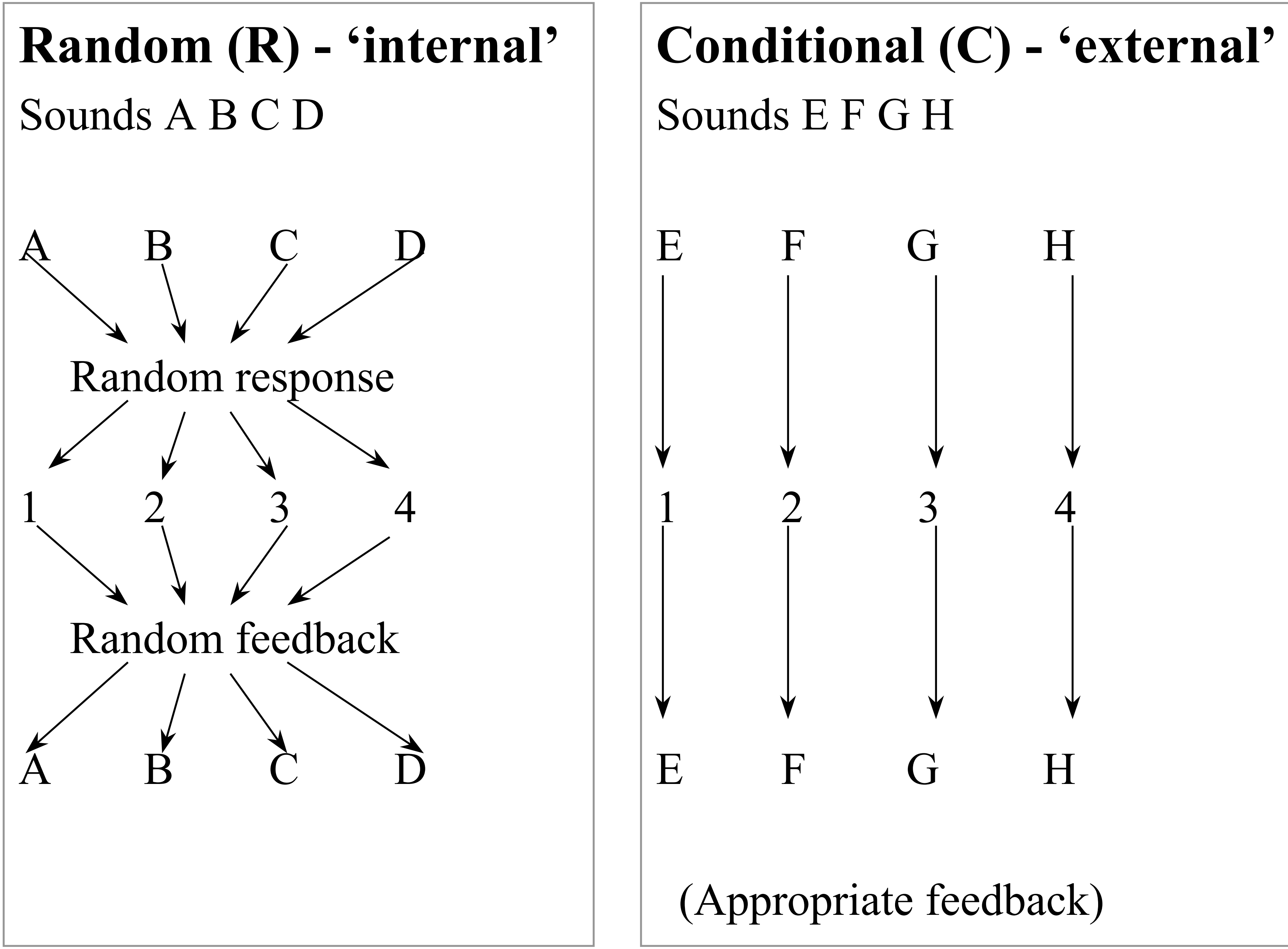
Movement selection without preparation does not activate the SMA

