Published in final edited form as:
*Mov Disord*. 2012 October ; 27(12): 1473–1474. doi:10.1002/mds.25186.

# Real and Imaginary Gait

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> "*Between the idea and the reality, between the motion and the act, falls the shadow*"
>
> The Hollow Men, T.S. Eliot

There is in fact only a thin line between imagination and reality. Our perceptions are creations of the brain, calculated from our limited sensory inputs from the real physical world. These perceptions are strongly influenced by our past experiences and beliefs, and we can conjure them up (imagine them) even if the physical objects are not there. Illusions and hallucinations seem real to the person experiencing them. On the motor side, it is possible to imagine doing a particular action. Such imagination can take two forms, imagining actually doing the action and imagining watching yourself doing the action. Imagining doing a new skill is almost as good as actual practice leading to performance improvement; and many athletes and musicians often imagine the performance just prior to actually doing it, which presumably improves the specific performance. Not only that, but because of mirror neurons in the brain, there is an overlap of activation of brain structures in the observation and performance of actions. While mirror neurons were first identified in monkeys, there is good evidence for them in humans with a full somatotopy, including the lower extremity, and resembling that of real motor performance.[1] It is likely that this is the explanation in part why people get almost as much enjoyment from watching a sports performance as actually doing it, since their brains are similarly active as if they were performing the action themselves. And watching will improve a person's own skill, but, of course, actually doing the activity is better for heart health and increasing levels of brain derived neurotrophic factor (BDNF).

Brain activity with imagination of motor actions has been compared with action. Hanakawa and colleagues, for example, carefully evaluated execution or imagery of sequential finger tapping movements.[2] Many frontoparietal and posterior cerebellar areas were active with both. Executive regions such as the primary motor and sensory cortex and anterior cerebellum were active mainly with actual performance. Imagery predominant regions were more frontal, such as the middle frontal gyrus, and more posterior, such as the precuneus. The thin line between imagination and execution is the boundary between Brodmann areas 6 and 4 (premotor and primary motor cortex).

It has been difficult to study real gait with neuroimaging, but there have been a number of studies now that have used imagination of gait as a proxy, and for all the reasons described so far, this is a quite reasonable approach. In fact, there are some advantages. In real gait, there is an effect of the visual environment which might be less confounding with imaginary gait. Additionally, it is possible with imagination to pass through objects, something impossible in real life.[3] On the other hand, the ability for imagery varies among subjects and the way of imagining, visual or kinetic, may differ as well. Importantly, there is no way to assess behavior other than self-evaluation following the experiment, and the experimenter has to hope that the subject was not asleep lying supine with eyes closed.

Using fMRI to evaluate imagination of gait, the first studies were done by Jahn and colleagues[4, 5] and then subsequently by others.[6, 7] The studies do reveal structures thought

to be involved in gait, and variations and modulations of these regions have been evaluated when imagining different gait situations. For example, there are activations in frontal cortex including supplementary motor area and cingulate motor area, posterior parietal area, cerebellum and the mesencephalon, the latter presumed to be the mesencephalic locomotor region (MLR) which is likely anatomically the pedunculopontine nucleus (PPN) region. Not surprisingly, there is no significant activity in the primary motor area, this being on the other side of the thin line. Snijders and colleagues[8] have studied gait in patients with Parkinson disease (PD), off medication, some with and without gait freezing. Patients, just as normal subjects, have similar timing for imagining walking a certain distance compared with actually walking that distance. Hence it is reasonable to study their gait imagery. In the Snijders et al. work, the task performance was matched as is common in fMRI experiments in order to conclude that any differences between groups is due to intrinsic brain processes rather than task performance itself. Patients compared with healthy subjects had less activity in the cingulate and posterior parietal areas, and those with gait freezing compared to patients without freezing had a trend for even less in those same regions, but also more activity in the mesencephalon.

In the current issue of *Movement Disorders*, Cremers et al.[9] have looked at a group of PD patients, on medication, compared with healthy controls, imagining walking at their own comfortable pace. Patients walked more slowly. They found less activity in patients in a variety of regions including the mesencephalic area. One region, the right posterior parietal cortex activity decreased in proportion to the severity of the gait disturbance. While this study has certainly been worth doing and the subjects are matched for effort, there is a problem because of the mismatching of performance. A previous study using Near Infrared Spectroscopy (NIRS) suggested that the brain activation changes according to the walking speed.[10] Another investigation will be needed to look at modulation of different brain regions with gait speed to be sure these results are not just a reflection of speed. Taking these results together with those of Snijders et al. it may well be true that PD patients have less brain activation than normal during gait. Interestingly, this would differ from skilled hand movements where cortical and cerebellar activation might be more than normal.[11] Thus, there might be an important difference, which speculatively could be related to another difference, that hand movements improve with levodopa, but gait may not.

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