Movement Features and Brain Mechanisms for the Recognition of Human Action

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Introduction

We are interested in the question of how human movement is recognized

What are the visual cues?

What neural circuits are involved?

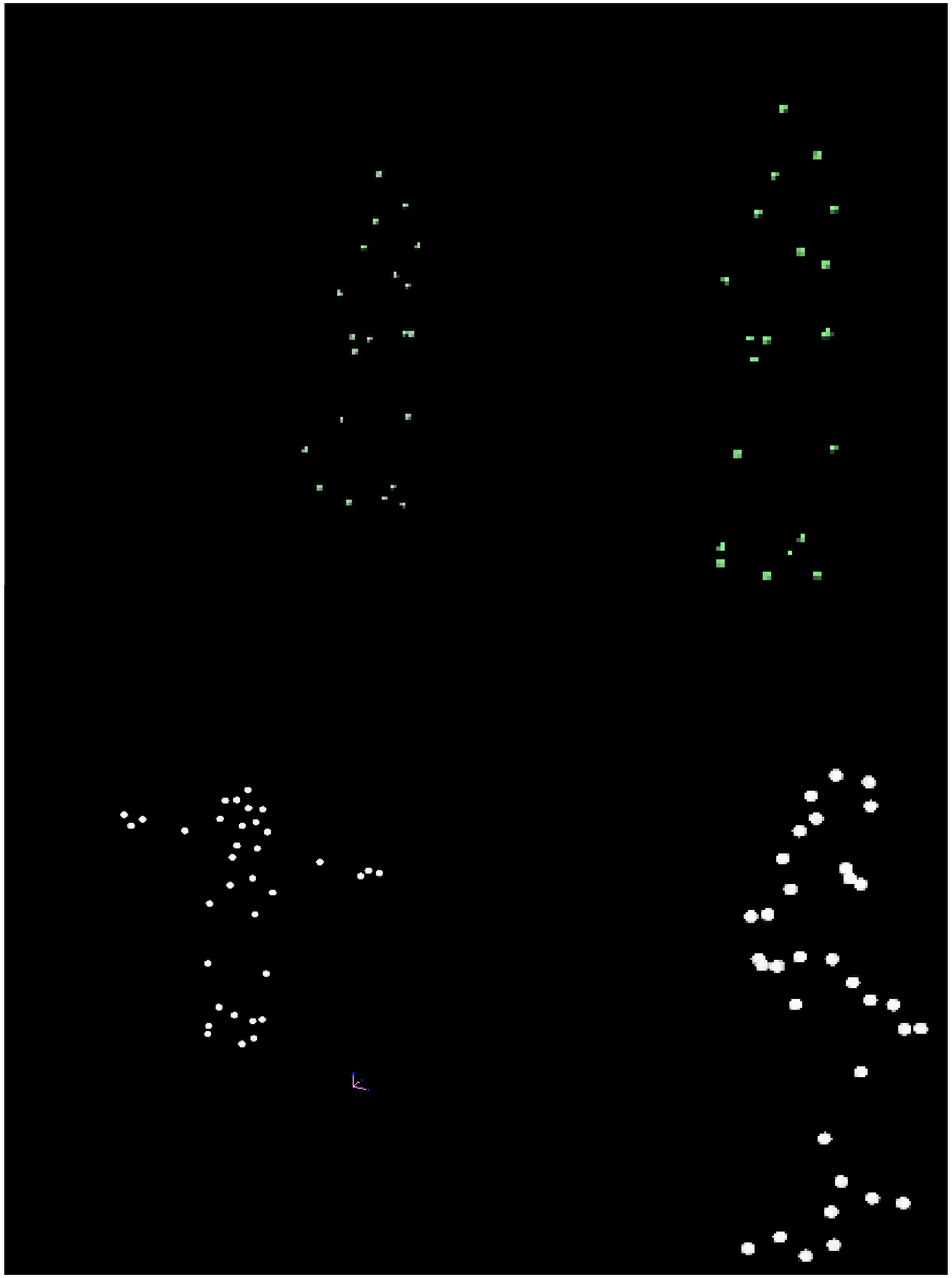
Human Movement can Inform Person Properties Such As

- affect
- Identity
- gender
- in the case of computer animation whether a movement appears natural (or possible)

Out in the World Human Movement is Complex

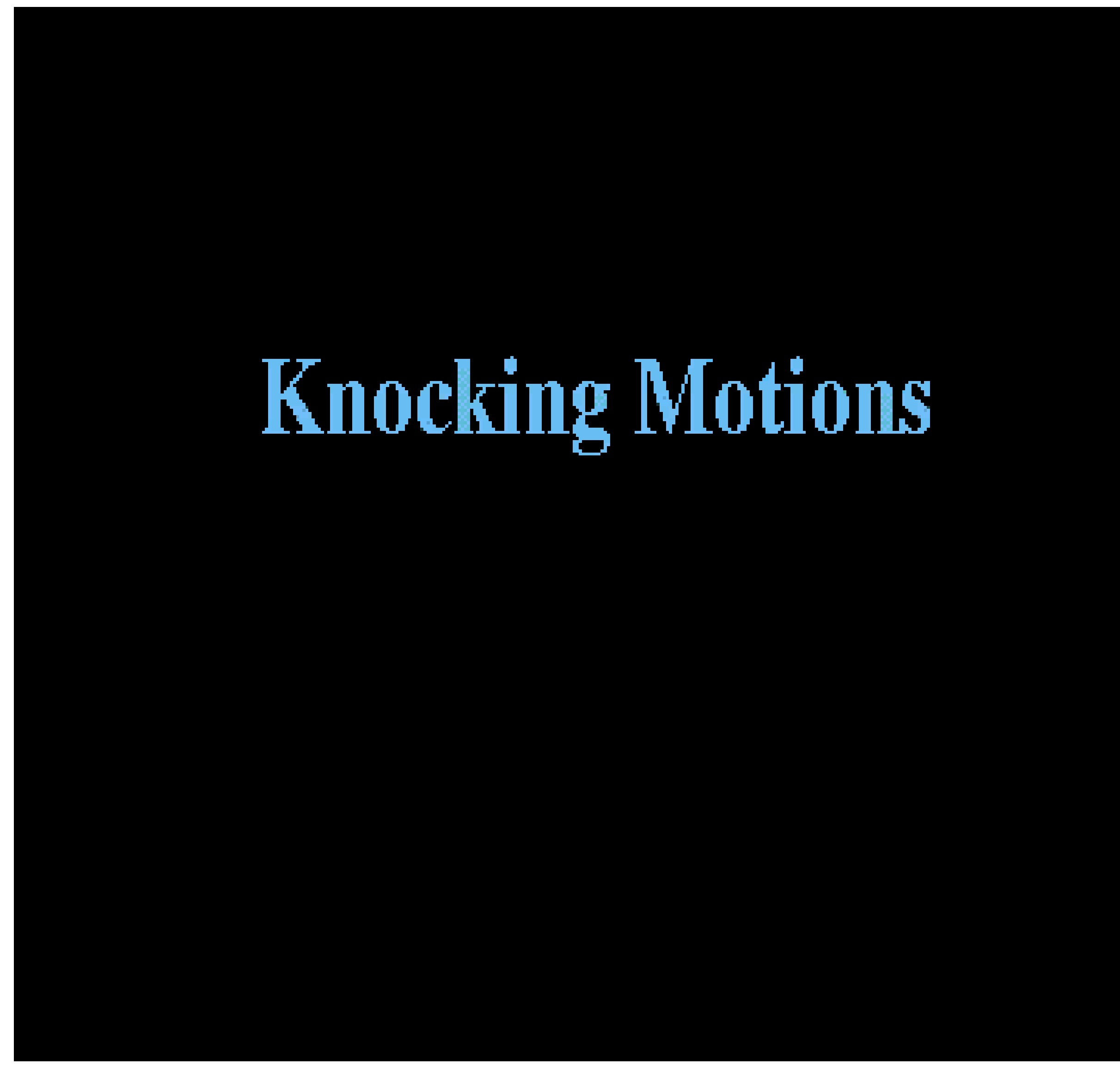
So In the Lab We Use Point-light Displays

