Discrimination of tactile trajectories on the fingertip: an fMRI study

Alhussain, AQ[1], Benattayallah A, Fulford J, Summers IR
Peninsula MR Research Centre, University of Exeter, UK

Introduction

Previous studies (e.g., [1, 2]) have identified brain regions associated with tactile movement. The present study investigates whether cortical activation depends on the nature of the movement, using stimuli moving in two dimensions over the fingertip (as opposed to the one-dimensional movement over the tongue investigated by Matteau et al. [3]).

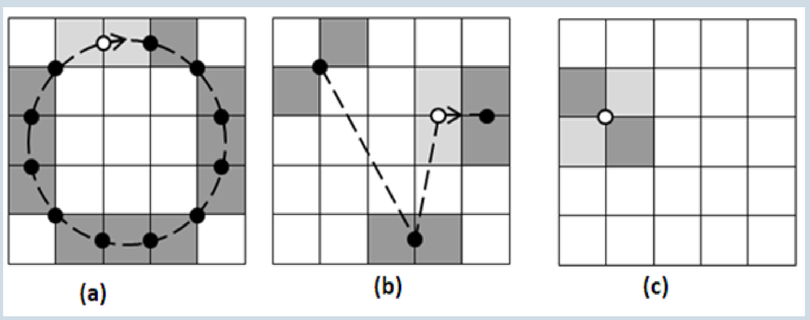

Fig. 1. Stimuli as a sequence of timeframes over the array (dots indicate apparent stimulus): (a) circle, (b) random (part of), (c) stationary.

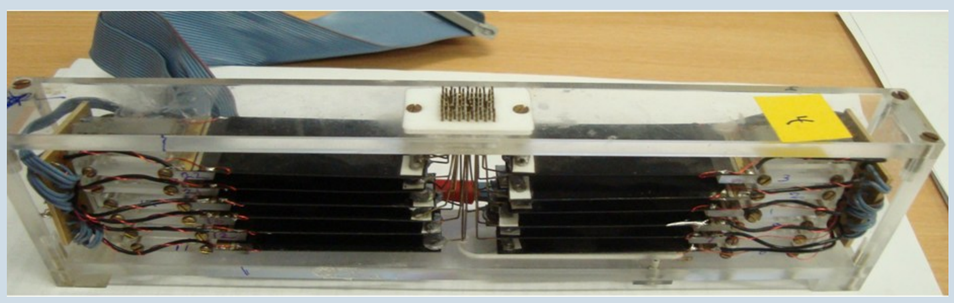

Fig. 2. The tactile display (contactors in centre of upper surface)

Response / Stimulation	Circle	Random	Stationary
Circle	144	45	9
Random	38	158	2
Stationary		5	193

Fig. 3. Confusion matrix for the identification scores.

Subjects and Methods

Eleven volunteers participated (excluding those with recognition scores < 66.7%), all male, 24-40 years. Images (EPI BOLD, TR = 3 s, TE = 45 ms, 39 slices of 3 mm thickness, in-plane resolution 3 mm) were acquired over 32.4 minutes, during which repeated blocks were presented: 9-s tactile stimulus followed by 9-s rest period, 5-s response period and further rest (21-33 s, variable). Stimuli were of three types (Figure 1). Within the 9-s stimulus period, “circle” stimuli followed 9 rotations around the fingertip, “random” stimuli followed a path of no obvious shape, and “stationary” stimuli involved alternating diagonals of a 2 × 2 square (giving sufficient modulation to minimise adaptation). Figure 2 shows the tactile display, which has 25 contactors at 2 mm spacing in a 5 × 5 array on the fingertip, driven by piezoelectric mechanisms which can operate in a high magnetic field. The 40 Hz vibrotactile stimulation was at a comfortable level. Subjects were required to identify the stimulus type via three buttons .

Results

Figure 3 shows a confusion matrix of identification scores for subjects included in the analysis. The overall mean score is 83%; there is some confusion between the circle and random stimuli. Functional MRI data were analysed using SPM8 software (www.fil.ion.ucl.ac.uk/spm). Results show a significant increase in BOLD signal in brain regions responsible for low-level and high-level aspects of tactile shape discrimination. Both the primary and secondary somatosensory cortices show a significant increase in BOLD signal during tactile stimulation, compared to rest (for all stimulus types: circle, random and stationary), as shown in figure 4. In brain areas BA40 and BA37, thought to be involved in high-level aspects of tactile perception [3,4], there is significant increase in BOLD signal during stimulation with moving stimuli (circle, random), compared to stationary stimuli (Figure 5).

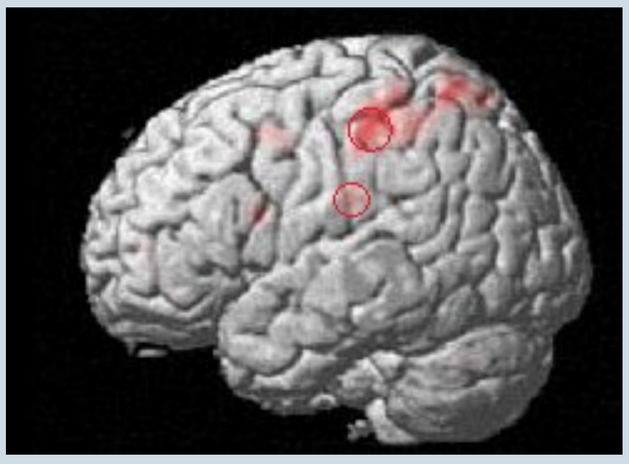

Fig. 4. SI and SII activations for contrast between stimulation and rest (group analysis, p < 0.001 uncorrected).

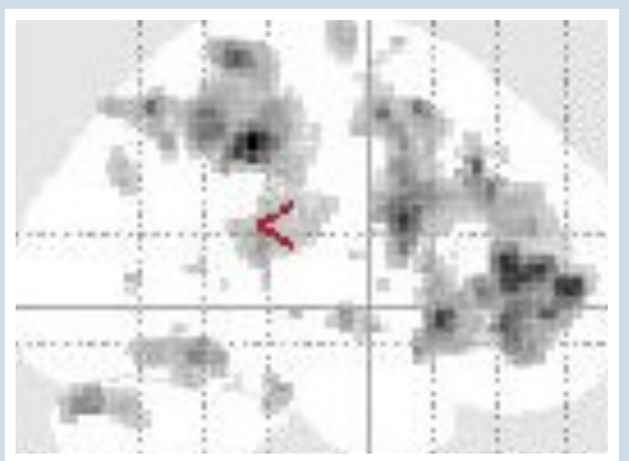

Fig. 5. Activation in Brodmann area 40 for contrast between moving (circle, random) and stationary stimuli (group analysis, p < 0.001 uncorrected)

Conclusions and future work

- ◊ Using fMRI during a discrimination task for tactile trajectories on the fingertip, activation was observed in brain areas SI, SII, BA40 and BA37.
- ◊ Brain areas associated with the circle/random contrast were not identified.
- ◊ There remains the interesting possibility of analysing the fMRI data according to the subject’s response, rather than stimulus type.
- ◊ The tactile display is easy to program and can produce many types of tactile stimuli (moving or stationary). Planned future studies include an investigation of the effect of movement speed.

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References
[1] Vanello N et al. (2004) Proc. HBM 2004, TU323; [2] Summers IR et al. (2009) J. Acoust. Soc. Amer. 125, 1033-39; [3] Matteau I et al. (2010) Brain Res. Bull. 82, 264-70.
[4] N Savini et al (2010) Brain Res. Bull. 83, 223-231.