High-density scalp somatosensory evoked potentials in macaque monkeys as follow-up of functional recovery from motor cortex lesion

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Introduction

Somatosensory evoked potential (SSEP) recordings from the scalp are commonly used in human for clinical applications. They are among others a good predictor of outcome after a brain injury such as stroke. Recordings from the scalp with a high-density electrode array are also relevant for research purposes to reveal the time course of evoked topographies based on the high temporal resolution of EEG.

In this pilot study, we made a transposition of SSEP recordings to macaque monkeys using a multichannel electrode array.

The goal of the present study was to develop a simple and minimally invasive method to record SSEPs from the whole scalp surface in anaesthetised adult macaque monkeys, with the prospect of allowing repeated assessment of the cortical activity in the context of a central nervous system lesion. It is expected that SSEPs will allow to assess the post-lesional cortical reorganisation of neuronal networks and relate it to functional recovery, following a permanent motor cortex lesion.

Materials and methods

I. SSEP recordings in macaque monkeys

- Three adult macaque monkeys (*Macaca fascicularis*)
- Recordings with a customised EEG cap containing 33 electrodes regularly distributed over the scalp (EASYCAP GmbH, EEG Recording Caps and Related Products, Herrsching, Germany)
- 2.5% sevoflurane anaesthesia
- Electrical stimulations to the median nerve at the wrist or to the tibial nerve at the ankle, successively on each side (400-µsec duration, 0.5 Hz repetition rate, intensity slightly above the visible motor threshold, total of 75 sweeps)

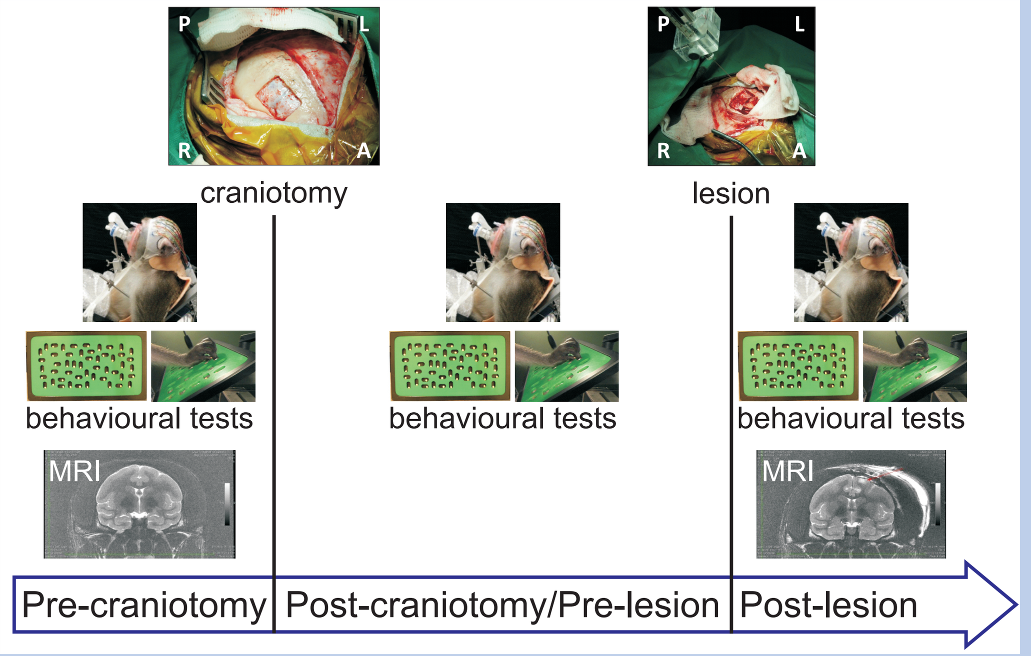
II. SSEP data analysis and source estimation

- SSEP data were analysed with the Cartool software (http://sites.google.com/site/fbmlab/cartool) and computed against the average reference.
- k-means cluster analysis of the SSEP voltage maps (data-driven approach revealing a series of scalp topographies reflecting the steps in information processing)
- LAURA (**L**ocal **Au**to**r**egressive **A**verage) inverse solution algorithm with LSMAC (**L**ocally **S**pherical **M**odel with **A**natomical **C**onstraints) head model

