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Magnetoencephalographic Response Characteristics Associated with Tongue Movement

Rainer Loose, PhD,[1] Shaheen Hamdy, MD,[2] and Paul Enck, PhD[3]
[1]Institute of Psychology, University of Regensburg, Regensburg, Germany; [2]Department of Medicine, Hope Hospital, Salford, United Kingdom; and [3]Department of General Surgery, University of Tuebingen, Tuebingen, Germany
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Abstract. Whole-head magnetoencephalography (MEG) was employed to study the sources of activation evoked by both active tongue movement and swallowing in five healthy subjects. Evoked magnetic fields were adequately explained in both paradigms by a time-varying single-dipole model which localized in the tongue in all subjects. No additional brain sources were detectable. Therefore, MEG detects fields associated with tongue movement that best fit a single-dipole source in the tongue. Future electrophysiological brain activation studies where tongue movement is likely should be aware of this observation since the tongue behaves like a strong current dipole.

Key words: Artifacts — MEG — Swallowing — Tongue movement — Deglutition — Deglutition disorders.

It has been shown that electrical stimulation of the tongue evokes cortical potentials detected by both electroencephalography [1] and magnetoencephalography [2]. By comparison, it has been shown that tactile stimulation of the tongue results in large artifacts in the recorded, cortically evoked potentials [3], presumably because the associated tongue motion generates shifts in the electrophysiological recording. Furthermore, tongue movements during speech can induce significant alterations in the measured pattern of electroencephalography (EEG) that are unrelated to cortical neural activity and may even mimic sources with asymmetric interhemisphere fields [4,5]. These findings suggest that measurements of cortical potentials associated with orofacial motor activities may be subject to considerable signal artifact problems. Despite these potential limitations, other studies have reported that brain activity associated with active tongue movement can be localized to the cortical motor tongue area when implanted subdural electrodes are used as the method of recording [6]. Thus, in order to account for these conflicting observations, we employed whole-head magnetoencephalography (MEG) to study the sources of activation evoked by active tongue movement with the aim of identifying the locality of the major contributors.

Methods

Five healthy right-handed male subjects (30–49 years old) participated in the study. Written informed consent was obtained from all subjects in accordance with local ethical committee guidelines. Magnetic brain responses were recorded (sample rate: 397 Hz, bandpass filter: 0.03–130 Hz) using a Neuromag-122™ whole-head neuromagnetometer (Neuromag, Helsinki, Finland) [7]. Neuromag-122 contains 122 superconducting planar gradiometers that detect the largest magnetic signal immediately over an active cortical area. During each study, subjects had to press their tongue against the hard palate every 10 s. As an additional condition, subjects swallowed a 5-mL water bolus once every 10 s. Subjects were instructed to inhibit jaw movements. For each condition, 100 epochs of 2-s duration were averaged time-locked to the electromyography signal, recorded at the mylohyoid muscle (from −500 to 1500 ms). A time-varying dipole model was fitted to explain the measured field pattern [8]. Only dipoles accounting for more than 85% of the field variance (goodness of fit) were accepted. Sources were then introduced into a time-varying current dipole model where locations and orientations of the dipoles were kept fixed but their amplitudes were allowed to vary over time, thus yielding source strength

Correspondence to: R. Loose, Ph.D., Institute of Psychology, University of Regensburg, D-93040 Regensburg, Germany. Telephone: +49-941-943-3846, Fax: +49-941-943-4496, E-mail: rainer.loose@psychologie.uni-regensburg.de

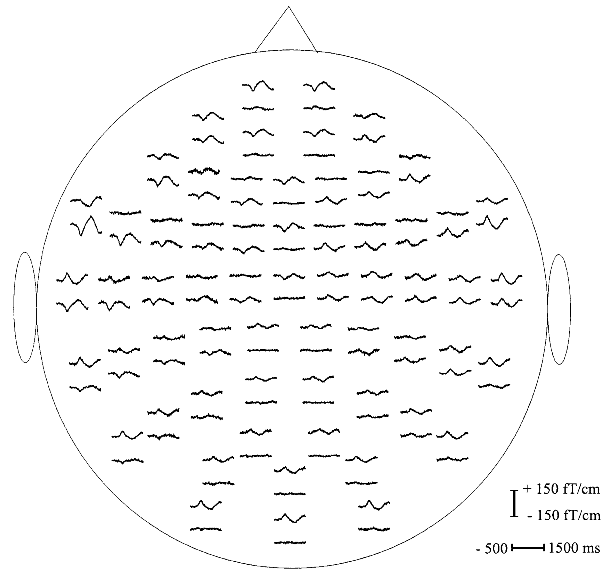

Fig. 1. Magnetic field signal distribution due to tongue movement for one subject over time (−500 to 1500 ms).

