Brushing stimuli in lower limb amputees evokes phantom limb perception; a fMRI study

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Synopsis

The phantom limb experience (PLE) paradigm has served to understand the workings of the brain from the neurophysiological to the neurocognitive aspects. PLE includes the phantom limb sensation and the conscious awareness of the phantom limb. Amputees report that moving stimuli on the intact leg evokes PLE. Brushing stimuli evoked cortical activations: (dorsolateral prefrontalcortex, posterior parietal cortex, posterior temporal lobe and posterior cerebellar), and subcortical activations: (basal ganglia, and thalamic nuclei). These activations can help to elucidate the neural circuitry activated during somatosensory stimuli for the conscious perception of the phantom limb in lower limb amputees.

Introduction

Brushing stimuli evokes cortical S1, SMA and parietal operculum together with subcortical putamen, anterior superior insula and cerebellum as part of the perceptual discriminatory neuronal ensemble [1]. Amputees report that moving stimulus in intact limb evokes dual percepts [2], in the intact leg and the phantom limb. The cortical-striatal loop subserves different functions: sensorimotor, motivational, attentional and memory process [3]. To understand how a moving sensory input evokes, in amputees, phantom limb awareness, brush stimulation was applied in amputees immediately above the stump scar and in homologous site in the contralateral intact leg, and in similar sites in controls. fMRI mapping was executed to visualize the activated areas.

Methods

Subjects. 6 healthy right-handed control subjects, with no history of neurological or psychiatric disorders and 6 lower limb amputees patients, participated in the study after informed voluntary consent.

Imaging Procedure. Imaging was performed on a 1.5 T GE LX Magnetic Resonance scanner (v 9.x G. E. Milwaukee, WI) equipped with 23 mT/m gradients using a standard quadrature headcoil. To minimize head movement the subject's head was securely fastened in the head holder. Functional images were acquired with SPIRAL BOLD, TR = 2600 ms using a 64x64 matrix, with a FOV 24 cm, over 20 contiguous axial slices 7.0 mm thick and zero gap [4]. Imaging was centered near the prefrontal gyrus. Structural images were obtained using a high resolution T1 weighted localized exactly over the same seven sections of the functional studies.

Functional Paradigm. Subjects started in resting block for the first 10 sets of images, brushing stimuli above the stump scar and in homologous site in the contralateral leg was applied in blocks of 10 sets of images continuing in on-off manner. Control subjects were presented with equivalent stimuli.

Image Analysis. All functional images were realigned, normalized (MNI space) and smoothed (8mm Gaussian kernel) in SPM2. A paradigm was defined, to create a statistical linear model using a hemodynamic response function [5]. Talairach coordinates of clusters with highest statistical signal were obtained and then passed to the Talairach Daemon (UTHSC, San Antonio TX) to identify activated areas.

Discussion

The functional control's average map depicted greater LDLPFC together with PPC activity and subcortical basal ganglia, activity (NC and thalamus) (fig.1.B), while functional amputees average maps, divided into left and right lower limb, depicted DLPFC and PPC activity (fig.1 A and C) but more restricted basal ganglia and thalamic activity. Frontal and parietal cortical activations participate in cognitive processes of attention/memory. Amputee patients reported to have felt the phantom limb as the stimuli was applied only in the intact leg, thus, brushing, as a mechanical moving stimulus, serves as a referred sensation which can evoke the phantom limb experience. Cortical and subscortical activations could very well form part of the loop that permits the amputees integrate into a conscious experience their phantom limb.

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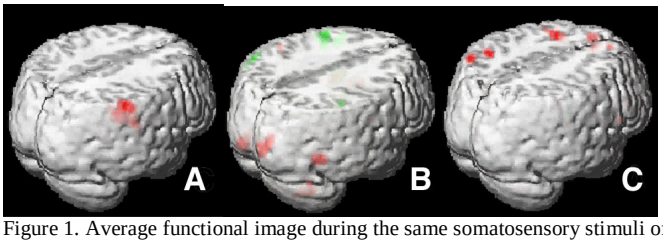

Figure 1. Average functional image during the same somatosensory stimuli of A) 3 left lower limb amputees. B) 6 control subjects. C) 3 right lower limb amputees.