TE-YI HSIEH
THE SOCIAL ROBOTICS JOURNAL CLUB
04/08/2017

The thing that should not be: Predictive coding and the uncanny valley in perceiving human and humanoid robot actions

Ayse Pinar Saygin, Thierry Chaminade, Hiroshi Ishiguro, Jon Driver, and Chris Frith (2012)
Social Cognitive and Affective Neuroscience, 7(4), 413-422

Background

- The mirror-neuron system (MNS) in the monkey brain (Gallese, Fadiga, Fogassi & Rizzolatti, 1996)

- motor resonance:
  Rizzolatti, Fogassi, and Gallese (2001) suggested that "We understand actions when we map the visual representation of the observed action onto our motor representation of the same action."

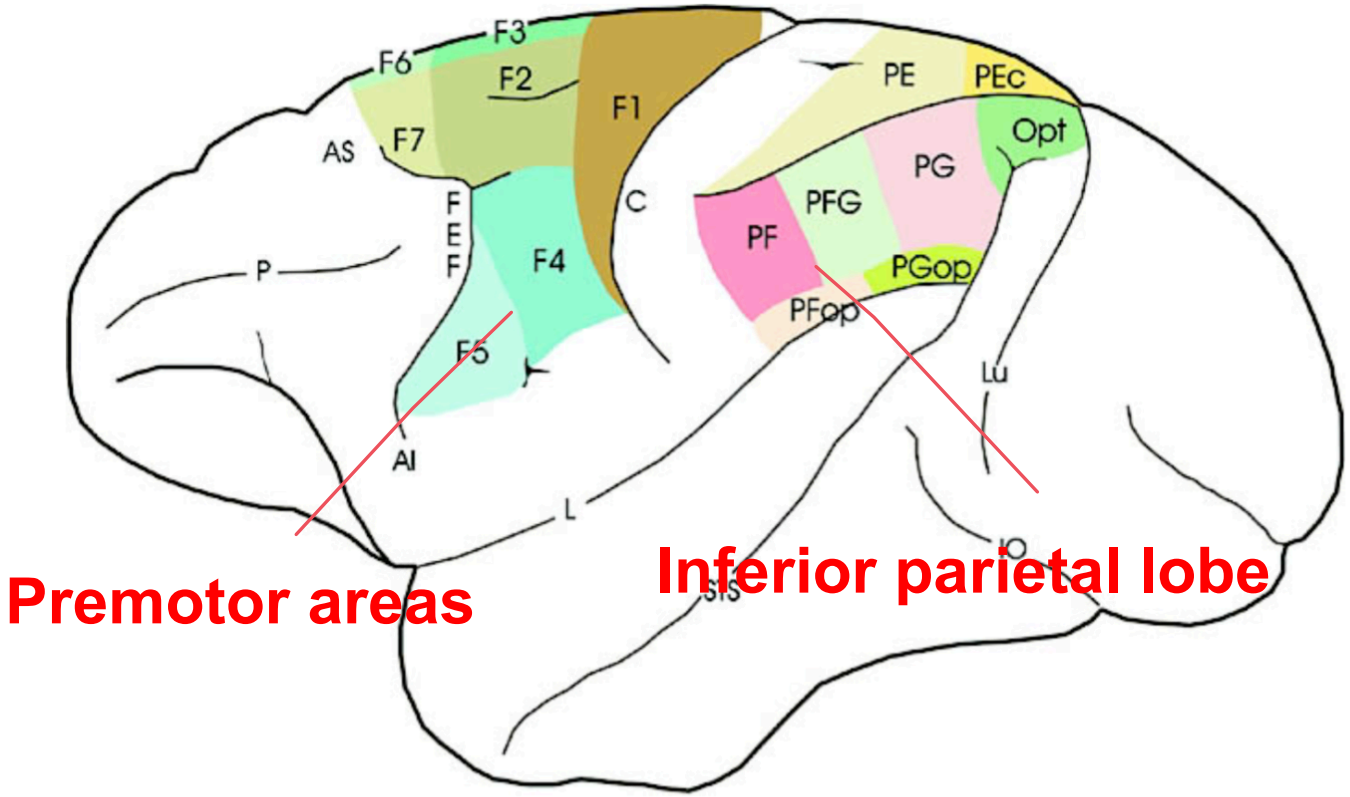
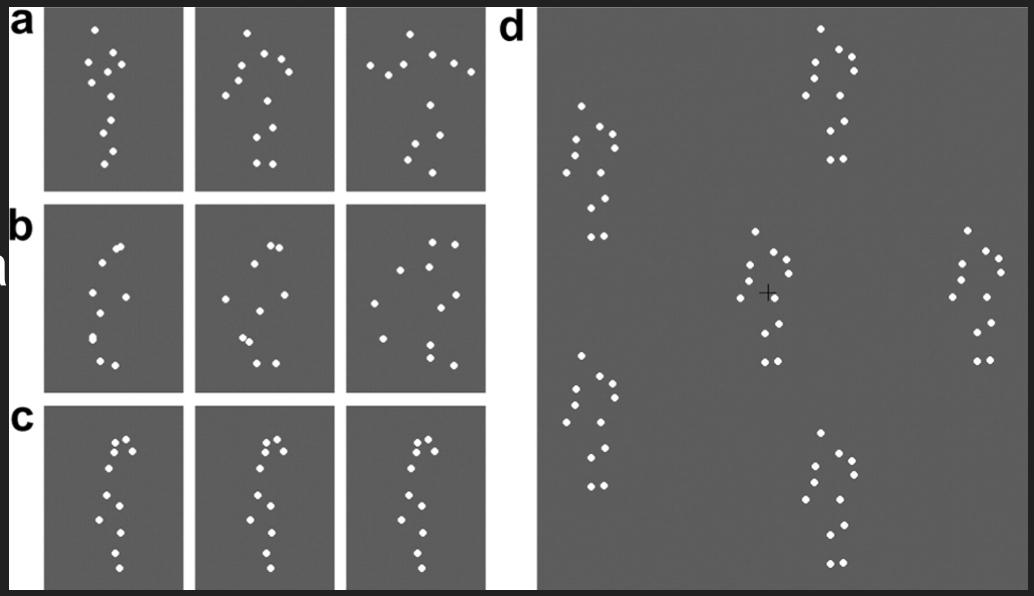


Figure 1 Lateral view of the monkey brain showing, in color, the motor areas of the frontal lobe and the areas of the posterior parietal cortex. For nomenclature and definition of frontal motor areas (F1–F7) and posterior parietal areas (PE, PEc, PF, PFG, PG, PF op, PG op, and Opt) see Rizzolatti et al. (1998). AI, inferior arcuate sulcus; AS, superior arcuate sulcus; C, central sulcus; L, lateral fissure; Lu, lunate sulcus; P, principal sulcus; POs, parieto-occipital sulcus; STS, superior temporal sulcus.

Background—motion perception in human brains

- Kilner, Neal, Weiskopf, Friston, and Frith (2009) have shown that human inferior frontal gyrus was involved in both observing and executing hand movements.

