HUMAN Connectome PROJECT

Washington University in St. Louis SCHOOL OF MEDICINE

Task fMRI and Behavioral Measures in HCP

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Human Connectome Project

Washington University in St. Louis
School of Medicine

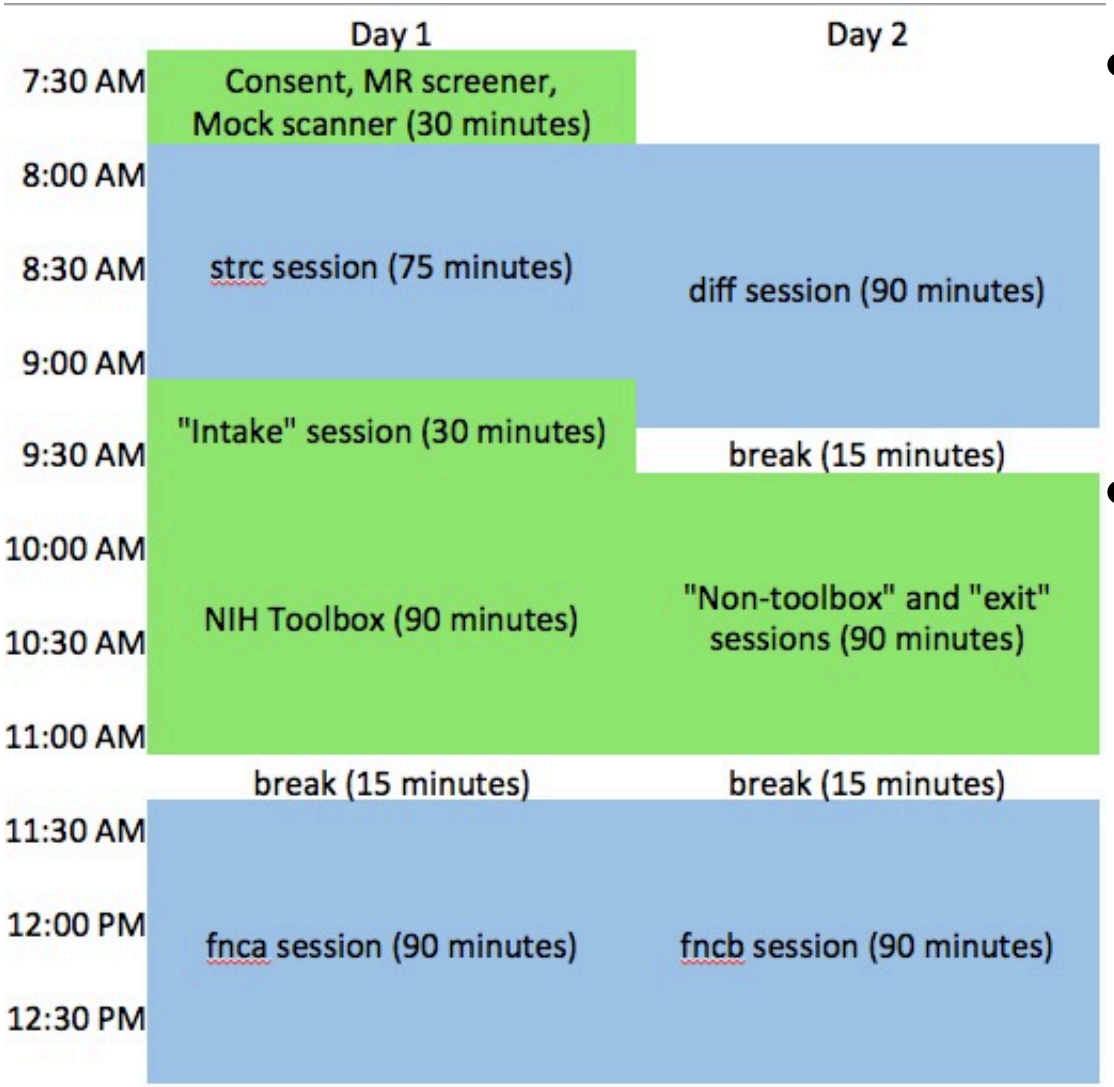
Overview

- Overview of HCP session structure
- Overview of fMRI tasks
  - Rationale for inclusion
  - Task design
  - Regions activated
- Customizing your own task fMRI analyses
- Overview of Behavioral Measures

HCP from the participant's perspective

- Typical participant experience
- Try to adhere to this general order for all participants
  - Reduce variance that might be confounded with individual differences
- Differs for some participants
  - due to scheduling issues:
    - Travel constraints
    - Scanner schedule
    - Three participants
  - data quality:
    - Rescan (xtra) sessions
  - scanner malfunction:
    - short downtime (reboot)
    - long downtime (repairs)

Day 1: participant's perspective

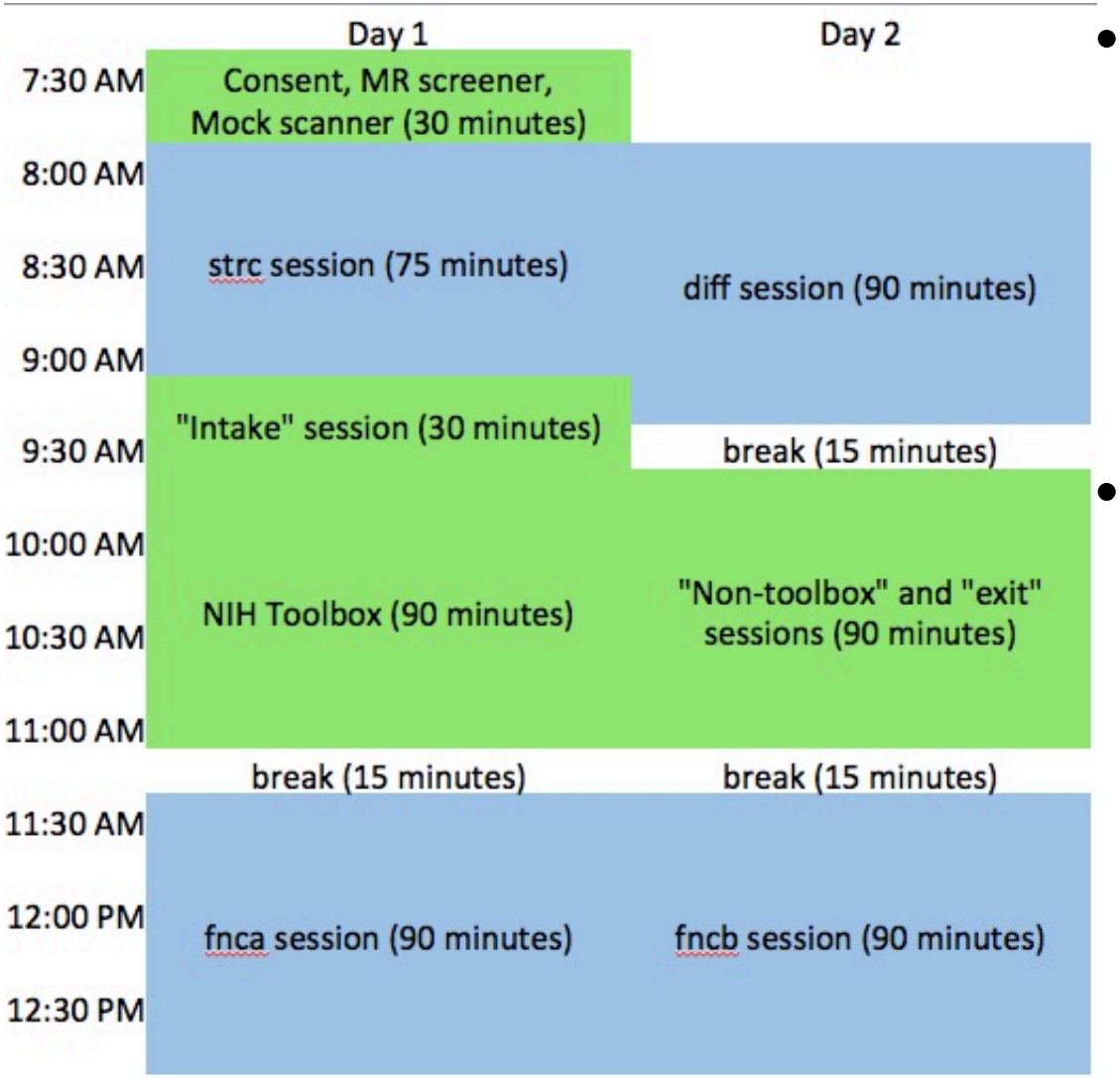


- Consent session
  - Read and sign consent
  - MR safety screen
- Mock scanner session:
  - motion training

Motion training

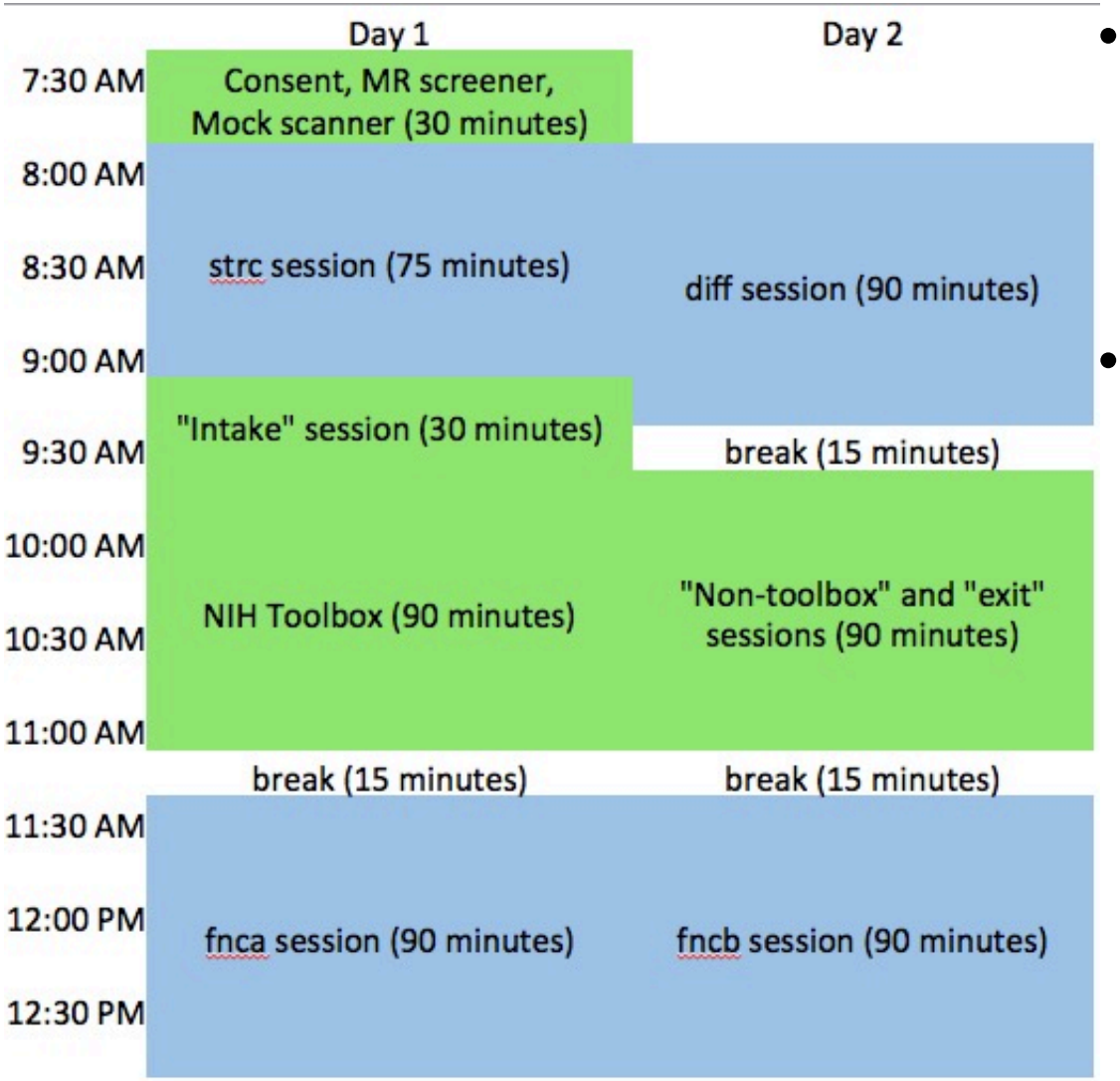
- Attach head tracker to participant's forehead
  - Motion displayed on LCD screen
- Ask them to make common movements
- Ask them to maintain head position for 5 minutes
- Play 5 minute movie (with motion feedback)

