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Somatosensory Evoked Potential Compotents With and Without Contact Cold Stimulus

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***Abstract*—In the present study, somatosensory evoked potentials following contact cold painful stimulation of the posterior tibial nerve (PTN) at left and right ankle were investigated in 4 normal subjects. By fitting dipole models to independent components, more sources were found in pain status than in non pain condition. Among these fitted components, three SEPs related components and one pain related component were observed. Corresponding to the specific components, generating sources of SEPs were located at primary somatosensory cortices, anterior cingulate and thalamus, supporting the previous findings, while the pain specific generator was found at primary somatosensory cortices or primary motor cortices. However, former reports have shown more sources than those found in this study, which may be caused by overlaping of conventional SEPs and pain sources. Consequently, the connectivity of these sources will be studied to better understandthe information flow and function of these components and sources.**

I. Introduction

Several researches were carried out on the recording of waveform or scalp topography changes of somatosensory evoked potentials (SEPs), by meas of multi-channel electroencephalography (EEG), during pain stimulus [1,2,3]. By applying time-locked pain stimulus, such as high density electrical pulse or laser, pain related SEPs can be recorded, and it was shown that middle and long latency SEPs were related with pain inputs. However, in contrast with time-locked pain stimulus, the pain sensation we suffer in real life possesses the property of persistence which lasts a period of time. Therefore, this study is to investigate how somatosensory perception changes during persistent pain stimulus by comparing SEPs between pain and non-pain status.

In conventional SEPs, electrical stimulation activates mechanoreceptors of the skin relating to touch or vibration sensation, and evoked signals, ascend through Aβfibers [4], reflect activities within the large fiber sensory systems [5]. Unlike other sensations, pain is evoked not only by physical stimulus but also by a combination of physical, emotional, psychological and social abnormalities [6]. In addition, pain related potentials ascend through nociceptive Aδ- and C-fibers [7]. Apart from noise and unrelated biological components, nociceptive and mechanoreceptive related components are merged in recorded potentials. It is difficult to separate these components due to the volume conduction of human brain and special processing.methoda need to be introduced.

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II. Methods

Four young (29±4.5 years) male healthy volunteers without low back pain history whthin the 6 months preceding the trial participated in this study. Informed consent was obtained before study, approved by the Institutional Ethical Committee.

During the experimental sessions, the electrical stimulus (1.1 Hz), with a constant current square wave pulse (0.1ms), was delivered transcutaneously to the posterior tibial nerve (PTN) at left and right ankle. The stimulus intensity was raised to just above motor threshold, until slight muscle contractions were reliably observed, and ranged from 14 to 20.5 mA. Contact cold pain administered with ice pack was imposed on the low back skin. The subject can withdraw from the experiment if the stimulus was intolerable. A whole experiment was divided into four trials (electrical stimulus were acted on left and right PTN separately at both non-pain and cold pain status). 5 minutes of data were recorded in every trail.

SEPs were recorded (NeuroScan System; band pass: 0.5–400 Hz, sampling rate: 1,000 Hz) from 122 electrodes. The electrodes were placed according to an augmented 10–20 system, and the vertex reference was used. Electrode impedance was kept lower than 10K Ohm. The data were converted and analyzed by EEGLAB [8]. The analysis time was from 300 ms to 600 ms. Baseline was removed according to the mean level of the pre-stimulus period. About 300 EEG trials were collected at each stimulus condition. To reduce the calculation complexity, data from 33 spatial distributed electrodes were chosen, and run through informax ICA available in EEGLAB. Finally, reconstructed sources were obtained by fitting independent components with the dipole models (threshold 15%), calculated using EEGLAB's dipole fitting routine (DIPFIT2) with a boundary element model.

As the above mentioed, mechanoreceptive afferents sensations ascend rapidly by Aβfibers, whereas, nociceptive afferents sensations ascend relatively slowly through

Aδ-fibers and C-fibers. These two kinds of afferent signals transmit different sense through separate systems, even though functional overlap occurs in some parts. After afferent signals reach the brain, multi-sources are activated for both nociceptive and mechanoreceptive systems. As a result of the colligation of different fibers and separated pathways, nociceptive and mechanoreceptive related components are believed to be linear mixed and statistically independent.

In order to separate these components, a linear transformation method, independent component analysis (ICA), was adopted. The goal of ICA was to find a linear representation of statistically independent data, which captured the essential properties of the pain related SEPs data. Accordingly, ICA algorithm was identified as an effective method to separate nociceptive and mechanoreceptive related components.

III. Results

To decompose the original data from scalp channels by ICA, maximal temporal independent signals were produced by the spatial independent component filters. These independent signals may represent neural activities of one or more cortical sources (including nociceptive and mechanoreceptive related components), and activities from non-cortical components (e.g., eyeball movements, muscle activity, line noise, etc.).