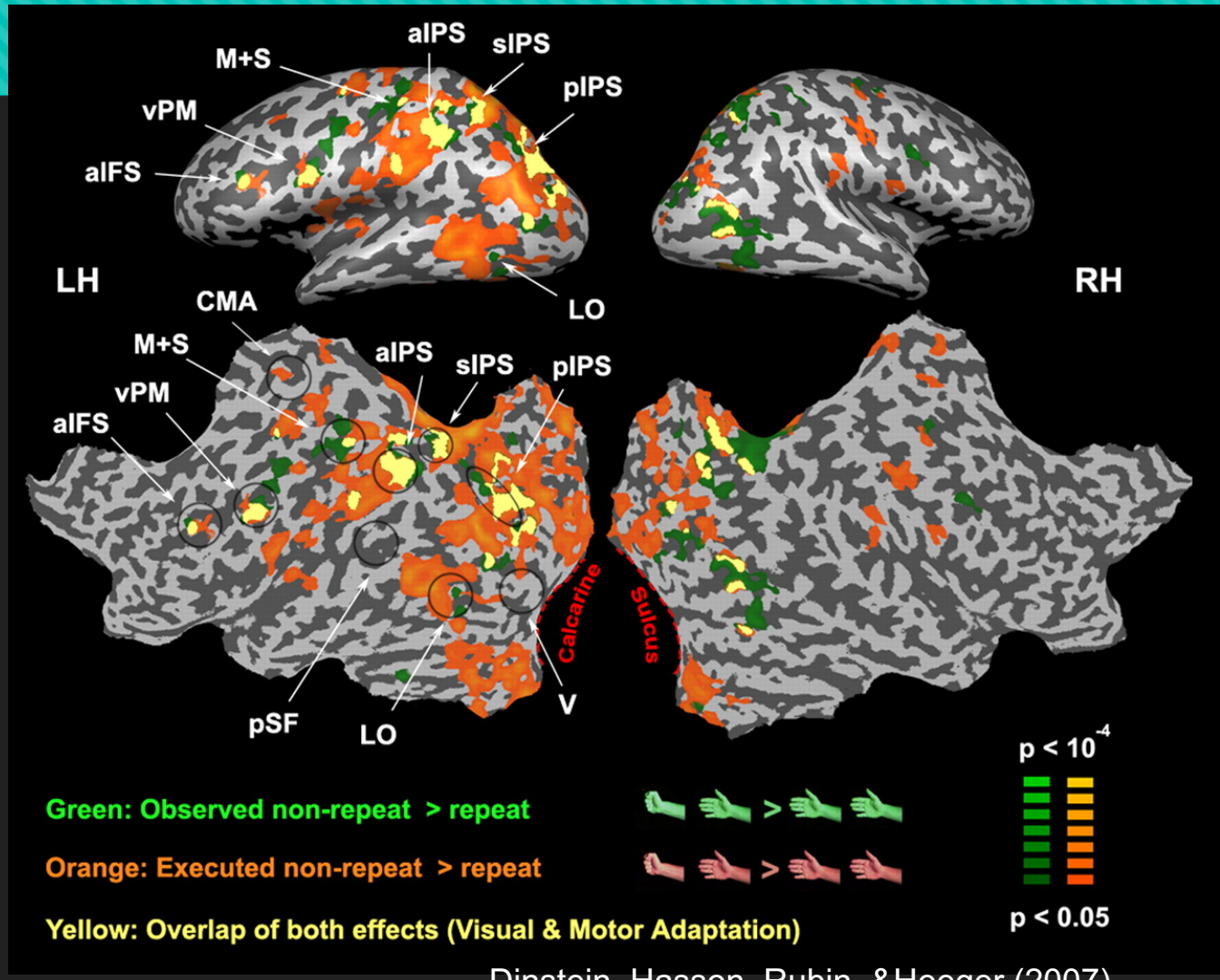
- Brain activation in the posterior superior temporal gyrus (pSTG) and sulcus (pSTS), premotor cortex and inferior frontal regions were constantly found in point-light biological motion perception (Saygin, 2007).



Saygin, Wilson, Hagler, Bates, & Sereno (2004)

Background—motion perception in human brains

- six brain regions are involved in the neural representation of both observed and executed movements:
  1. anterior inferior frontal sulcus (aIFS)
  2. ventral premotor (vPM) cortex
  3. anterior intraparietal sulcus (aIPS)
  4. superior intraparietal sulcus (sIPS)
  5. posterior intraparietal sulcus (pIPS)
  6. an area within lateral occipital (LO) cortex



Dinstein, Hasson, Rubin, &Heeger (2007)

Background

- Action Perception System (APS) :
  - lateral temporal cortex
  - inferior frontal/ventral premotor cortex
  - anterior intraparietal cortex
- Higher similarity between observed action and one's sensorimotor representation of this action results in stronger motor resonance.

Appearance? Biological motion?

Background

- How does the APS respond to artificial agents?
  - Interference effect was not found when incongruent movements was performed by a robot (Kilner, Paulignan, & Blakemore, 2003).
  - Observing a robot arm picking up something could activate mirror neuron system in human brains (Oberman, McCleery, Ramachandran, & Pineda, 2007)
  - Inferior parietal, premotor, and occipitotemporal cortices showed higher activation when observing robotic movements than natural biological movements (Cross, Liepelt, Parkinson, Ramsey, Stadler , & Prinz , 2012).

Aim of this study

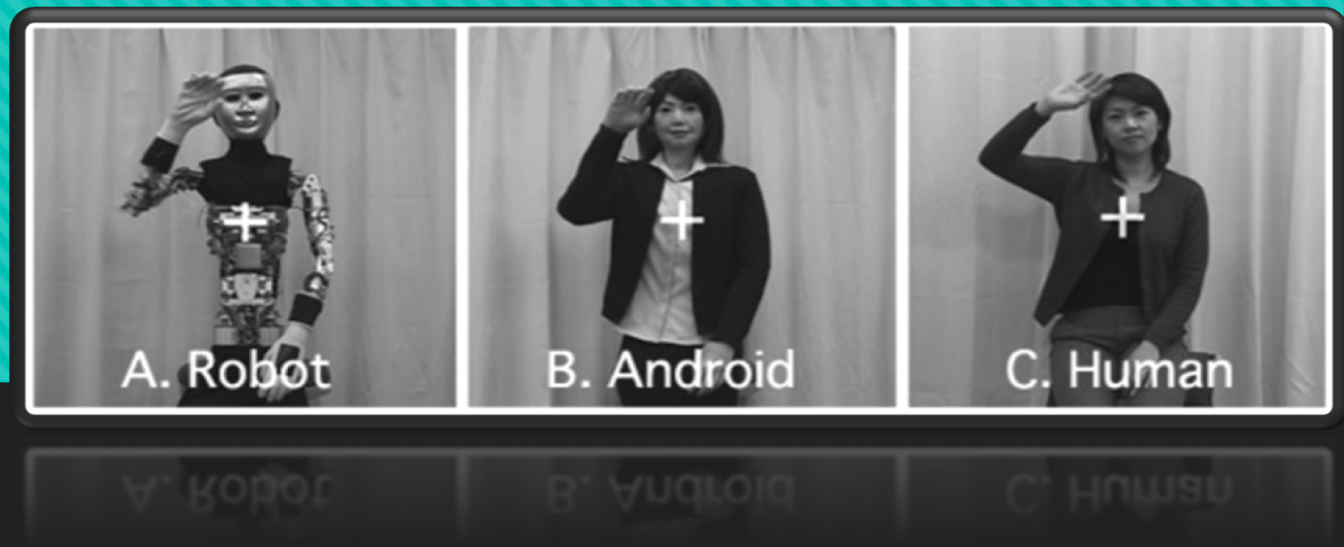
1. Using an fMRI-adaptation protocol to explore the roles of an agent's appearance and motion in affecting activation in APS
   - Repetition will lead to a suppressed activation in brain regions selectively responding to the repeated properties
2. Provide a neural basis for the uncanny valley
   - internal models of motor control

