Abstract:

Movements are humans interface to their social and physical environment. The human brain processes numerous complex computations during everyday actions, such as reaching for a door knob. It must recognize and localize the knob visually, and calculate its spatial relation to the hand. Then, the movement of the arm and hand with all their muscles has to be planned. During the movement, these parameters are monitored, and when the environment changes, for instance when the door is opened, the movement is adapted on the fly. Sensorimotor integration processes during a movement take 60-160ms, thus are much faster than processes for conscious perception. The mechanisms and cortical localization of these processes is the topic of the present dissertation. Perturbation paradigms are utilized for investigating reach adjustments: Participants have to reach for a target, and a perturbation, such as a displacement of the target, is introduced during the ongoing movement. Thus, the participant must adjust the movement, and the brain has to integrate the newly arriving sensory information into the current movement plan. The first project investigated the chronometry of the processes responsible for the integration of visual and proprioceptive information. I measured with electromyography (EMG) the neural latency from the perturbation to the response. This method provided the computation time necessary for integrating and transforming sensory to motor signals. Furthermore, the paradigm allowed breaking down the sensorimotor processes and assessing the time for coordinate transformations from eye- to body-centered representations of information. The second project studied the cortical localization of sensorimotor processes. The focus of this project was on visual information, both about the target and about the acting body part. First, I used functional magnetic resonance imaging (fMRI) for a rough localization of areas involved in visuomotor integration in the parietal cortex. Based on these results, I tested several parietal sub-regions for their necessity with transcranial magnetic stimulation (TMS). Due to the large inter-individual differences in functional neuroanatomy, I used individual and group fMRI data for localizing TMS coil positions. This yielded a grid of coil positions with distances of 1-2cm. The distinct behavioral effects of TMS on adjacent stimulation sites demonstrated the good functional resolution of TMS. These results also demonstrate that planning TMS coil positions on individual fMRI data is a promising approach. Furthermore, the results show that the network of parietal regions involved in sensorimotor control extends further inferior than previous studies have suggested. Finally, they demonstrate that the anterior intraparietal sulcus (aIPS), which is usually associated with grasping movements, is a crucial structure for visually guided arm movements as well. The final project focused on the cortical localization of processes integrating proprioceptive information during online movement control. The perturbation consisted of a force impulse administered with a robot arm, and the entire anterior parietal cortex was tested with TMS. Dependent on the visual feedback about the hand position, i.e. participants could react either based on visual and proprioceptive information or based on proprioception alone, different cortical areas were susceptible to TMS. When visual information was available, stimulation over the same area as in the previous study (aIPS) led to behavioral deficits. When only proprioception was available, stimulation over a site more posterior and medial led to behavioral deficits. Thus, different parietal sub-regions are crucial for the processing of visual vs. proprioceptive information for sensorimotor integration. These three studies shed light on the chronometry of sensorimotor integration processes in online motor control, as well as on their localization in the parietal cortex.

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