waveforms as a function of time. Before the recording, a head position indicator with three coils was attached to the scalp to give exact information of the location and orientation of the sensor array with respect to the head. The sites of the coils with respect to external anatomical landmarks (left and right preauricular points and nasion) were determined with a 3-D digitizer (Isotrak 3S1002, Polhemus Navigator Sciences, Colchester, UK), allowing realignment of MEG data and structural magnetic resonance images in the same coordinate system. For source localization, a spherical head model was individually fitted to the previously acquired magnetic resonance imaging whole-brain image (Siemens–Magnetom™-3D-Flash, Siemens, Erlangen, Germany) in each subject.

Results

Tongue movement evoked bilateral magnetic fields in the first 500 ms starting with the muscle activity with amplitudes about 250 fT/cm (Fig. 1). These evoked fields were adequately explained by a time-varying single-dipole model that was consistently localized to the muscle of the tongue in all subjects (Fig. 2). Analysis of the MEG data failed to identify any clear or reliable cortical source occurring during the motor task. This was mainly because the strong dipole generator of the tongue was masking any cortically generated fields.

As with the tongue condition, swallowing resulted in bilateral evoked magnetic fields in the first 500 ms starting with the muscle activity, with amplitudes similar those associated with tongue movements. Dipole modeling yielded an almost identical fit, with the generator being the posterior tongue.

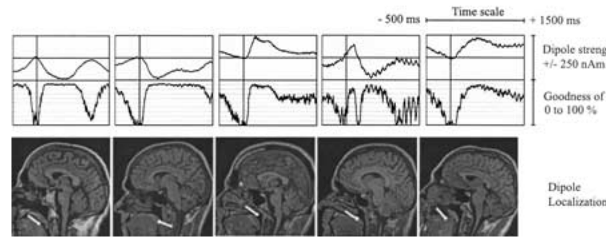

Fig. 2. Time-varying single-dipole model and source localization after active tongue movement for all five subjects. **Top** The dipole signal strength (± 250 nA) over time (−500 to 1500 ms) is shown (first curve) next to the goodness of fit (0%–100%, second curve). **Bottom** Localization of the source is shown rendered onto each MRI image, in the sagittal plane. The evoked magnetic fields were adequately explained by a time-varying single-dipole model consistently localized to the muscle of the tongue in all subjects.

Discussion

Our study has shown that active tongue movement will induce clear magnetic fields when measured using whole-head MEG. The main source of the evoked fields was, however, the tongue, there being no additional brain sources overtly detectable. Our findings indicate the significant difficulties may be encountered when MEG (and EEG-related) techniques are used to explore relevant brain neural activity resulting from orofacial and swallow-related motor tasks. In particular, caution must be applied when interpreting the patterns of fields generated, as in electrophysiological studies of active tongue movement [9] and oral reading [4,10–14]. The application of skillful condition to control for such investigations, e.g., additional silent reading when assessing verbal reading [10,12], should be emphasized.

Ikeda et al. [6] recorded movement-related potentials from subdural electrodes chronically implanted in the interhemispheric fissure of two patients. He distinguished between ‘‘Bereitschaftspotential’’ that preceded electromyogram onset and the motor potential that started just at electromyogram onset and peaked after onset of glossokinetic potentials. Both potentials were localized in supplementary motor areas. It is difficult to investigate motor potentials using EEG or MEG techniques because of myogenic artifacts produced by tongue movement [1]. Glossokinetic activity correlated significantly with EEG signals at inferior frontal and precentral sites [5]. In addition, a sharp distinction between premovement and postmovement potentials is difficult because, prior to a sharply defined electromyogram burst, a lower-level slowly rising increment in electromyogram activity could be observed [15].

Our inability to detect any associated cerebral activity during the tasks of active tongue movement or swallowing can be attributed solely to the masking effect of orofacial muscular EMG signals when recording small fields using a very sensitive detection system, such as MEG. Indeed, other studies using complementary functional imaging modalities, such as positron emission tomography and functional magnetic resonance imaging, have clearly demonstrated that cortical and subcortical activation to both tongue and swallow-related movements can be identified [16,17]. Thus, at present, we would not recommend the use of MEG to study similar motor tasks, as the data is likely to be contaminated by noncortical signals. Future MEG studies using more sophisticated analysis systems may concentrate on successful removal of artifacts regarding tongue movements. As cardiac artifact removal has been previously been performed [18], tongue movement artifacts may also be amenable to controlling paradigms.