Day 1: participant's perspective



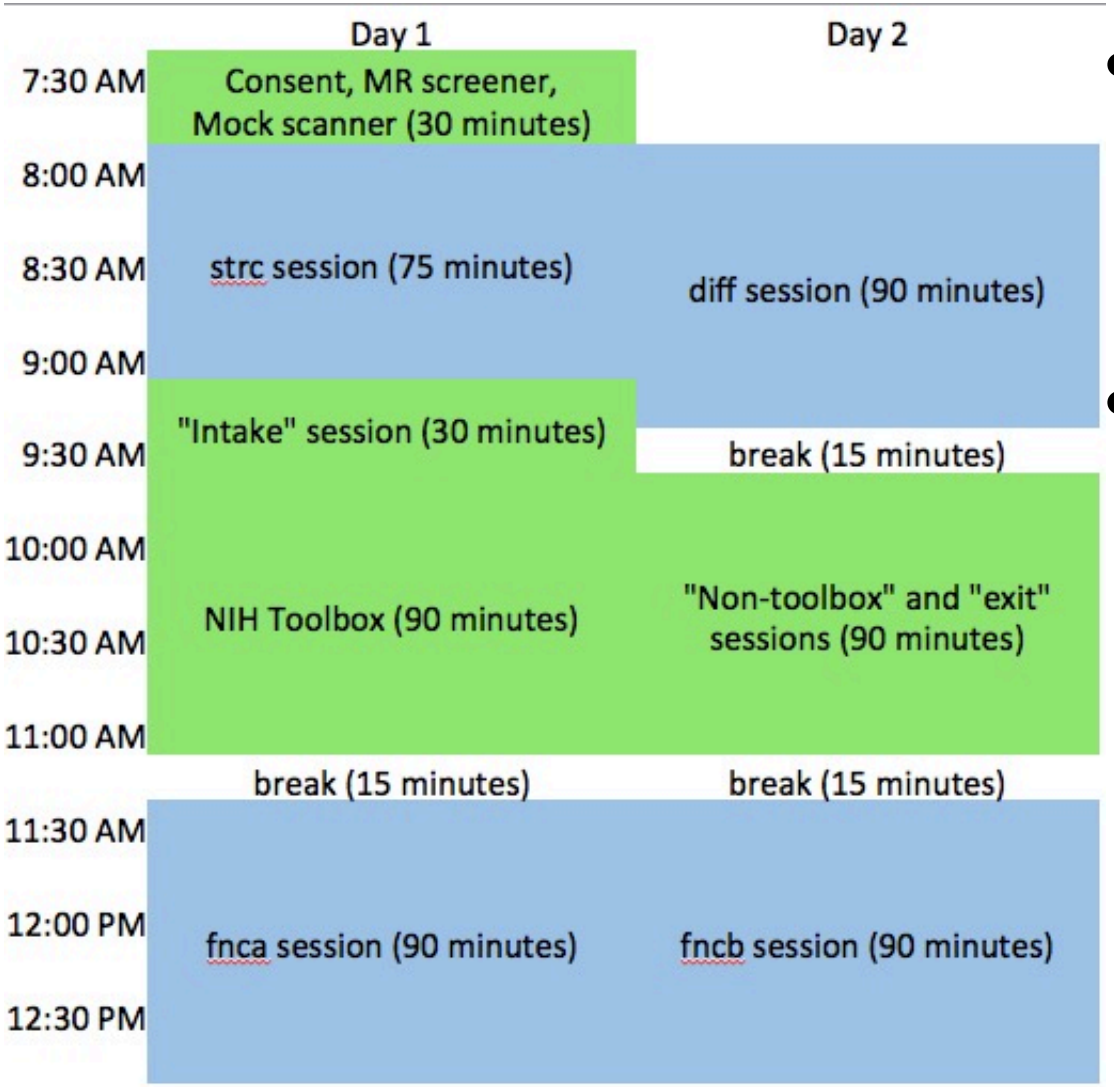
- "strc" session:
  - acclimation to scanner
  - T1w & T2w structural pairs
  - watch movies
    - Reduce anxiety and motion
- "intake" session:
  - alcohol & tobacco retrospective
    - use in previous 7 days
  - Handedness, PSQI, etc.
  - drug screen (urine)

Day 1: participant's perspective



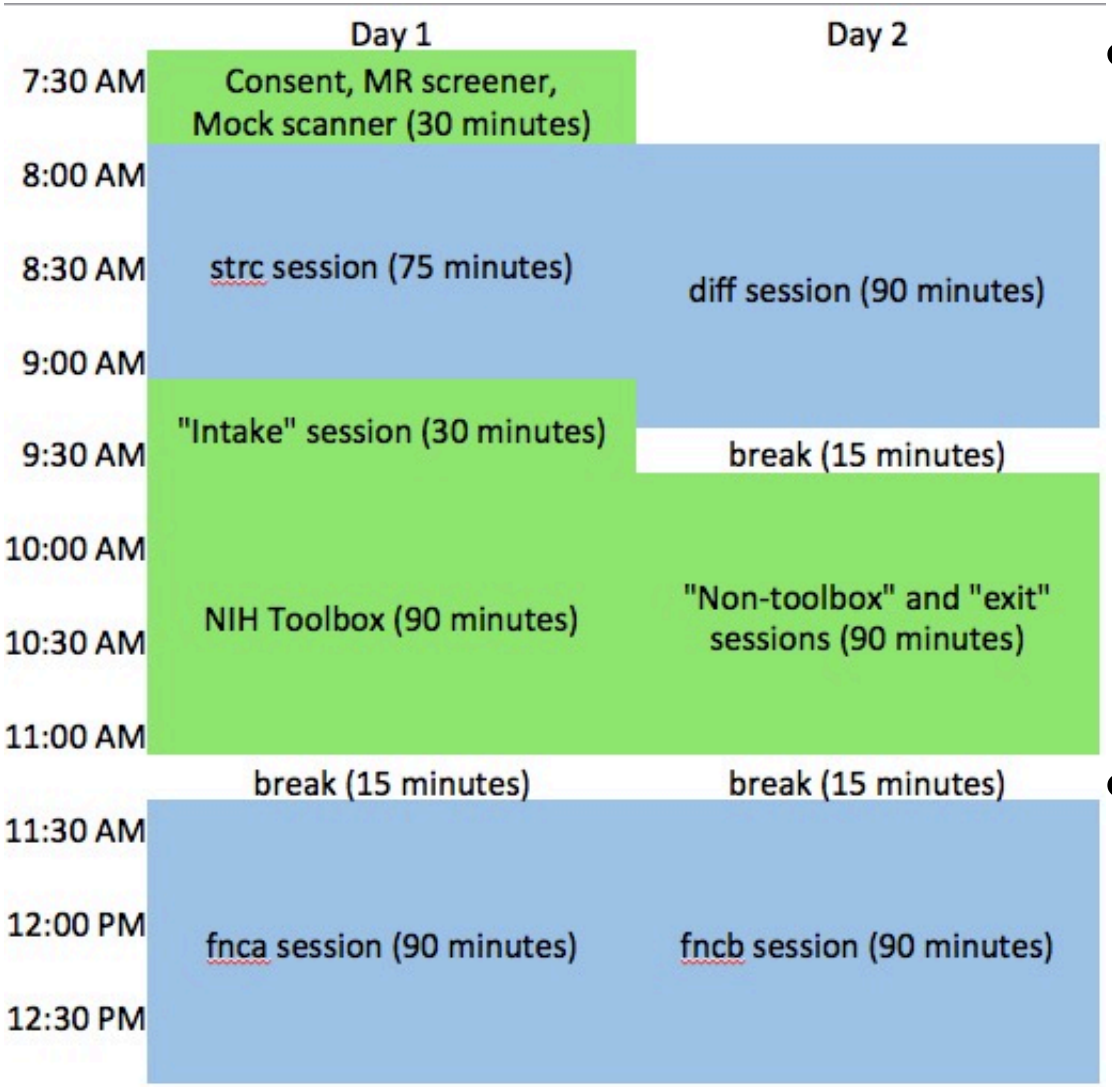
- NIH Toolbox session
  - Cognition
  - Emotion
  - Motor
  - Sensory
- "fnca" session:
  - Practice tasks:
    - immediately before session
    - outside of scanner
  - 30 min resting state
    - always before task
  - WM, GAMBLING, MOTOR
  - Surprise RECognition task (outside of scanner)

Day 2: participant's perspective



- "diff" session:
  - 3 pairs of dMRI
  - watch movies
- non-toolbox:
  - Penn CNB
  - Delay Discounting
  - NEO-FFI
  - Achenbach Adult Self-Report

Day 2: participant's perspective



- fncb:
  - practice outside of scanner
  - resting state first
  - Task: LANGUAGE, RELATIONAL, SOCIAL, EMOTION
- "exit" interview:
  - Satisfaction survey
  - Drug screen

Imaging Tasks: Selecting Appropriate Tasks

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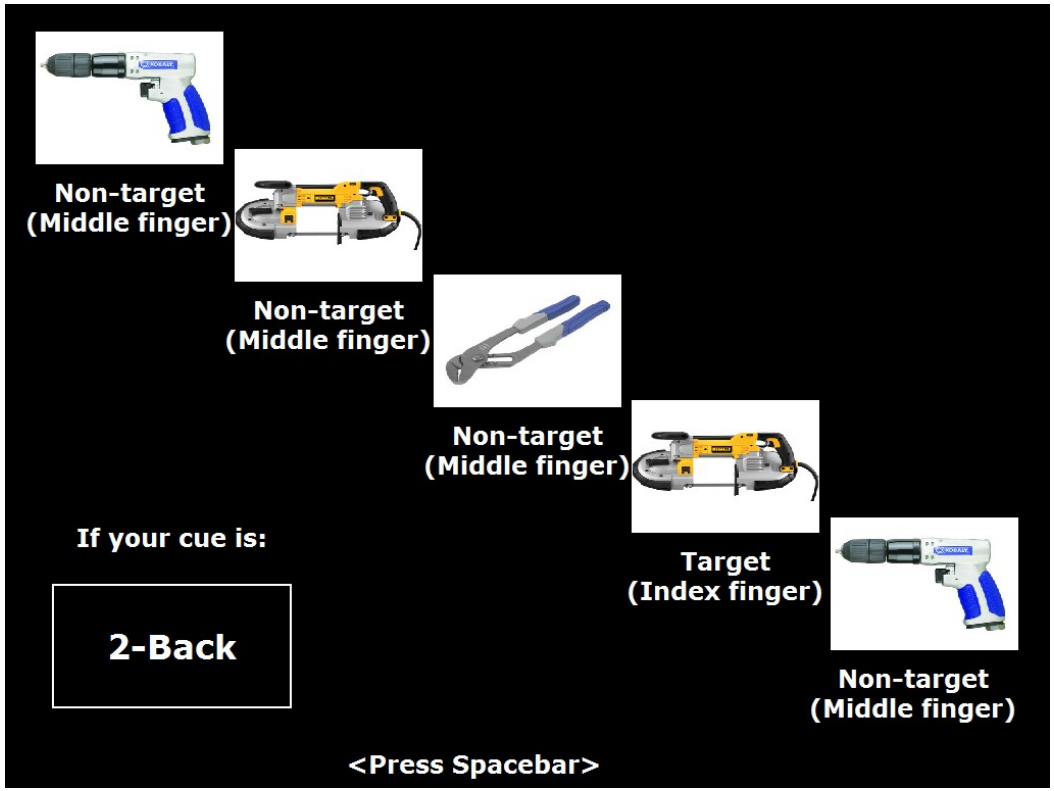
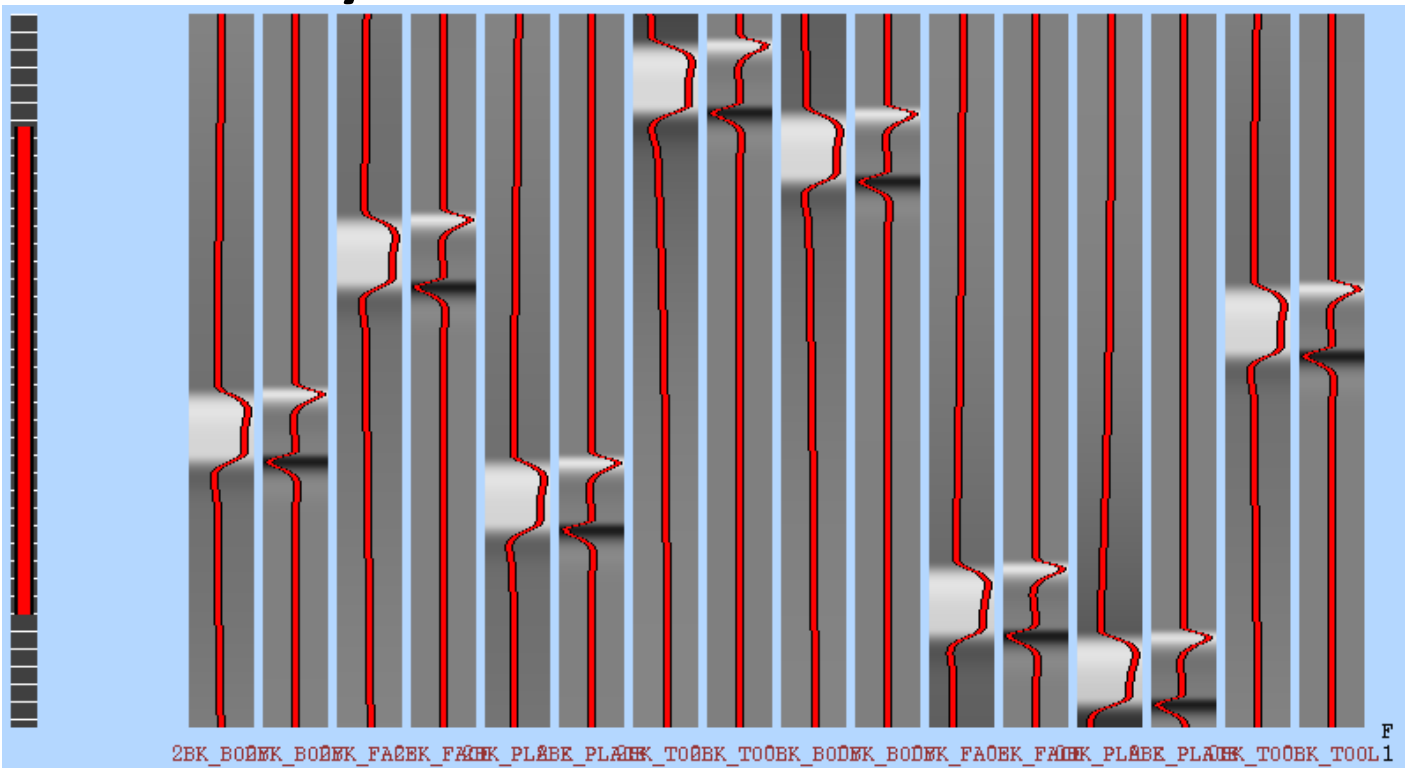
- Goals for selecting tasks:
  - Broad range of cognitive and affective processes
  - As wide a range of neural systems as possible
  - Well-characterized neural systems
  - Activation reliable over time in individual subjects
  - Activation detectable in most individuals

