

Imagined Movement and Actual Movement

– The Brainy Bit

The following references and abstracts define the similarities and differences between actual and imagined movement. In general they all agree on a high degree of concordance in brain activity between real and imagined activities.

Kuhtz-Buschbeck, J. P., C. Mahnkopf, et al. (2003). "Effector-independent representations of simple and complex imagined finger movements: A combined fMRI and TMS study." European Journal of Neuroscience **18**(12): 3375-3387.

Kinesthetic motor imagery and actual execution of movements share a common neural circuitry. Functional magnetic resonance imaging was used in 12 right-handed volunteers to study brain activity during motor imagery and execution of simple and complex unimanual finger movements of the dominant and the nondominant hand. In the simple task, a flexible object was rhythmically compressed between thumb, index and middle finger. Premotor, posterior parietal and cerebellar regions were significantly more active during motor imagery of complex movements than during mental rehearsal of the simple task. In 10 of the subjects, we also used transcranial magnetic brain stimulation to examine corticospinal excitability during the same motor imagery tasks. Motor-evoked potentials increased significantly over values obtained in a reference condition during imagery of the complex, but not of the simple movement. Imagery of finger movements of either hand activated left dorsal and ventral premotor areas and the supplementary motor cortex regardless of task complexity. The effector-independent activation of left premotor areas was particularly evident in the simple motor imagery task and suggests a left hemispherical dominance for kinesthetic movement representations in right-handed subjects. (PsycINFO Database Record (c) 2010 APA, all rights reserved)

la Fougère, C., A. Zwergal, et al. (2009). "Real versus imagined locomotion: A [18f]-fdg pet-fmri comparison." NeuroImage.

The cortical, cerebellar and brainstem BOLD-signal changes have been identified with fMRI in humans during mental imagery of walking. In this study the whole brain activation and deactivation pattern during real locomotion was investigated by [18F]-FDG-PET and compared to BOLD-signal changes during imagined locomotion in the same subjects using fMRI. Sixteen healthy subjects were scanned at locomotion and rest with [18F]-FDG-PET. In the locomotion paradigm subjects walked at constant velocity for 10 min. Then [18F]-FDG was injected intravenously while subjects continued walking for another 10 min. For comparison fMRI was performed in the same subjects during imagined walking. During real and imagined locomotion a basic locomotion network including activations in the frontal cortex, cerebellum, pontomesencephalic tegmentum, parahippocampal, fusiform and occipital gyri, and

deactivations in the multisensory vestibular cortices (esp. superior temporal gyrus, inferior parietal lobule) was shown. As a difference, the primary motor and somatosensory cortices were activated during real locomotion as distinct to the supplementary motor cortex and basal ganglia during imagined locomotion. Activations of the brainstem locomotor centers were more prominent in imagined locomotion. In conclusion, basic activation and deactivation patterns of real locomotion correspond to that of imagined locomotion. The differences may be due to distinct patterns of locomotion tested. Contrary to constant velocity real locomotion (10 min) in [18F]-FDG-PET, mental imagery of locomotion over repeated 20-s periods includes gait initiation and velocity changes. Real steady-state locomotion seems to use a direct pathway via the primary motor cortex, whereas imagined modulatory locomotion an indirect pathway via a supplementary motor cortex and basal ganglia loop. (PsycINFO Database Record (c) 2010 APA, all rights reserved) (journal abstract)

Lotze, M., P. Montoya, et al. (1999). "Activation of cortical and cerebellar motor areas during executed and imagined hand movements: An fMRI study." Journal of Cognitive Neuroscience **11**(5): 491-501.

Brain activation during executed (EM) and imagined movements (IM) of the right and left hand was studied in 10 healthy right-handed Ss using functional magnetic resonance imaging (fMRI). Low electromyographic (EMG) activity of the musculus flexor digitorum superficialis and high vividness of the imagined movements were trained prior to image acquisition. Regional cerebral activation was measured by fMRI during EM and IM and compared to resting conditions. Anatomically selected regions of interest (ROIs) were marked interactively over the entire brain. In each ROI activated pixels above a t value of 2.45 ($p < 0.01$) were counted and analyzed. In all Ss the supplementary motor area (SMA), the premotor cortex, and the primary motor cortex showed significant activation during both EM and IM; the somatosensory cortex was significantly activated only during EM. Ipsilateral cerebellar activation was decreased during IM compared to EM. In the cerebellum, IM and EM differed in their foci of maximal activation: Highest ipsilateral activation of the cerebellum was observed in the anterior lobe (Larsell lobule H IV) during EM, whereas a lower maximum was found about 2-cm dorsolateral (Larsell lobule H VII) during IM. (PsycINFO Database Record (c) 2010 APA, all rights reserved)

Michelon, P., J. M. Vettel, et al. (2006). "Lateral Somatotopic Organization During Imagined and Prepared Movements." Journal of Neurophysiology **95**(2): 811-822.

