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Research Report

Effect of the number of pins and inter-pin distance on somatosensory evoked magnetic fields following mechanical tactile stimulation

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ABSTRACT

Magnetoencephalography (MEG) recordings were collected to investigate the effect of the number of mechanical pins and inter-pin distance on somatosensory evoked magnetic fields (SEFs) following mechanical stimulation (MS). We used a 306-ch whole-head MEG system. SEFs were elicited through tactile stimuli with 1-, 2-, 3-, 4- and 8-pins using healthy participants. Tactile stimuli were applied to the tip of the right index finger. SEF following electrical stimulation of the index finger was recorded in order to compare the activity in the primary somatosensory cortex (S1) following MS. Prominent SEFs were recorded from the contralateral hemisphere approximately 54 ms (P50m) and 125 ms (P100m) after MS regardless of the number of pins. Equivalent current dipoles were located in the S1. The source activities for P50m and P100m significantly increased in tandem with the number of pins for MS. However, the increased ratios for the source activities according to the increase in the number of pins were significantly smaller than that induced by electrical stimulation, and when the number of the pins doubled from 1-pin to 2-pins, from 2-pins to 4-pins, and from 4-pins to 8-pins, S1 activities increased by only 130%. Additionally, source activities significantly increased when the inter-pin distance increased from 2.4 to 7.2 mm. The number of stimulated receptors was considered to have increased with an increase in the inter-pin distance as well as an increase in the number of pins. These findings clarified the effect of the number of pins and inter-pin distance for MS on SEFs.

Abbreviations: MEG, magnetoencephalography; SEF, somatosensory evoked magnetic field; S1, primary somatosensory cortex; MS, mechanical stimulation; ES, electrical stimulation; ECD, equivalent current dipole; MRI, magnetic resonance image; SSS, signal space separation; ST, sensory perception threshold

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1. Introduction

Tactile input from the periphery activates several cortical areas. The primary somatosensory cortex (S1), located in the postcentral gyrus, carries out the first stage in cortical processing of somatosensory stimuli. Human somatosensory magnetic fields (SEF) following median nerve stimulation have been widely used to investigate the physiology of normal somatosensory cortical processing (Forss and Jousmaki, 1998; Hari and Forss, 1999; Huttunen et al., 2006; Inui et al., 2004; Kakigi et al., 2000; Kawamura et al., 1996; Mima et al., 1998; Nagamine et al., 1998; Wikstrom et al., 1996). Previous studies have reported that the amplitude of SEF components following median nerve stimulation is influenced by stimulus intensity and that S1 responses increase in amplitude with the increase of stimulus intensity (Hoshiyama and Kakigi, 2001; Jousmaki and Forss, 1998; Torquati et al., 2002; Tsutada et al., 1999). Electrical stimuli (ES), which have been used in numerous somatosensory research studies, have been a useful tool for investigating cortical processing of somatosensory stimuli, but are considered to be unnatural stimuli.

There have been several SEF studies using mechanical stimuli (MS), e.g. pneumatic stimulation and finger clips (Hoechstetter et al., 2000, 2001; Karageorgiou et al., 2008; Lin et al., 2003, 2005). However, the rise time for MS has not been clearly defined in these studies. Therefore, the temporal aspect of cortical activity following MS has not been identified as clearly as that following ES. Additionally, pneumatics and finger clip stimuli have limited points of application at various parts of the body. Although only Jousmaki et al. (2007) have presented a novel solution to produce tactile stimuli on various parts of the body in MEG studies, the stimulus intensity of their device is unclear. Previously, we have reported that SEF waveforms could be obtained following MS using a precise and consistent tactile stimulator driven by piezoelectric actuators, and clear SEF responses at S1 contralateral to the stimulated side were induced not only by mechanical-on stimulation, but also mechanical-off stimulation (Onishi et al., 2010). However, the relationship between the MS conditions (e.g. number of pins and area of stimuli) and SEF response remains unclear.

Franzen and Offenloch (1969) reported that the cortical response increased when the amplitude of indentation for mechanical stimulation increased. Additionally, Wu et al. (2003) indicated that the skin′s surface became widely indented around the diameter of the pin when the skin was mechanically stimulated with a tiny pin. Therefore, it has been speculated that the number of pins and area of stimuli, similar to the increased amplitude of an S1 response with the increase of intensity of ES, influence the SEFs elicited by MS. It is thus worthwhile to examine the relationship between the conditions of life-like tactile stimuli and cortical activities. In clinical practice, two-point discrimination has been used extensively to evaluate the severity of peripheral nerve injuries (Jerosch-Herold, 2005; Lundborg and Rosen, 2004). However, the relationship between the inter-pin distance of 2-pins and S1 activity remains unclear. It is thus important to investigate the effect of the number of stimulus pins or inter-pin distance on S1 activities, before two-point discrimination is increasingly used clinically or in research. The present study was designed to investigate the effect of the number of stimulus pins or inter-pin distance of 2-pins on SEF response following MS in the S1 area contralateral to the stimulation. We measured SEFs following the use of a varying number of pins and the inter-pin distance for MS applied to the index finger of healthy participants. Following several different

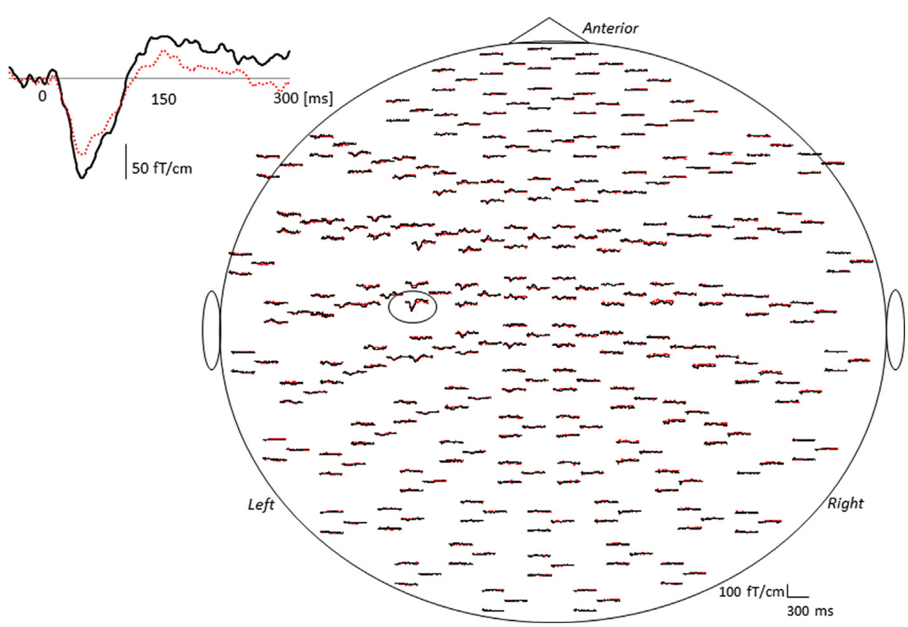

Fig. 1 – Representative whole-scalp SEF waveforms elicited by mechanical stimulation with 4-pins (dashed lines) and 8-pins (solid lines) with a period between 50 ms before and 300 ms after the onset of stimulation. The enlarged waveforms above whole-scalp waveforms indicate the waveforms in the encircled area over the sensorimotor area contralateral to the stimulation.