This review focuses on the cognitive neuroscience of Attention Deficit Hyperactivity Disorder (ADHD) based on functional magnetic resonance imaging (fMRI) studies and on recent clinically relevant applications such as fMRI-based diagnostic classification or neuromodulation therapies targeting fMRI deficits with brain stimulation or neurofeedback. Meta-analyses of fMRI studies of executive functions show that ADHD patients have cognitive-domain dissociated complex multisystem impairments in several right and left hemispheric dorsal, ventral and medial fronto-cingulo-striato-thalamic and fronto-parieto-cerebellar networks that mediate cognitive control, attention, timing and working memory. There is furthermore emerging evidence for abnormalities in orbital and ventromedial prefrontal and limbic areas that mediate motivation and emotion control. In addition, poor deactivation of the default mode network suggests an abnormal interrelationship between hypo-engaged task-positive and poorly “switched off” task-negative networks, both of which are related to impaired cognition.

Translational cognitive neuroscience in ADHD is still in its infancy. Pattern recognition analyses have attempted to provide diagnostic classification of ADHD using fMRI data with respectable classification accuracies of over 80%. Necessary replication studies, however, are still outstanding. Brain stimulation has been tested in heterogeneously designed, small numbered proof of concept studies targeting key frontal functional impairments in ADHD. Transcranial direct current stimulation appears to be promising to improve ADHD symptoms and cognitive functions based on some studies, but larger clinical trials of repeated stimulation with and without cognitive training are needed to test clinical efficacy and potential costs on non-targeted functions. Only three studies have piloted neurofeedback of fMRI-based frontal dysfunctions in ADHD using fMRI or near-infrared spectroscopy, with the two larger ones finding some improvements in cognition and symptoms, which, however, were not superior to the active control conditions, suggesting potential placebo effects. Neurotherapeutics seem attractive to ADHD due to their safety and potential longer-term neuroplastic effects, which drugs cannot offer. However, they need to be thoroughly tested for short- and longer-term clinical and cognitive efficacy and their potential for individualized treatment.