Isolate motion information - static frame is uninformative



Affect

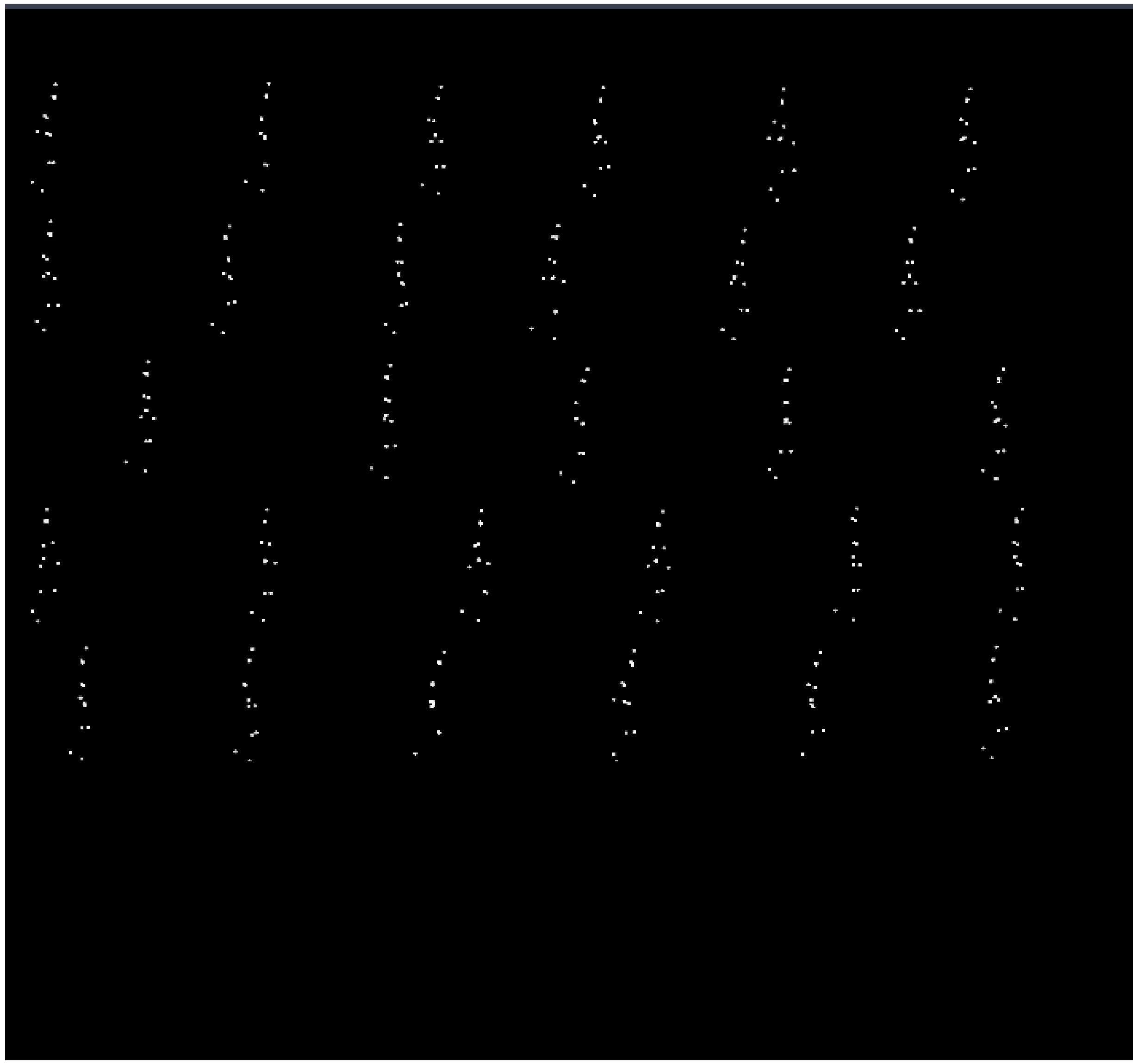
- Consistent with a cognitive model specifying dimensions of activation and valence (positive-negative affect)
- activation correlated to velocity, valence appears to be subtle spatial cue



Pollick, F.E., Paterson, H., Bruderlin, A. & Sanford, A.J. (2001) Perceiving affect from arm movement. Cognition, 82. B51-B61.

Identity

- Duration of step cycle appears more influential than average velocity
- Upper and lower body have different contributions



Pollick, FE, Ma, Y, Tsao, J & Nixon, M (2005) Attitudinal and Biometric Contributions to the recognition of identity from point-light walkers. Poster presented at VSS05

Possibility/Naturalness

- If we introduce noise into a hierarchical joint representation we preserve form but distort coordination
- It takes a substantial amount of distortion before a movement is seen as definitely an impossible movement

Hadjigeorgieva, M., Jang, S. H., Park, S.-J., Jung, W. H., Chung, C. S., & Pollick, F. E. (2004). The influence of temporal offset noise on the perception of possible versus impossible movement. Poster presented at VSS04

Summary & Questions

- Stimulus features important for action recognition vary with the action viewed and property to be recognized
    - It appears useful to distinguish between temporal (e.g. duration, velocity) from spatial (e.g. path) properties.
- *Can the task dependency be systematized?*
- *How far can we go to describe human recognition of action by concerning ourselves only with low-level stimulus features?*
- *How good are observers at recognizing human actions?*

Human Performance at Gender Recognition

How to effectively estimate human performance at recognizing gender from point-light walkers

Special thanks to Jim Kay, Department of Statistics, University of Glasgow

Gender Recognition

- Cutting et al (1978) showed that gender could be recognized from point light display and proposed center of moment (CM) as a distinguishing feature
  - CM isdefined as ratio of shoulder width to the sum of the shoulder & hip widths
- For years this was taken as evidence of exquisite tuning of the perceptual system. Recently, we revisited this problem by exploring the efficiency at which gender is recognized

Recognition Efficiency

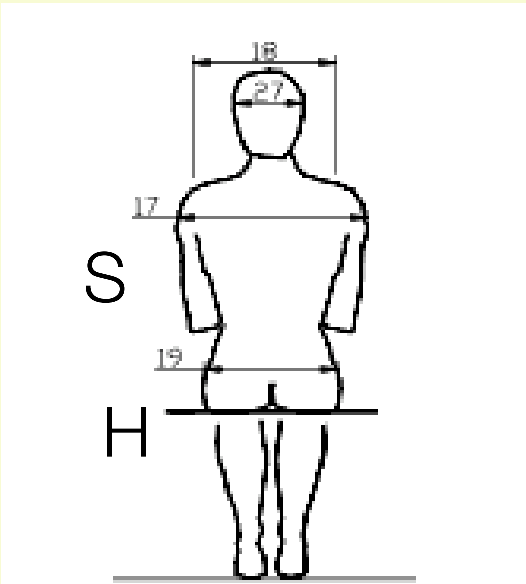
- Efficiency provides a means to quantify human performance by indicating what proportion of information available is used by human observers
  - Efficiency defined as the ratio of squared senstivity (d') of human performance to that of an "ideal observer" that can use all the possible information.

Pollick, F.E., Lestou, V., Ryu, J. & Cho, SB. (2002) Estimating the efficiency of recognizing gender and affect from biological motion. Vision Research, 42, 2345-2355.

Efficiency of Gender Recognition

- Human performance
  - Meta analysis of 21 experiments investigating gender recognition reveals performance of 66% correct (d'=0.82)
- Ideal performance based on CM
  - Anthropometric databases allow us to estimate male and female distributions of the center of moment and from this we can obtain a prediction of ideal performance, 79% correct (d' =1.6)