Repliee Q2

Aim of this study

3. Compare brain responses to
   - Biological appearance (human, android) vs. mechanical appearance (robot)
   - Biological motion (human) vs. nonhuman motion (android, robot)
   - Congruence (human, robot) vs. incongruence (android)

Methods

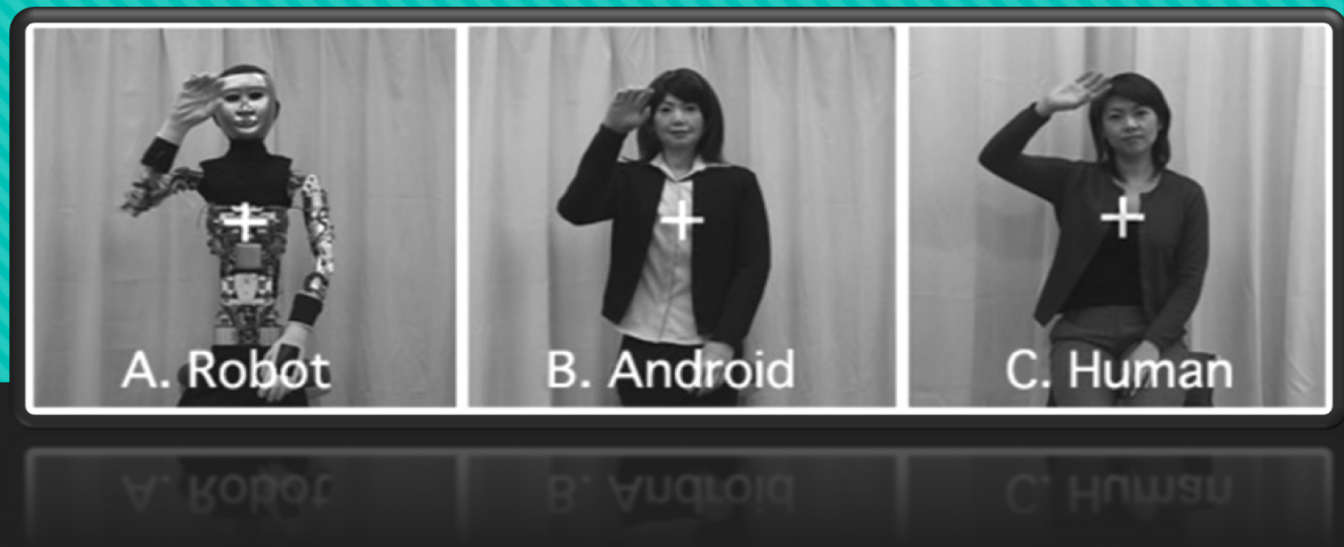


- Participants: 19 adults (aged 20–36 years) included for analysis

  → no experience working with robots, had not spent time in Japan, nor had close friends or family from Japan

- Stimuli: video clips
  - Robot: robotic appearance/ robotic movements
  - Android – Repliee Q2: human-like appearance/ robotic movements
  - Female adult: human appearance/ biological movements