Imaging Task: WM



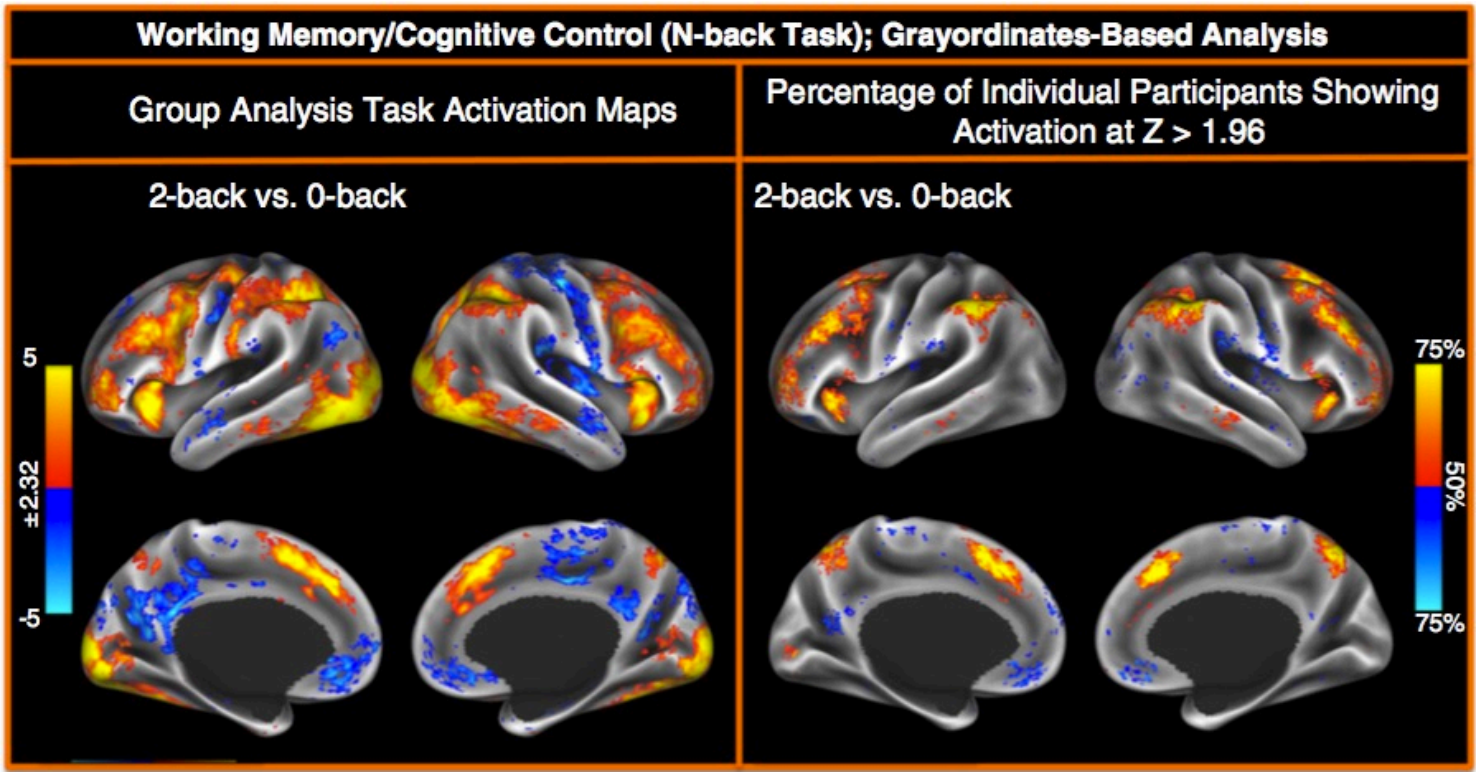
- N-back task
  - 2-back, 0-back
- Embedded category specific representation task
  - FACE, PLACE, BODY, and TOOLS
- Total of 8 task blocks per scan run

Imaging Task: WM
Sensitivity to individual conditions



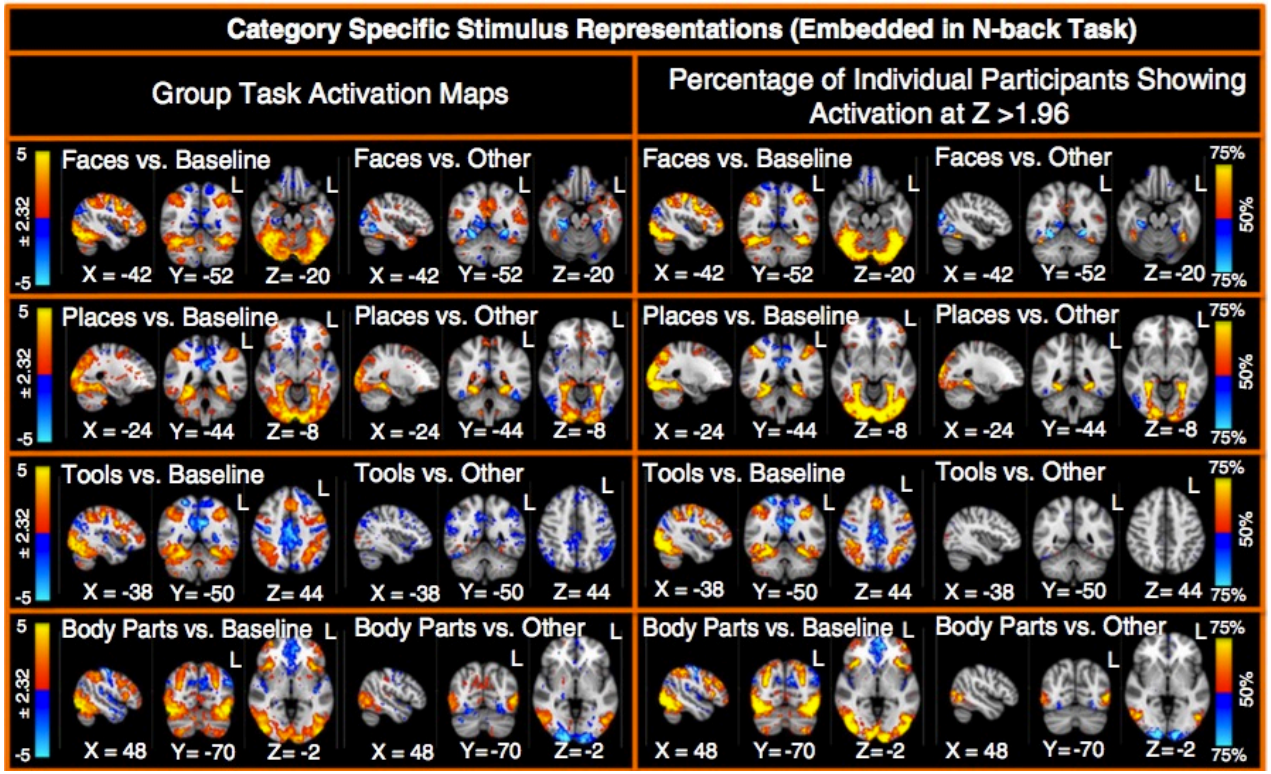
- Primary contrasts were averages of multiple blocks
  - 2BK, 2BK-0BK
  - FACES-AVG; PLACES-AVG
- Individual condition have lower sensitivity
  - Only seen once in each scan run
  - Can be confounded with linear trend
    - For this scan: 2BK_TOOL; 0BK_PLACE

Imaging Task: WM



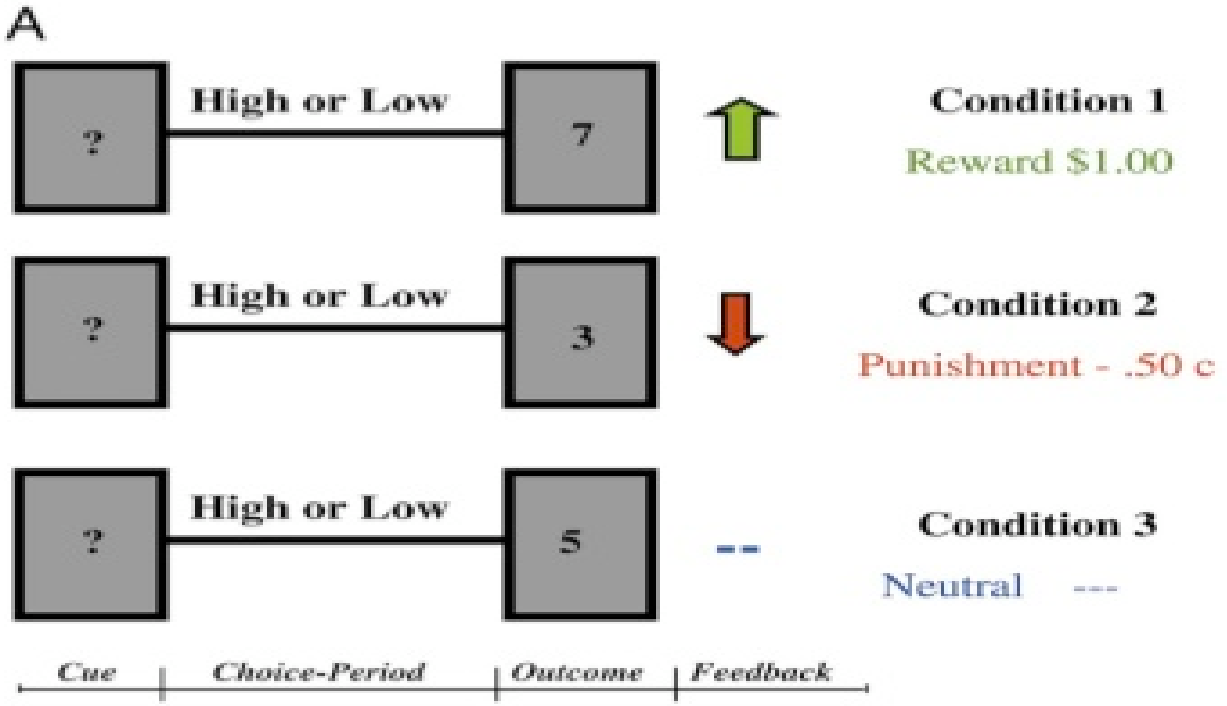
- WM activation:
  - Dorsolateral + anterior prefrontal; inferior frontal; precentral gyrus; anterior cingulate; dorsal parietal

