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Trigeminal somatosensory evoked magnetic fields to tactile stimulation

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Abstract

Objective: To characterise the activation of the contra- and ipsilateral primary somatosensory cortex (SI) after tactile stimulation of the face.
Methods: Trigeminal somatosensory evoked magnetic fields (TSEFs) were recorded after tactile stimulation of the lower lip, cheek, chin and forehead in 11 healthy subjects. The responses were determined visually from the waveforms and modelled with equivalent current dipoles (ECDs).
Results: Contralateral SI responses were evoked in all subjects after lip stimulation, and in 91% and 64% after right and left cheek, 73% and 82% after chin and 64% and 27% after forehead stimulation. The responses usually showed an early double-peak wave pattern, the underlying sources localising to the SI. In addition, altogether 37 ipsilateral SI responses were evoked in eight subjects. Fourteen of these responses were amenable to ECD modelling and localised to ipsilateral SI.
Conclusions: Tactile stimulation of the lip area reliably activates the contralateral SI in normal subjects, but the success rate for other trigeminal areas is lower. Ipsilateral responses can be present after stimulation of any of the trigeminal branches in normal subjects.
Significance: Recording of TSEFs after tactile stimulation of particularly the lip area provides a non-invasive technique to study the function of the trigeminal nerve.

Keywords: Magnetoencephalography (MEG); Somatosensory evoked magnetic fields (SEF); Tactile stimulation; Trigeminal nerve

1. Introduction

Trigeminal somatosensory evoked responses have been investigated relatively little. Recordings have been generally performed using electroencephalography (EEG) to measure trigeminal somatosensory evoked potentials (SEPs) to electrical (Bennett and Jannetta, 1980; Drechsler and Neuhauser, 1986; Dalessio et al., 1990; Polich et al., 1995; Van Vliet et al., 2002), mechanical (Larsson and Prevec, 1970) and air puff stimulation (Hashimoto, 1988). SEPs have been recorded both contralaterally and ipsilaterally to the stimulation of the trigeminal nerve (Larsson and Prevec, 1970; Bennett and Jannetta, 1980; Drechsler and Neuhauser, 1986; Hashimoto, 1988; Dalessio et al., 1990; Polich et al., 1995): however, in most studies only a few measurement channels have been used and the underlying sources have not been characterised.

Beyond EEG, magnetoencephalography (MEG) can be applied for non-invasive recording of evoked responses. MEG detects the weak extracranial magnetic fields produced by currents generated in the cerebral cortex. Unlike EEG, MEG is not affected by the differences in

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conductivity between the active brain source and the measuring device, which offers unique advantages in characterising the underlying cerebral activity (Hämäläinen et al., 1993). In the studies of cranial nerves, MEG has mostly been used for its localisation accuracy to map the cortical representation areas of different facial and oral structures (Karhu et al., 1991; Yang et al., 1993; Mogilner et al., 1994; Hoshiyama et al., 1996; Nakamura et al., 1998; Yamashita et al., 1999; Nakahara et al., 2004; Nguyen et al., 2004). Sources of SEFs elicited by lip stimuli have been used as landmarks in preoperative neurosurgical planning to identify eloquent cortical areas (Mäkelä et al., 2001; Vates et al., 2002). In four of the studies conducted with multichannel devices, also the ipsilateral responses were investigated and localised to the ipsilateral SI cortex (Karhu et al., 1991; Hoshiyama et al., 1996; Nagamatsu et al., 2001; Disbrow et al., 2003). However, ipsilateral responses were recorded only after stimulation of the lips and tongue.

The aim of this study was to use a whole-head MEG device to characterise the activation of the contra- and ipsilateral primary somatosensory cortices after individually stimulating the three trigeminal branches with a tactile stimulus.

2. Methods

Eleven healthy control volunteers (7 females) participated in the study. The subjects' age ranged from 19 to 51 years (mean 26.6); all 11 subjects were right handed. Informed consent was obtained from all subjects. The study protocol was approved by a local ethical committee.

