Neuroscience Letters 594 (2015) 46–50

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

Research article

Excitability changes in the left primary motor cortex innervating the hand muscles induced during speech about hand or leg movements

Yusuke Onmyoji[a], Shinji Kubota[a,b], Masato Hirano[a], Megumi Tanaka[a], Takuya Morishita[a,b], Kazumasa Uehara[a,b], Kozo Funase[a,*]

[a] *Human Motor Control Laboratory, Graduate School of Integrated Arts and Sciences, Hiroshima University, 1-7-1 Kagamiyama, Higashi-Hiroshima 739-8521, Japan*
[b] *Research Fellow of the Japan Society for the Promotion of Science, Japan*

HIGHLIGHTS

- Excitability in left-M1 hand area during speech was investigated.
- The increase in M1 excitability during speech was not related to the content.
- During silent reading, the marginal increase in M1 excitability was observed.
- The excitability was increased during reading aloud and non-vocal oral movement.
- There were no significant changes in SICI during all experimental conditions.

ARTICLE INFO

Article history:
Received 3 February 2015
Accepted 24 March 2015
Available online 26 March 2015

Keywords:
Speech
Sentence
Motor cortex excitability
Transcranial magnetic stimulation

ABSTRACT

In the present study, we used transcranial magnetic stimulation (TMS) to investigate the changes in the excitability of the left primary motor cortex (M1) innervating the hand muscles and in short-interval intracortical inhibition (SICI) during speech describing hand or leg movements. In experiment 1, we investigated the effects of the contents of speech on the amplitude of the motor evoked potentials (MEPs) induced during reading aloud and silent reading. In experiment 2, we repeated experiment 1 with an additional condition, the non-vocal oral movement (No-Voc OM) condition, and investigated the change in SICI induced in each condition using the paired TMS paradigm. The MEP observed in the reading aloud and No-Voc OM conditions exhibited significantly greater amplitudes than those seen in the silent reading conditions, irrespective of the content of the sentences spoken by the subjects or the timing of the TMS. There were no significant differences in SICI between the experimental conditions. Our findings suggest that the increased excitability of the left M1 hand area detected during speech was mainly caused by speech-related oral movements and the activation of language processing-related brain functions. The increased left M1 excitability was probably also mediated by neural mechanisms other than reduced SICI; i.e., disinhibition.

1. Introduction

Humans gesture unconsciously whilst speaking. Furthermore, gestures are rarely seen in the absence of speech. Therefore, it is considered that language function and hand movement are closely related because Broca's area is activated when humans recognize gestures performed by other people [1–3] or are using sign language [4]. In addition, it has been hypothesized that gesturing might represent the origin of the advanced language skills seen in humans [5]. Recently, it was reported that the cerebral cortices that manage language and movement are functionally related [6,7], and that speech affects the excitability of the left primary motor cortex (M1) innervating the hand muscles. Several studies in which the left M1 hand area was subjected to transcranial magnetic stimulation (TMS) demonstrated that M1 excitability, as assessed using TMS-induced motor evoked potentials (MEPs), was increased during speech, and this increase was much greater during reading aloud [8–11]. In addition, it was reported that the excitability of the left M1 hand area gradually increases from the preparatory state to the execution of speech and peaks just before the first syllable is

* Corresponding author. Tel.: +81 82 424 6590; fax: +81 82 424 6590.
E-mail address: funase@hiroshima-u.ac.jp (K. Funase).

http://dx.doi.org/10.1016/j.neulet.2015.03.052
0304-3940/

produced [12]. Furthermore, the primary motor cortices involved in the somatotopic representation of the hands or legs exhibited decreased excitability when the subjects recognized that other people were speaking about hand or leg movement, respectively [13]. Moreover, some functional magnetic resonance imaging (fMRI) studies have detected activation of the regions of the premotor cortex and central sulcus involved in the somatotopic representation of the hands, legs, or mouth when subjects heard words or sentences about hand, leg, or mouth movement, respectively [14–17]. These results suggest that the relevant motor and premotor areas are activated when linguistic information about physical movement, such as movement of the hands, legs, or mouth, is heard and recognized.

However, previous TMS studies have not examined how the excitability of the left M1 hand area is affected by (a) speech about movements that involve the hands, and (b) speech about movements that do not involve the hands. In the present study, we aimed to investigate the changes in the excitability of the left M1 hand area (which was assessed by evaluating the MEP evoked by the administration of a single magnetic pulse) induced during verbal descriptions of hand or leg movements to verify, whether the excitability of the left M1 hand area is dependent on speech content. In addition, the changes in short-interval intracortical inhibition (SICI), which was assessed using the paired TMS paradigm, during speech were also examined.