Imaging Task: WM



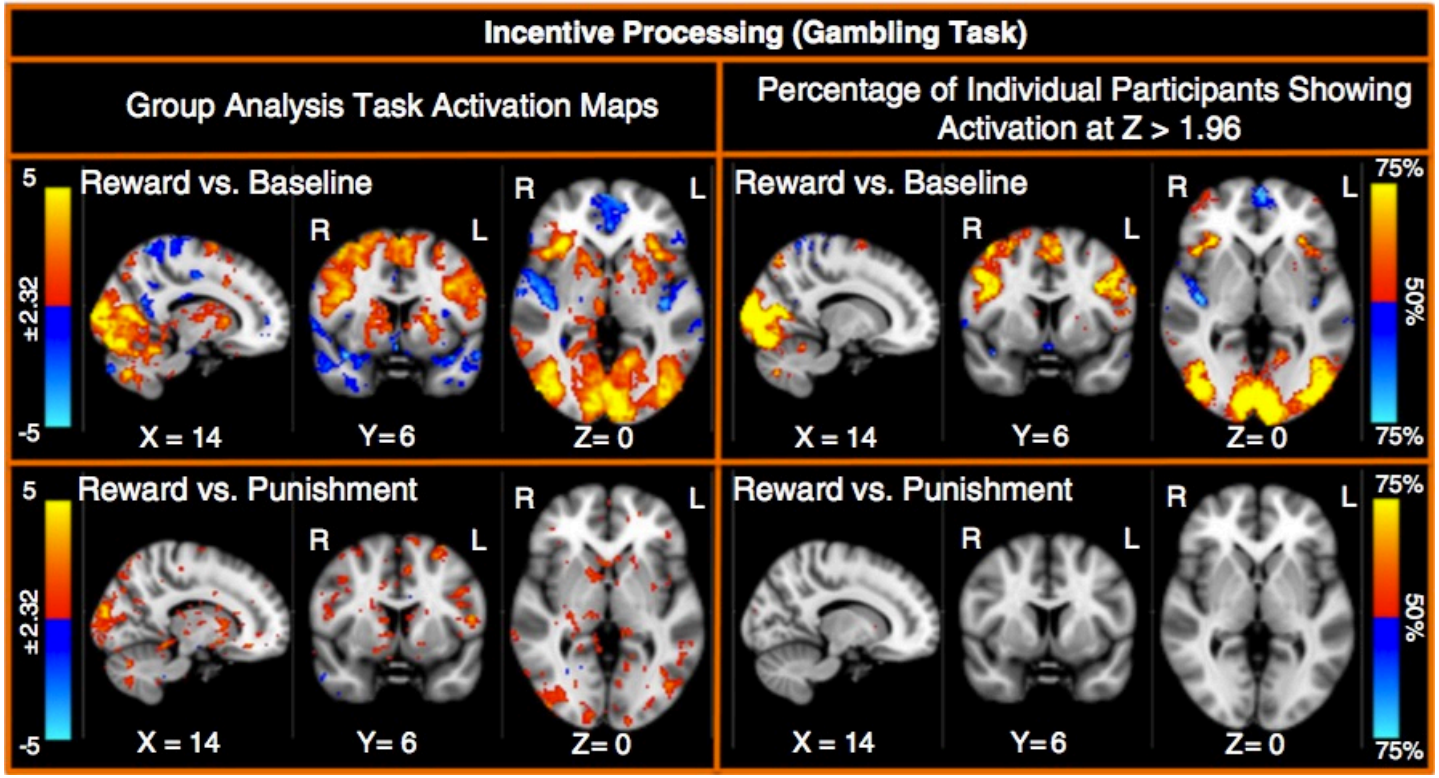
- Category-specific representations:
  - FACES-AVG: Fusiform face area, occipital face areas
  - PLACES-AVG: Parahippocampal gyrus
  - BODY-AVG: Extrastriate body area
  - TOOLS-AVG: Posterior parietal lobe

Imaging Task: GAMBLING



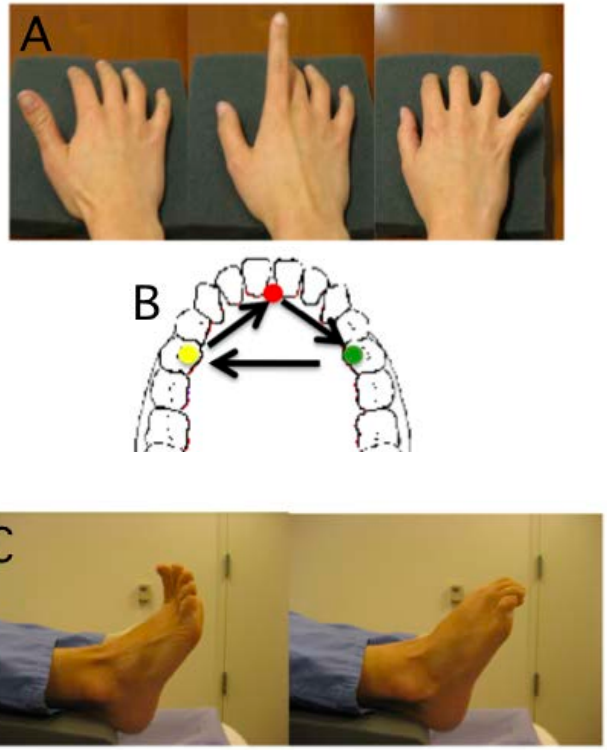
- Modeled after Delgado et al. (2000)
  - High-low game; get money at end of scan session
- Blocks of mostly reward or mostly loss trials
  - 4 blocks per run
  - 8 trials in each block: 6 matching block type and 2 not matching
  - Keep participants naïve

Imaging Task: GAMBLING



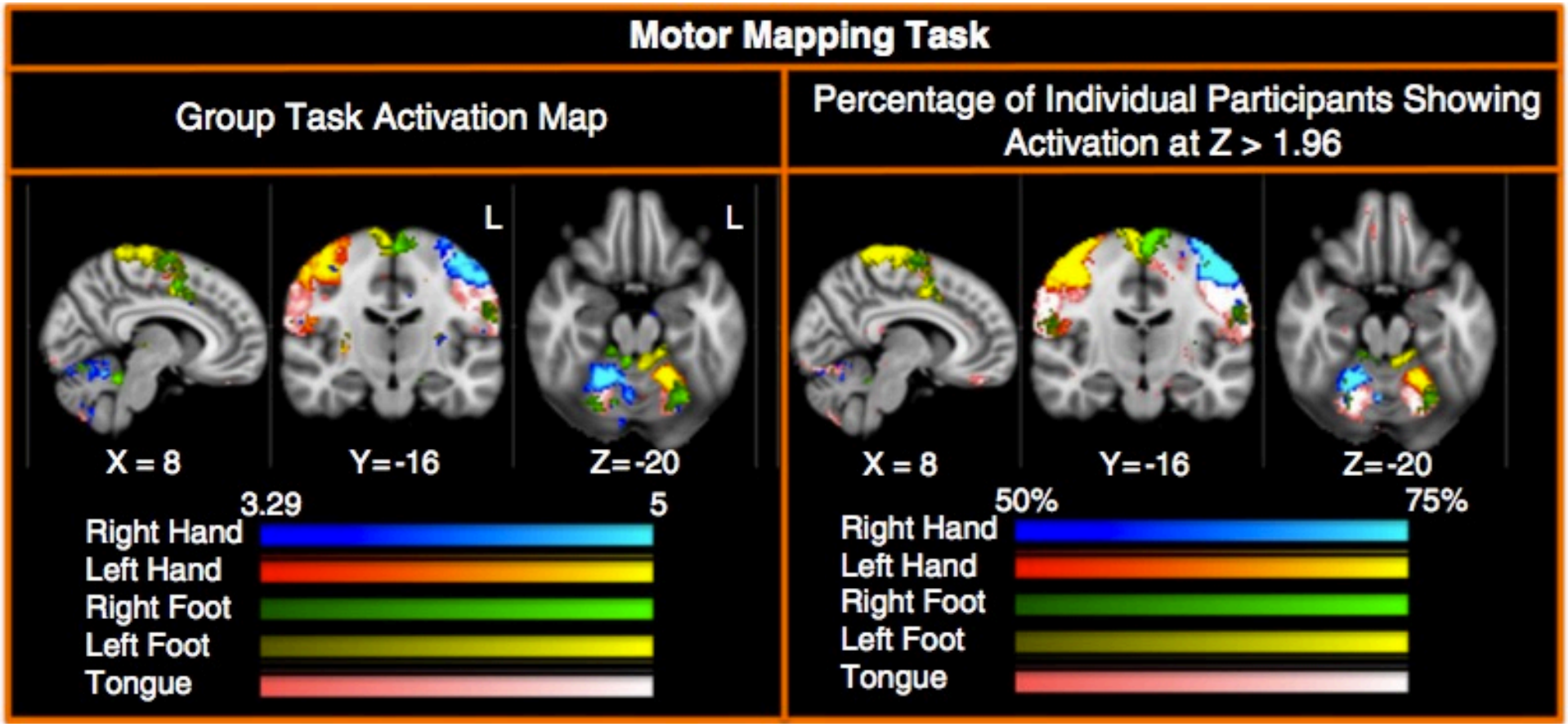
- Activated regions:
  - Caudate; ventral medial prefrontal; orbitofrontal cortex
- N.B. Activation in GAMBLING task is weaker than other tasks
  - Subcortical SNR
  - Task design?

Imaging Task: MOTOR



- Modeled after Bizzi et al., 2008
- 10 blocks per scan run
  - left hand, right hand, left foot, right foot, and tongue

Imaging Task: MOTOR



- Primary motor and somatosensory cortex
- Secondary motor and somatosensory cortex
- Motor mapping in primary motor, cerebellum, SMA, and putamen

Imaging Task: LANGUAGE

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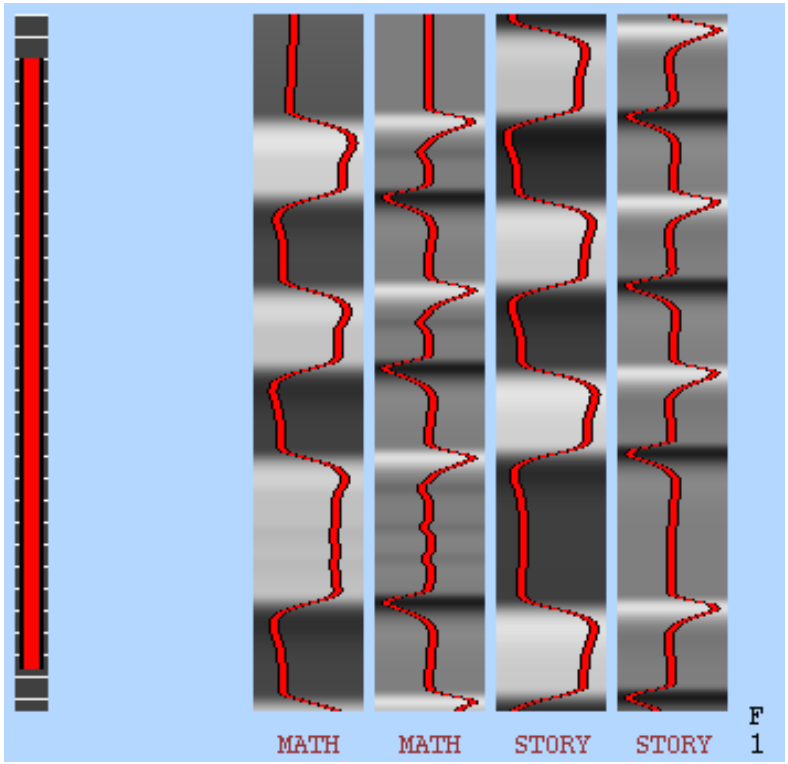
Story	Math
Listen short stories	Listen to set of arithmetic problems
Answer questions about the story	Answer correct or incorrect?

