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Slow cortical potential shifts preceding sensorimotor interactions

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Abstract

It is well known that synchronization of cortical neurons is modulated ("gating") by the chronological interaction between somatosensory and sensorimotor events. This study tested the hypothesis that the anticipatory processes for this interaction increase the synchronization of cortical neurons as revealed by negative event-related potentials (contingent negative variation, CNV). High-resolution electroencephalographic data (128 electrodes) were recorded in 14 subjects. In the "sensorimotor interaction" condition, the subjects were waiting for a galvanic somatosensory stimulation at the left hand concomitant with a Go or NoGo stimulus (50% of Go trials triggering right hand movements). In the control condition, the Go/NoGo stimulus followed the somatosensory stimulation of 1.5 s. The electroencephalographic data were spatially enhanced by surface Laplacian estimation. In the control condition, the CNV was observed only in the foreperiod between the somatosensory stimulation and Go/NoGo task (i.e. no CNV before the somatosensory stimuli). It was spatially localized in the primary sensorimotor area contralateral to the possible motor response. In the "sensorimotor interaction" condition, the CNV preceded the concomitant somatosensory stimulation and Go/NoGo task and was distributed to the frontocentral midline other than the contralateral sensorimotor area. These results suggest that the anticipatory processes for sensorimotor interactions increase the synchronization of cortical neurons in the frontocentral midline, possibly due to mechanisms sub-serving top–down attentional processes.

Keywords: Go/NoGo task; Somatosensory stimulation; Expectancy; High-resolution electroencephalography (EEG); Contingent negative variation; Primary sensorimotor cortex

1. Introduction

The effects of sensorimotor interactions on the synchronization of cortical neurons have been investigated during galvanic somatosensory stimulations concomitant with passive movements, cutaneous sensory stimulations, and the execution or mental simulation of hand movements [18,24,25,31–33,41,42,47,48]. These interactions have been found to result in a reduction of the global synchronization of cortical pyramidal neurons generating somatosensory evoked potentials (SEPs) or magnetic counterpart, as an effect of a decreased summation of post-synaptic potentials at the arrival of peripheral sensory input. Such a "desynchronization" of the cortical pyramidal neurons decreases the amplitude of the SEPs ("gating"). The gating effects observed in the mentioned studies would result from centrifugal and/or centripetal interfering influences at the level of sensorimotor cortex, brainstem, and spinal somatosensory relays [18,41]. An open issue is whether such sensorimotor interactions, when warned, are prepared by specific anticipatory

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processes. Where are these anticipatory processes localized? Do they increase or decrease the synchronization of the cortical neurons?

The synchronization of cortical neurons accompanying anticipatory processes has been studied in humans during the expectancy of warned stimuli. It has been shown that the development of slow event-related potentials (ERPs) of negative polarity is supposed to denote effective–motivational cortical processes and preparatory sensorimotor processes [13,14]. When no motor response is required, anticipatory ERPs preceding warned stimuli are termed stimulus-preceding negativity (SPN). Conversely, these potentials are termed contingent negative variation (CNV) when a motor response is required [15,16]. The CNV also develops before stimuli triggering Go/NoGo tasks in which the motor response is required only after Go stimuli [20]. Source localization of CNV has been mainly elucidated by intracerebral stereo-electroencephalography (sEEG) technique showing that CNV preceding motor activity originates from a distributed neural network with both cortical and subcortical nodes [11,29,37–39]. On the whole, CNV and SPN express ongoing slow increment in the synchronization of post-synaptic neuronal activity hidden into electroencephalographic (EEG) rhythms, which enhances the efficiency of brain information processing and corresponding cognitive performance [12,15].

According to the mentioned CNV literature, the present high-resolution EEG study tested the hypothesis that the anticipatory processes for sensorimotor interactions, induced by concomitant somatosensory stimuli and sensorimotor demands (Go/NoGo task), increase the synchronization of cortical neurons as revealed by the amplitude of the CNV.

2. Materials and methods

2.1. Subjects

Fourteen young (mean age ± standard error (S.E.) = 26 ± 2.7 years) healthy volunteers (seven males and seven females) participated in the present study. All subjects were right-handed as revealed by an interview. They all gave written informed consent according to the Declaration of Helsinki and could freely request an interruption of the investigation at any time. The local Institutional Ethics Committee approved the general procedures.

2.2. Stimulation procedure

Subjects were seated in a comfortable reclining armchair in front of a computer monitor. A typical trial of the experimental design is shown in Fig. 1. Three visual stimuli (yellow target with black background, 500 ms duration) preceded an electrical sensory stimulus (constant current monophasic pulse of 5 ms intracutaneously). The electrical stimulus was applied slightly above (10%) subjective somatosensory threshold to the tip of the left index finger. The interval between the four (three visual and one somatosensory) stimuli was of 4000 ms. The Go or NoGo stimulus was concomitant with the electrical somatosensory stimulus in the condition of "sensorimotor interaction" ('Go/NoGo 0') and was delayed 1.5 s from the sensory stimulus in the control condition ('Go/NoGo + 1.5'). The two conditions were performed in two separate pseudo-randomized recording blocks. Subjects had to perform either a right hand movement after a green stimulus (Go stimulus) or no movement after a red

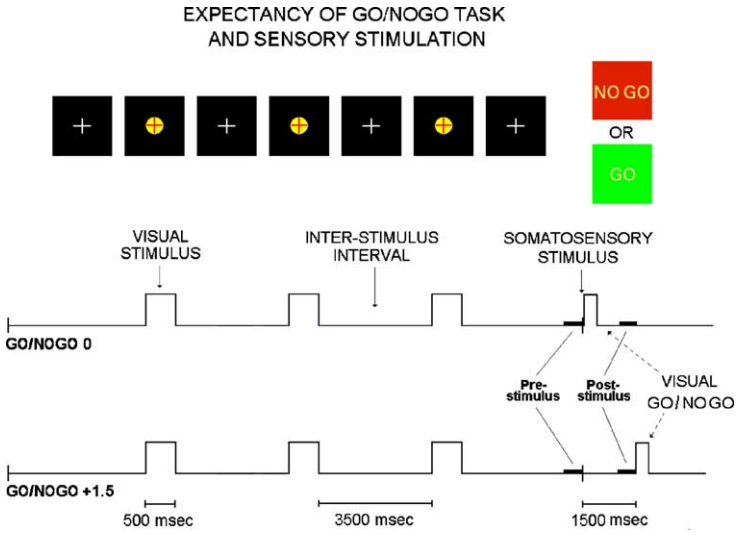

Fig. 1. Sketch of the experimental design for the study of expectancy of the Go/NoGo task. The experimental paradigm consisted of a sequence of three visual stimuli (red cross within a yellow target) and a sensory stimulus having a constant inter-stimulus interval of 4 s. This stimulus was followed by a Go/NoGo task, consisting in either a green visual stimulus triggering a Go response (i.e. right hand movement) or a red visual stimulus triggering no movement. In the 'Go/NoGo 0' condition, the sensory stimulus and the Go/NoGo visual stimulus were delivered at the same moment. In the 'Go/NoGo + 1.5' condition, the Go/NoGo visual stimulus was delivered 1500 ms after the sensory stimulus. The periods of interest of the study (pre-stimulus, post-stimulus) are emphasized. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.)