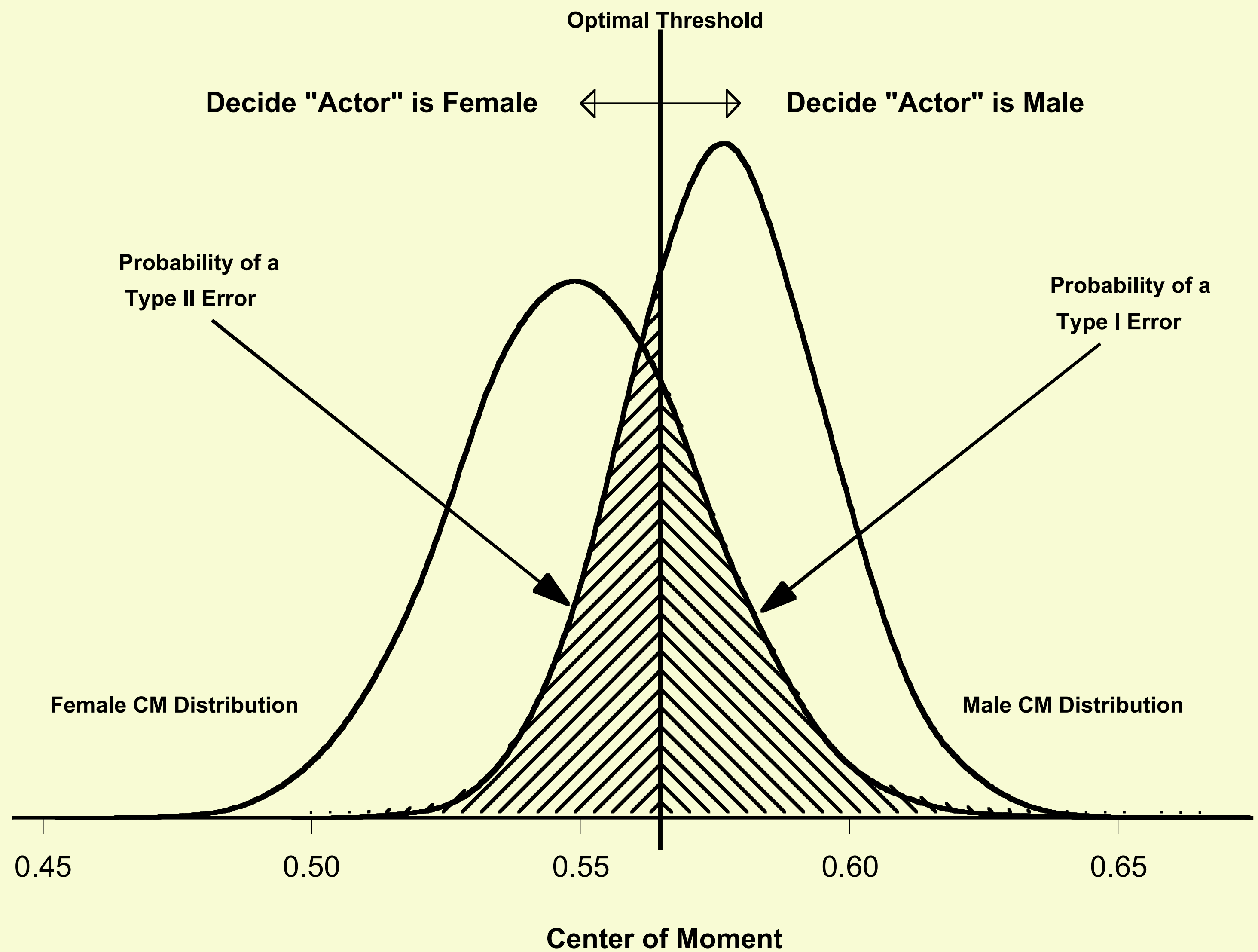
Pollick, F.E., Kay, J., Heim, K. & Stringer, R. (In Press) Gender Recognition from Point-Light Walkers. Journal of Experimental Psychology: Human Perception and Performance



$$CM = S/(S+H)$$

	Percentiles		
Males	5th	50th	95th
S	417	465	526
H	296	341	398
Females			
S	390	437	517
H	311	358	439

Simulated CM distributions for male and female US 18-25 year-olds



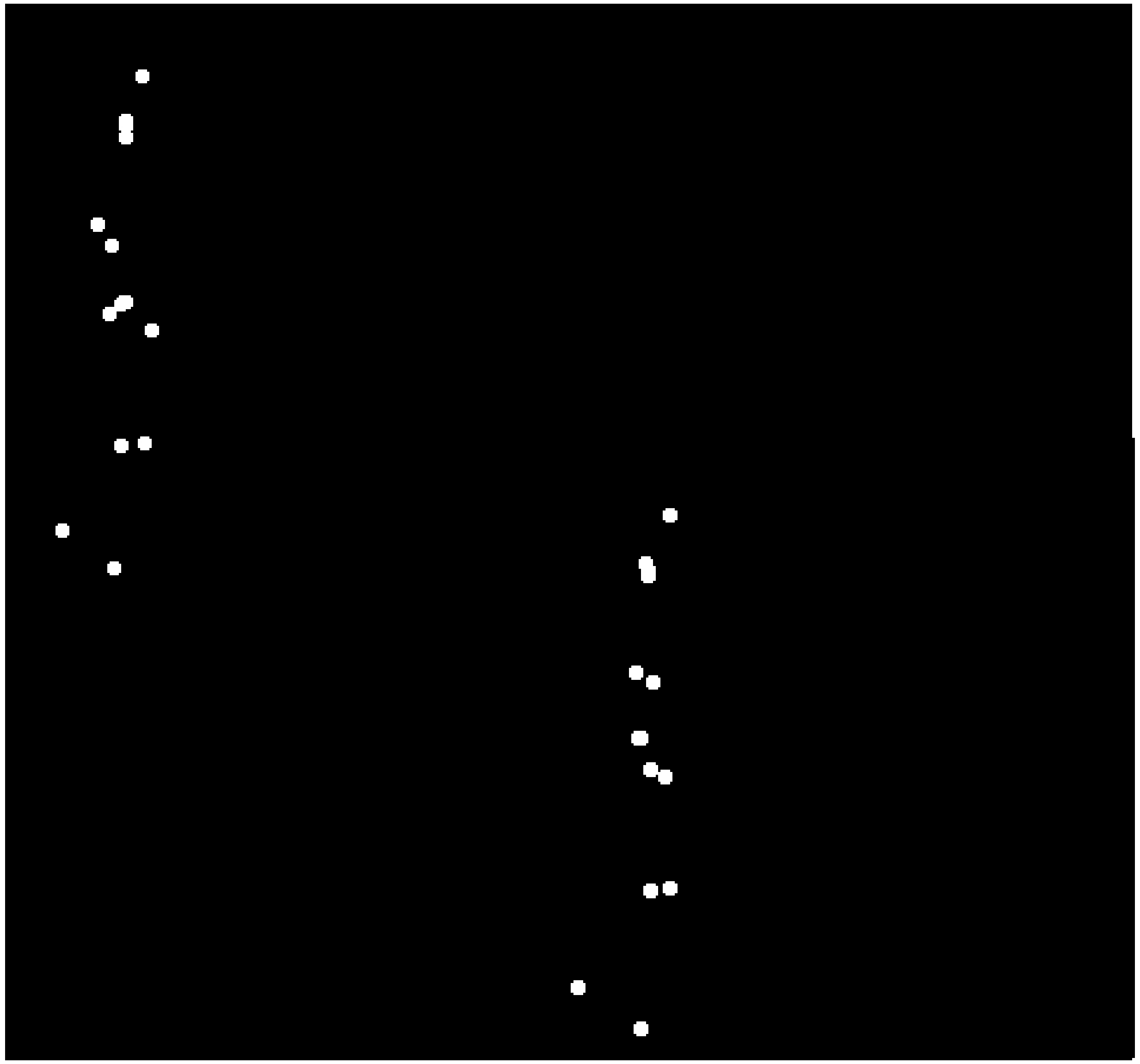
Optimal Threshold

Results

- Accuracy at recognizing gender is not so high at only 66% correct (chance = 50%)
- However, efficiency of approximately 26% suggests that observers are tuned to the available information

A Loose End

- Center of Moment (CM) is a *form* cue and is available via structure-from-motion
- If a “pure” ***motion*** cue (or indeed, any other cue) was generally available in gait then efficiency will go down



Take Home Experiment

- Mather & Murdoch (1994) suggest lateral sway (male shoulders, female hips) informs gender recognition
  - How common is male lateral sway of the shoulders?
  - Is the female hip motion really lateral? (biomechanics literature suggests vertical)

Robots

Discuss the visual evaluation of humanoid robot movement and illustrate the significance of goals in the interpretation of human actions

Special thanks to Josh Hale* (jhale@atr.jp), Ales Ude, Gordon Cheng and Mitsuo Kawato of the ATR Computational Neuroscience Labs *and Dept of Computer Science, University of Glasgow

Sticky Hands Exercise

We achieved the goal of getting the humanoid to do the exercise but wanted to change the motor control mechanism to one that appeared natural to human observers

Hale, J. & Pollick, F.E. (In Press) “Sticky Hands” Learning and generalization for cooperative physical interactions with a humanoid robot. IEEE Transactions on Systems, Man and Cybernetics, Part C: Applications and Reviews