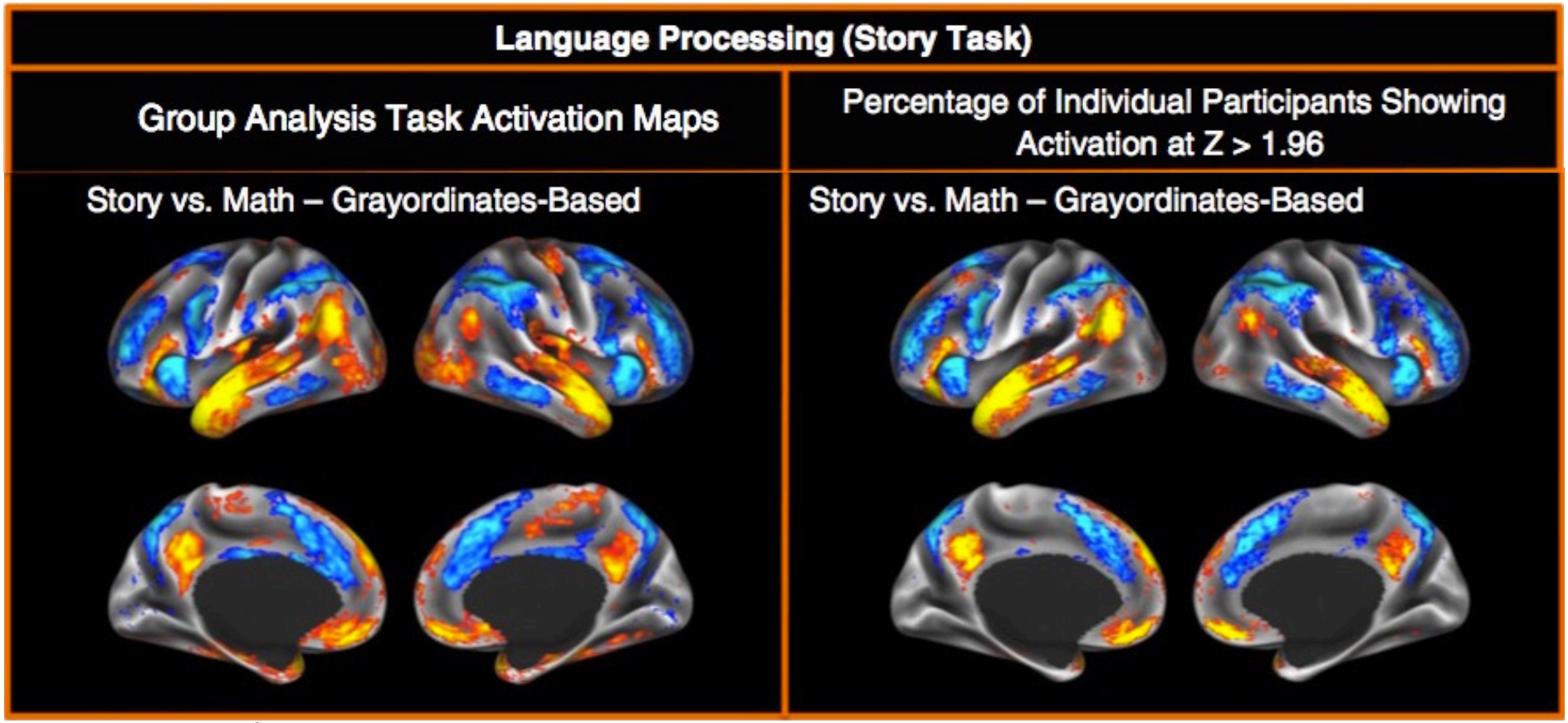
- Placed at beginning to allow adjustments to earbuds / volume prior to other task fMRI scans
- 4 STORY blocks, 4 MATH blocks
- No visual stimulation

Imaging Task: LANGUAGE



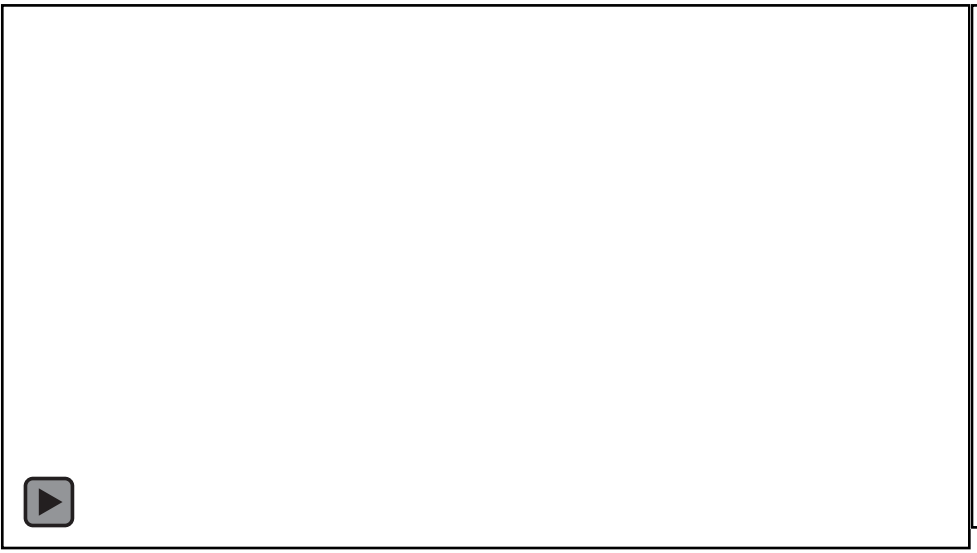
- Modeled after Binder et al., (2011): stimuli titrated to performance
  - Length of last MATH block depends on difficulty of previous blocks
- N.B. There are no rest blocks during this task
  - No valid estimate of “resting baseline”
- STORY-MATH and MATH-STORY are still valid contrasts

Imaging Task: LANGUAGE

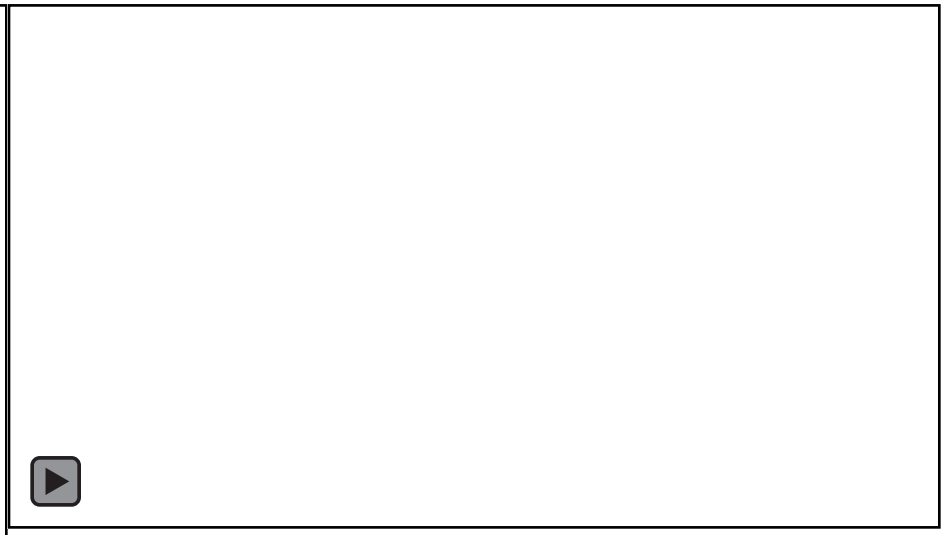


- Regions:
  - anterior and superior temporal lobe
  - angular gyrus, ventral inferior frontal gyrus

Imaging Task: SOCIAL



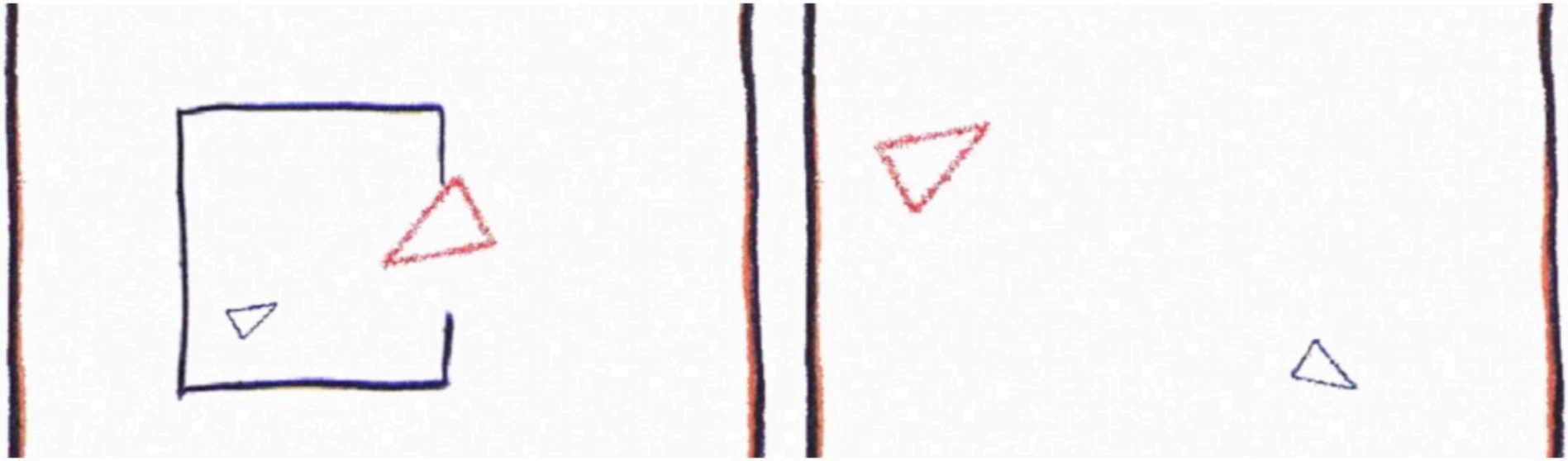
Social



Random

- Modeled after White et al., 2011:
  - Stimuli: Frith–Happe animations of social and random interactions
- Movies were designed to be “social” or “random”

