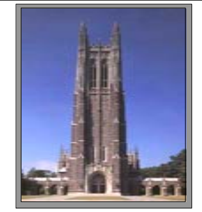

Neurofunctional Organization of Biological Motion Perception: An fMRI Study of Eye, Hand, and Mouth Movements

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INTRODUCTION

In an early fMRI study, our lab demonstrated that the human superior temporal sulcus (STS) region is activated by observed eye and mouth movements (Puce et al., 1998). We later demonstrated that STS activity is modulated by the perceived intentionality of gaze shifts (Pelphrey et al., 2003). Numerous other studies have confirmed that viewing human movements (e.g., ambulation, hand, eye, mouth movements) preferentially engages the STS (reviewed in Allison et al., 2000). However, the experimental control stimuli used in prior studies of whole body biological motions have typically been point-light displays with elements moving randomly or in a scrambled (non-biological) fashion. Although these studies have established that biological motion activates the posterior STS relative to a subset of possible controls, control stimuli involving complex coherent motion of non-biological entities have not been employed. Thus, ***it is still not clear the activity in the STS region is elicited by biological motion or by any complex coordinated meaningful motion.*** In a preliminary study, using fMRI, we first sought to determine whether biological motion preferentially activates the STS region compared to complex, meaningful, and coordinated mechanical motion.

Next, we compared, on a within-subjects basis, activity in the STS elicited by three kinds of biological motion – ***eyes***, ***mouth***, and ***hand*** movements. A ***distribution*** for the type of biological motion observed in the STS region has not yet been described. Allison et al. (2000, see their Figure 3, p. 269) suggested an ***anterior-to-posterior (A-P) distribution*** similar to that observed for the supplementary motor area (SMA; Allison et al., 1996), with hand movements activating posterior and eye and mouth movements activating more anterior regions of the STS. However, inferences about a possible topography remain equivocal because they have been based solely on between-studies comparisons. There may be no STS topography, or the topography may be organized according to a principal other than somatotopy (e.g., by social relevance).

Does the STS activate more strongly to biological motion compared to another complex, meaningful, and coherent motion?

Do distributions of activity in the STS differ as a function of movement type (eye, hand, mouth)?

METHODS

Subjects

- ❖ Study 1: 13 healthy young adults (6 females)
- ❖ Study 2: 11 healthy young adults (6 females)

Functional MRI at 4T

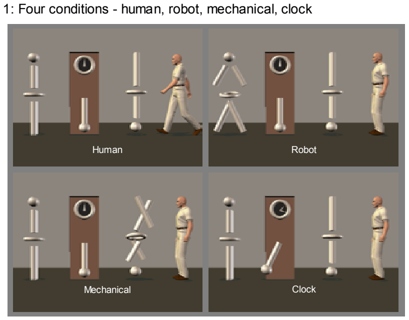
- ❖ Study 1: 28 5 mm-thick coronal slices acquired along AC-PC line - 20th slice at the PC; gradient-recalled spiral pulse sequence [TR: 1.5 s, TE: 30 ms, Flip Angle: 62°, voxel size: 3.75 × 3.75 × 5.00 mm, (64^2 matrix, 24 cm FOV)]
- ❖ Study 2: 34 axial slices were acquired using a gradient-recalled inverse spiral pulse sequence (Glover & Law, 2001) [TR: 1.5 s TE: 35 ms, Flip Angle: 62°, voxel size: 3.75 × 3.75 × 3.80 mm, (64^2 matrix, 24 cm FOV)]

Analyses

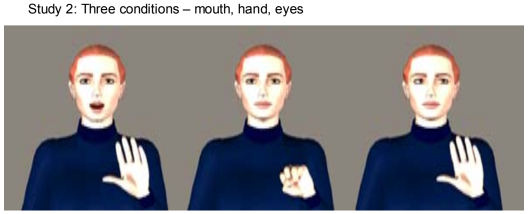
- ❖ Event-related design; epochs, time-locked to the onset of the stimulus, extracted and averaged according to trial type
- ❖ Anatomical region-of-interest (ROI) analyses of the STS
- ❖ Voxel-based analyses: after normalization (SPM99; Wellcome Department of Cognitive Neurology, London, UK), across-subjects functional time course volumes and *t*-statistic activation maps computed for each subject for each condition
  - ❖ Combined across subjects in a random-effects analysis and used to identify and interrogate regions of activation that differentiated conditions

Stimuli

Study 1: Four conditions - human, robot, mechanical, clock



Study 2: Three conditions – mouth, hand, eyes

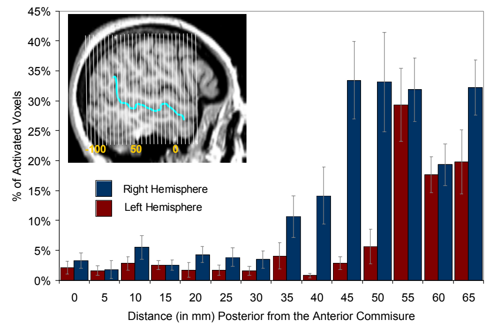


RESULTS

1 Percentages of voxels activated by biological motion for the L and R STS displayed by slice:

More voxels were activated in the R compared to the L STS on most slices.

