Does reading words associated with body parts somatotopically activate the motor cortex?

Natasha Postle[1], Rod Ashton[1], Katie McMahon[2], Greig de Zubicaray[2]

[1]School of Psychology, University of Queensland, http://www.psy.uq.edu.au [2]fMRI Laboratory, Centre for Magnetic Resonance, University of Queensland, http://www.fmrilab.net

BACKGROUND

- There is considerable transcranial magnetic stimulation (TMS) and neuroimaging evidence of general action word processing activating areas in the vicinity of the left precentral gyrus.
- Only a handful of neuroimaging studies have examined whether a somatotopic activation of primary motor (BA4) and premotor (BA6) cortices occurs for verbs associated with specific body parts [1 2 3]

ISSUES WITH EXISTING EVIDENCE

- No previous studies used cytoarchitectonically defined probabilistic maps, instead relying on functional and/or macrostructural information to define BA6 and BA4. As such their peak maximas for overlapping action meaning representations did not accord well with the cytoarchitectonic boundaries of BA4 and BA6 (see Fig.1).
- What other levels of lexical processing activate the motor cortices?

THIS STUDY

- We combined functional MRI with cytoarchitectonically defined probabilistic maps plus used control stimuli with different levels of lexical information to examine the somatotopic involvement of BA4 and BA6 in processing words with specific motor valence.
- We defined ROIs according to action observation and execution.

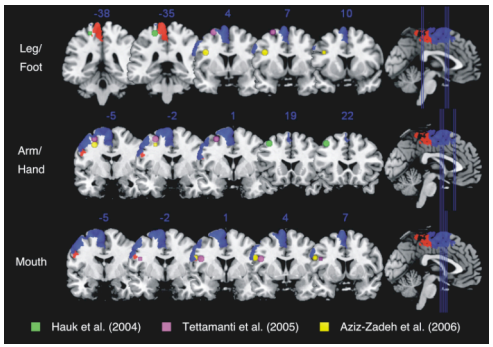


Fig. 1: Peak maxima from previous fMRI studies vs. cytoarchitectonic maximum probability maps of BA4 (in red) and BA6 (in blue)

METHOD

- 17 healthy right handed, native English speakers (13 female; mean age 28.72 years, SD = 7.21) participated
- Lexical Stimuli: 75 effector related verbs with 25 each specific to the hand, foot and mouth, 25 concrete words unrelated to body parts, 25 non-words and a series of six hashes (control for generic meaning, phonological and visual character processing).
- Video Stimuli: 40 silent video clips with ten each involving the hand, foot or mouth performing simple actions repeatedly and 10 of frequently encountered stimuli moving as they would in their natural environments.
- Lexical task: Block design (five items per block, presentation time 3 sec per item) for silent reading task. After six blocks (one for each category), a fixation cross was presented for 15 seconds.
- Video task: Event design (presentation time 10 sec per item). Video's were followed by a green dot (replicate the movement just viewed; always followed action video) or red dot (remail still; always followed control video) for 10 seconds and a blank screen for 5 seconds.

IMAGE ACQUISITION

- T2* weighted gradient echo EPI BOLD images (TE 30 ms) acquired on a 4T Bruker Medspec system.
- Lexical task: 176 brain volumes (36 planes, in-plane resolution 3.60mm, slice thickness 3mm [0.60mm gap], TR 3 s). Video task: 405 brain volumes (resolution as above, TR 2.50 s).
- High-resolution MP-RAGE 3D T1 image (TI 1500 ms, TR 2500 ms, echo TE 3.83 ms, resolution 0.73 mm3 [0.90 x 0.90 x 0.90mm]).

ANALYSIS & CONTRASTS

- Data were analysed with SPM5 using standardised procedures.
- Second level group random effects analyses: Linear contrasts of the parameter estimates analysed using one-sample t-tests
- BA4 (4a&4p) and 6 were identified using cytoarchitectonic probability maps.[4] Video observation and execution cluster-based ROI's (signal height threshold $p < .001$, cluster threshold > 25 contiguous voxels) generated within these regions and used to interrogate the lexical task data. Contrasts for each effector were exclusively masked (at $p < .05$, uncorrected) with contrasts involving the other two effectors and the mean percent BOLD signals for each lexical condition extracted from each ROI.

RESULTS

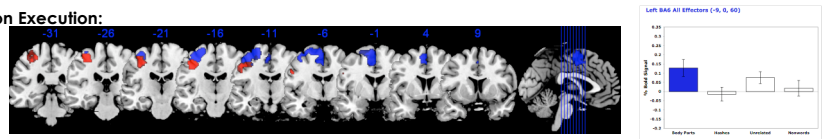
SPECIFIC BODY PART ACTIONS

- Repeated measures ANOVAs on mean BOLD signal responses within effector specific ROIs showed no congruent somatotopic activation for action words in BA4 or BA6 action execution ROIs ($p > .05$).
- Repeated measures ANOVAs on mean BOLD signal responses within effector specific ROIs showed no congruent somatotopic activation for action words in BA4 or BA6 action observation ROIs ($p > .05$).

GENERIC ACTIONS

- We identified action execution and observation ROIs within BA4 and BA6 that were common to hand, foot and mouth (height threshold $p < .001$, cluster threshold > 25 contiguous voxels). Next, we combined action words.
- There was no effect of lexical category in BA4 (red; $p > .05$). Generic action execution and observation ROIs located in the rostral medial portion of BA6 (blue): the pre-SMA; showed an effect of lexical category (peak x,y,z: -9, 0, 60; Z = 4.78, peak x,y,z: -6, 3, 54; Z = 4.97, respectively). Paired t-tests showed general action words had significantly increased BOLD responses compared to other stimuli in the observation ROI (see Fig. 2).

Action Execution:



Action Observation:

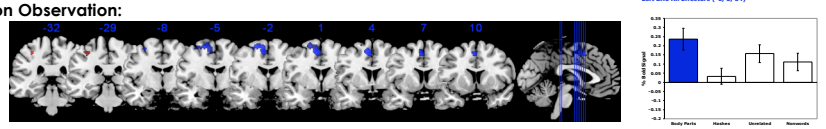


Fig. 2: Generic ROIs in BA4 (in red) and BA6 (in blue) and BOLD signal

CONCLUSIONS

- There is currently no unequivocal, compelling evidence using cytoarchitectonic and functional criteria of a somatotopic representation of body part specific verbs on the primary motor or premotor cortex.
- Rather there appears to be a general representation of body part verbs on the pre-SMA (rostral medial BA6), but this is not somatotopically organised. The pre-SMA is probably responsible for abstract representations of instruction cues (i.e., recognising that a general instruction to perform an action has been given), without being effector specific.

REFERENCES

1. -Aziz-Zadeh L et al. Curr. Biol., 16: 1818-1823, 2006; 2. Hauk O et al. Neuron, 41: 301-307, 2004; 3. Tettamanti M et al. J. Cog. Neurosci., 17: 273–281, 2005; 4. Eichkoff S et al. NeuroImage. 32: 570-582.