Imaging Task: SOCIAL

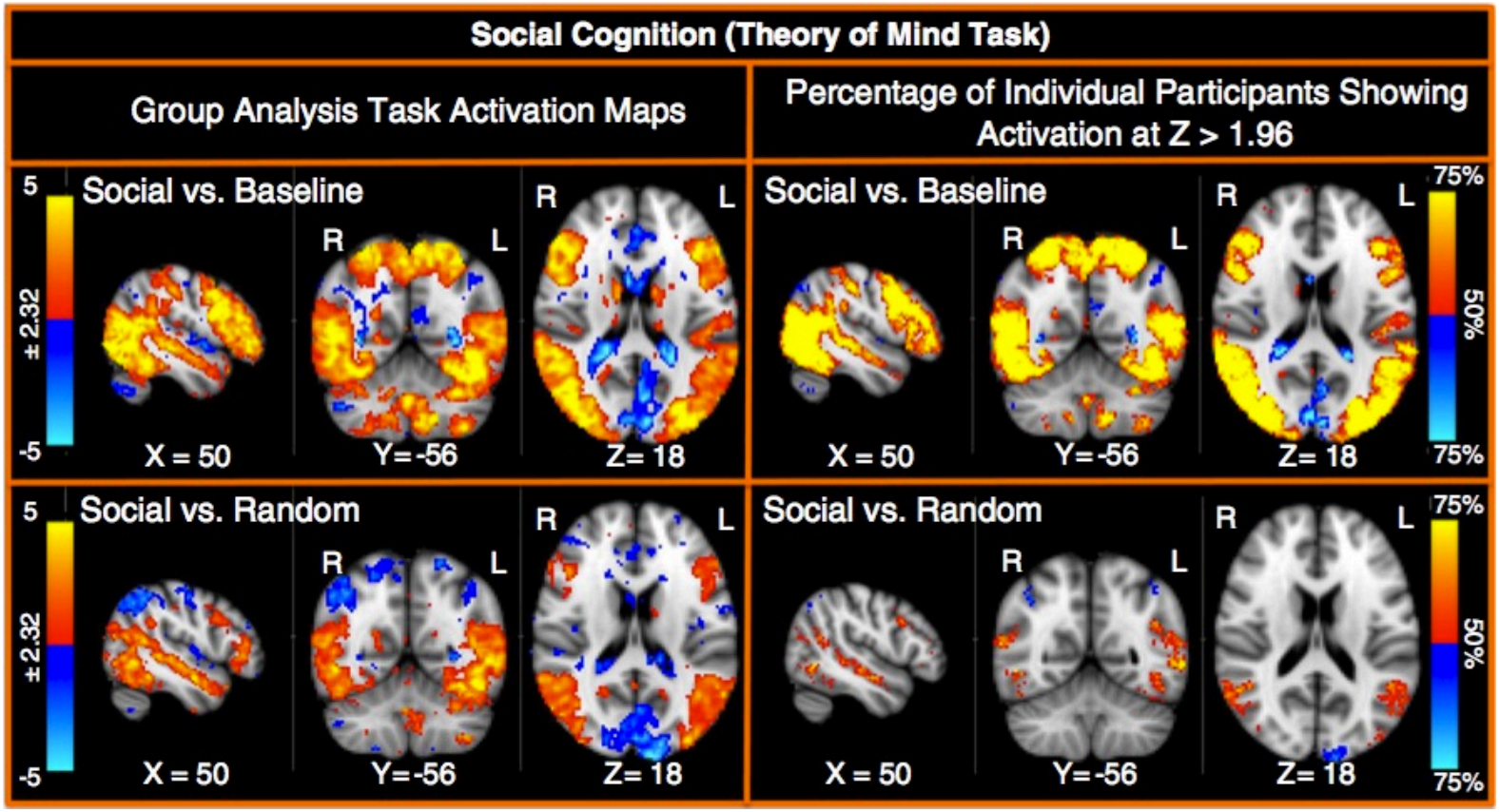


Social

Random

- Modeled after White et al., 2011:
  - Scan 1: 2 Social and 3 Random motion movies
  - Scan 2: 3 Social and 2 Random motion movies
- Subjects respond “social”, “random”, or “not sure”

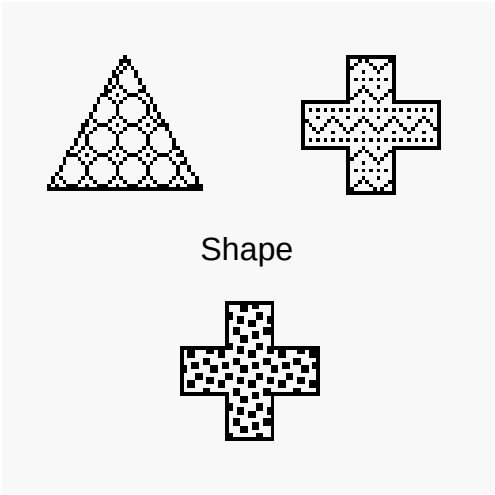
Imaging Task: SOCIAL



- Temporal parietal junction (TPJ)
- Medial prefrontal cortex; inferior and superior temporal sulcus

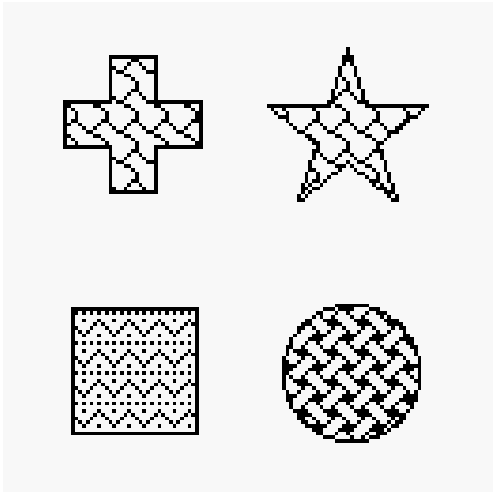
Imaging Task: RELATIONAL

Does the bottom stimulus match either of the top two stimuli on the dimension indicated (shape or texture)



Match

Does dimension of change for bottom two stimuli match dimension of change for top two stimuli

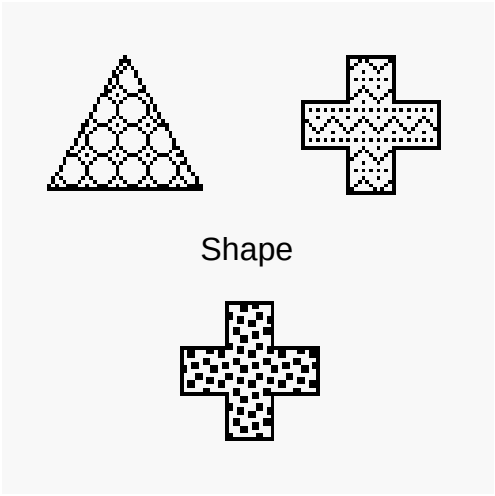


Relational

- Modeled after Smith et al. 2007
- Six blocks: half “match” and half “relational”
  - Three Relational blocks
  - Three Match blocks

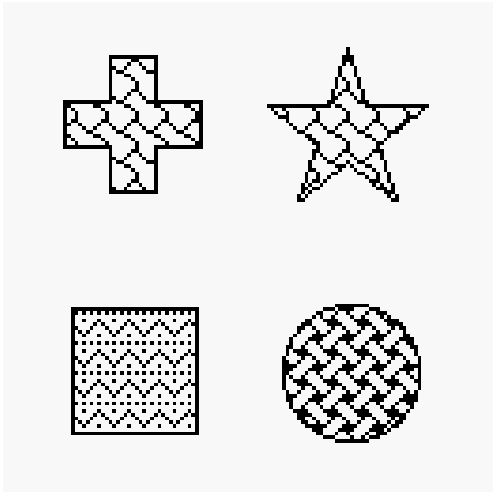
Imaging Task: RELATIONAL

Does the bottom stimulus match either of the top two stimuli on the dimension indicated (shape or texture)



Match

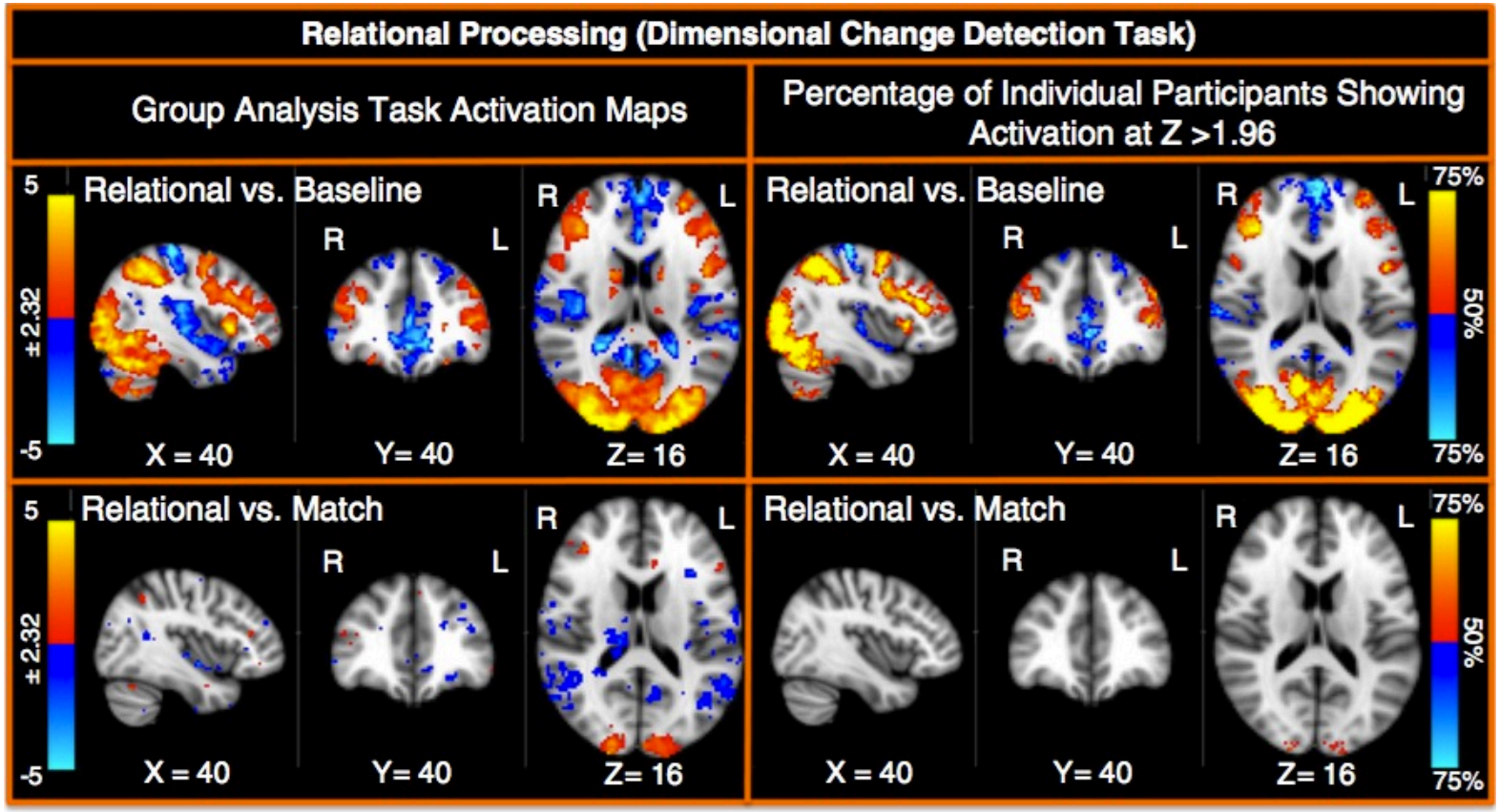
Does dimension of change for bottom two stimuli match dimension of change for top two stimuli



Relational

- Relational trials were more difficult than match trials
  - Relational trials = 4 seconds; 4 trials per block
  - Match trials = 3.2 seconds; 5 trials per block
- N.B Participants often had difficulty doing relational task

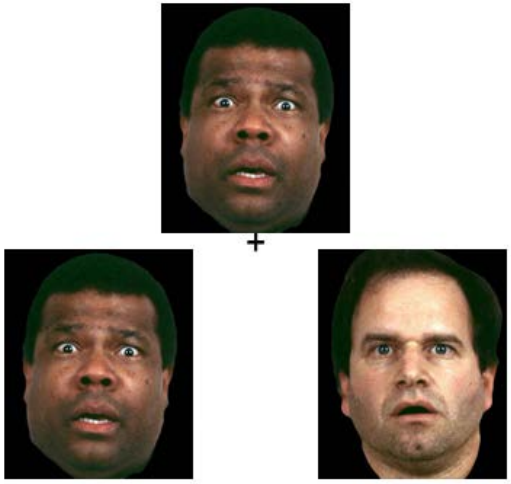
Imaging Task: RELATIONAL



- Anterior prefrontal cortex

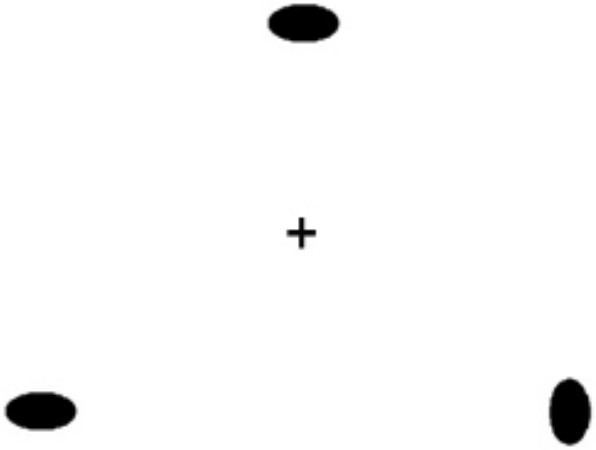
Imaging Task: EMOTION

Does the top stimulus match the left stimulus or the right stimulus?