The MEG recordings were performed in a magnetically shielded room (Euroshield Ltd., Finland) in the BioMag Laboratory at the Helsinki University Central Hospital. The MEG device had 306 independent channels arranged in to a shape of a helmet (Vectorview, Electa Neuromag Oy, Helsinki, Finland). The signals were recorded with a 0.03–300 Hz bandpass filter and digitized at a sampling rate of 942 Hz. An epoch lasted 600 ms, including a 100-ms prestimulus baseline.

The tactile stimulator was a thin rubber membrane surrounded by a harder plastic outer shell. The membrane gently tapped the skin when expanded by an air pressure pulse delivered through a plastic tube (Somatosensory Stimulus Generator, 4-D NeuroImaging Inc., San Diego, USA). The pressure onset had a delay of 33 ms relative to the trigger. This delay was automatically subtracted from the responses, and thus the latencies reported in the study represent the true latencies (Fig. 1). (For more details about the stimulator see Pihko et al., 2004.)

Prior to the recording, an individual cartesian coordinate system was defined with a three-dimensional digitizer. The preauricular points determined the *x*-axis, which pointed to the right. The nasion was used to establish the *y*-axis pointing towards it. The *z*-axis pointed upwards. Four position indicator coils were attached, and their

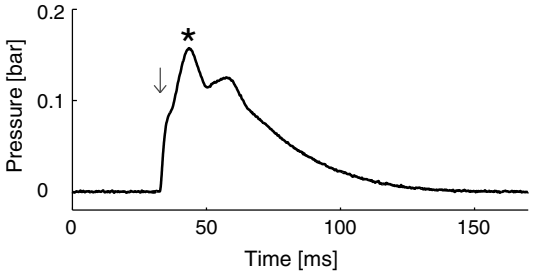

Fig. 1. The pressure pulse produced by the stimulator is shown. Zero point on the pressure scale refers to the ambient air pressure. The arrow indicates the onset of the pressure pulse at 33 ms. The peak of the pressure pulse indicated by the star is at 43 ms. The response latencies are determined according to the pressure pulse onset at 33 ms.

locations were found with the digitizer. Two vertical electro-oculogram electrodes (EOGs) were placed in order to remove periods with eye movement artefacts from the data.

During the measurement the subject was seated in the magnetically shielded room with his/her head inside the helmet shaped sensor array. The subject was advised to sit still and keep eyes closed but to stay awake. Continuous white noise was delivered binaurally through earphones during the whole measurement to mask the sound the stimulator made. The loudness of the white noise was set individually on a satisfactorily high level without being disturbing. At the beginning of each recording, the exact head position inside the helmet was determined by using the signals from the indicator coils.

Each measurement consisted of three sessions. In the first two measurement runs, the subjects received stimuli to four different areas. In the first measurement run (Fig. 2A), the four areas were stimulated in the following order: 1. right side of the lower lip, 2. left side of the lower lip (mandibular branch), 3. right cheek and 4. left cheek (maxillary branch). In the second session (Fig. 2B), the corresponding order was: 1. right side of the chin, 2. left side of the chin (mandibular branch), 3. right side of the forehead and 4. left side of the forehead (ophthalmic branch). The inter-stimulus interval (ISI) was 1 s, consequently the ISI between two stimuli at the same location was 4 s. In a third measurement run, the skin of the tip of the index finger of the right hand was stimulated with an ISI of 2 s. Two hundred artefact-free responses were averaged for each stimulus site. Epochs with amplitudes over 3000 ft/cm in any of the MEG channels or 150 μV in the EOG channels were automatically rejected.

The waveforms were first analysed visually to determine the presence of the responses contra- and ipsilaterally. A response was determined to be present on visual analysis, if it was seen on several channel pairs, and if its strength was above two standard deviations of the baseline signal calculated –100 – 1 ms prior to the stimulus. If distinct responses were present, their peak latencies were determined. The field distribution at the peaks of the responses were evaluated, and if a dipolar field pattern was observed,