Visual Evaluation of Humanoid Movement

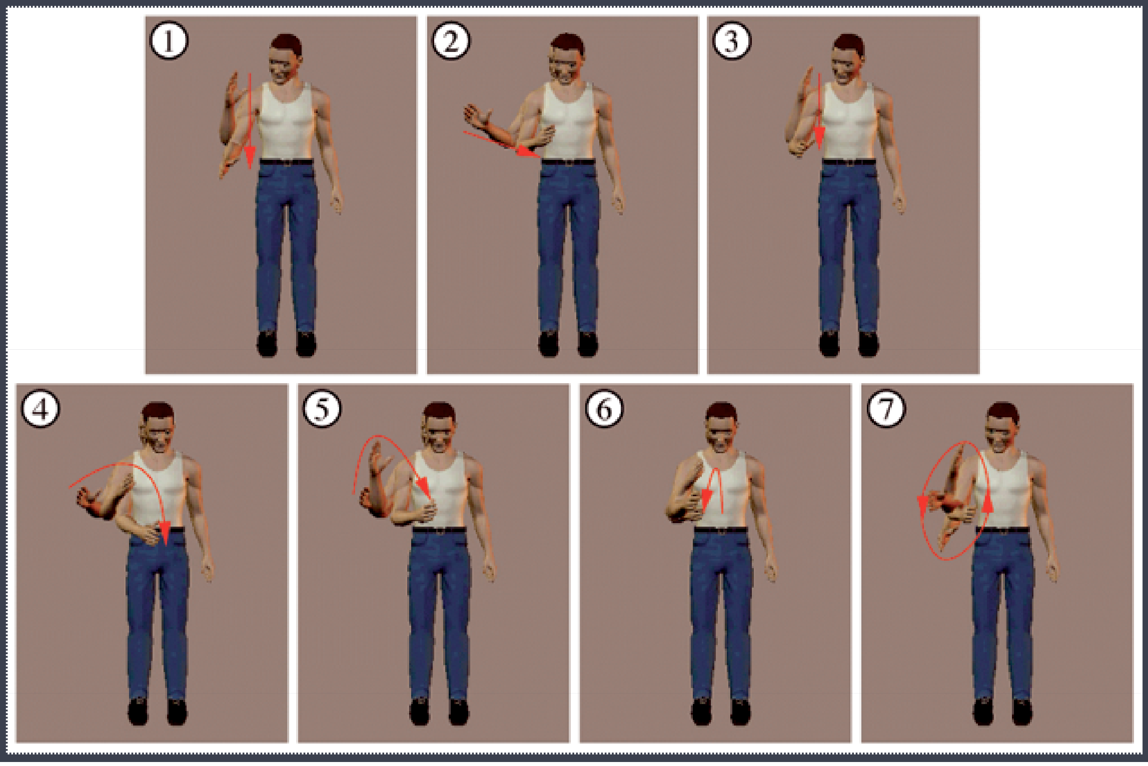
- Choose 7 movements and generated each with 14 different biomimetic control strategies
- As a control obtained human data on these 7 movements
- Produced all combinations of movement and control strategy and presented them on a humanoid robot and a computer graphics character
- Obtained observers' judgments of the naturalness of the movement

Pollick, F.E., Hale, J.G. & Tzoneva-Hadjigeorgieva, M. (In Press). Perception of humanoid movement. International Journal of Humanoid Robotics

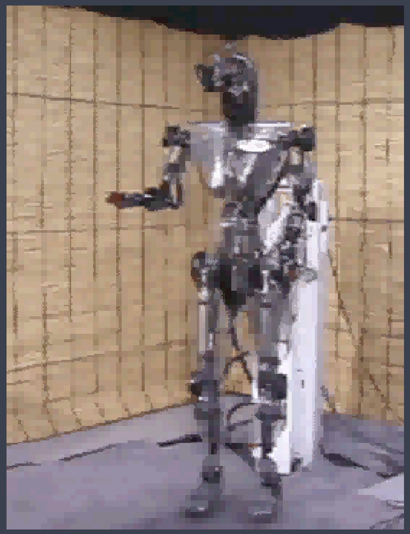
14 Control Strategies

Name	Model	Planning space	Planning level	FD
MV	Min. velocity	Extrinsic	Kinematic	No
MA	Min. acceleration	Extrinsic	Kinematic	No
MJ	Min. jerk	Extrinsic	Kinematic	No
MS	Min. snap	Extrinsic	Kinematic	No
MAV	Min. angular velocity	Intrinsic	Kinematic	No
MAA	Min. angular acceleration	Intrinsic	Kinematic	No
MAJ	Min. angular jerk	Intrinsic	Kinematic	No
MAS	Min. angular snap	Intrinsic	Kinematic	No
MJVT	Min. jerk virtual trajectory	Intrinsic	Kinematic	Yes
EPH	Equilibrium point hypothesis	Intrinsic	Dynamic	Yes
MT	Min. torque	Intrinsic	Dynamic	No
MTC	Min. torque change	Intrinsic	Dynamic	No
MTP	Min. torque postures	Intrinsic	Dynamic	No
MTPVT	MTP virtual trajectory	Intrinsic	Dynamic	Yes

7 Movements



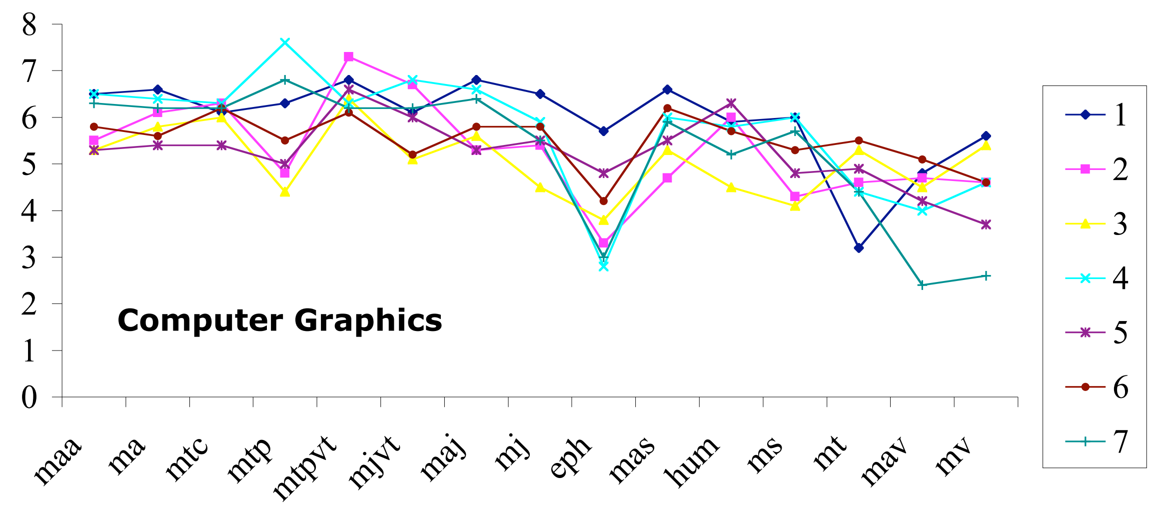
Display Examples

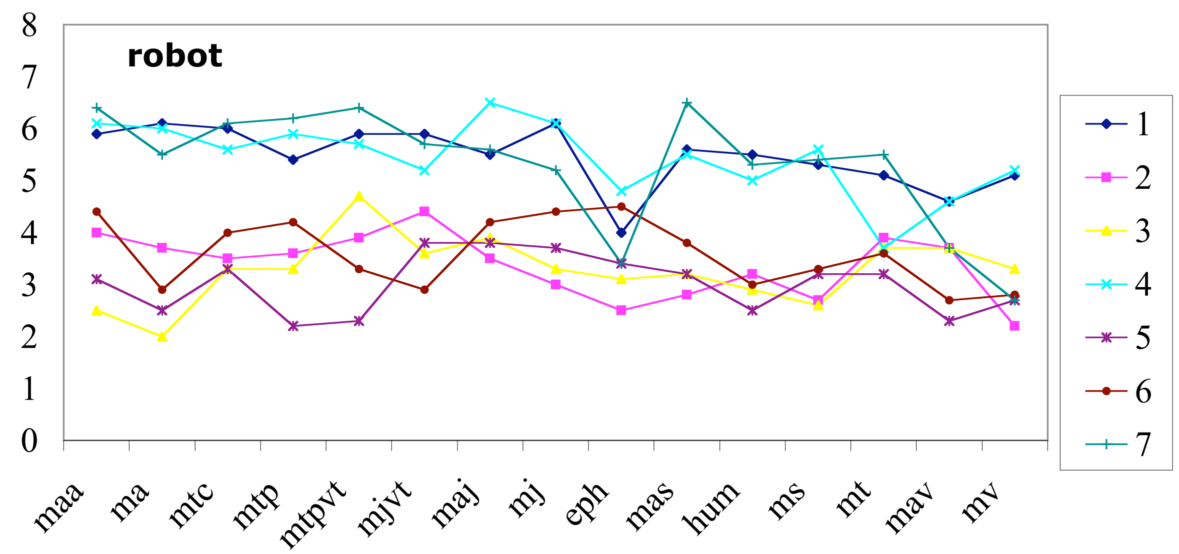


Hale J.G. and Pollick F.E. (2002) Biomimetic motion synthesis for the upper limb based on human motor production, Workshop on motor control in humans and robots (SAB 2002), Edinburgh University, August 10 - 11, 2002.

