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Effects of rearranged vision on event-related lateralizations of the EEG during pointing

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Abstract

We used event-related lateralizations of the EEG (ERLs) and reversed vision to study visuomotor processing with conflicting proprioceptive and visual information during pointing. Reversed vision decreased arm-related lateralization, probably reflecting the simultaneous activity of left and right arm specific neurons: neurons in the hemisphere contralateral to the observed action were probably activated by visual feedback, neurons in the hemisphere contralateral to the response side by the somatomotor feedback. Lateralization related to the target in parietal cortex increased, indicating that visual to motor transformation in parietal cortex required additional time and resources with reversed vision. A short period of adaptation to an additional lateral displacement of the visual field increased arm-contralateral activity in parietal cortex during the movement. This is in agreement with the Clower et al. study (1996), which showed that adaptation to a lateral displacement of the visual field is reflected in increased parietal involvement during pointing.

Keywords: EEG; Event-related lateralizations; Reversed vision; Pointing

1. Introduction

When we direct our hand towards a visual target, our brain uses proprioceptive information about the position of our arm and visual information about the target of the reach. Visual

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feedback about the current position of the hand as well as about the location of the target can also be used to compute the appropriate movement. The interaction between proprioceptive and visual information can be studied by introducing a discrepancy between visual and proprioceptive feedback. This is usually done by rearranging vision, since proprioceptive information is difficult to manipulate. Insights into the significance of visual feedback in motor control have been gained from psychophysical experiments that used modified visual feedback and typically behavioral measures (Welch et al., 1979; Yoshimura, 1996). These studies typically use prisms that distort the visual field, resulting in a conflict between visual and proprioceptive information.

According to the framework proposed by Milner and Goodale, vision for action is the function of the dorsal stream (Goodale and Milner, 1992; Milner and Goodale, 1995). Thus, correlates of the effect of modified vision on motor tasks are likely to be found in parietal cortex. In fact, imaging studies have identified parietal areas that are specifically involved in the recalibration of the visual to motor transformation process induced by distortions of the visual field (Clower et al., 1996; Inoue et al., 1997). Imaging techniques like functional magnetic resonance imaging (fMRI) or positron emission tomography (PET), which measure changes in the regional metabolism of the brain, have the advantage of identifying the sources of activation with high accuracy but provide very low temporal resolution. Therefore, they can assess only one aspect of plasticity, namely which areas undergo changes due to the exposure to rearranged vision. These studies cannot assess the modifications in the sensorimotor transformation process in the situation of conflicting inputs.

Such transformation processes can be studied by measuring brain activity online by means of EEG recordings. By recording event-related EEG potentials, the cortical activity at different stages in the visual to motor transformation process can be monitored with high temporal resolution. Several studies have assessed changes in the EEG during the preparation and execution of movements. The EEG has been shown to contain a lateralized component indicative of movement preparation. De Jong et al. (1988) and Gratton et al. (1988) first used the method of subtracting the activity at the electrode over the motor cortex ipsilateral to a hand movement from that at the contralateral electrode. This revealed the lateralized readiness potential (LRP) over contralateral hand motor areas prior to movement onset. The LRP like subtraction method has since been used to investigate event-related lateralizations of EEG activity (ERLs) not only relative to the side of the response but also in relation to the laterality of a visual stimulus (e.g. Luck and Hillyard, 1994; Wascher and Wauschkuhn, 1996; Verleger et al., 2000).

Besides the LRP, other lateralized components play a role in reaching movements as well. In a previous study, we identified parietal and premotor ERLs in a pointing task (Berndt et al., 2002). Two of these ERLs were evident at around 350 ms after target onset, following target detection and preceding the start of the movement. Over frontal motor areas the ERL reflected increased activity contralateral to the active arm. Contrastingly, parietal activity around the same latency was lateralized with respect to the target position, which coincided with pointing direction. A further target-oriented ERL over parietal areas was evident during the execution of the pointing movement. These ERLs were context dependent. When the pointing direction was predictable and visuomotor codes could be predefined, the ERLs decreased in amplitude. This responsiveness to direction predictability showed that these