Motor imagery is a complex cognitive operation that requires memory retrieval, spatial attention, and possibly computations that are analogs of the physical movements being imagined. Likewise, motor preparation may or may not involve computations that are analogs of actual movements. To test whether motor imagery or motor

preparation activate representations that are specific to the body part whose movement is imagined or prepared, participants performed, imagined, and prepared hand movements while undergoing functional MRI scanning. Actual hand movements activated components of the motor system including primary motor and somatosensory cortex, the supplementary motor area, the thalamus, and the cerebellum. All of these areas showed strong lateral organization, such that moving a given hand activated the contralateral cortex and ipsilateral cerebellum most strongly. During motor imagery and motor preparation, activity throughout the motor system was much reduced relative to overt movement. However, significant lateral organization was observed during both motor imagery and motor preparation in primary motor cortex, the supplementary motor area, and the thalamus. These results support the view that the subjective experience of imagined movement is accompanied by computations that are analogs of the physical movement that is imagined. They also suggest that in this regard motor imagery and motor preparation are similar. (PsycINFO Database Record (c) 2010 APA, all rights reserved) (journal abstract)

Nair, D. G., K. L. Purcott, et al. (2003). "Cortical and cerebellar activity of the human brain during imagined and executed unimanual and bimanual action sequences: A functional MRI study." Cognitive Brain Research **15**(3): 250-260.

Used functional magnetic resonance imaging (fMRI) to study the neural (blood oxygenation level dependent) correlates of executed and imagined finger sequences, both unimanual and bimanual, in 8 adult right-handed volunteers (aged 25-40 yrs). Each experimental condition consisted of overt movement of the fingers in a prescribed sequence and imagery of the same task. An intricate network consisting of sensorimotor cortex, supplementary motor area, superior parietal lobule and cerebellum was identified when the tasks involved both planning and execution. During imagery alone, however, cerebellar activity was largely absent. This apparent decoupling of sensorimotor cortical and cerebellar areas during imagined movement sequences suggests that cortico-cerebellar loops are engaged only when action sequences are both intended and realized. In line with recent models of motor control, the cerebellum may monitor cortical output and feed back corrective information to the motor cortex primarily during actual, not imagined, movements. (PsycINFO Database Record (c) 2010 APA, all rights reserved)

Oullier, O., K. J. Jantzen, et al. (2005). "Neural Substrates of Real and Imagined Sensorimotor Coordination." Cerebral Cortex **15**(7): 975-985.

Much debate in the behavioral literature focuses on the relative contribution of motor and perceptual processes in mediating coordinative stability. To a large degree, such debate has proceeded independently of what is going on in the brain. Here, using blood oxygen level-dependent measures of neural activation, we compare

physically executed and imagined rhythmic coordination in order to better assess the relative contribution of hypothesized neuromusculoskeletal mechanisms in modulating behavioral stability. The executed tasks were to coordinate index finger to thumb opposition movements of the right hand with an auditory metronome in either a synchronized (on the beat) or syncopated (off the beat) pattern. Imagination involved the same tasks, except without physical movement. Thus, the sensory stimulus and coordination constraints were the same in both physical and imagination tasks, but the motoric requirements were not. Results showed that neural differences between executed synchronization and syncopation found in premotor cortex, supplementary motor area, basal ganglia and lateral cerebellum persist even when the coordinative patterns were only imagined. Neural indices reflecting behavioral stability were not abolished by the absence of overt movement suggesting that coordination phenomena are not exclusively rooted in purely motoric constraints. On the other hand, activity in the superior temporal gyrus was modulated by both the presence of movement and the nature of the coordination, attesting to the intimacy between perceptual and motoric processes in coordination dynamics.
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