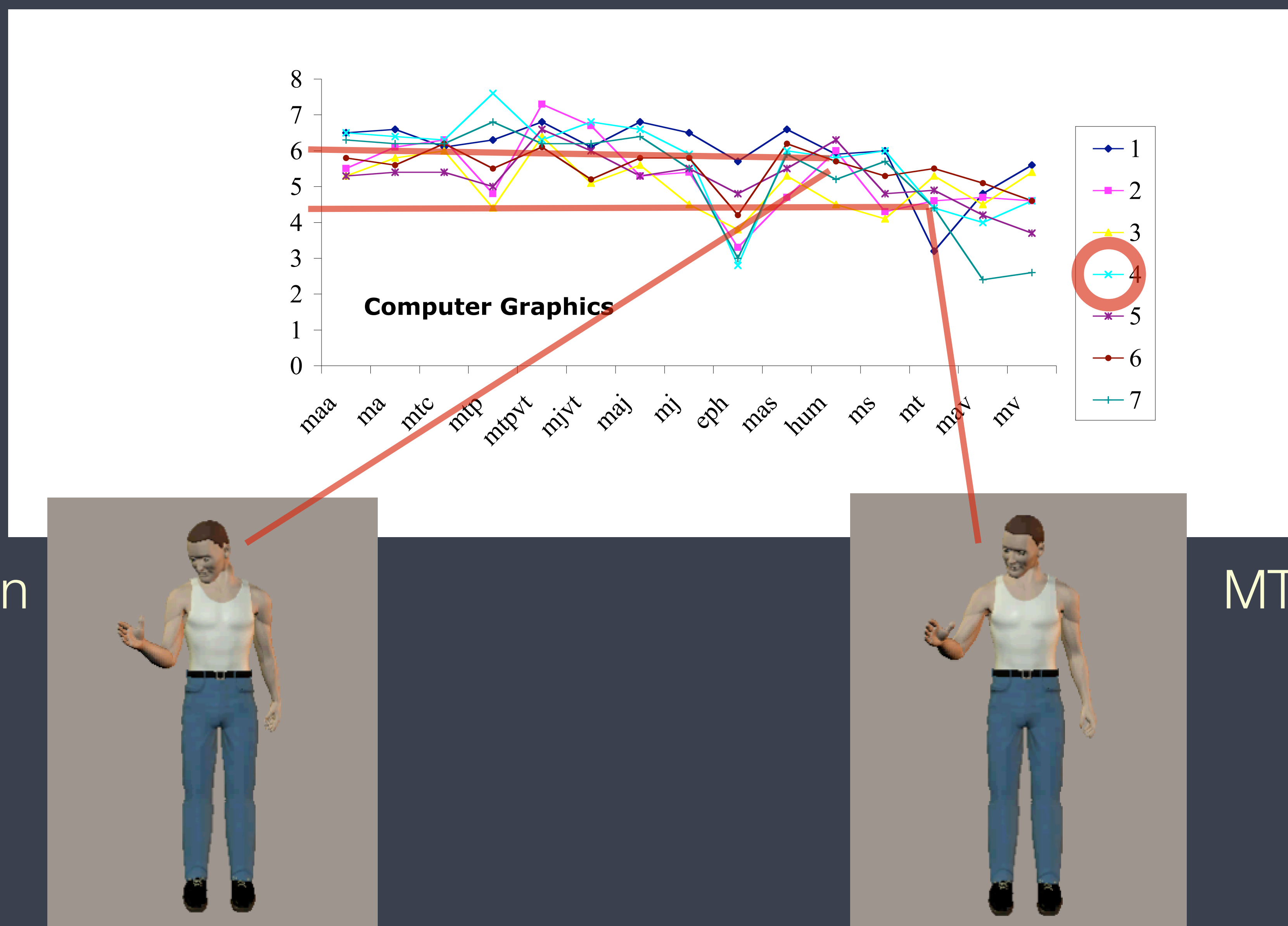
Results of Naturalness Ratings

- Complex interaction of movement and control strategy for computer graphics character
- Substantial effect of movement type for robot (caused by movement speed as shown in subsequent experiment)





However......



Human

MT

Effect of Goals

- It is difficult to interpret naturalness ratings independent of action goals
    - This poses a challenge for any “data-driven” or “bottom-up” description of human movement perception
- In the next section we explore the neural basis of why goals are important

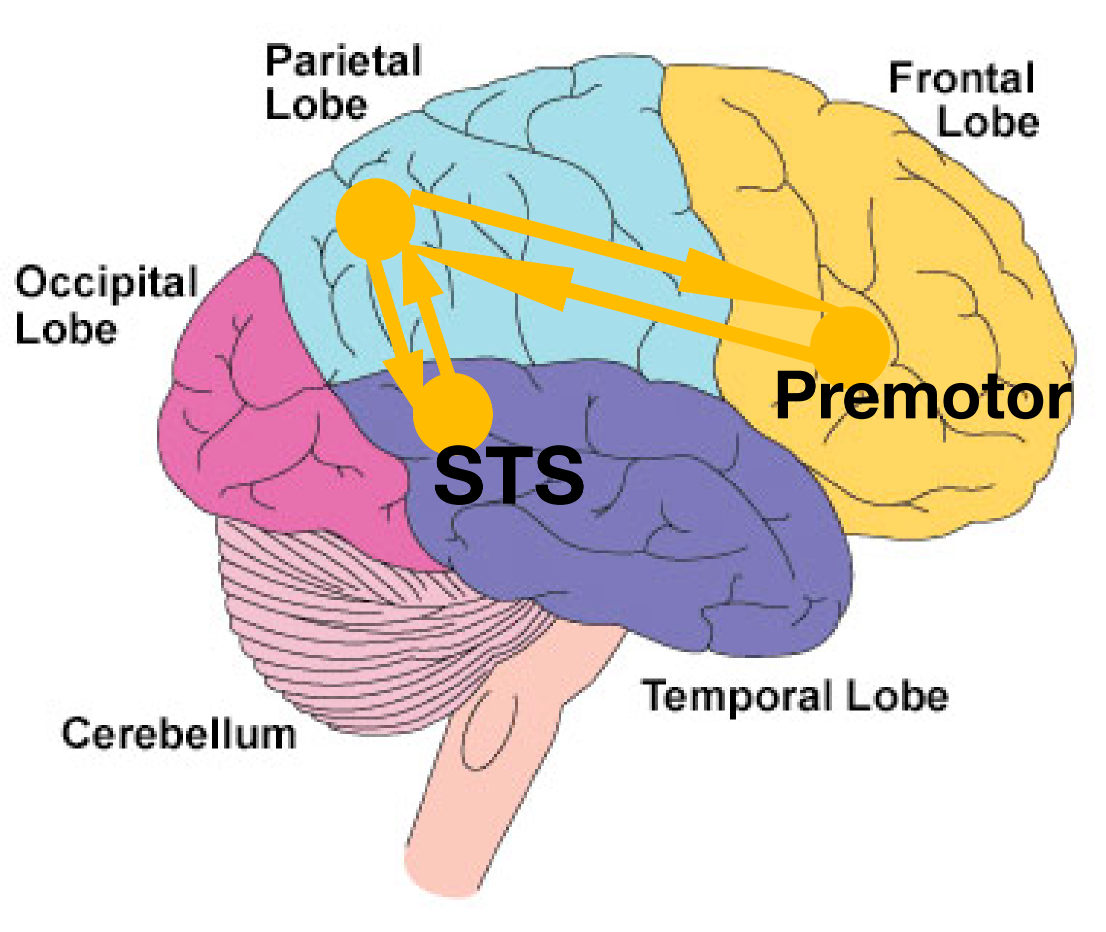
Brains

Describe a neural circuit for action understanding and a brain imaging experiments that explore its function

Special thanks to Zoe Kourtzi of the Max Planck Institute, Tuebingen

Brain Circuit for Action Understanding

- temporal (STS) and frontal (Premotor) areas are connected via the parietal cortex. Hypothesized functionality:
  - frontal (premotor): motor repertoire of goal states - mirror area
  - parietal - mirror area
  - temporal (STS) - visual region where form and motion are combined



Fogassi et al, 1998 SFN abstract
Koski, et al (2003) J Neurophysiol
Iacaboni, in press

