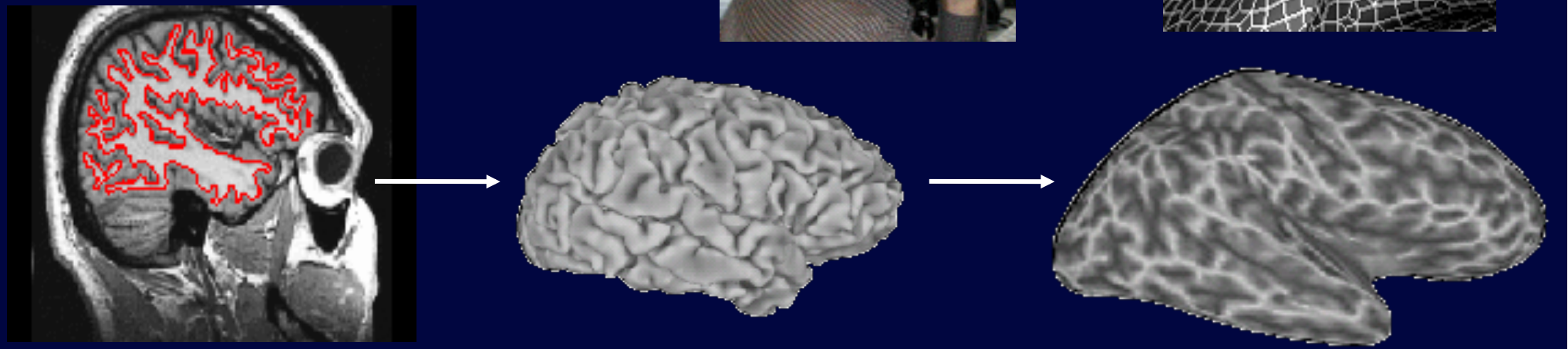


Data Analysis & Visualization II: Cortical Surface Models

SUMA

Ziad Saad, SSCC, NIMH





FreeSurfer—Marty Sereno, Anders Dale, Bruce Fischl

Caret—David Van Essen

Acknowledgements

Alex Martin, Jim Haxby

Brenna Argall, Kathryn Lee

Jerzy Bodurka

+ subjects!