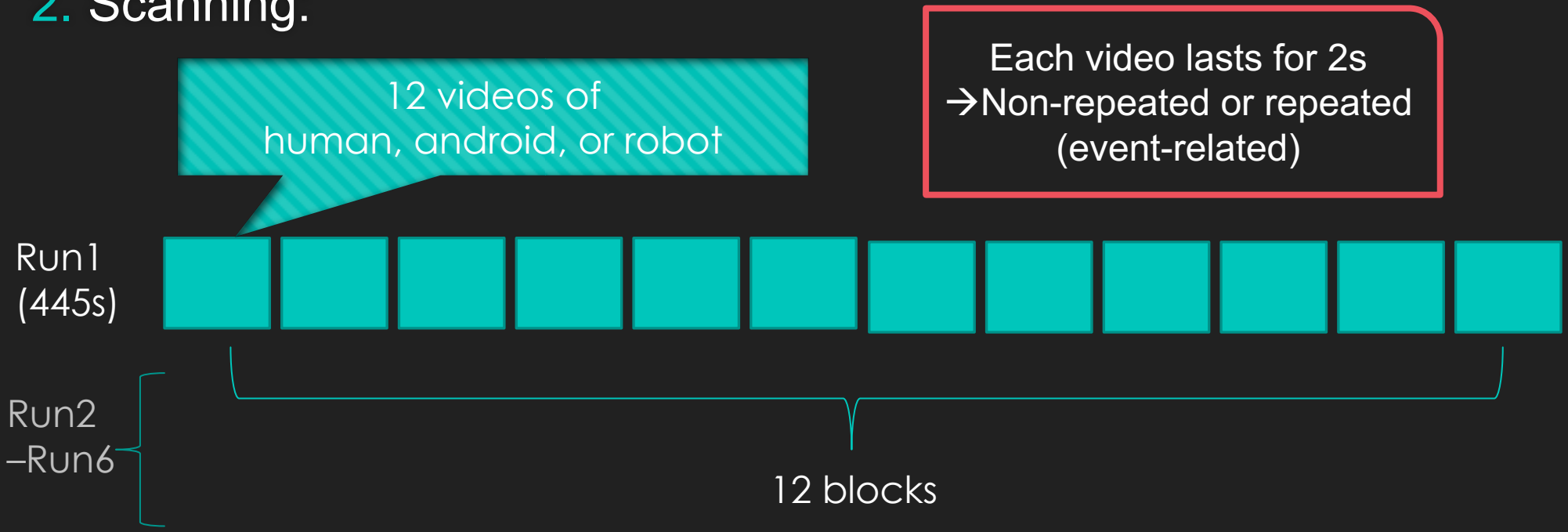
Methods

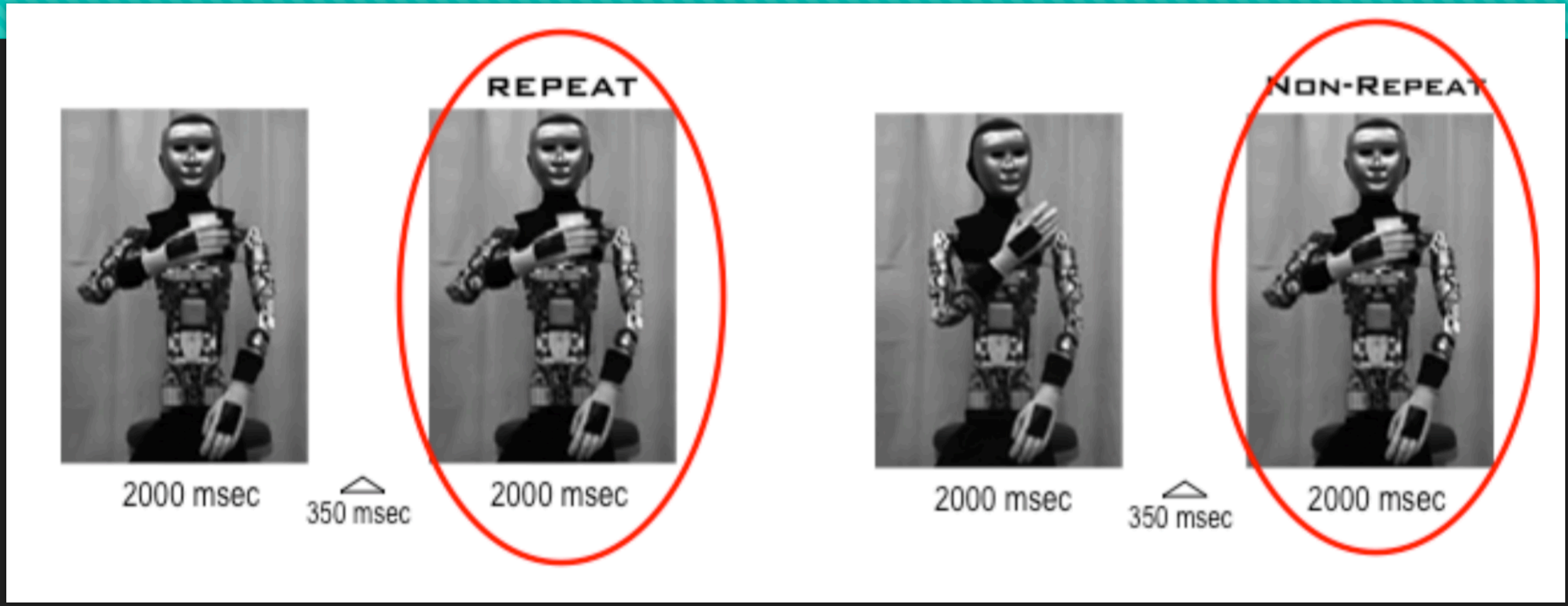


- Video clips consisted of 8 actions per actors
  - drinking water from a cup, picking up a piece of paper from a table, grasping a tube of hand lotion, wiping a table with a cloth
  - waving hand, nodding affirmatively, shaking head (to convey no) and introducing self (Japanese bow)

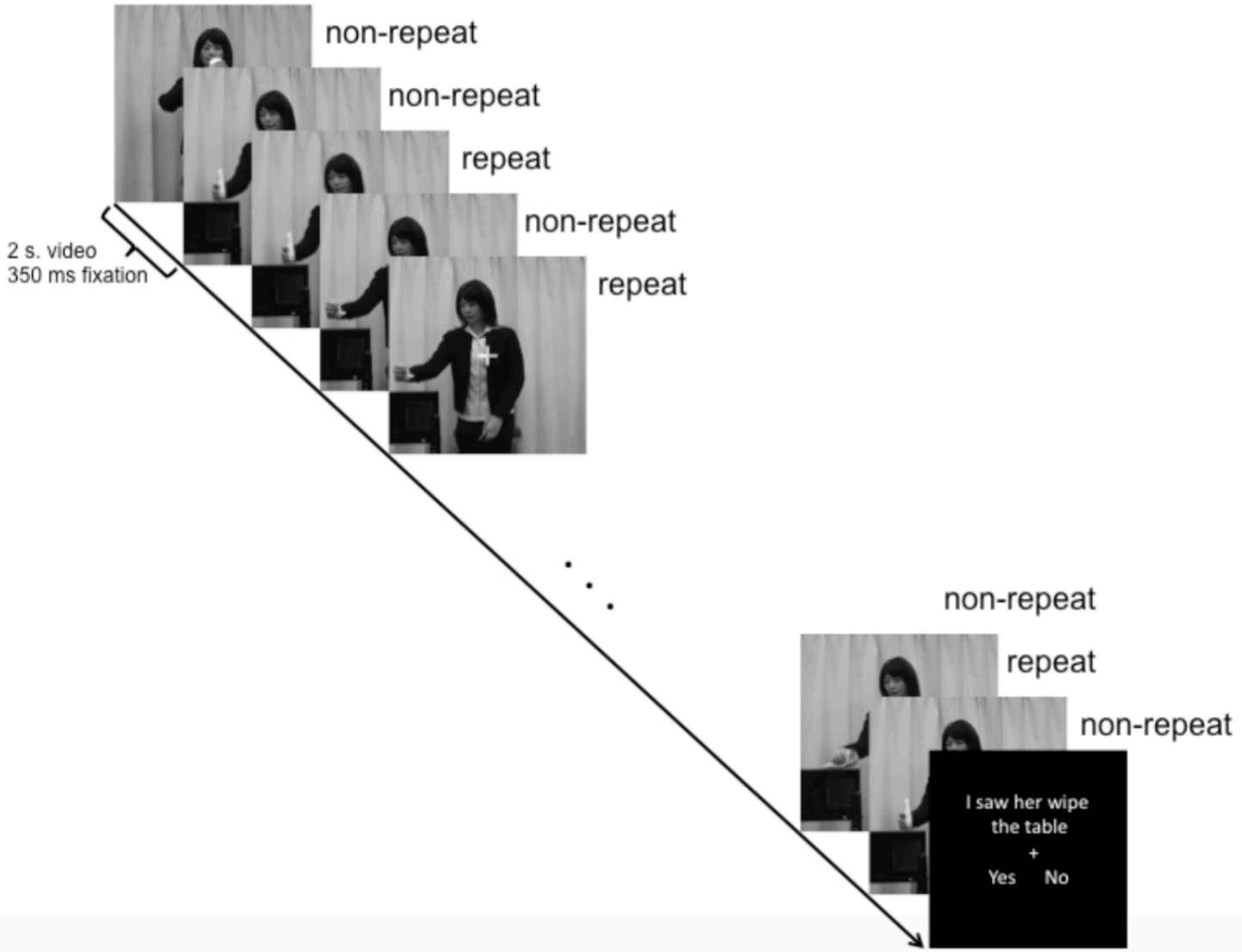
Experimental procedures

1. Participants watched video clips outside the scanner, and were told whether an actor was a human or a robot.
2. Scanning:




REPEAT
2000 msec
350 msec
2000 msec
NON-REPEAT
2000 msec
350 msec
2000 msec

B. Blocks were 30 seconds long and ended with a comprehension question to keep subjects attending the stimuli.



Experimental procedures

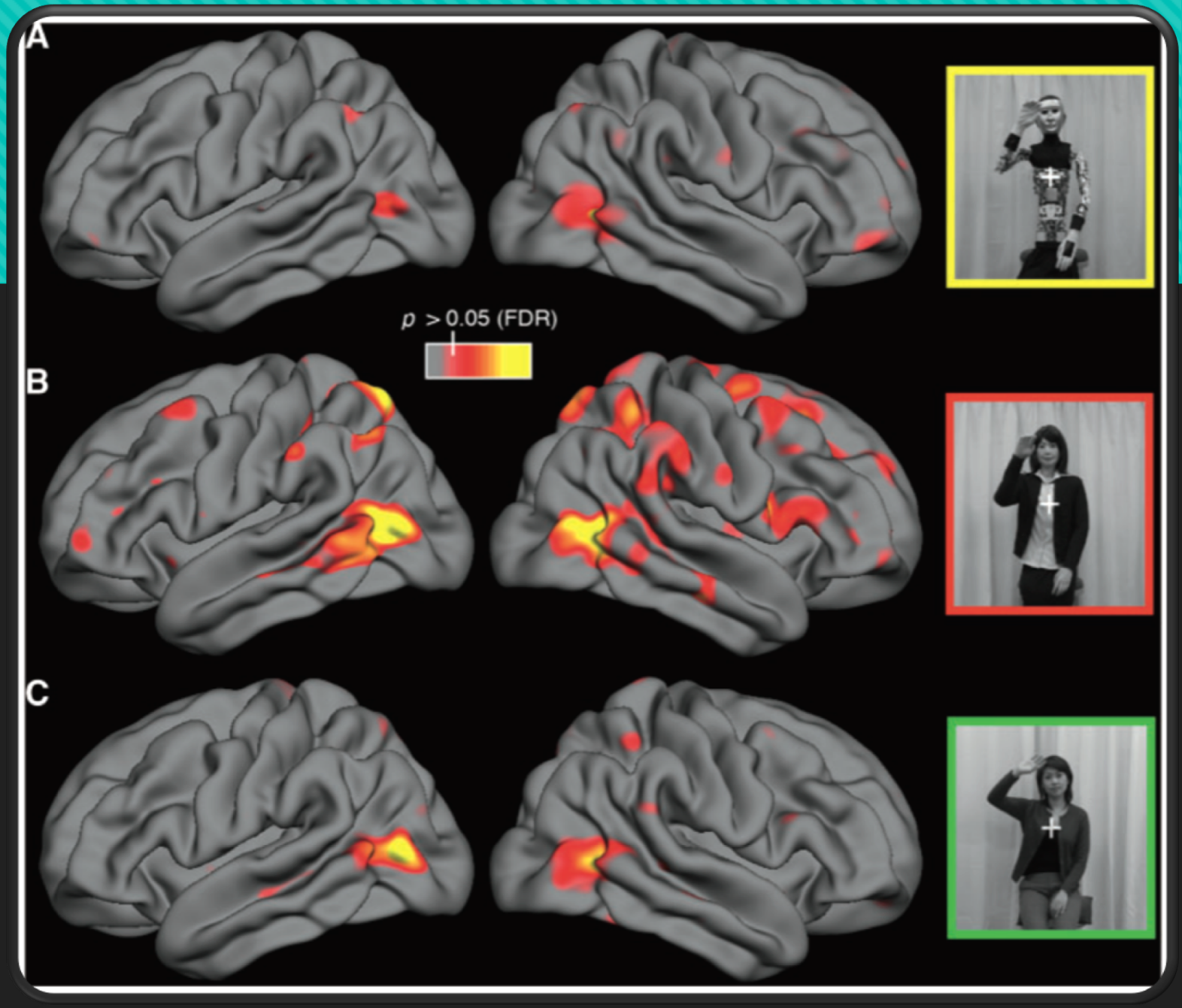
- Scanning procedures:
  - MR-compatible eye tracker
  - 3T Siemens Allegra scanner / a standard gradient echo pulse sequence
  - The way of identifying regions of interest (ROIs) was by selecting brain regions that showed significant repetition suppression (main effect of repetition).

Results

- Accuracy for the comprehension questions and eye movements did not differ across conditions.

Results

- Suppression in the lateral temporal cortex was evidenced in all three conditions.
- The human condition showed similar results to the robot condition.
- Repeated android videos leaded to wider range of suppressed brain regions (including parietal and frontal cortex).



