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The effects of alteration of effector and side of movement on the contingent negative variation

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Abstract

Objective: The contingent negative variation (CNV) is a widespread electroencephalographic (EEG) potential that occurs during the interval between a warning stimulus and a subsequent imperative stimulus if a mental or motor response is required. The present study was designed to explore the impact of the previous trial on the CNV of the forthcoming trial, that is, how a previous movement affects brain activation preparing the next movement. Effects of alteration of finger (from index to middle, and vice versa) and hand (from left to right, and vice versa) were examined independently from each other.

Methods: CNV was recorded in 20 right-handed healthy subjects with electrodes placed at F7, F5, F3, F4, F6, F8, FC5, FC3, FC1, FC2, FC4, FC6, T7, C5, C3, C1, C2, C4, C6, T8, CP5, CP1, CP2, CP6, P7, P3, P4 and P8. In a visual/visual S1-choice paradigm, an earlier informative (S1) stimulus which instructed for side and finger of the following movement was followed 3 s later by an imperative (S2) stimulus providing the command to move. Subjects had to respond to each imperative stimulus with an appropriate button press made by brisk flexion movements with the index or middle finger of each hand. The CNV recorded in the interval between the informative and the imperative stimulus was analysed with respect to finger and hand of the present and the preceding movement.

Results/Conclusions: (1) A change of the side of movement is associated with a widespread increase of negativity contralateral to the currently prepared movement. (2) A change of finger is associated with a focal increase of negativity contralateral to the side of the current movement over temporoparietal and mid-parietal areas. (3) A change of finger results in a widespread increase of negativity over the left hemisphere.

Keywords: Contingent negative variation; Event related potential; Premotor cortex; Parietal cortex; Laterality physiology; Motor activity; Electrophysiology

1. Introduction

The contingent negative variation (CNV) is a widespread electroencephalographic (EEG) potential which can be recorded from the scalp in the interval between an earlier warning stimulus and a later imperative stimulus if a cognitive or motor response is required. If part or all of the information needed to prepare the appropriate response is provided with the earlier stimulus, preparatory activity can occur in the interval between the two stimuli. Amplitude and distribution of the CNV are considered to reflect information processing and response preparation (Simson et al., 1977; Gratton et al., 1990; Rösler, 1991). Previous research has examined how the characteristics of the earlier or later of the two stimuli, the time interval between them, and the details of the instructed response do affect amplitude and distribution of the CNV. Little is known, however, about the impact of the previous trial on the CNV of the forthcoming trial and how a previous movement affects brain activation preparing the next movement.

In a previous study (Dirnberger et al., 2002) with movement-related cortical potentials (MRCPs), we reasoned that for repetitive movements some part of pre-movement activity may remain in place between two identical actions and is still available for the next movement. This might concern working memory processes, but could also apply to facilitation or updating processes on a lower level which might be required to prepare motor areas prior to alternating but not repetitive movements. Some processes may stay active across two identical successive trials. These processes would then be included into

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the baseline of the second trial and not found in this second measurement. Other processes might be set-related when switching from one to another type of movement. These processes would not be required to be re-done after a preceding identical movement, and therefore the premovement EEG signal would be larger in an alternating than in a repetitive task. In addition, inhibitory processes might be required in an alternating task to erase any trace of activation related to a non-identical previous movement. Alteration of the effector or the side of movement could thus explain some effects found for other types of complex movement which may also make higher preparatory demands than repetitive movements.

In our previous MRCP study (Dirnberger et al., 2002) we found that effector and side of the previous movement affect the amplitude of the MRCP in the current trial. Negativity over contralateral sensorimotor and parietal areas did increase when subjects changed the side of movement but not after a change of finger within one hand. We also found that alteration of either side or finger was associated with a widespread increase of negativity over the left hemisphere, probably related to some 'supramotor' function of the left hemisphere in the organization of voluntary movement. These findings were attributed to attentional processes, motor preparation, and decoding of somatosensory inputs.

Previous research has found profound differences in preparatory activity preparing self-initiated versus externally paced movements (for a review see Goldberg, 1985). Therefore, it is not clear to what extent effects of alteration found in our previous study on self-initiated movements can be also found in an externally paced motor task. The aim of this study was to test the generality of the these results in an externally triggered CNV paradigm

2. Methods

2.1. Subjects

Twenty subjects (9 males) aged 21–34 years (mean 26 years, SD 3 years) participated in the study. All were right-handed (Oldfield, 1971), had normal or corrected-to-normal vision and no history of psychiatric or neurological disease. Written informed consent was obtained from each subject.

2.2. Design

Subjects performed a visual/visual S1-choice reaction time task. A white fixation cross appeared in the middle of a black computer screen viewed by the subjects from a distance of approximately 120 cm. On each side of the fixation cross, two quadratic white frames (length: 18 mm) were positioned symmetrically representing the 4 possible response positions. The cross and the 4 frames remained visible for the entire experiment. A change of colour from black to white of the interior of one of the frames served as the informative (S1) stimulus. The informative stimulus appeared for 200 ms and instructed for side and finger of the forthcoming movement, with the far left position representing the left middle finger, the inner left position representing the left index finger, etc. After an interval of precisely 3000 ms after the onset of the informative stimulus, a second change of colour from black to green occurred in the interior of the same frame as the informative stimulus before. This second change of colour served as the imperative (S2) stimulus, which also appeared for 200 ms. Subjects were instructed to respond to each imperative stimulus with the required unilateral flexion movement as quick as possible.

Stimuli were presented in a pseudo-random order so that every finger of a previous trial could be followed by the same or every other finger in the next trial with the same probability. Sequences of stimuli were constructed with a modified tuple algorithm as described by Popper (1959). The sequences used in our experiments were 4-free, that is, every sub-sequence of up to 5 movements with the left or right index or middle finger occurred with the same frequency. The arrangement of transitions was counterbalanced within subjects up to the third order. Four different sequences were used so that the order of transitions was also counterbalanced between subjects. The interval between the imperative stimulus for the preceding trial and the informative stimulus for the subsequent trial was varied randomly from 4 to 7 s. A total of 1034 trials was recorded for each subject, with the first 10 trials not used in further analysis.

The meaning of this design was that the factors change of finger and change of side of movement were independent from each other: In the sequence of trials, subjects could change the moving finger (from index to middle, or vice versa) within one hand or coincident with a change of the side of movement, and they could change the side of movement (from left to right, or vice versa) moving the same finger on the other side or coincident with a change of finger.

2.3. Procedure

Subjects were comfortably seated with their arms supported by padded armrests. At the end of the left and right armrests were two buttons placed at a distance so that they could be reached comfortably by the subjects with the index or middle fingers. The inter-button distance on each side was 2.5 cm. Subjects were instructed always to rest all 4 fingers on the appropriate buttons. Before starting the task, and during its execution, subjects had to fixate on the fixation cross straight ahead in order to minimize eye movements. Subjects were required to make brisk flexion movements according to our instructions immediately after the imperative stimulus. The total time taken to complete the tasks was about 3 h. Task performance was video-monitored. Subjects had two breaks of 10 min in the course of testing.