Perception of visual and tactile flow activates common cortical areas in the human brain

Emiliano Ricciardi[1] Nicola Vanello[2], Davide Dente[2], Nicola Sgambelluri[2], Enzo P Scilingo[2], ClaudioGentili[3,4], Lorenzo Sani[2], Vincenzo Positano[5], Filomena M Santarelli[5], Mario Guazzelli[4], James V. Haxby[6], Luigi Landini[7], Antonio Bicchi[2], Pietro Pietrini[1]

[1]Laboratory of Clinical Biochemistry, University of Pisa, Italy
ricciardi.emiliano@tiscali.it
[2] Interdepartmental Centre E. Piaggio, University of Pisa, Italy
[3]Laboratory of Clinical Biochemistry, University of Pisa, Italy,
[4]Chair of Psychology, University of Pisa, Italy,
[5]C.N.R. Institute of Clinical Physiology, Pisa, Italy
[6]Department of Psychology, Princeton University, Princeton, NJ, USA
[7]Department of Information Engineering, University of Pisa, Italy

Abstract. We report results of a pilot study using functional magnetic resonance imaging aimed at determining the neural correlates of tactile flow. We hypothesized that brain response to tactile flow would involve the same cortical areas (V5/MT) that respond to optic flow. Our results showed that V5/MT cortex indeed is activated by tactile flow perception. These findings are consistent with a supramodal organization of brain regions involved in optic and tactile flow processing.

1 Introduction

An equivalent phenomenon to optic flow exists in the tactile modality that encodes information on softness discrimination of objects by palpation. Tactile flow has been defined as the flow associated with the displacement of iso-stress curves on the surface of the contacting fingertips [1]; thus it has been related to the perception of relative motion and pressure between the fingertip and objects in contact.

In the brain, V5/MT complex responds to the perception of visual and tactile motion [2] and during perception of optic flow [3]. Since similarities exist between visual and tactile perception [4], we hypothesized that tactile flow might also rely on V5/MT response. We and others have shown recently that visual extrastriate cortical areas respond both during visual and tactile recognition of different categories of objects, indicating that these cortical regions are organized in a supramodal fashion [4,5]. In the present study, we measured the neural response evoked during visual and tactile perception of coherently rotational and translational moving dot patterns.

2 Material and Methods

In order to explore brain activity during visual and tactile stimulation by using fMRI we originated a block design approach with a stimulation of 12 seconds, an interstimulus interval of 21 seconds, an initial and a final baseline condition of 30 seconds each. Images were acquired using a Gradient echo EPI sequence with a Ge Signa 1.5Tesla (TE/TR=40/3000 msec, bandwidth 62.5 kHz, FOV 24 cm, resolution 64x64 pixels, Flip angle 90°, Slice thickness 5 mm). We examined seven right-handed healthy volunteers (1F/6M; mean age±s.d.=27±2 years). Stimuli consist in motion-specific (left-to-right/right-to-left translational or clockwise-rotational) tactile and visual dot patterns stimuli, during stimulation periods, and static dot patterns, during baseline and interstimulus periods. The visual stimuli were formed by grey dots on a black background and were back-projected onto a screen, while tactile stimulation was performed through tactile Braille-like dot patterns assembled on a plastic surface. An MRI compatible device was used to reproduce translational and circular movement of these patterns. In order to diminish cross-modal priming, imagery or facilitation processes, the different kind of stimulus, visual or tactile, moving in a circular or in a translational fashion, were randomized across runs. During tactile stimulation subjects were asked to keep their eyes closed. In a first experiment five subjects received a tactile stimulation of the left index finger only, while in a second ongoing study, two subjects were stimulated on the index and middle fingers of the left hand.

The analysis was performed using multiple regression analysis in order to identify regions significantly involved in the processing of moving stimuli versus static ones. Cortex that responded significantly during tactile recognition was identified based on the omnibus effect of all regressors of interest for tactile (corrected $p<0.005$) and visual (corrected $p<0.0001$) perception.

3 Results

Visual motion perception evoked robust activation in V5/MT, with additional activations in ventral temporal and inferior occipital extrastriate cortices, posterior intraparietal sulci, posterior cingulate and precuneus. Similarly to the visual stimulation, tactile motion stimulation also activated V5/MT and posterior intraparietal sulci. When tactile flow stimulation involved two fingers of the left hand, neural response in V5/MT became significantly stronger. In addition, tactile perception evoked activity in large bilateral areas in the hand region of SI, SII, anterior frontal areas, subcortical structures and insula.

4 Discussion

Both tactile and visual perception of moving dot patterns consistently activated the V5/MT complex and posterior intraparietal sulci, accompanied respectively by activations in primary visual and somatosensory cortices and other brain regions.

Thus, these results suggest that V5/MT responds not only to the visual but also to the tactile sensory modality. Furthermore, the observation that neural response in V5/MT becomes stronger when two fingers are stimulated, suggests that the involvement of this cortical complex is truly associated with tactile perception of moving dots and not merely due to visual imagery of tactile flow. Additional studies in congenitally blind subjects will clarify to which extent, if any, visual imagery may affect neural response in V5/MT complex. The study of how the brain process simple sensorial stimuli could improve our knowledge about haptic perception and boost together the technology of new haptic displays.

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