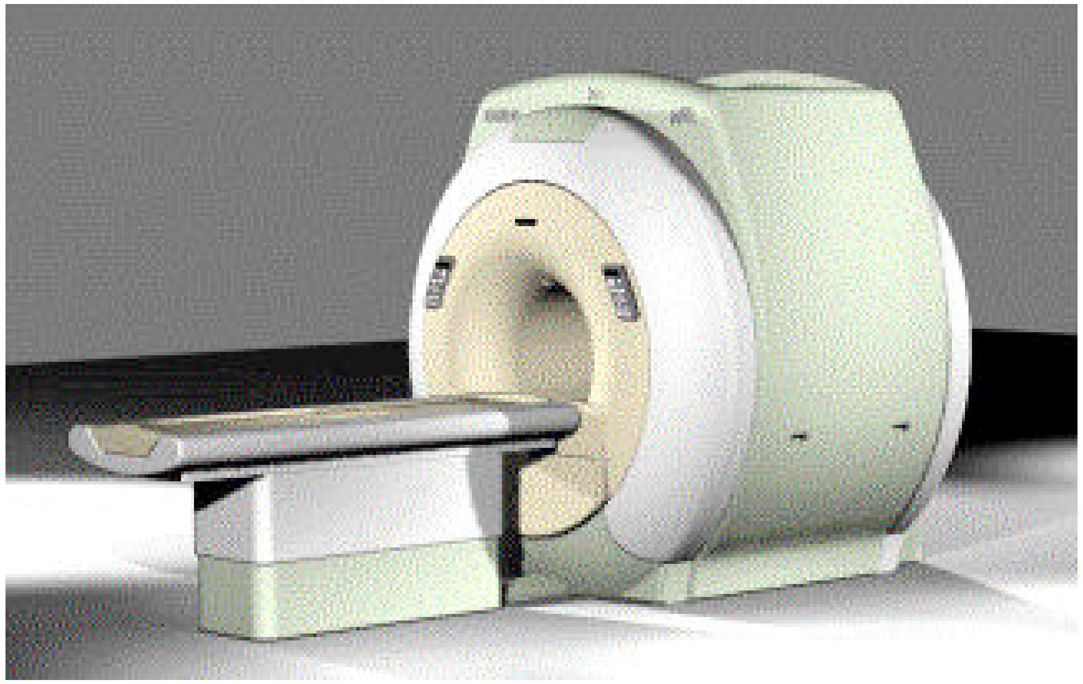
Our approach

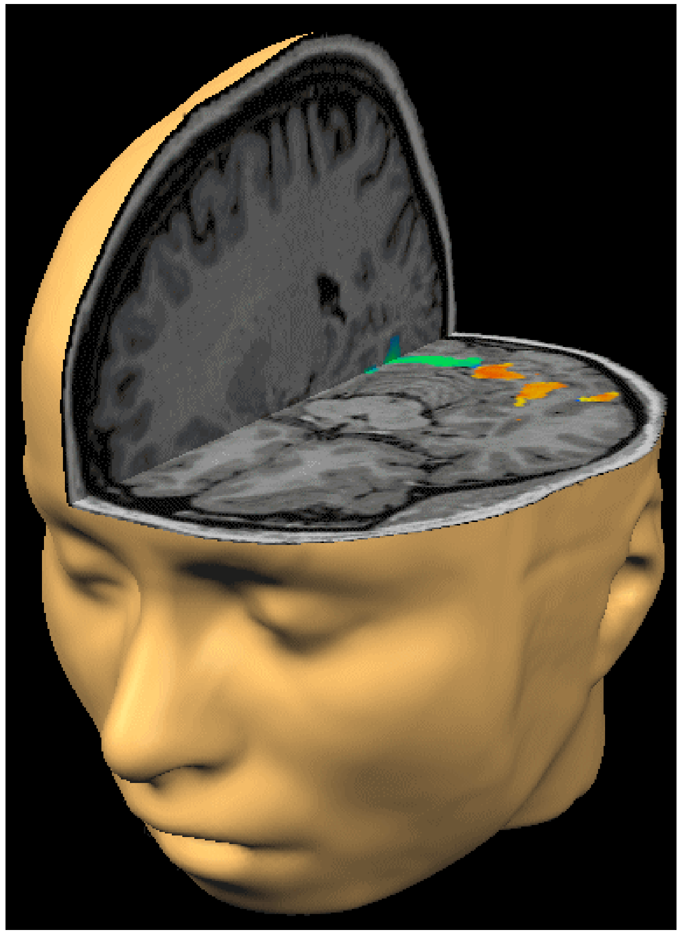
- Movement decomposition into:
  - Goals - the purpose of the movement
  - Kinematics - the motion pattern of the movement
- Examine how this fronto-parietal-temporal circuit differentially processes goals and kinematics

Lestou, V., Pollick, F.E., Kourtzi, Z. (Very nearly submitted. Honest!). Neural substrates for the imitation of action goals and kinematics in the human brain.