FACES

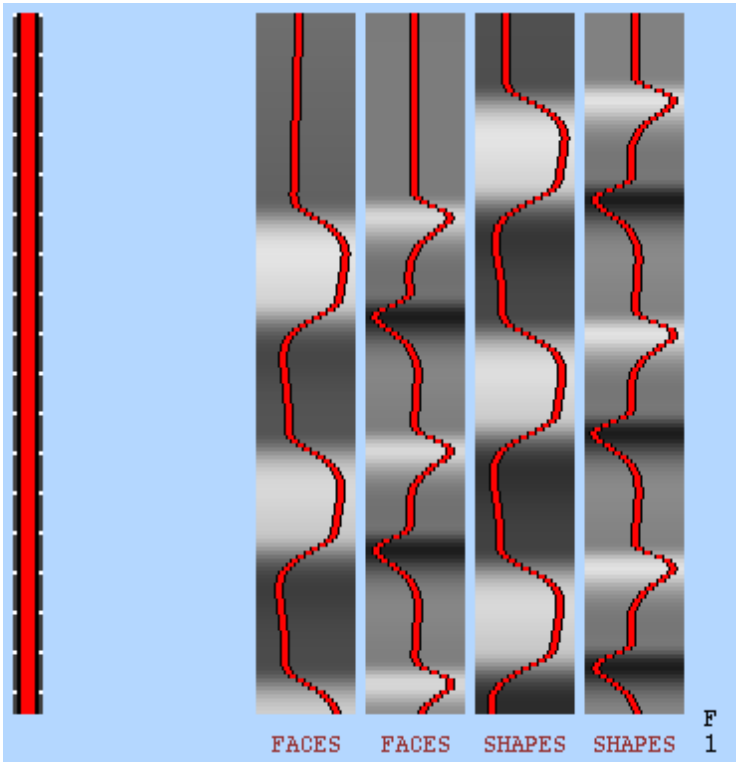
Does the top stimulus match the left stimulus or the right stimulus?



SHAPES

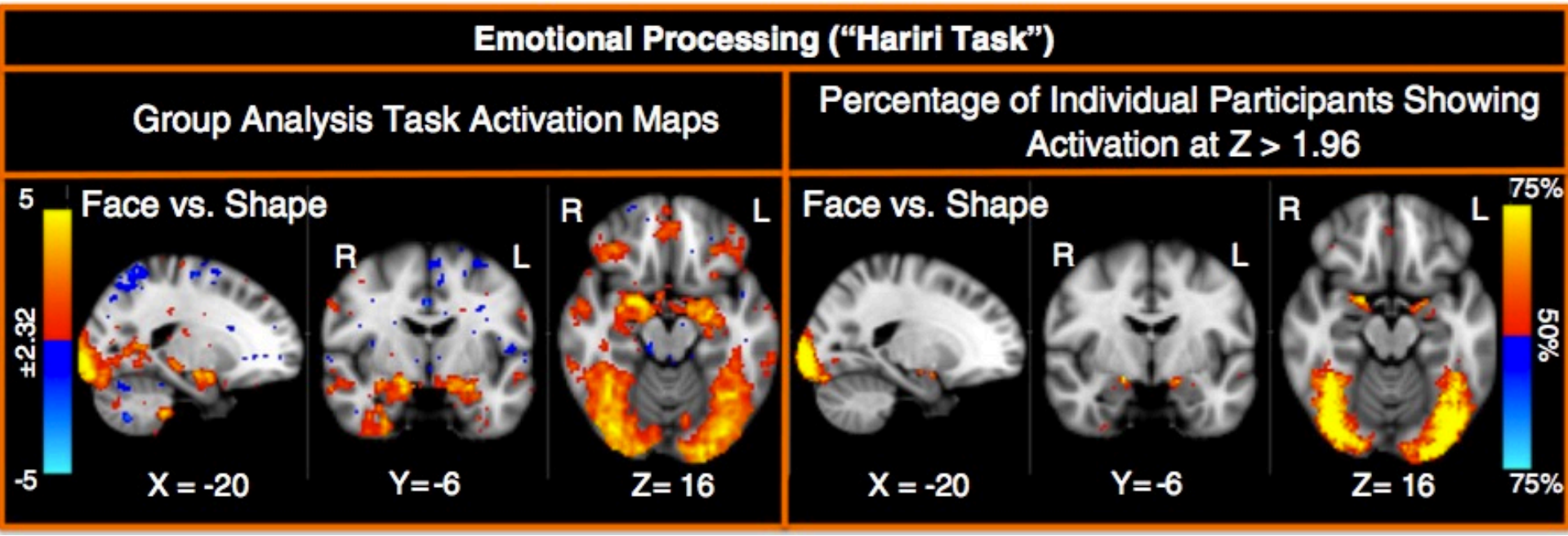
- Six block:
  - three using fear/anger faces; three using shapes
  - match images at bottom with images on left or right

Imaging Task: EMOTION



- N.B. There are no rest blocks during this task
  - No valid estimate of “resting baseline”
  - FACE-SHAPE and SHAPE-FACE are still valid contrasts
- Bug in E-Prime program ended last block early

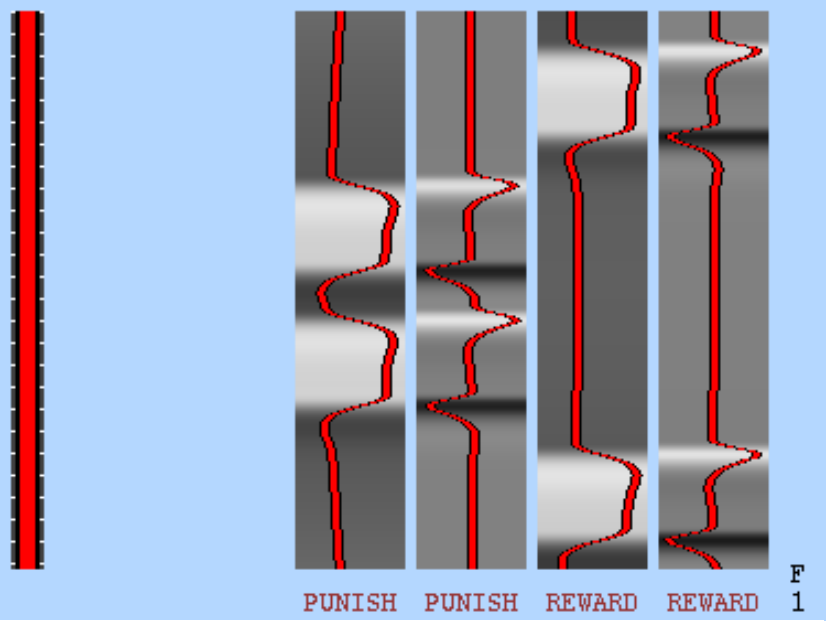
Imaging Task: EMOTION



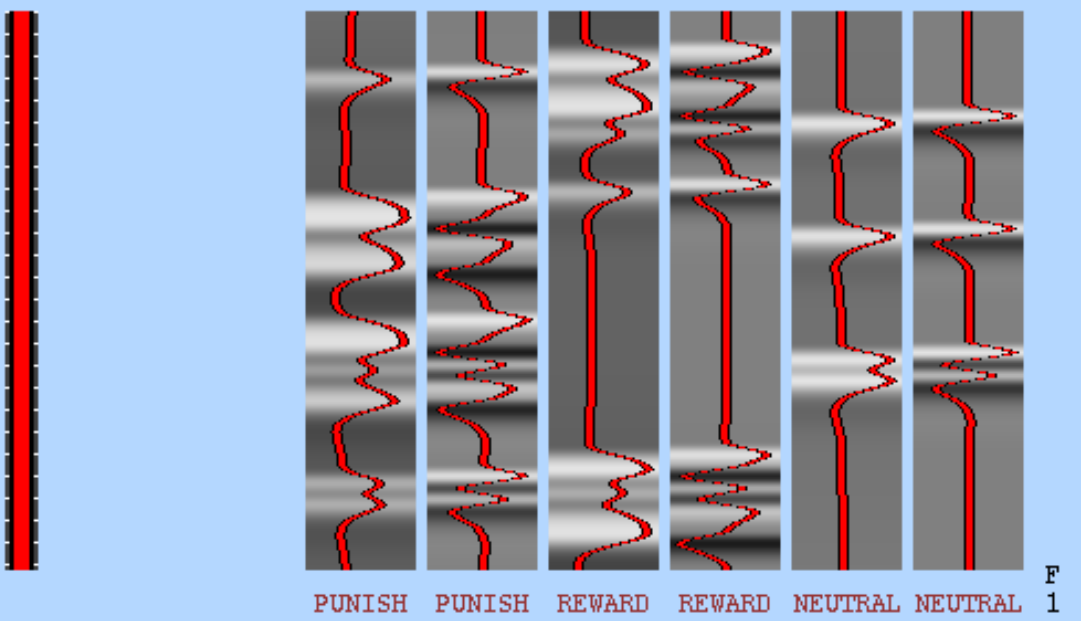
- "Hammer" Task
  - "Like a hammer to the amygdala"
  - hippocampus; insula; medial prefrontal
- Put at end to avoid mood induction effects on other scans

Customizing your analyses

GAMBLING: BLOCKED



GAMBLING: EVENT-RELATED



- What kinds of custom task analyses can I do?
- Create custom EVs from TAB.txt files
- Run new Level 1 (lower-level) and Level 2 (mid-level) analyses

Customizing your analyses

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TrialType

BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR	BS	BT	BU
Block	Procedure[Trial]	Run1List	R1MostlyReward1	TrialType	Running[Trial]	Run1List.Cycle	Run1List.Sample	RunTrialNumber	TotalRespGreater200	ConsecRTLess200	ConsecNonResp	ConsecSmallerGuesses
1												
2												
3												
4												
5	GamblingTrialPROC			Punishment	Run2List			2	1	0	0	0
5	GamblingTrialPROC			Punishment	Run2List			3	2	0	0	0
5	GamblingTrialPROC			Reward	Run2List			4	3	0	0	0
5	GamblingTrialPROC			Punishment	Run2List			5	4	0	0	1
5	GamblingTrialPROC			Reward	Run2List			6	5	0	0	2
5	GamblingTrialPROC			Punishment	Run2List			7	6	0	0	3
5	GamblingTrialPROC			Punishment	Run2List			8	7	0	0	0
5	GamblingTrialPROC			Punishment	Run2List			9	8	0	0	0
5	FixationBlockPROC				Run2List							
5	GamblingTrialPROC			Reward	Run2List			10	9	0	0	0
5	GamblingTrialPROC			Neutral	Run2List			11	10	0	0	1
5	GamblingTrialPROC			Reward	Run2List			12	11	0	0	0
5	GamblingTrialPROC			Reward	Run2List			13	12	0	0	1
5	GamblingTrialPROC			Reward	Run2List			14	13	0	0	0
5	GamblingTrialPROC			Reward	Run2List			15	14	0	0	0
5	GamblingTrialPROC			Neutral	Run2List			16	15	0	0	1
5	GamblingTrialPROC			Reward	Run2List			17	16	0	0	2
5	FixationBlockPROC				Run2List							
5	GamblingTrialPROC			Punishment	Run2List			18	17	0	0	0
5	GamblingTrialPROC			Punishment	Run2List			19	18	0	0	1
5	GamblingTrialPROC			Reward	Run2List			20	19	0	0	2
5	GamblingTrialPROC			Punishment	Run2List			21	20	0	0	0
5	GamblingTrialPROC			Reward	Run2List			22	21	0	0	1
5	GamblingTrialPROC			Punishment	Run2List			23	22	0	0	2
5	GamblingTrialPROC			Punishment	Run2List			24	23	0	0	0
5	GamblingTrialPROC			Punishment	Run2List			25	24	0	0	0
5	FixationBlockPROC				Run2List							
5	GamblingTrialPROC			Reward	Run2List			26	25	0	0	1
5	GamblingTrialPROC			Reward	Run2List			27	26	0	0	2
5	GamblingTrialPROC			Punishment	Run2List			28	27	0	0	0
5	GamblingTrialPROC			Reward	Run2List			29	28	0	0	1
5	GamblingTrialPROC			Punishment	Run2List			30	29	0	0	2
5	GamblingTrialPROC			Reward	Run2List			31	30	0	0	3
5	GamblingTrialPROC			Reward	Run2List			32	31	0	0	0
5	GamblingTrialPROC			Reward	Run2List			32	32	0	0	0
5	FixationBlockPROC				Run2List							

- TAB.txt files: converted E-Prime files (tab-delimited)