Since many independent ICA components we obtained have scalp maps that nearly perfectly match a single equivalent of brain dipole model, finding neural sources by fitting a single equivalent dipole to ICA component can overcome the ill posed difficulty of the inverse problem, and to obtain reliable, consistent results. To fit dipole models to ICA components well, the maximum residual variance was set as 15%, which meant only components that resembled a dipolar field distribution within 85% would be accepted. The number of fitted dipoles (sources) from 4 subjects at different conditions are shown in table 1. For each subject, electrical stimulus was imposed on the posterior tibial nerve (PTN) at left and right ankle, and contact cold pain stimulation was administered on the surface of subject's low back.

TABLE 1: The Number of Fitted Dipoles

		Subjects			
		1	**2**	**3**	**4**
Left PTN	**Non pain**	23	13	9	9
	Pain	24	14	10	14
Right PTN	**Non pain**	23	10	11	11
	Pain	25	15	13	12

From table 1, the number of fitted dipoles of pain status was consistently more than that of the non pain status. It suggested that the cold pain sensation evoked some pain specific potentials and sources which merged in the original SEPs signals. However, there were some unrelated sources and noise in these fitted dipoles (shown in table 1), the pain related components are not easy to be recognized automatically. Consequently, some reliable components were obtained by comparing the topography and source location of these components, and chosen with experience.

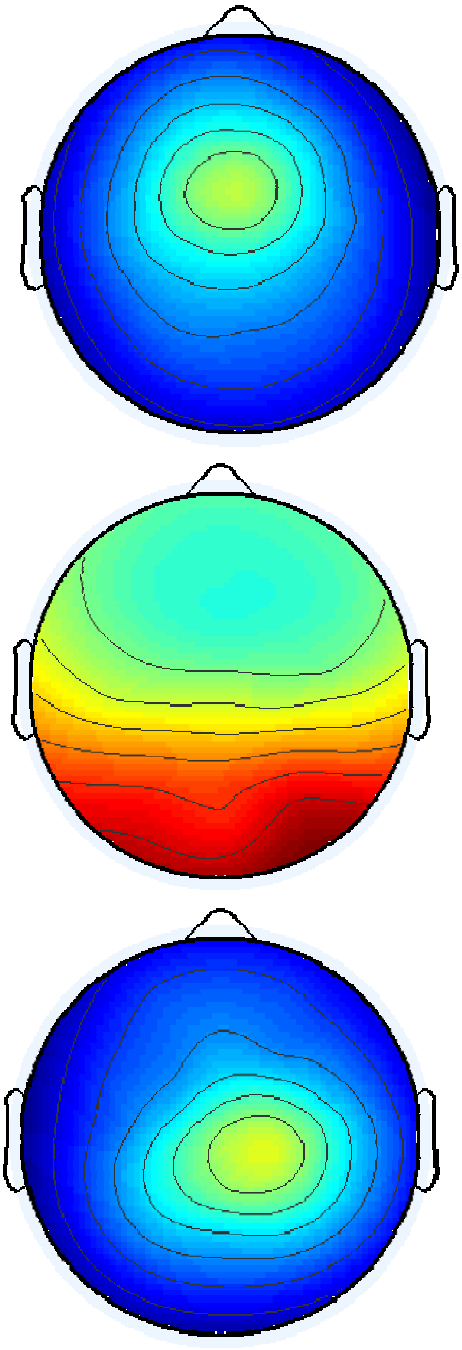

Figure 1: Topography of SEPs related components

For the conventional SEPs, there were 3 SEPs related components of which topography was shown in figure 1. In addition, there was a pain specific component, shown in figure 2. However, there may be some pain related components merged in the SEPs components in respect that there were some overlaps of nociceptive and

mechanoreceptive systems, and some cortical regions processed these two sensations simultaneously.

Sources of related components were obtained by the dipole fitting to conventional SEPs and pain related components. Basically, source modeling suggested loci of 3 SEPs generators: primary somatosensory cortices, anterior cingulate and thalamus (figure 3), supporting previous findings [9,10]. Regarding the cold pain effects, there was a specific generator located at primary somatosensory cortices or primary motor cortices (figure 4).