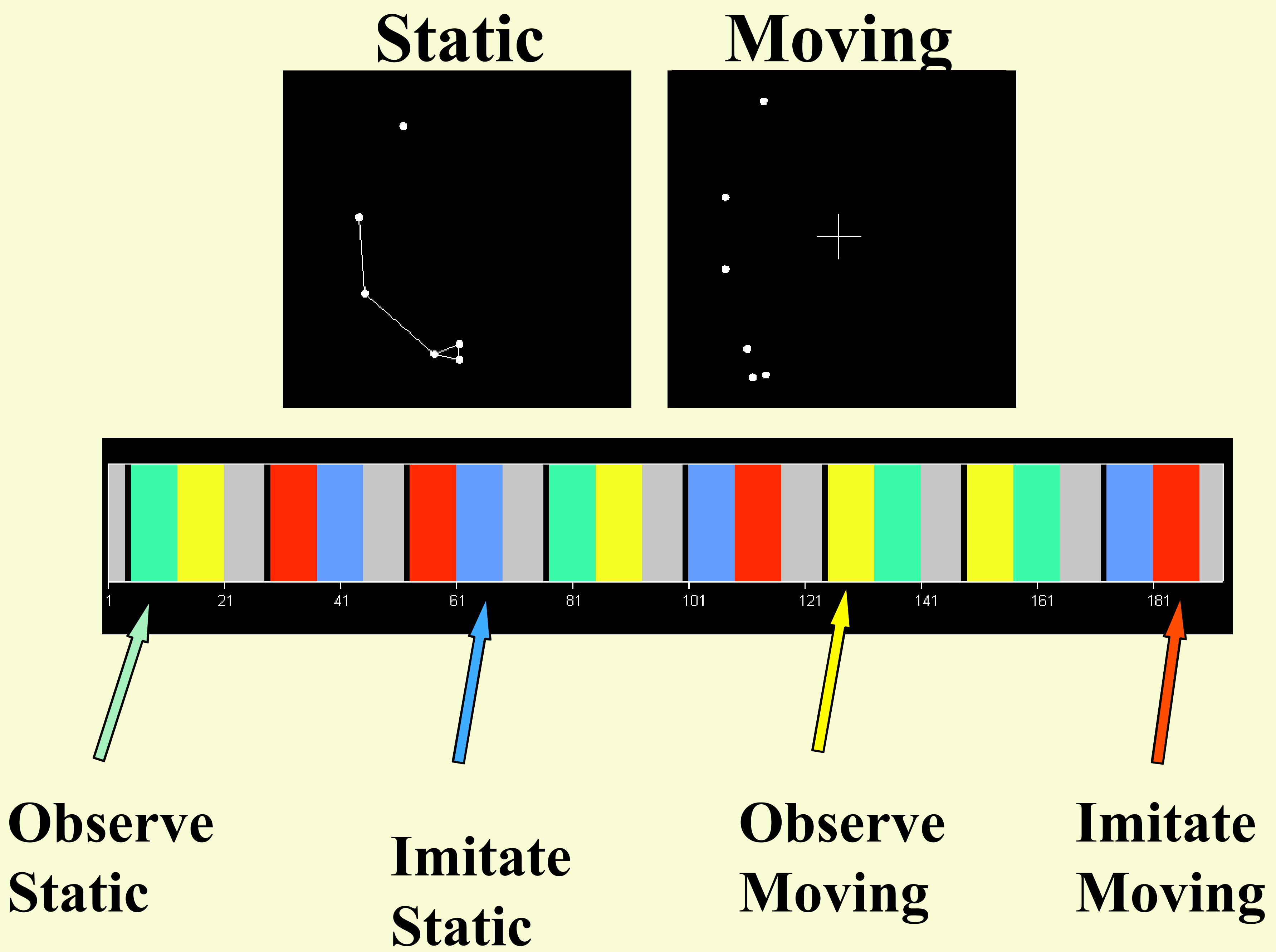
fMRI Experiments

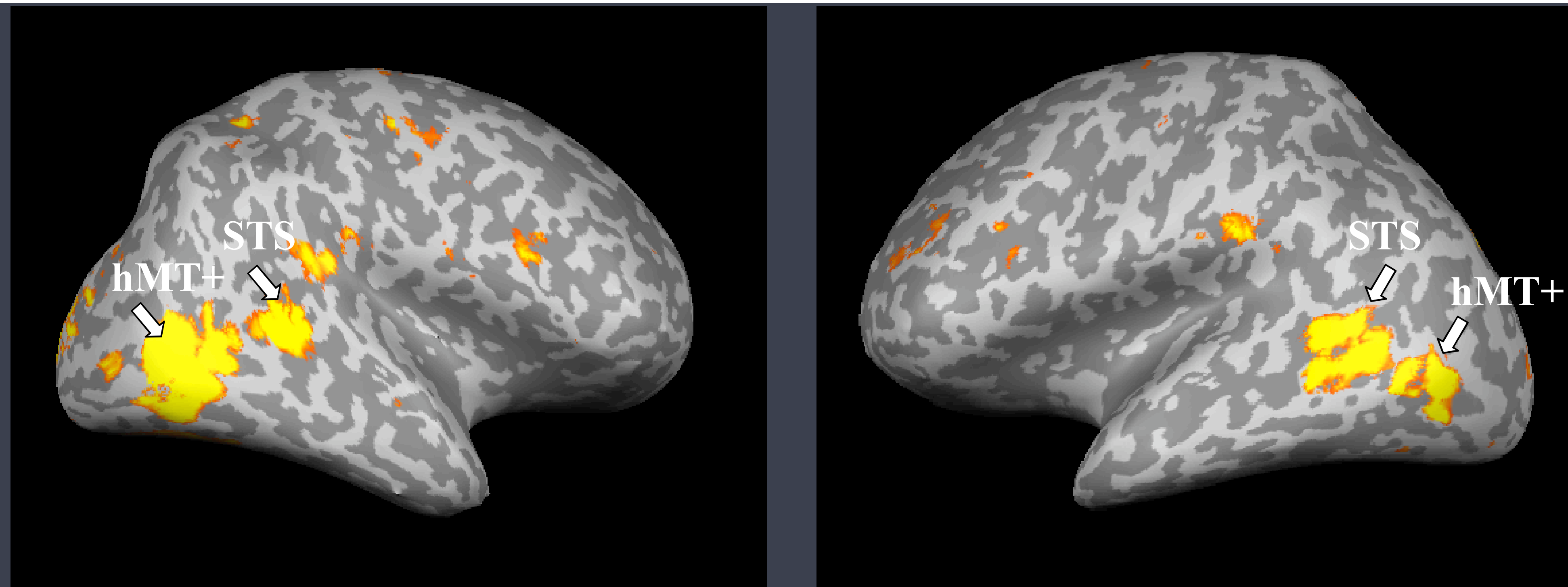
- Region of interest adaptation design
  - define regions of interest (ROI)
  - measure adaptation of ROI across different conditions of stimuli pairs