Customizing your analyses

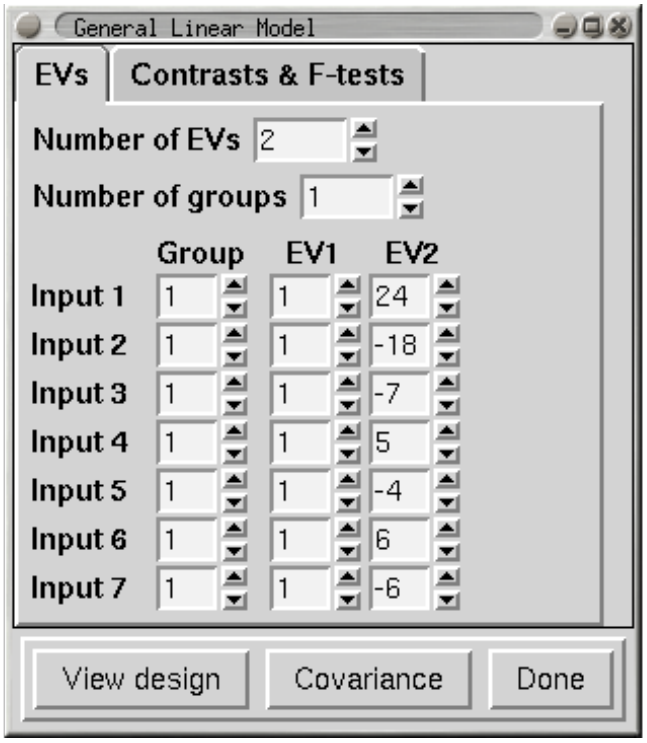
HUMAN Connectome PROJECT

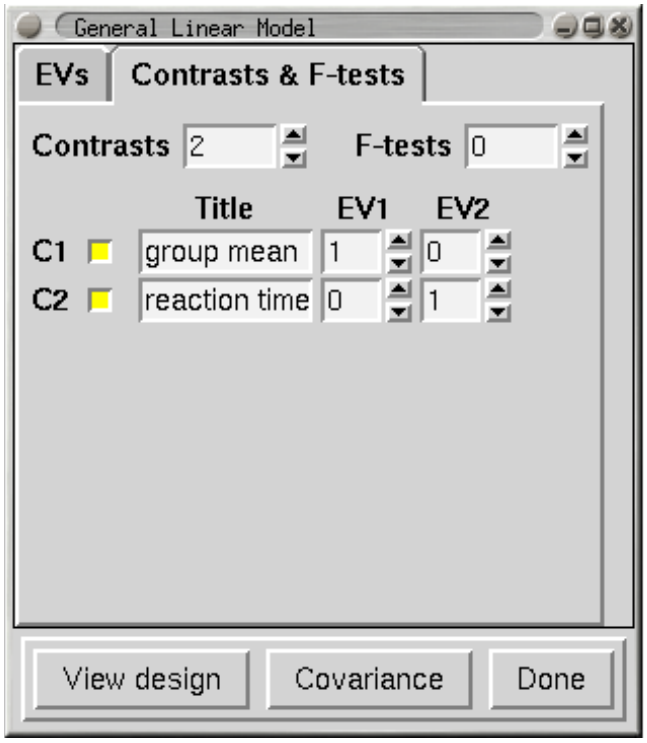
WU-Minn HCP 500 Subjects + MEG2 Data
Release:
Reference Manual

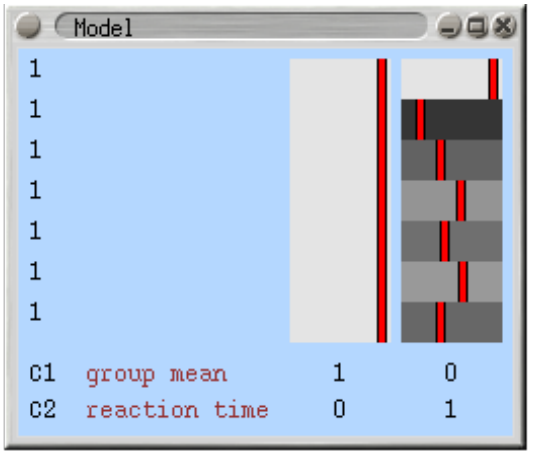
Appendix VI – Task fMRI and tMEG E-Prime
Key Variables

http://www.humanconnectome.org/documentation/S500/HCP_S500+MEG2_Release_Appendix_VI.pdf

Group-level Analyses







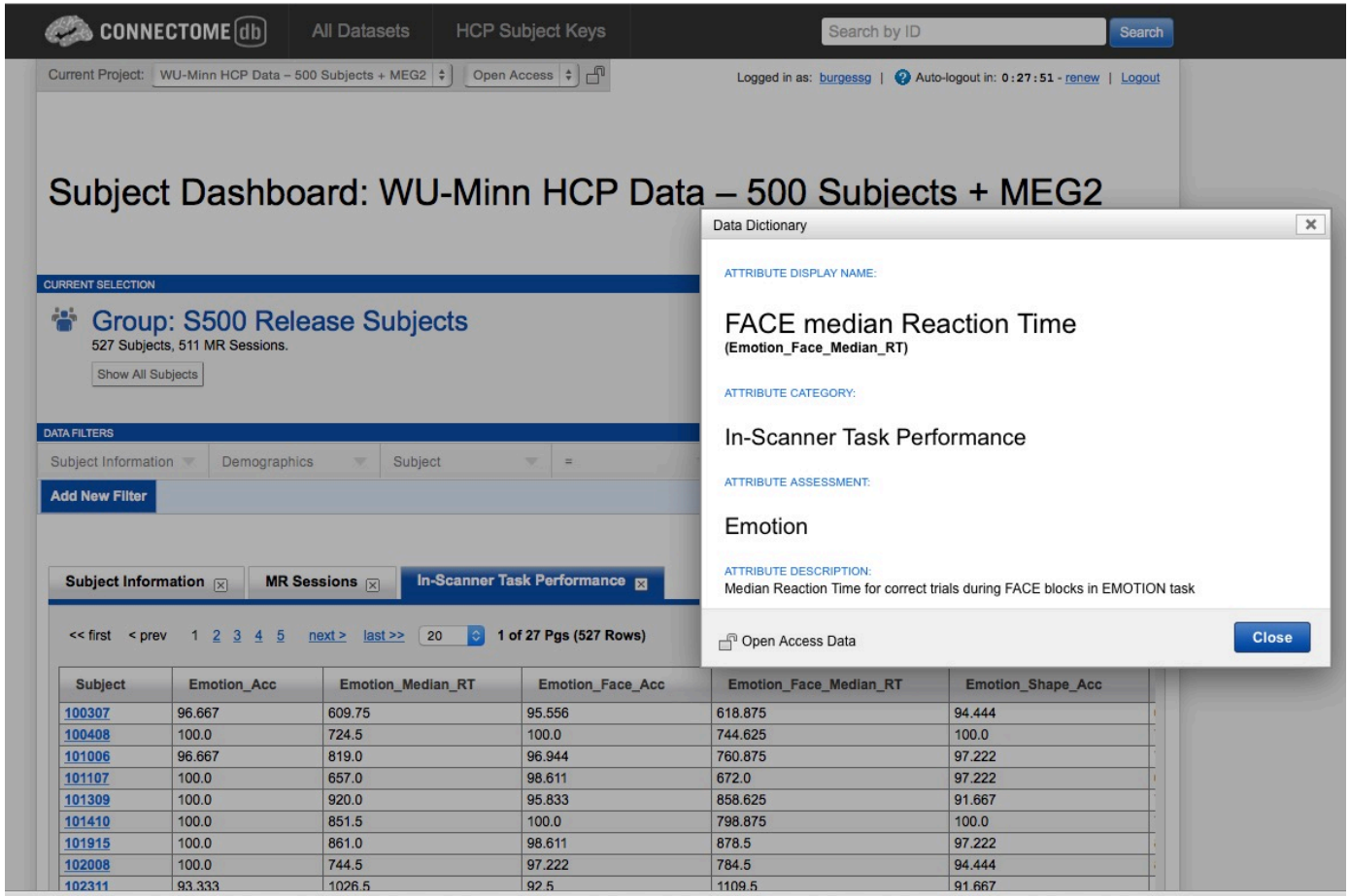
- Variables in HCP are typically continuous
  - Even “handedness” is continuous
- Most likely want to do a correlation analysis
  - http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/GLM
- More about using HCP Pipelines for task fMRI analyses during practical session!

In-Scanner Task Performance Measures

	A	B	C
1	Value	ConditionName	Measure
2	0.933333333	FACE	ACC
3	636.5	FACE	MEDIAN_RT
4	0.944444444	SHAPE	ACC
5	607	SHAPE	MEDIAN_RT

- Performance measures for individual scan runs can be extracted from TAB.txt files
- Select summary statistics are provided in ${task}_Stats.csv files in HCP task fMRI packages

In-Scanner Task Performance Measures



- ConnectomeDB contains subject-level performance measures
  - Created by averaging summary statistics from all runs of task
  - Description of variables available in “data dictionary”

Documentation about behavioral variables

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- HCP Data Dictionary
  - https://wiki.humanconnectome.org/display/PublicData/HCP+Data+Dictionary+Public-+500+Subject+Release
- NIH Toolbox
  - http://www.nihtoolbox.org/WhatAndWhy/Pages/default.aspx
- Barch, D. M. et al. (2013). Function in the human connectome: Task-fMRI and individual differences in behavior. *NeuroImage*, *80*, 169–189.

NIH Toolbox Measures

- Cognition
  - Episodic Memory (Picture Sequence Memory)
  - Executive Function/Cognitive Flexibility (Dimensional Change Card Sort)
  - Executive Function/Inhibition (Flanker Task)
  - Language/Vocabulary Comprehension (Picture Vocabulary Computer Adaptive Test)
  - Processing Speed (Pattern Comparison Processing Speed)
  - Working Memory (List Sorting)
  - Language/Reading Decoding (Oral Reading Recognition)
- Emotion
  - Negative Affect (Sadness, Fear, Anger)
  - Psychological Well-being (Positive Affect, Life Satisfaction, Meaning and Purpose)
  - Social Relationships (Social Support, Companionship, Social Distress, Positive Social Development)
  - Stress and Self Efficacy (Perceived Stress, Self-Efficacy)
- Motor
  - Dexterity (9-hole Pegboard)
  - Endurance (2 minute walk test)
  - Locomotion (4-meter Walk Test)
  - Strength-Upper Extremity (Grip Strength Dynamometry)
- Sensory
  - Audition (Words in Noise)
  - Olfaction (Odor Identification Test)
  - Taste (Regional Taste Test)
  - Vision (Visual Acuity): **USING EVA INSTEAD**

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Penn Computerized Neuropsychological Battery

- Cognition/Emotion
  - Sustained Attention (Penn Continuous Performance Test)
  - Verbal Memory (Word Memory Test)
  - Fluid Intelligence (Penn Matrix Reasoning)
  - Spatial Processing (Line Orientation)
  - Emotion Detection (Penn Emotional Faces Task)
  - Impulsivity (Delay Discounting)
- Personality/Adaptive Function
  - Personality (NEO Five Factor Inventory II)
  - Adaptive Function (Achenbach Adult Self-Report)
- Sensory
  - Color Vision (Farnsworth Color Vision)
  - Contrast Sensitivity (MARS Contrast Sensitivity)

Additional Questionnaires

- Demographics
  - Age
  - Gender
  - Personal Education
  - Personal Occupation
  - Parental Education
  - Parental Occupation
- Physical
  - Height
  - Weight
  - Blood Pressure
  - Hematocrit
- Psychiatric/Substance
  - Detailed Assessment of Axis I Psychiatric Symptoms
  - Detailed Drug and Alcohol History
  - Fagerstrom Assessment of Smoking
  - 7 day retrospective alcohol, substance and tobacco
    - Completed at exit interview (if contiguous testing, completed each day if sessions more than 1 week apart)
  - Breathalyzer
  - Urine Drug Screen (Cocaine, THC, Opiates, Amphetamine, Meth Amphetamine, Oxycontin)
  - Family History of Psychiatric and Neurological Disorders
- Other
  - Mini Mental Status Exam
  - Handedness
  - Menstrual Cycle Information (if female)
  - Pittsburgh Sleep Questionnaire

Documentation about behavioral variables

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- HCP Data Dictionary
  - https://wiki.humanconnectome.org/display/PublicData/HCP+Data+Dictionary+Public-+500+Subject+Release
- NIH Toolbox
  - http://www.nihtoolbox.org/WhatAndWhy/Pages/default.aspx
- Barch, D. M. et al. (2013). Function in the human connectome: Task-fMRI and individual differences in behavior. *NeuroImage*, *80*, 169–189.