III. Lesion

- Future permanent unilateral lesion performed in the hand area of the right primary motor cortex, requiring a craniotomy
- "Sham lesion" consisting in the craniotomy alone over the hand area of the right sensorimotor cortex, with bone flap resuture and fixation with bone substitute HydroSet (Stryker®)

IV. Experimental design



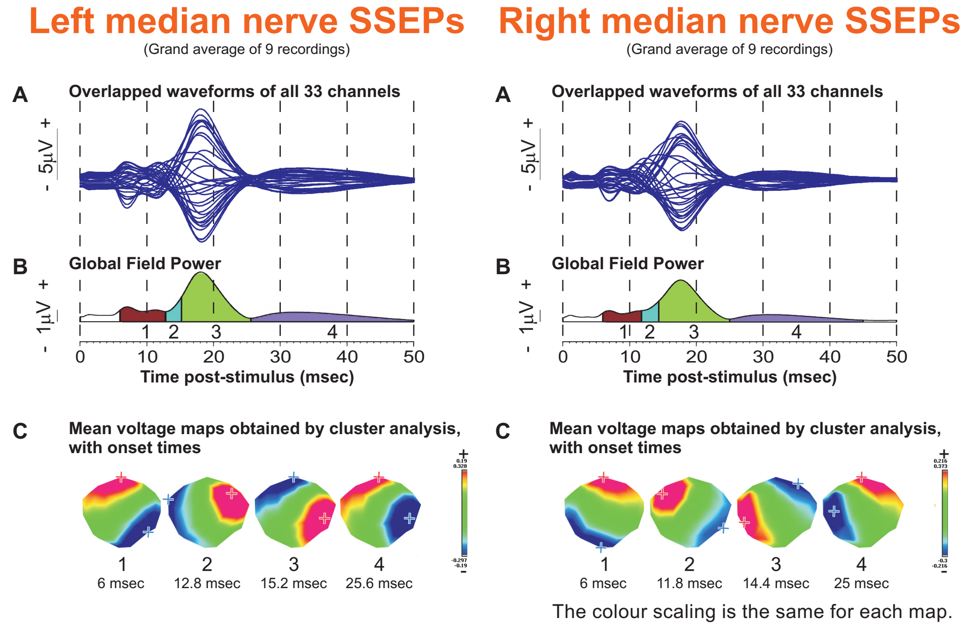
V. SSEP recordings and analysis in human

- One awake male subject (29 yo)
- Recordings with an EEG cap containing 65 active electrodes regularly distributed over the scalp (actiCAP, Brain product GmbH, Gilching, Germany)
- Electrical stimulations to the median nerve at the wrist (400-µsec duration, 2 Hz repetition rate, intensity slightly above the visible motor threshold, total of 600 sweeps)
- SSEP data were analysed with the Cartool software (http://sites.google.com/site/fbmlab/cartool) and computed against the average reference.
- SSEP voltage maps obtained at the global field power peaks

Results

1) Pre-craniotomy SSEPs

Left median nerve SSEPs
Right median nerve SSEPs



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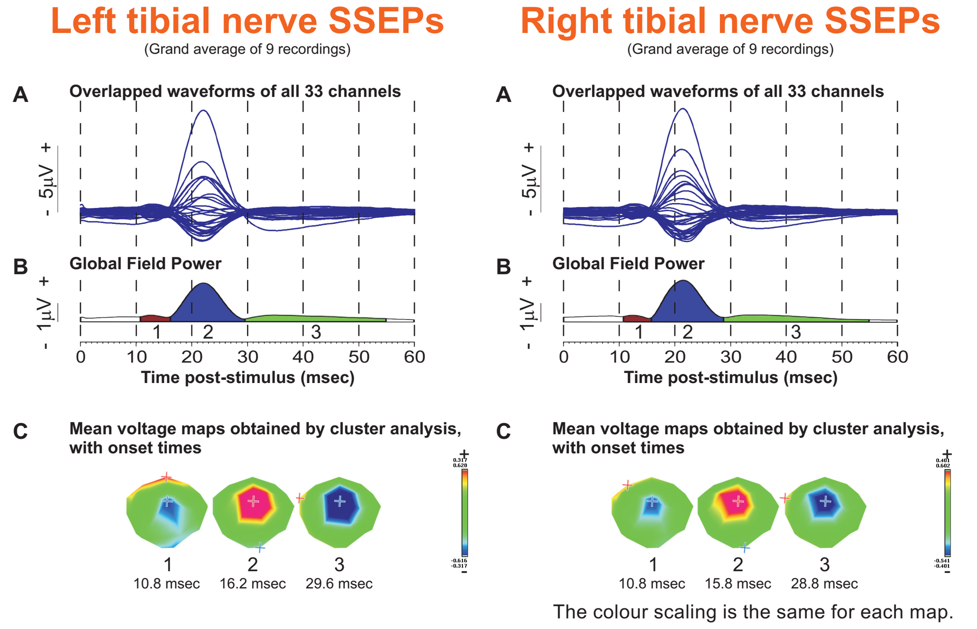
Left tibial nerve SSEPs
Right tibial nerve SSEPs