M. Brett, I.H. Jenkins, J.F. Stein
and D.J. Brooks
MRC Cyclotron unit, London, UK

- The roles of the premotor areas in the selection of action are still controversial. One influential theory is that of Passingham (1). He proposed that the lateral premotor cortex (LPMC) has a specific role in ‘externally generated’ movement, whereas the supplementary motor area (SMA) is more involved in action that is ‘internally generated’. Action generation is external if the choice of action is conditional on some external sensory cue, and internal if the choice of action is not dictated by an external stimulus. An early PET study of paced joystick movements gave only qualified support (2). It found that LPMC did not activate specifically when the direction of movement was conditional on the pitch of a tone cue, but SMA was more activated than other premotor areas during random movements. This result was confounded by the fact that subjects could prepare responses in the random condition. We therefore designed a PET study that is not confounded by motor preparation in order to test Passingham’s hypothesis.

- Random (‘internal’) compared to conditional (‘external’) responses
- Intention - that subjects unable to predict timing or nature of response required
- Stimuli - two sets of four musical sounds - one set signals Random response, the other a Conditional response
- Responses were button press on four button keypad under fingers of right hand
- Stimuli randomly 4 - 6 seconds apart
- 8 normal right handed volunteers (aged 35-58, 6 male, 2 female)


Random (R) - ‘internal’
Sounds A B C D
A B C D
Random response
1 2 3 4
Random feedback
A B C D
Conditional (C) - ‘external’
Sounds E F G H
E F G H
1 2 3 4
E F G H
(Appropriate feedback)

- Training
  - 45 minutes of alternating periods of training on random (R) and conditional (C) tasks, then
  - 45 minutes with R and C randomly intermixed
- Scans
  - Between scans - practice on a random intermixture of R and C stimuli
  - 12 scans - bolus of 9.2 mCi $H_2{}^{15}0$ every 10 minutes - scan acquisition for 90 seconds
  - During rise of blood concentration of $H_2{}^{15}0$: set proportion of R and C: 2 all R, 2 all C, 6 with intermediate mixtures, 2 rest scans