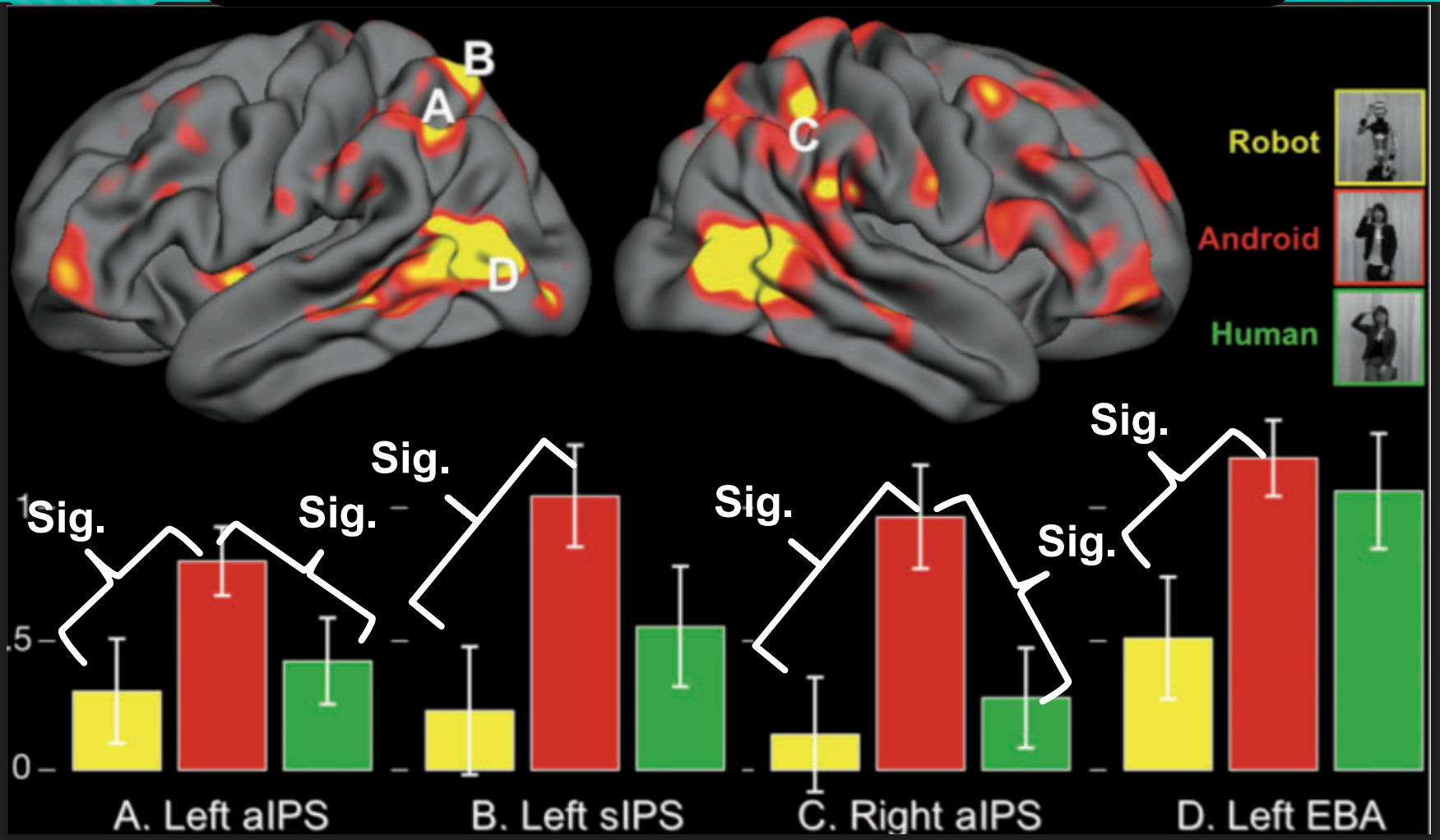
Results

Main effect of Repetition

- ROIs include: occipital, lateral and ventral temporal, parietal, frontal, parahippocampal and cerebellar regions
- ventral premotor cortex did not show significant repetition suppression
- One repetition suppression foci in frontal cortex extended into dorsal premotor cortex.

Results

Repetition × Agent interaction



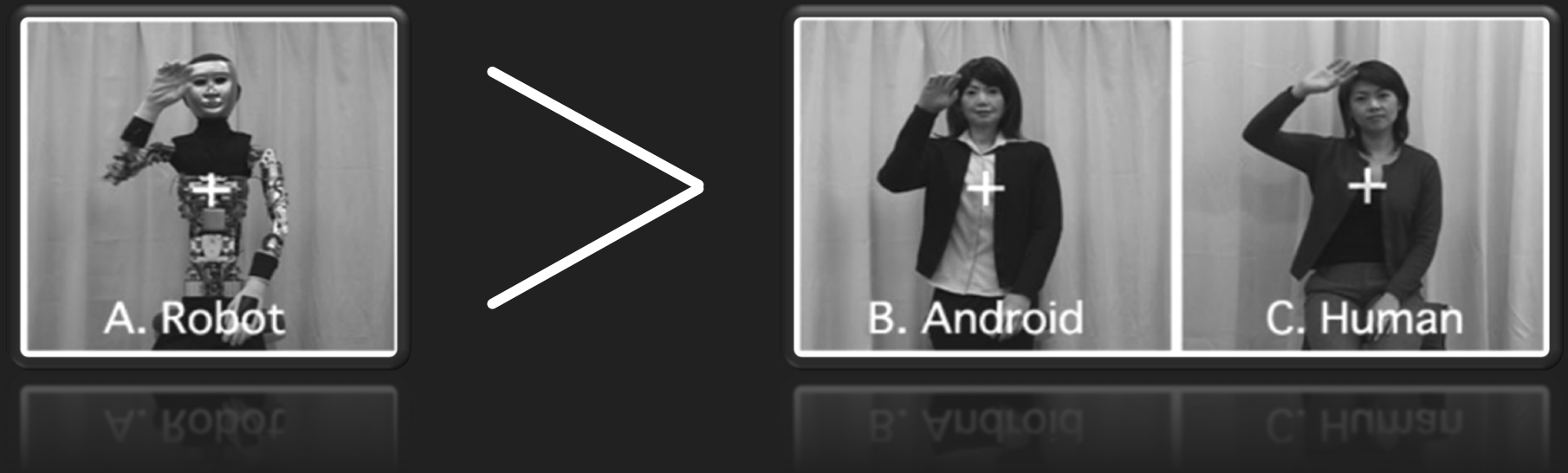
Sig. (p<.05)

Results

Main effect of agent

- visual cortex in both left and right hemispheres

  (MNI coordinates -30, -92, 2 and 38, -80, -16)