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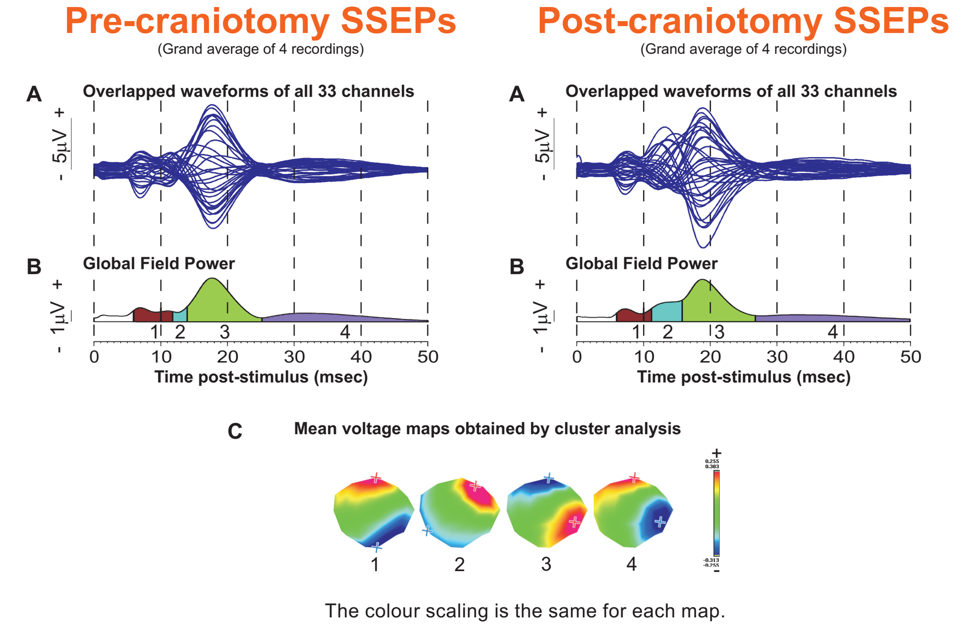
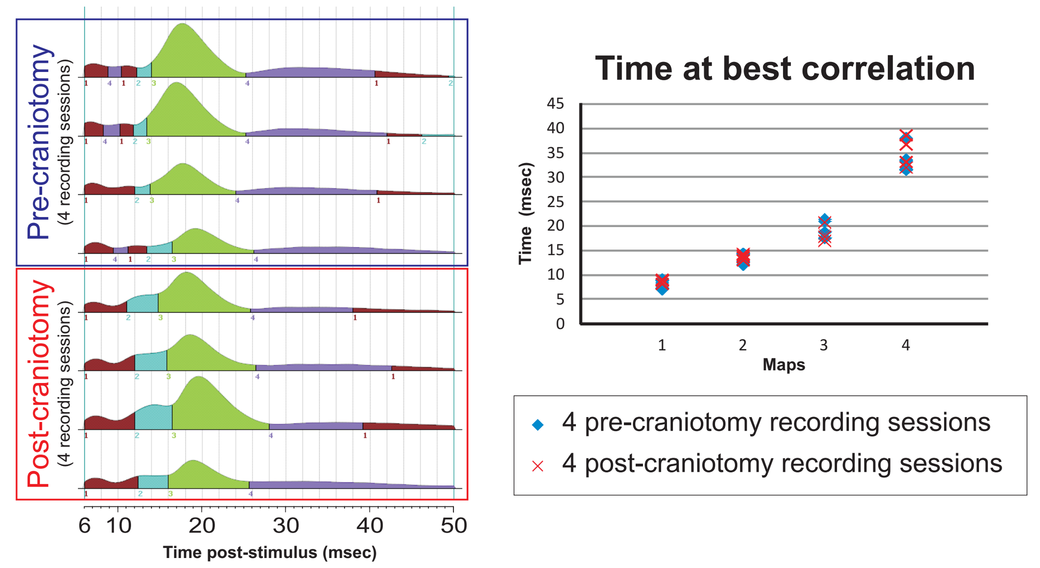
2) Effect of the craniotomy on left median nerve SSEPs

Pre-craniotomy SSEPs
Post-craniotomy SSEPs



The colour scaling is the same for each map.