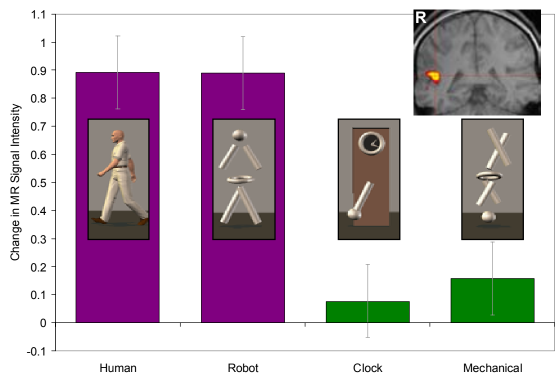
Across hemispheres, more voxels were activated in the posterior than in the anterior slices.



2 Peak Hemodynamic response from the STS by condition:

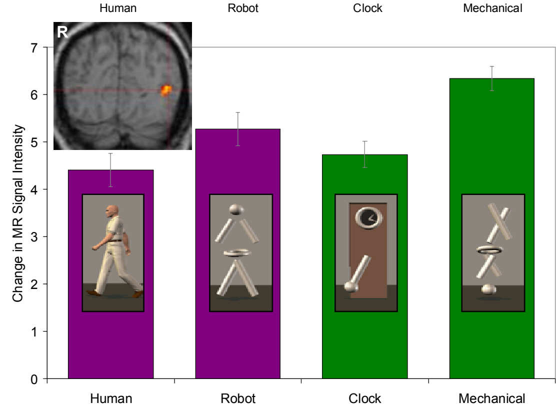
Equivalent responses were evoked for robot and human.

These responses were greater than those evoked by clock and mechanical.



3 A second motion sensitive region localized posterior and inferior to the STS, likely corresponding to MT/V5, showed a different pattern of results:

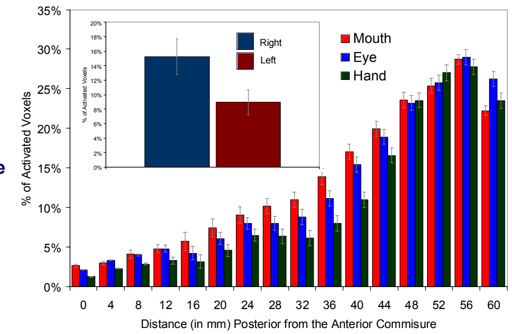
This region responded strongly to all four stimulus conditions, and responded most strongly to mechanical.



4 Percentages of STS voxels activated by each condition displayed by slice:

More voxels were activated in the posterior than in the anterior slices.

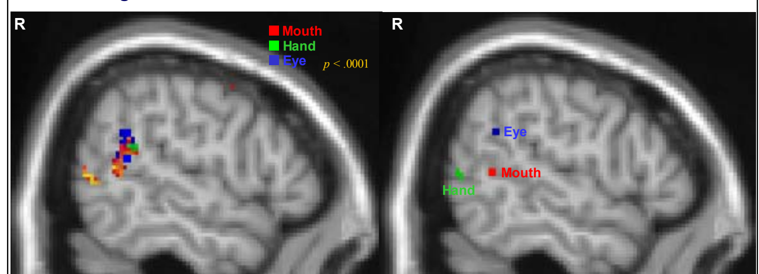
In anterior slices, more voxels were activated by mouth compared to eye and hand.



Inset: More voxels were activated in the R than L STS.

5 Strong activation occurred for all movement conditions, in the crux of the R STS.

While there was substantial overlap of the activation maps in this region, the distribution of amplitudes differentiated the movement conditions in this region.



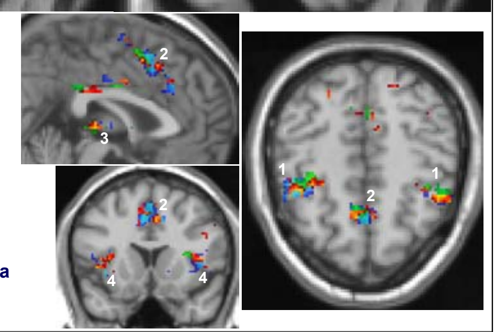
6 Activations were also observed in the:

(1) Premotor Cortex

(2) SMA

(3) Thalamus

(4) Inferior Frontal/Insula



CONCLUSIONS

- ❖ The posterior STS region responds to different kinds of biological motion including walking, hand, eye and mouth movements.
- ❖ This response is driven by characteristics of the motion *per se* and not the specific form of the figure executing the motion.
- ❖ Activations to eye, hand, and mouth movements generally overlapped, although amplitude analyses suggested a distribution within the R STS and MT/V5 such that mouth was inferior to eye and hand posterior to mouth and eye.
- ❖ Previously unreported regions including the SMA, thalamus, and insula activated to observed biological motion.

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