2. Materials and methods

2.1. Subjects

A total of 18 healthy right-handed native Japanese speakers participated in experiment 1 (5 males and 4 females, mean age: 24.8 ± 2.9, mean laterality index: +95) and 2 (4 males and 5 females, mean age: 24.3 ± 2.4, mean laterality index: +94) after giving their written informed consent. Their handedness was assessed using the Edinburgh Handedness Inventory [18]. All experimental procedures were carried out in accordance with the Declaration of Helsinki and approved by the local ethics committee at the Graduate School of Integrated Arts and Sciences, Hiroshima University.

2.2. Experimental protocols

In both experiments 1 and 2, the subjects were instructed to sit on a reclining chair; to put both hands in a pronated position on a horizontal plate attached to the chair's armrests; and watch a 12-inch computer display, which was put on the plate 1 m in front of the subjects. A Japanese sentence was presented on the display in font size 72. The subjects were asked to read the sentence at a guided speed (each character in the sentence was successively underlined from left to right at constant speed; total reading time for each sentence: 3 s) and a volume of approximately 80 dB, which was monitored using a digital sound level meter (AR814, Intell Instruments Plus, China) placed on the plate 50 cm in front of the subject. A volume of approximately 80 dB is similar to that used during normal conversation.

In experiment 1, MEP measurements were obtained in the following 4 conditions, which were presented in random order: (1) resting conditions (baseline control), (2) reading sentences about hand movement aloud (hand), (3) reading sentences about leg movement aloud (leg), and (4) reading sentences that were unrelated to movement aloud (No-Mov). Each reading condition was composed of three sentences. In addition, the subjects read each of the 3 sets of sentences silently. The Japanese sentences (*with English translations*) are shown in Table 1. The sentences all had the same syntax; i.e., subject + object + predicate.

Table 1
Sentences employed in experiment 1.

Category	Sentence
Hand movement	Watashi wa Bo-ru wo Nageru *Eng. I throw a ball* Watashi wa Koppu wo Motsu *Eng. I have a cup* Watashi wa Hashi wo Tsukau *Eng. I use chopsticks*
Leg movement	Watashi wa Bo-ru wo Keru *Eng. I kick a ball* Watashi wa Kaidan wo Noboru *Eng. I climb the stairs* Watashi wa Gurando wo Hashiru *Eng. I run across the ground*
Unrelated to movement	Watashi wa Tomo wo Shinpaisuru *Eng. I worry my friend* Watashi wa Oya ni Kanshasuru *Eng. I appreciate my parents* Watashi wa Mukashi wo Omoidasu *Eng. I remember the old days*

In experiment 2, further MEP measurements were taken during the resting conditions and as the subjects read one of the sentences about hand movement, "Watashi wa Bo-ru wo Nageru" (*Eng. I throw a ball.*), which was chosen based on the results of experiment 1. The subjects read the latter sentence aloud and silently. In addition, they also produced non-vocal oral movements that simulated the oral movements required to verbalize the sentence (No-Voc OM). All of the conditions in experiment 2 were performed in random order.

2.3. Transcranial magnetic stimulation (TMS)

A magnetic stimulator (Model 200, Magstim, Whitland, UK) and a figure-of-eight coil were used to deliver the electromagnetic stimuli. Care was taken to maintain the same coil position relative to the scalp throughout the experiment. The coil was placed tangentially to the scalp with its handle pointing backward and rotated approximately 30° away from the mid-sagittal line. TMS was delivered to the optimal spot in the left M1; i.e., the location at which MEP of maximal amplitude were induced in the contralateral right first dorsal interosseous muscle (FDI). The subjects wore a swimming cap, and the optimal stimulation spot was marked on the cap with a marker pen. All electromyographic (EMG) signals were recorded using paired Ag/AgCl surface electrodes, and the signals in the bandwidth range from 5 Hz to 3 kHz were amplified and filtered (model 7S12, NEC San-ei Co. Ltd., Japan). The analog EMG signals were digitized at a sampling rate of 10 kHz and saved to a computer for off-line analysis. During the off-line analysis, the MEP amplitudes (mV) of the signals were measured using scope for Windows (PowerLab system, Scope version 3.7.6, AD instruments Pty. Ltd., Australia). In experiment 1, TMS intensity was adjusted to 120–130% of the resting motor threshold (RMT) in order to evoke MEP with amplitudes of approximately 1 mV. The RMT was defined as the minimum TMS intensity at which MEP with peak-to-peak amplitudes of >50 μV were induced in the FDI 5 times in 10 successive trials under resting conditions. The TMS was triggered at 1000 or 2000 ms after the first character in the Japanese sentence was underlined. Ten single MEP were evoked and recorded in each condition. MEP were recorded three times in the resting conditions; i.e., during the initial, middle, and last phases of the experiment. In each condition, the mean peak-to-peak amplitude of the MEP induced in the FDI was calculated as an index of M1 excitability.

In experiment 2, two magnetic stimulators connected to a Bistim module (Magstim, Whitland, UK) designed for use with the paired TMS paradigm were used to assess SICI. Ten MEP were induced in the M1 for the right FDI in each condition. The intensity of the