In conclusion, MEG can detect fields associated with tongue movement that best fit a single-dipole source in the tongue. Future electrophysiological brain activation studies in which tongue movement is likely should be aware of problems with artifacts, as the tongue will behave like a strong dipole.

References

1. Altenmüller E, Cornelius CP, Buettner UW: Somatosensory evoked potentials following tongue stimulation in normal subjects and patients with lesions of the afferent trigeminal system. *Electroencephalogr Clin Neurophysiol 77:*403–415, 1990
2. Karhu J, Hari R, Lu S-T, Paetau R, Rif J: Cerebral magnetic fields to lingual stimulation. *Electroencephalogr Clin Neurophysiol 80:*459–468, 1991
3. Ishiko N, Hanamori T, Murayama N: Spatial distribution of somatosensory responses evoked by tapping the tongue and finger in man. *Electroencephalogr Clin Neurophysiol 50:*1–10, 1980
4. Szirtes J, Vaughan HG: Characteristics of cranial and facial potentials associated with speech production. In: Desmedt JE (ed): *Language and Hemispheric Specialization in Man: Event-Related Potentials.* Basel: Karger, pp 112–126, 1977
5. Brooker BH, Donald MW: Contribution of the speech musculature to apparent human EEG asymmetries prior to vocalization. *Brain Lang 9:*226–245, 1980
6. Ikeda A, Lüders HO, Burgess RC, Sakamoto A, Klem GH, Morris HH, Shibasaki H: Generator locations of movement-related potentials with tongue protrusions and vocalizations: subdural recording in human. *Electroencephalogr Clin Neurophysiol 96:*310–328, 1995
7. Ahonen AI, Hämäläinen MS, Kajola MJ, Knuutila JET, Laine PP, Lounasmaa OV, Simola JT, Tesche CD, Vilkman VA: A 122-channel magnetometer covering the whole head. *Proc Satellite Symp Neurosci Technol, 14th Ann Int Conf IEEE Eng Med Biol Soc, Lyon, France,* pp 16–20, 1992
8. Hämäläinen M, Hari R, Ilmoniemi RJ, Knuutila J, Lounasmaa OV: Magnetoencephalography—theory, instrumentation, and applications to noninvasive studies of the working human brain. *Rev Modern Phys 65:*413–497, 1993
9. Pfurtscheller G, Flotzinger D, Neuper C: Differentiation between finger, toe and tongue movement in man based on 40 Hz EEG. *Electroencephalogr Clin Neurophysiol 90:*456–460, 1994
10. Galin D, Raz J, Fein G, Johnstone J, Herron J, Yingling C: EEG spectra in dyslexic and normal readers during oral and silent reading. *Electroencephalogr Clin Neurophysiol 82:*87–101, 1992
11. Licht R, Bakker DJ, Kok A, Bouma A: The development of lateral event-related potentials (ERPs) related to word naming: a four year longitudinal study. *Neuropsychologia 26:*327–340, 1988
12. Salmelin R, Hari R, Lounasmaa OV, Sams M: Dynamics of brain activation during picture naming. *Nature 368:*463–465, 1994
13. van Strien JW, Licht R, Bouma A, Bakker DJ: Event-related potentials during word-reading and figure-matching in left-handed and right-handed males and females. *Brain Lang 37:*525–547, 1989
14. van Turennout M, Hagoort P, Brown CM: Electrophysiological evidence on the time course of semantic and phonological processes in speech production. *J Exp Psychol 23:*787–806, 1997
15. Morrel LK, Huntington DA: Electrocortical localization of language production. *Science 174:*1359–1360, 1971
16. Hamdy S, Rothwell JC, Brooks DJ, Bailey D, Aziz Q, Thompson DG: Identification of the cerebral loci processing human swallowing with H2(15)O PET activation. *J Neurophysiol 81(4):*1917–1926, 1999
17. Hamdy S, Kikulis DJ, Crawley A, Xue S, Lau H, Henry S, Diamant NE: Cortical activation during human volitional swallowing: an event-related fMRI study. *Am J Physiol 277(1):*G219–G225, 1999
18. Jousmaki V, Hari R: Cardiac artifacts in magnetoencephalogram. *J Clin Neurophysiol 13:*172–176, 1996