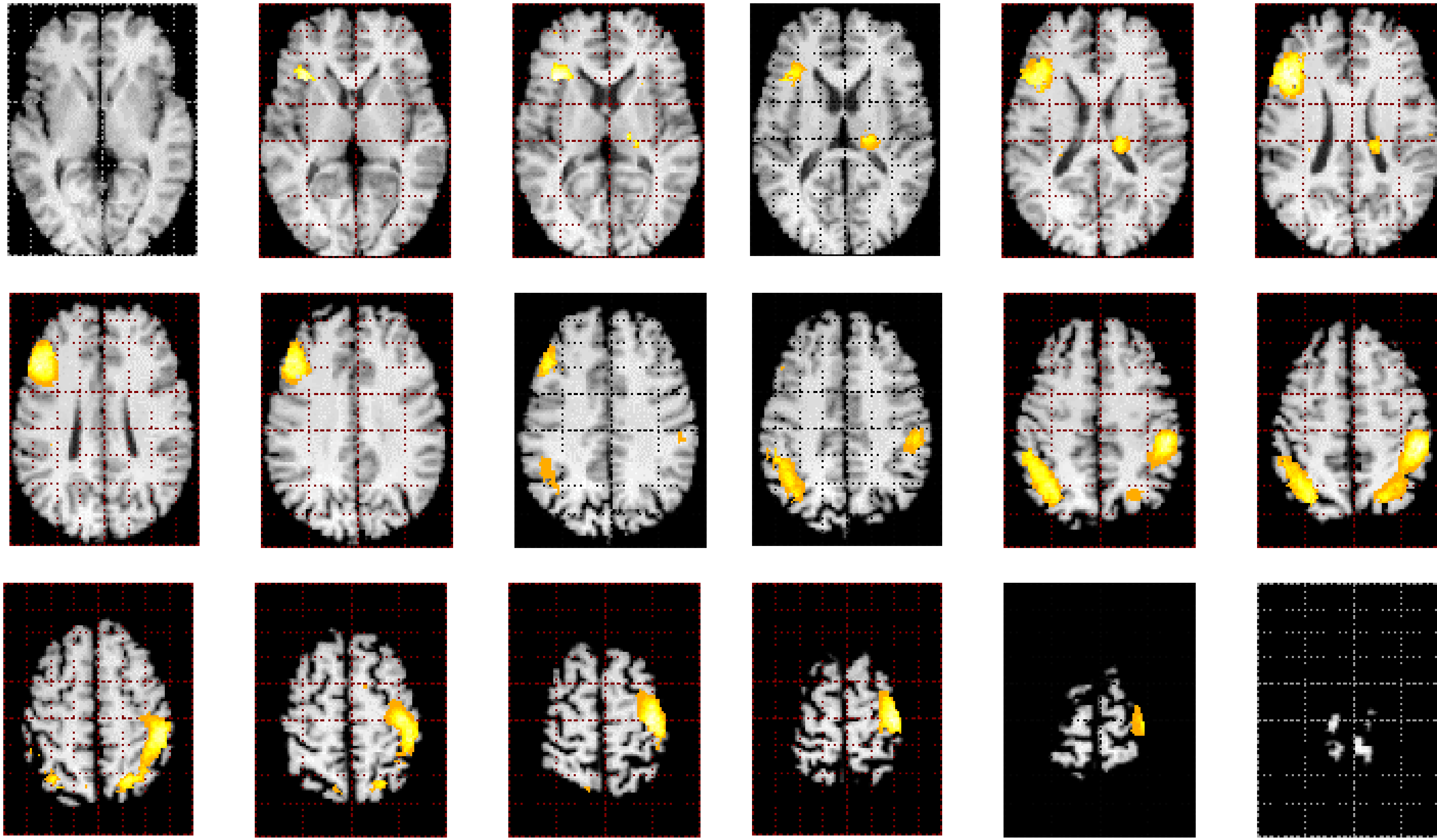
Data processing

- Acquired on CTI 953B PET scanner
- Attenuation corrected using data from transmission scan at beginning of scan session
- Realigned within subject using SPM 95 software
- Spatially normalised to standard brain of Talairach and Tournoux atlas using default SPM 95 settings
- Smoothed with gaussian filter of Full Width at Half Maximum of 16 mm in X, Y and Z
- Voxel values normalised relative to mean voxel for scan using proportional scaling