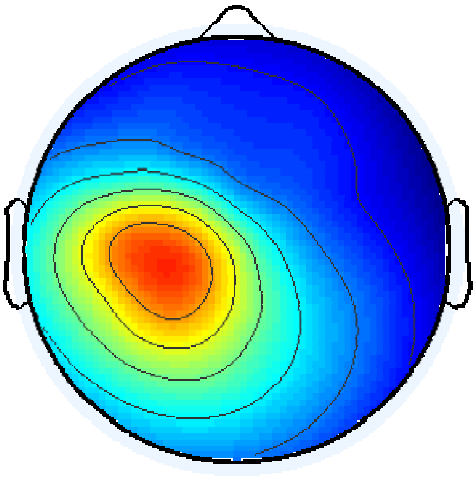

Figure 2: Topography of Pain related component

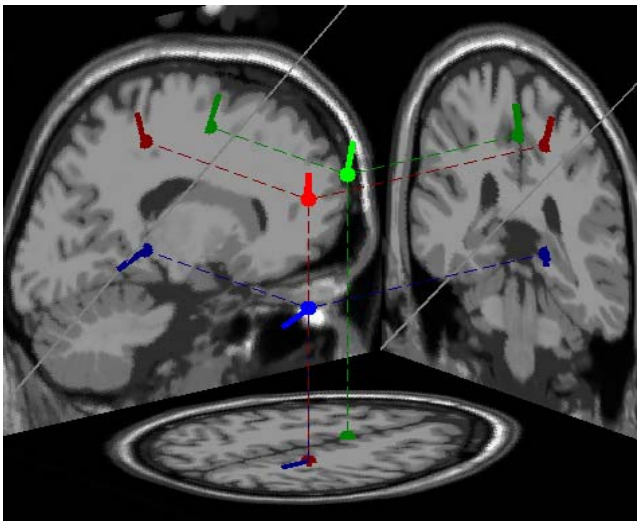

Figure 3: SEPs source model consisting of 3 dipolar sources at the primary somatosensory cortices, anterior cingulate and thalamus

IV. Discussion

In previous pain related SEPs studies, electrical and laser stimulation [3,11] were often chosen as the pain stimulus because of their controllable, repeatable and short duration properties. In particular, laser stimulus was considered as the ideal pain stimulation for its nociceptive specificity [3]. Nevertheless, the pain sensation in real life, , as a kind of persistent feeling for both acute and chronic pain, is not time-locked as in formal studies. With the direction of studying pain in real life, persistent pain stimulus should be adopted in the experiment. However, the pain triggered by ice was considered as a surface pain, while chronic pain, such as chronic low back pain, was a kind of inner pain. Consequently, the inner pain stimulation is a crucial problem to be investigated.

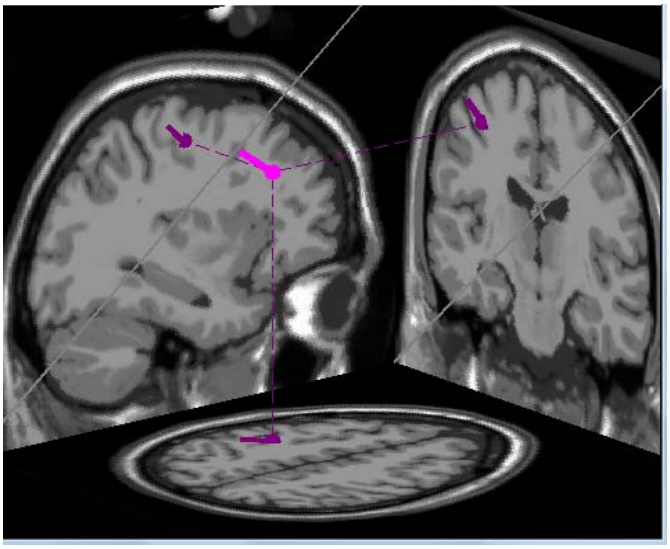

Figure 4: Pain special source model located at primary somatosensory cortices or primary motor cortices

SEPs, activated by pain and electrical stimulation of the skin, showed consistent middle-latency negative and positive potentials, of which peak latencies were approximately 100 to 150 and 200 to 250 milliseconds, respectively [3,11]. Similarly, the mean peak latency of predominantly negative and positive potentials of the SEP produced by laser pain stimulation were approximately 250 to 300 and 350 to 420 milliseconds, respectively [3,12]. Generator sources of conventional SEPs were located at brain-stem, thalamus and somatosensory cortex [13], while pain related SEPs were considered to be generated in primary somatosensory cortex, second somatosensory cortex, insula, and cingulate cortex [3].

In the present study, significant differences of conventional SEPs and pain related SEP waveforms might not be attribute to the reason that the cold pain stimulus was not time-locked, and were not enhanced by the average processing.

At the same time, the present results indicated that the number of sources of pain status was relatively larger than non-pain status. After the signals be separated by ICA, consistent nociceptive related components and mechanoreceptive related components were found, and the corresponding generator sources of these components were

obtained. The SEP related sources were similar to those found in previous studies. However, not so many obvious sources were found in present study as those reported by former researches [3], which may be caused by overlaping of conventional SEPs and pain related SEPs sources. That is to say some sources, such as thalamus and primary somatosensory cortices, were activated no matter whether there was a pain sensation or not.

By reasoning the pain plasticity, the contact pain sensation could be alternated during the whole 5 minutes, and may induced changes would happen in brain activity. And this can be avoided by multi-time stimulation with short duration. In previous studies [9,10], the information flow pathways of nociceptive and mechanoreceptive sensation were overlaped in some locations. Therefore, the connectivity of these sources should be investigated further to distinguish pain sensation from other inputs.

V. Conclusion

Persistent pain sensation related components existed and merged in the SEP signals in the present experiment. By ICA decomposition, one pain specific component was obtained, and others may be missed by the overlapping of different SEP components transmission systems.

In this study, it was found that a consistent source in all subjects was correlated with low back pain (LBP). Even this finding requires further study to verify, the results of the present study proposed a potential use of SEPs for pain investigation and LBP diagnosis.

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