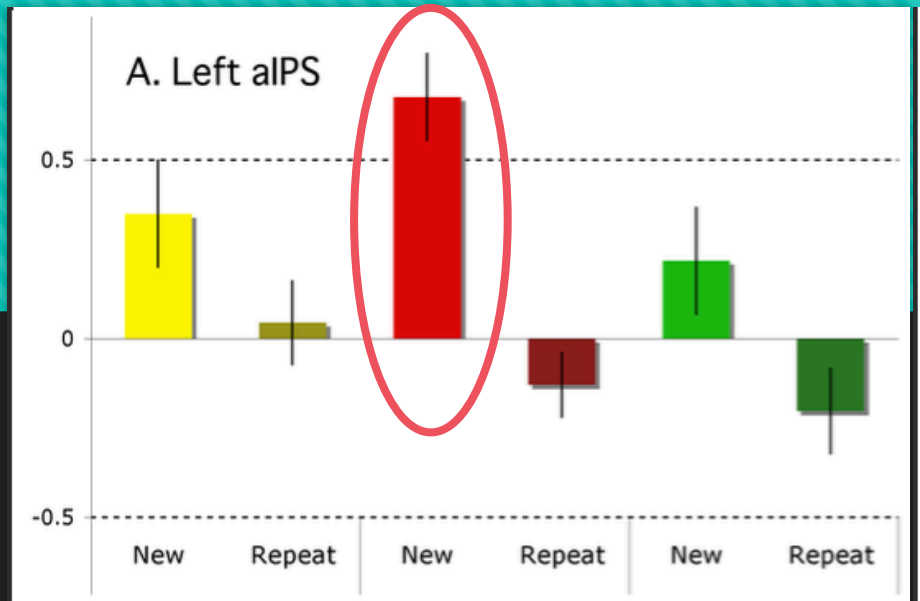


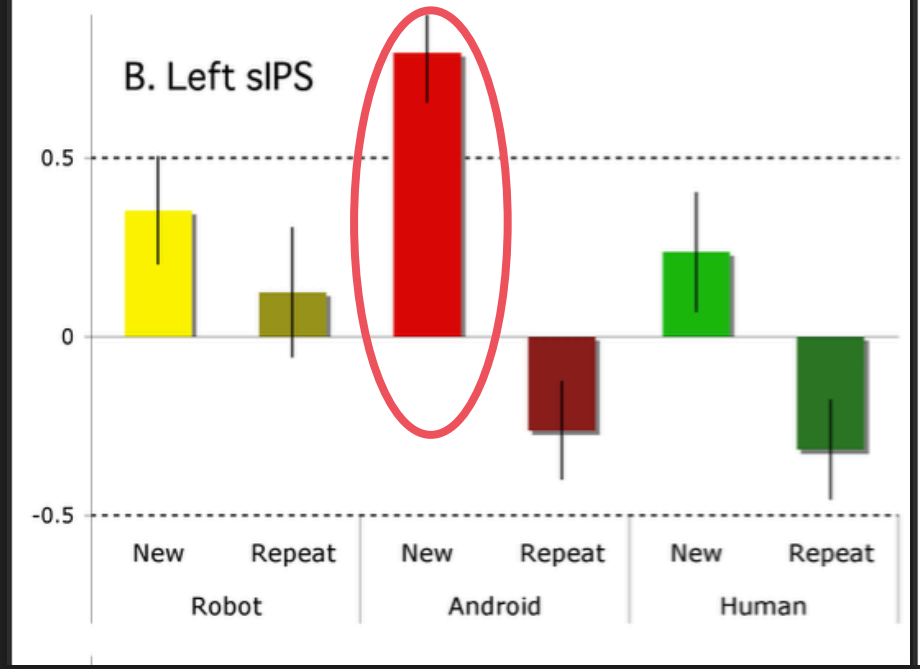
Discussion

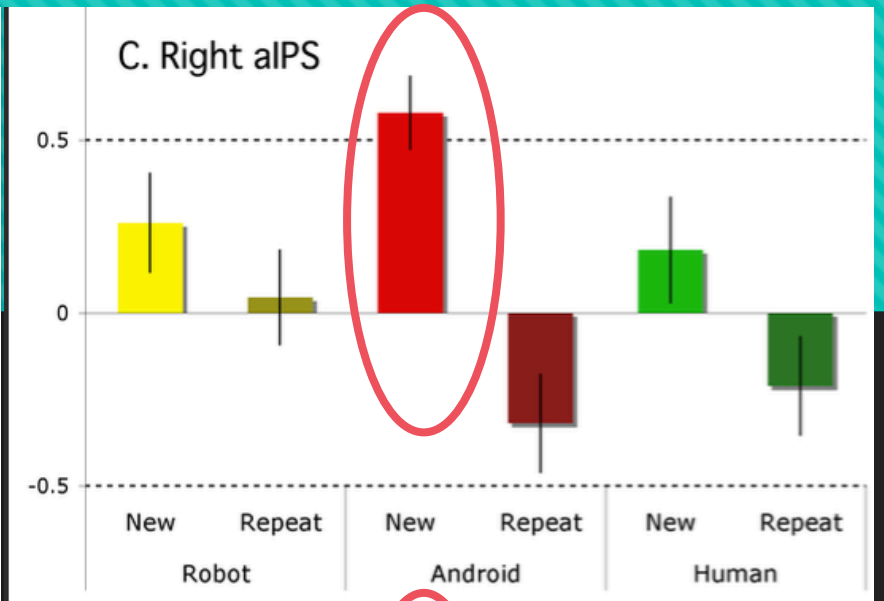
- In bilateral aIPS, EBA, left sIPS, the android condition showed greater repetition suppression than other conditions.
- After analysing brain activation of non-repeated and repeated videos respectively, the android condition showed significantly greater brain activities than other two conditions.

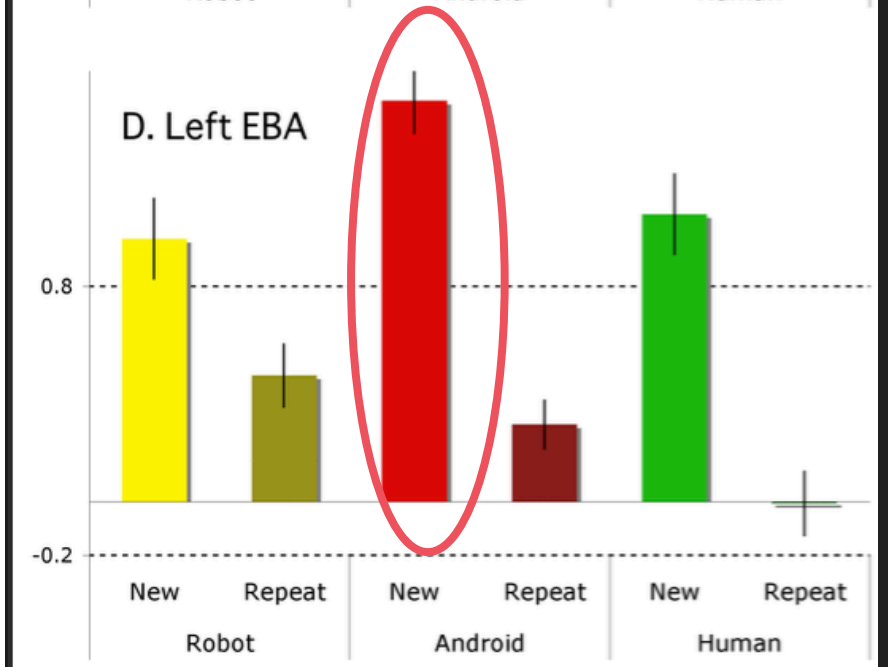
  → higher brain activation was caused by a mismatch of sensory stimuli (prediction error) →uncanny valley

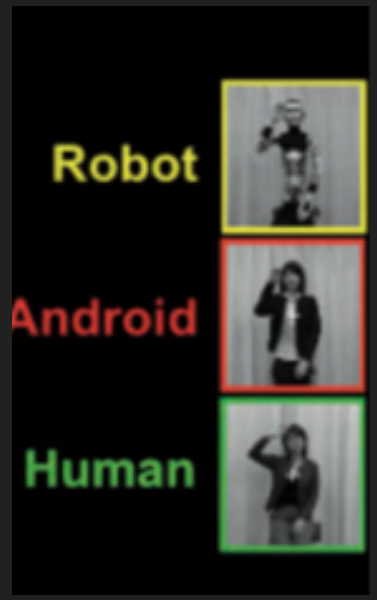
aIPS
The link between visual and motor processing in the APS
→ Generate sensory predictions