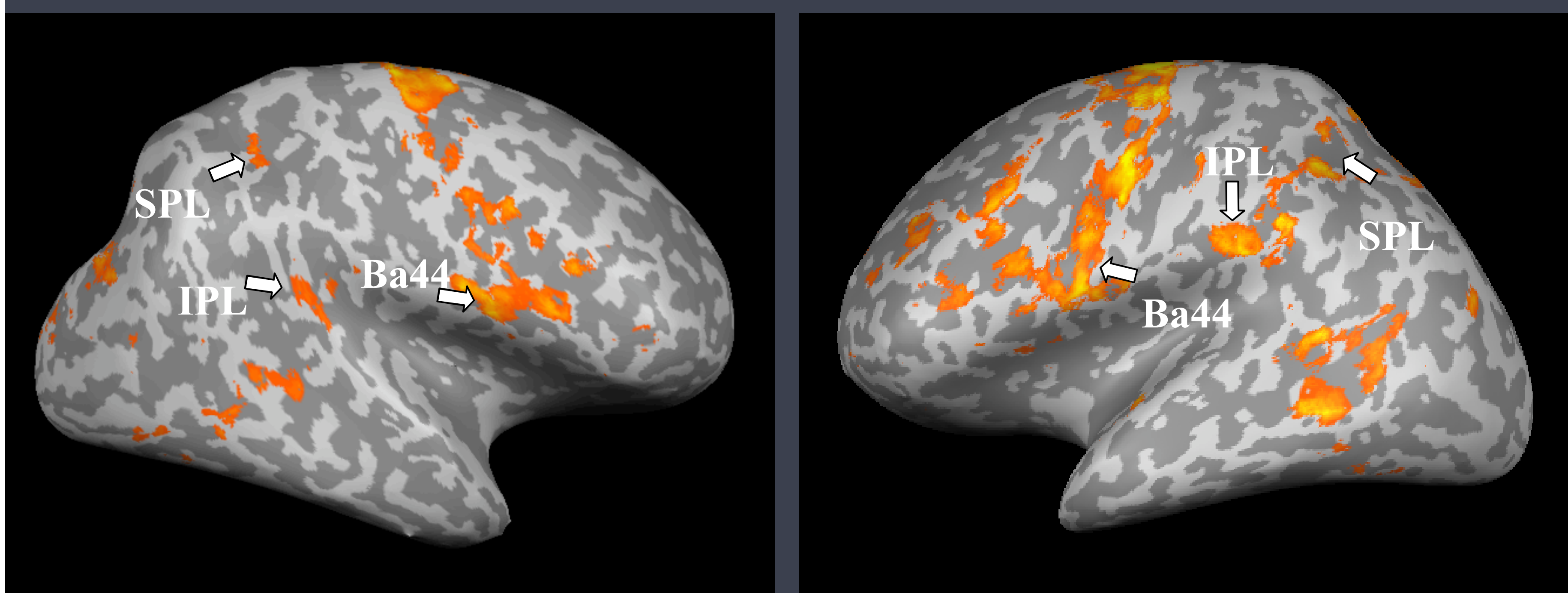


Defining Regions of Interest

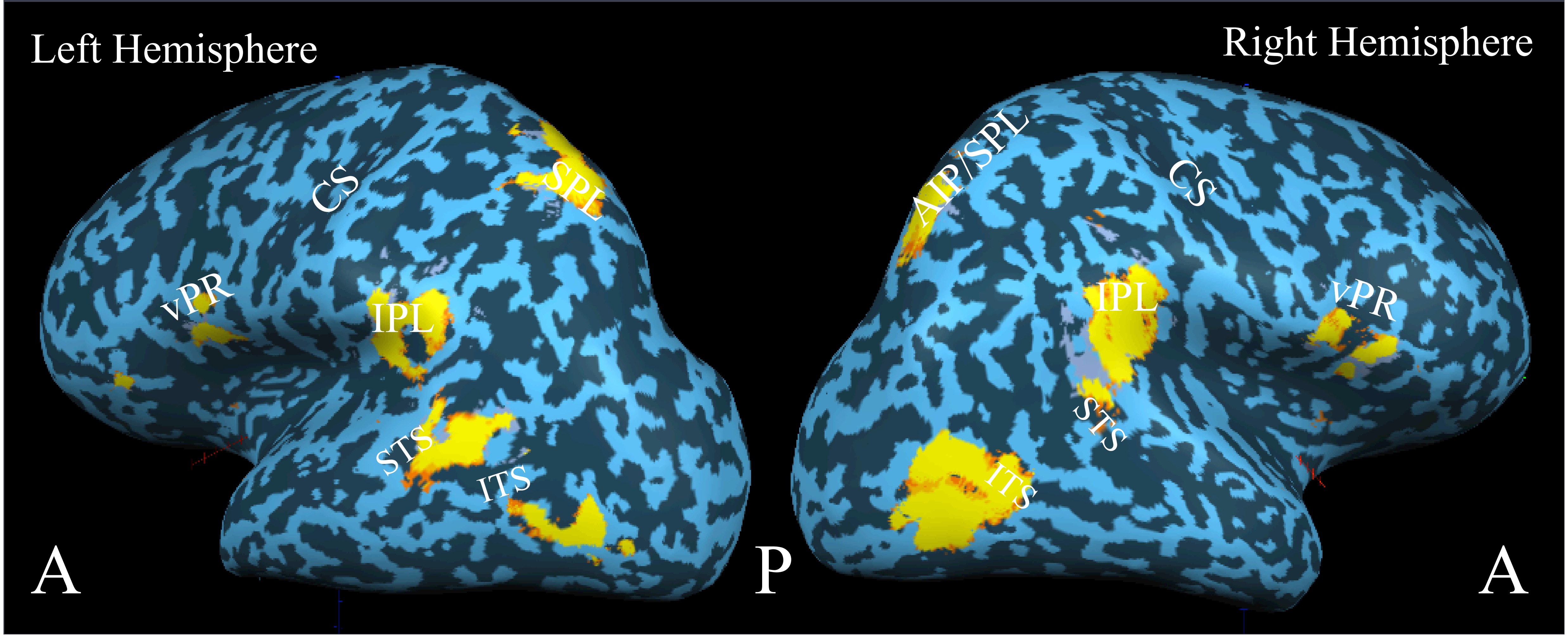




Moving > Static - motion & biological motion areas

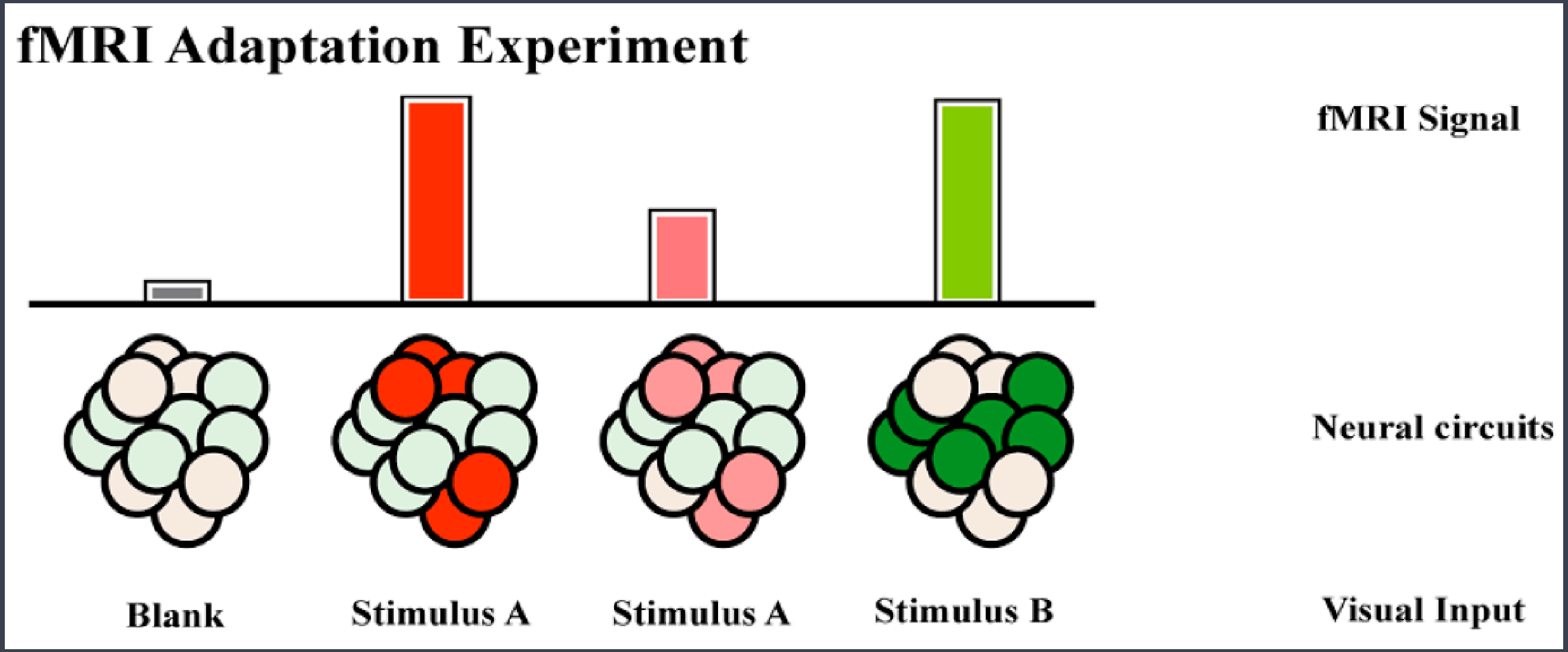


Imitation > Observation - imitation areas



Regions of interest

Adaptation & Rebound



Adaptation - activity decreases as a brain region is exposed to the same stimulus property to which it is sensitive

Rebound - activity increases when a brain region is exposed to a different stimulus property to which it is sensitive

Adaptation Predictions: Goals & Kinematics

- If a brain region is sensitive to only goals then we expect no rebound when the kinematics changes and goal stays the same
- Rebound with same goal but different kinematics reflects processing of “raw” movement properties
- Rebound with the same kinematics but different goals reflects processing of action goals

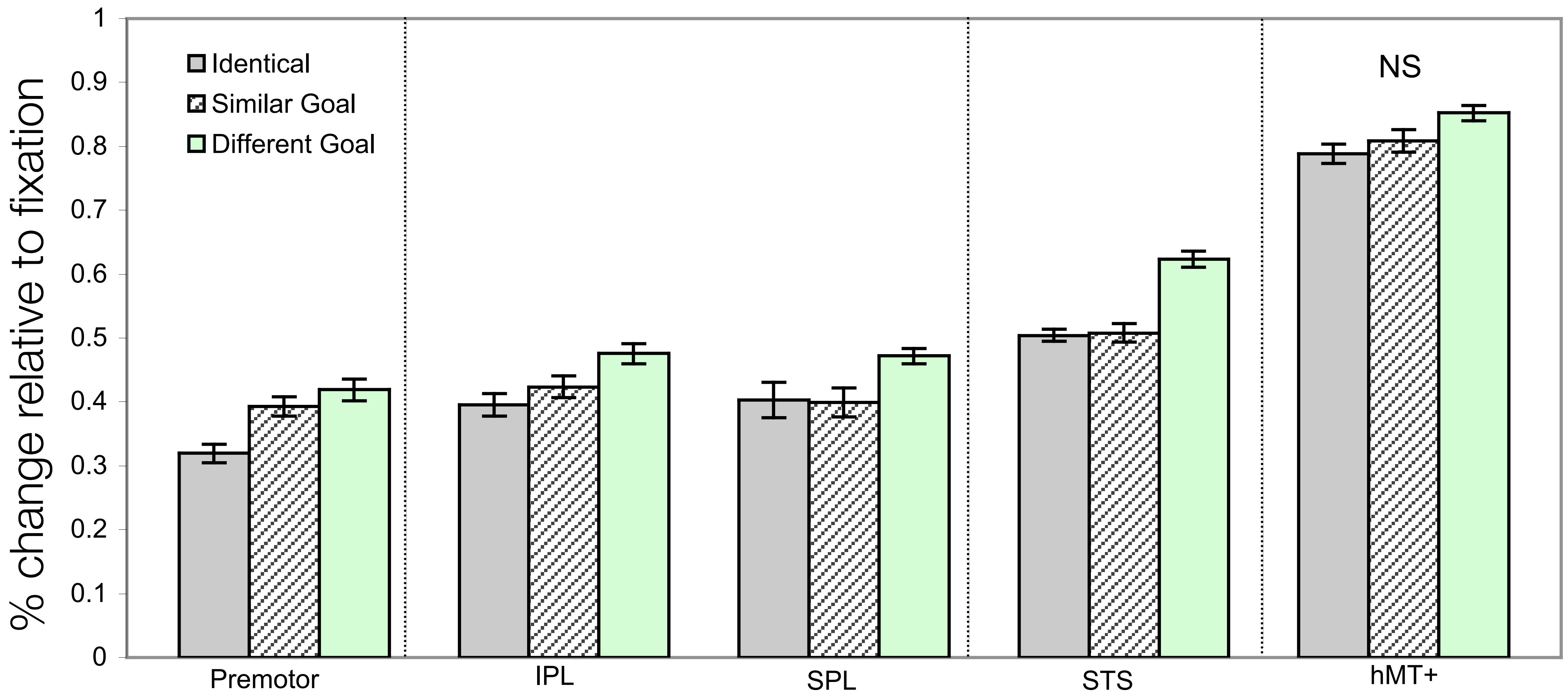
Experimental Stimuli: Forward and Backward Playback

- any movement played forwards or backwards has the same average kinematics. Not so for goals
- knocking and waving
  - similar goal
- lifting and throwing
  - different goal

Experimental Conditions and Predictions

- Identical Condition
  - same movie played twice - provides a baseline for the adaptation
- Similar Goal Condition
  - pair of forward and backward movies (knocking or waving) - *predict adaptation in all areas (identical to baseline)*
- Different Goal Condition
  - pair of forward and backward movies (lifting and throwing) - *predict rebound in goal areas (different from baseline)*

Results



% change relative to fixation
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Identical
Similar Goal
Different Goal
NS
Premotor
IPL
SPL
STS
hMT+

Summary & Conclusion

- Premotor region reveals fine-grained discrimination of goals
- Parietal and STS regions show clear effect of goals
- The effect of movement goals can be seen at the STS which has been thought to primarily involve the combination of visual form and motion in the visual processing of human actions.

Take Home Messages

- Observers might not always display high accuracy at action recognition tasks but they do appear efficient at using the available information. There is no one single visual cue that predominates
- Once you are interested with a question as simple as “Do you think that motion looks OK?” you confront a complex interaction with cognitive processes involving action goals
- The neural circuitry involved in the processing of human movement incorporates the goal of the movement at a very early stage of processing

Thanks!

Talk available at:

www.psy.gla.ac.uk/~frank/talks.html

Demos available at:

paco.psy.gla.ac.uk