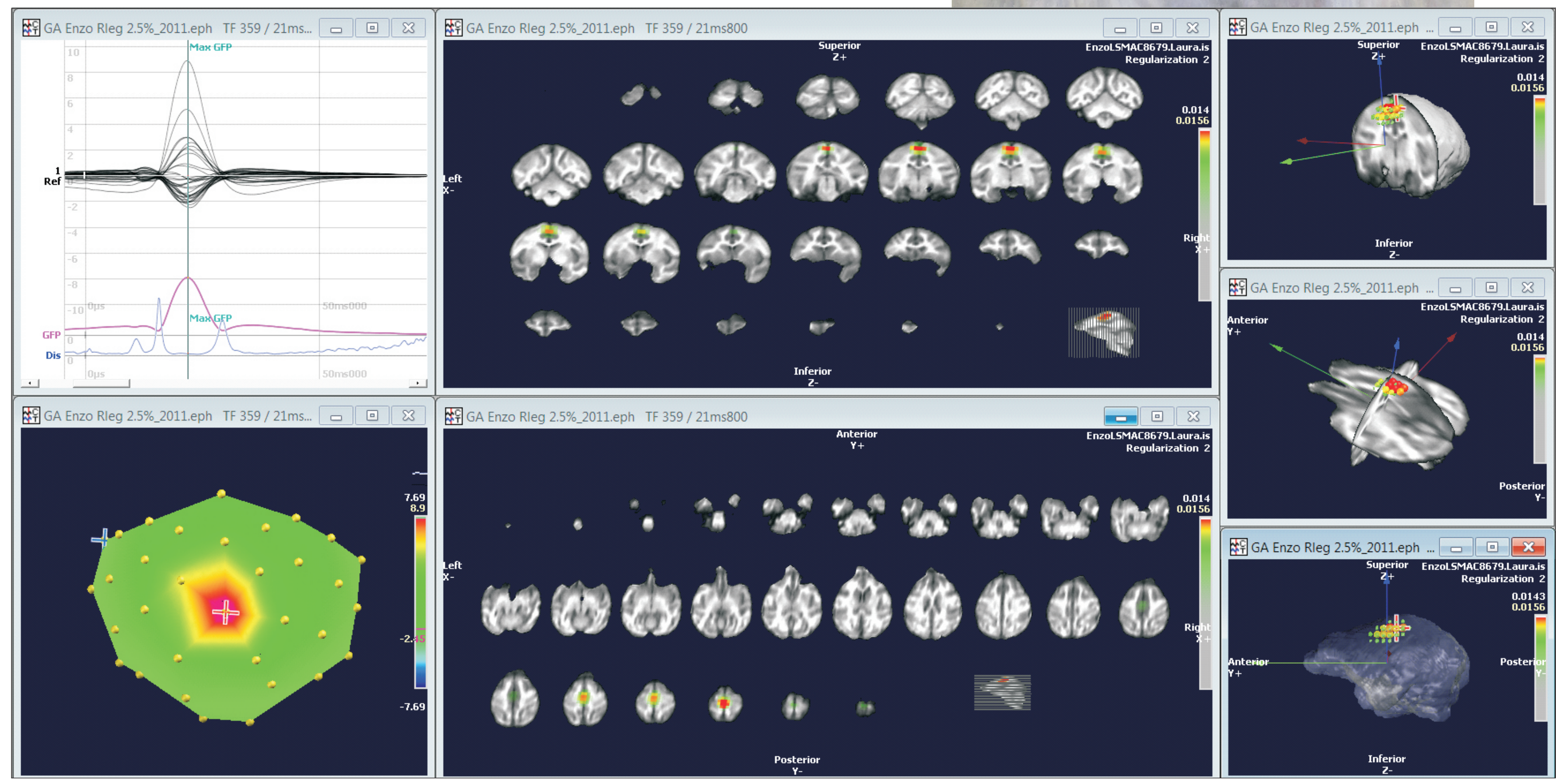
Fitting of the maps back to each recording session



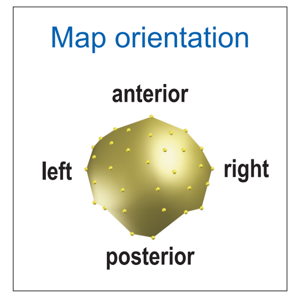
All the data presented here were acquired in the same monkey.