A. Left aIPS
0.5
0
-0.5
New
Repeat
New
Repeat
New
Repeat


B. Left sIPS
0.5
0
-0.5
New
Repeat
New
Repeat
New
Repeat
Robot
Android
Human


C. Right aIPS
0.5
0
-0.5
New
Repeat
New
Repeat
New
Repeat
Robot
Android
Human

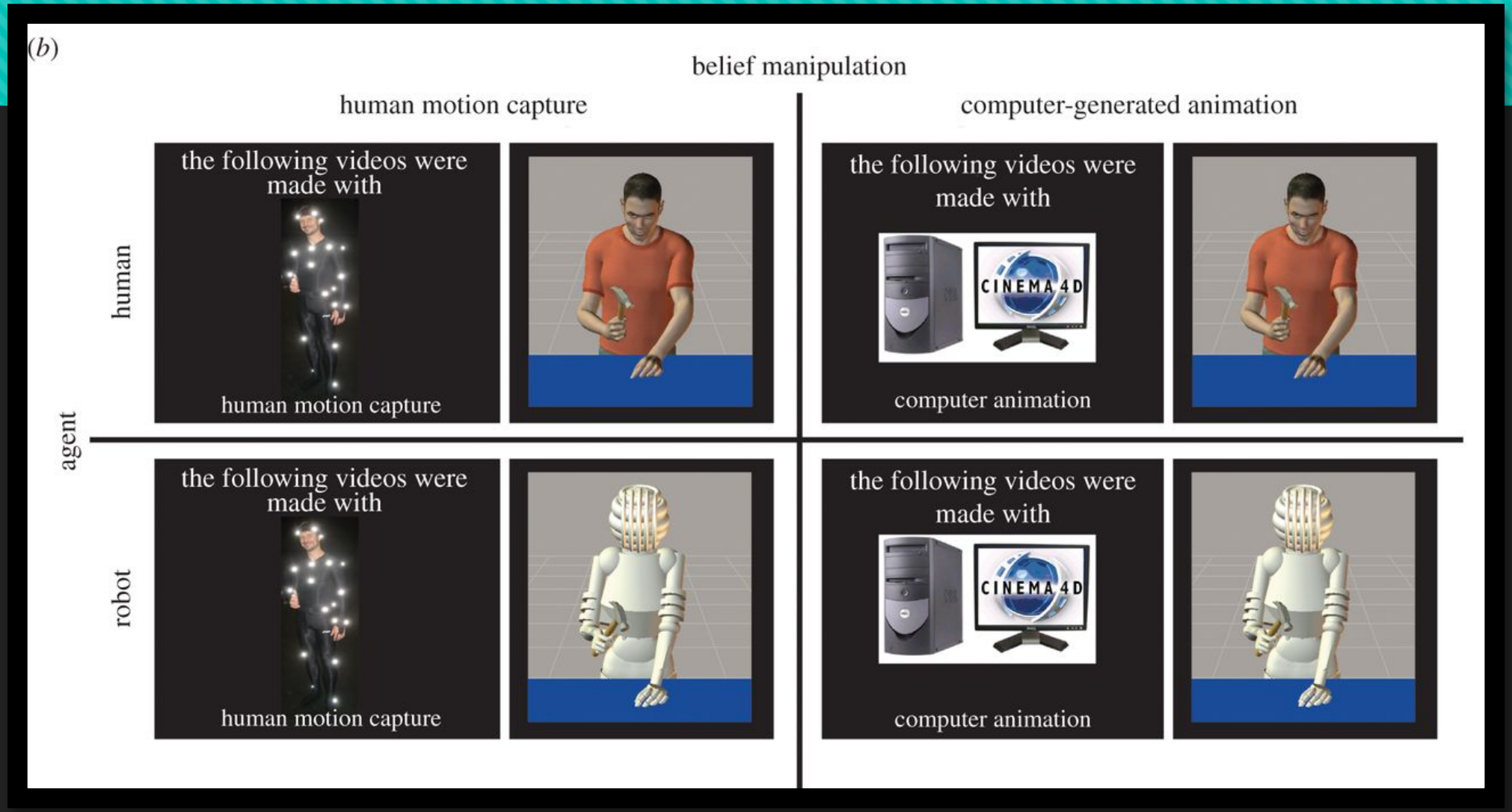

D. Left EBA
0.8
-0.2
New
Repeat
New
Repeat
New
Repeat
Robot
Android
Human


Robot
Android
Human

Discussion

- Likability towards robots in this study
- “Effectance motivation” describes humans’ motivation to interact effectively or a desire for a sense (Epley, Waytz, & Cacioppo, 2007)
- People possess some prior ideas of how robots should move.
- Expectations may vary according to robots’ appearance.

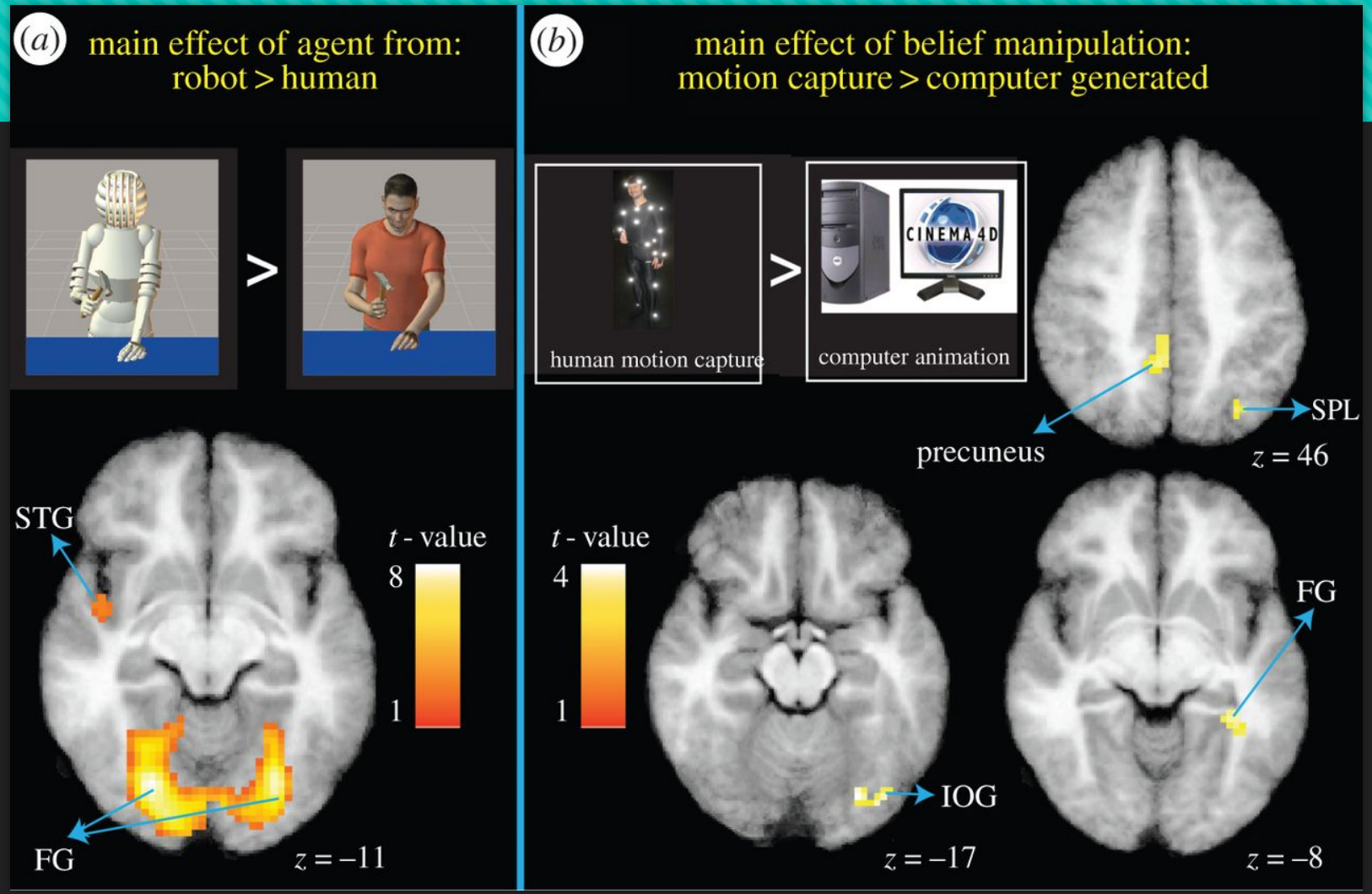
Discussion



Cross, Ramsey, Liepelt, Prinz, & Hamilton (2015)

Discussion

- Congruence > Incongruence
  →middle and posterior cingulate cortices
- Incongruence > Congruence
  →right inferior frontal gyrus the cerebellum



Cross, Ramsey, Liepelt, Prinz, & Hamilton (2015)

Thank You for Listening!