Statistical analysis

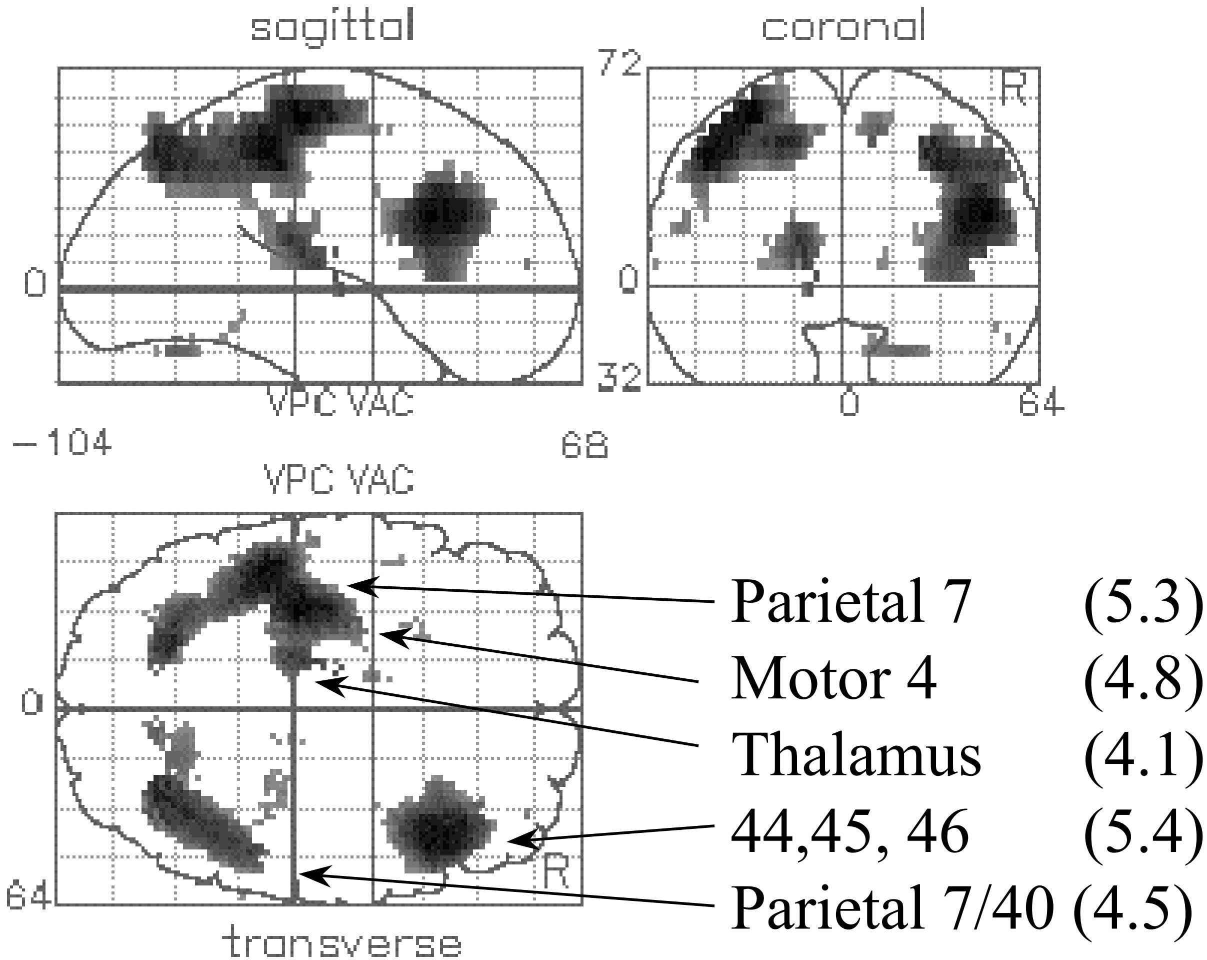
- Voxel by voxel analysis using SPM95
- Analysis of variance applied at each voxel using the General Linear Model
- 2 analyses presented here:
  - Subtractions - 96 scans - model was:
    - factors: conditions (all R, all C, rest, 6 intermediate R and C mixtures), subjects (1-8), first scan in session (Yes, No)
    - Covariates: scan order (1-12), scan order squared (1-144)
  - Correlations - 80 scans (no rest scans) - model was:
    - factors: subjects (1-8), first scan (Yes, No)
    - Covariates: number of R stimuli during active period of scan (0-5), scan order (1-12), scan order squared (1-144)