3) First data of inverse solution

Pre-craniotomy right tibial nerve SSEPs

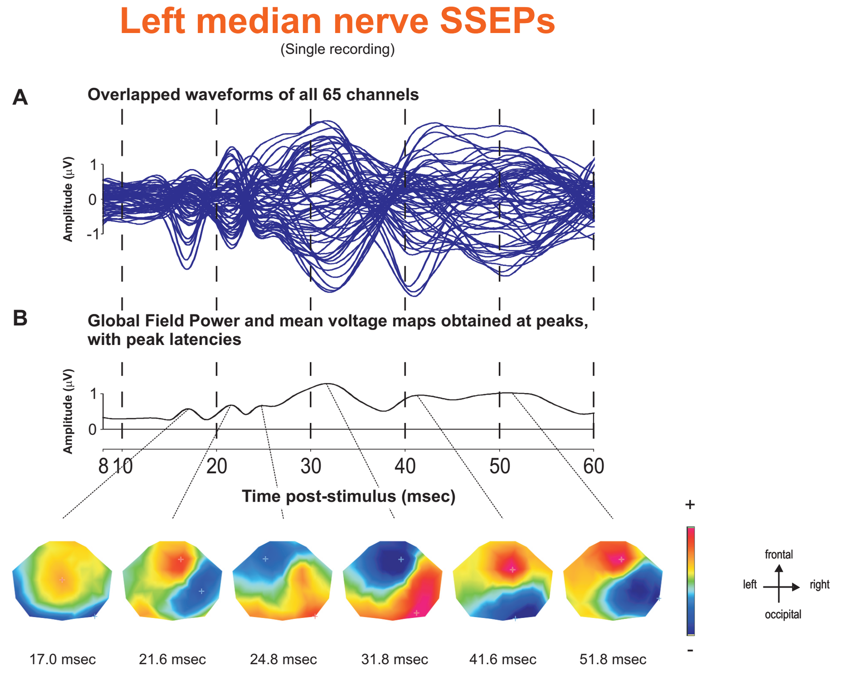


The overlapped waveforms and the scalp voltage topography at 21.8 msec (maximum of the GFP peak) are represented on the left part. The right windows show different views of the source estimation on MRI at this same time point.



4) Comparison with human SSEPs

Left median nerve SSEPs



The colour scaling is the same for each map.

- As expected, voltage topographies obtained after stimulation on one side are essentially mirror images of those of the other side in relation to the antero-posterior axis.
- The voltage topography of the responses obtained after either median or tibial nerve stimulations is in line with the somatotopical organisation of the sensorimotor cortex.
- Similar pre-craniotomy data were obtained in two other animals.
- Post-craniotomy voltage topographies do not show any artefact and are similar to pre-craniotomy maps, indicating that the craniotomy itself does not have any strong adverse effect on the recorded SSEPs.
- The first version of the inverse solution model shows an appropriate localisation of the main cortical activation after tibial nerve stimulation, that is to say in the leg representation of the sensorimotor cortex.
- Median nerve SSEPs are less complex in macaque monkeys than in human but comparable voltage topographies at the scalp are conserved between both species.

Conclusion

- The present data show that SSEPs can be successfully and reproducibly recorded from a high-density EEG cap in macaque monkeys.
- The inverse solution algorithm allowing source estimation seems to be a very promising tool to better understand the different mechanisms involved in post-lesional cortical reorganisation.
- The experiment will continue with the permanent cortical lesion performed in the near future in a first monkey, followed by regular post-lesional SSEP recordings in parallel with motor performance assessment in the acute phase and in the recovery phase until the animal reaches a post-lesional behavioural plateau.
- Based on human studies, SSEPs are expected to help to investigate the post-lesional cortical reorganisation of neuronal networks, especially to highlight which areas of the brain will take over the function of the primary motor cortex after the lesion. From a clinical point of view, we also hope that post-lesional modifications in SSEP signals will help us to predict the level of recovery after the lesion.

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