Random minus rest



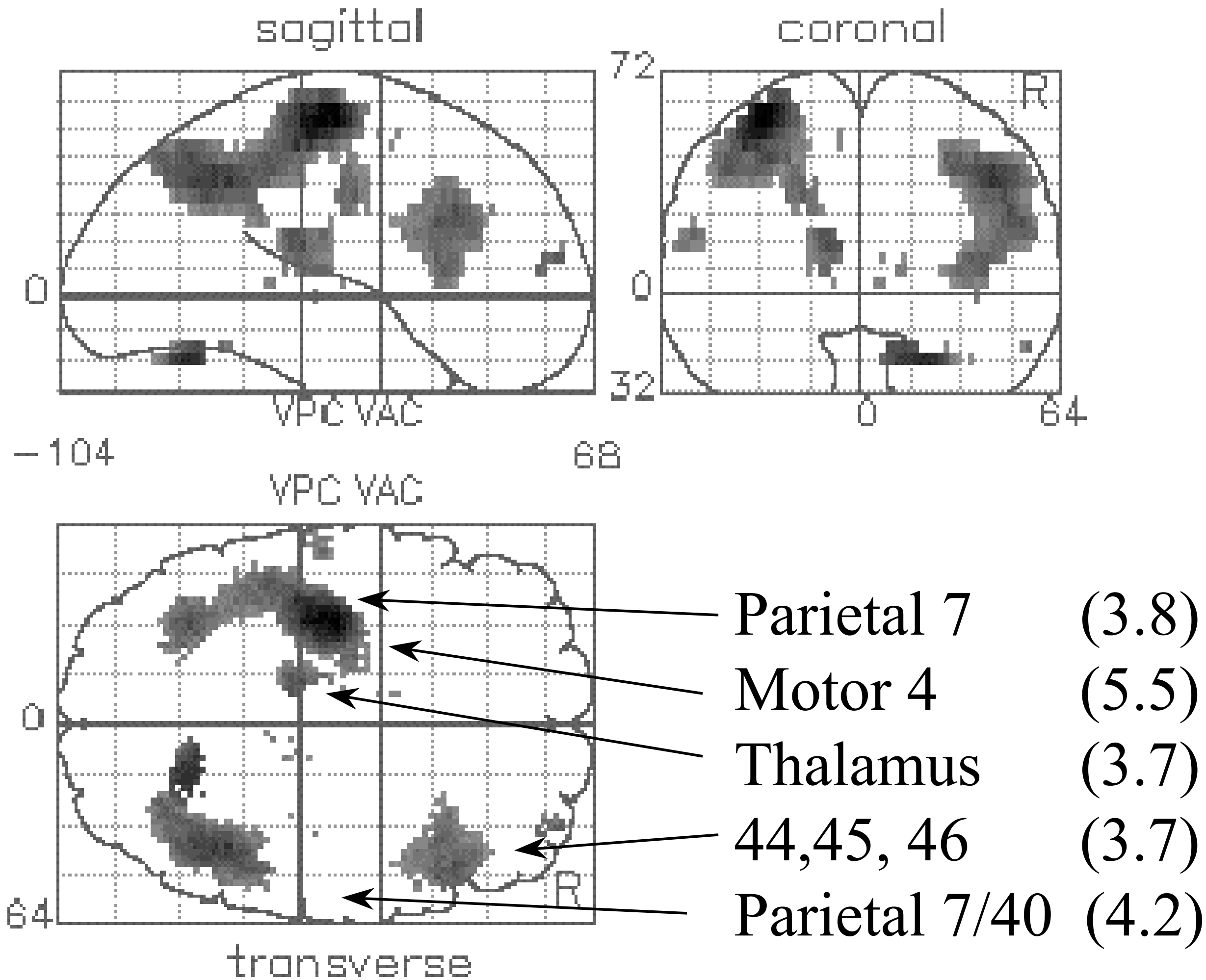
Voxels with significant differences between means ($p < 0.01$) shown projected onto standard MRI (Z planes 0 - 68) Left = Right

All Random minus rest



Voxels having significant differences between means across conditions (uncorrected $p < 0.01$, peak Z scores in brackets)

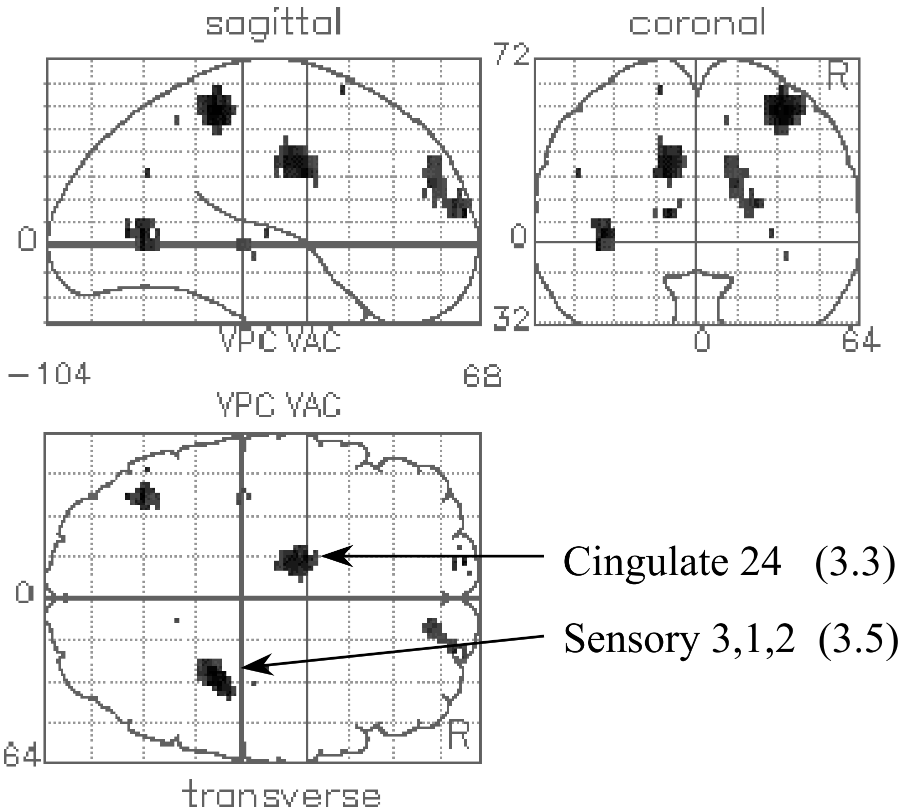
All Conditional minus rest



Voxels having significant differences between means across conditions (uncorrected $p < 0.01$, peak Z scores in brackets)

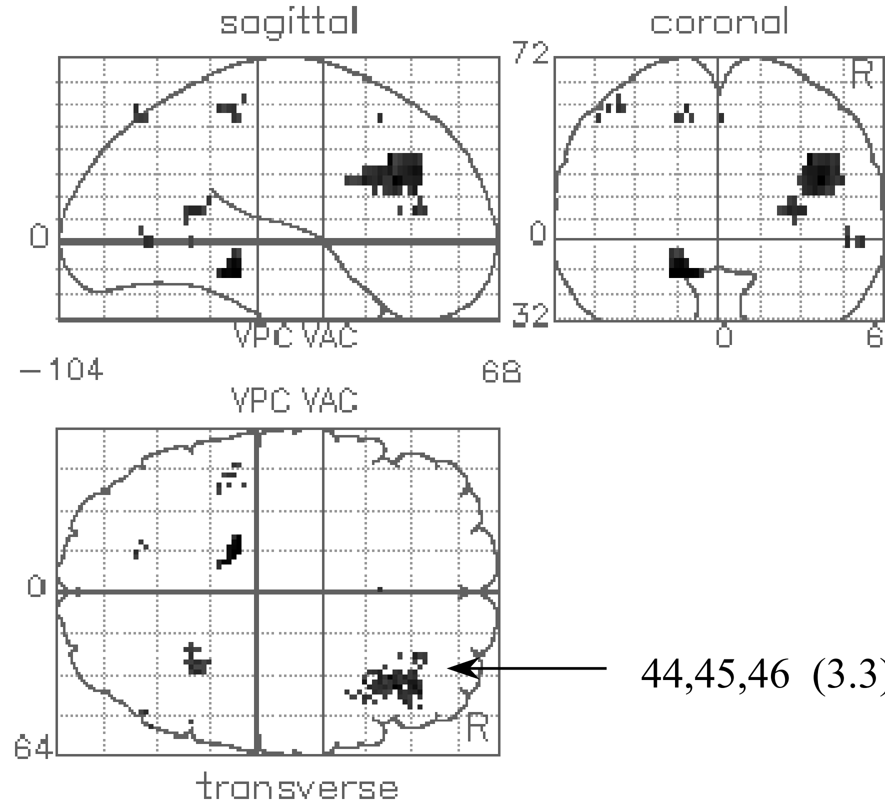
Positive correlation with Random

(Negative with Conditional)



Negative correlation with Random

(Positive with Conditional)



Voxels having significant positive (left) and negative (right) linear relationship with number of Random responses (uncorrected $p < 0.01$, peak Z scores in brackets)

Our study was intended to test the hypothesis that the SMA has a specific role in internal action selection. We believe our design has removed the effect of motor preparation that confounded previous studies; subjects could not prepare how to respond or when to respond. Our results show no evidence for a specific role of the SMA in either mode of movement selection. There was very little activation of the SMA during the performance of the tasks. Previous findings of SMA activation during random movement might be explained by the increased motor preparation such tasks allow. Once this confound has been removed, the distinction between internal and external action selection may not be of fundamental importance in explaining PET activation.

References

1. Passingham, R.E. in *Motor areas of the cerebral cortex* (ed. Porter, R.; Wiley, Chichester) 1987, 151-164.

2. Deiber, M.P., *et al. Exp Brain Res. 1991,* 84, 393-402.