



NeuroTracker Relevance to medical conditions







www.NeuroTracker.net ∩

Scientific evidence has demonstrated that NeuroTracker can **track and improve a robust range of cognitive functions**.





Here, we present a series of **medical** and **clinical domains** of direct relevance to these improvements, based on substantial findings by independent researchers.

MEDICAL CONDITIONS

Scientific Literature Statements	NeuroTracker Relevance
Deficits in <u>executive functions</u> in ADHD^{1,2}, aging^{3,4}, Parkinson⁵⁻⁷ and patients with learning disability⁸, fall risk⁹⁻¹³, mild cognitive impairments^{14,15} and mTBI ¹⁶	Improvement in executive functions
Deficits in <u>working memory</u> in ADHD ^{17,18} , aging ¹⁹⁻²¹ , Parkinson ^{22,23} and patients with learning disability ²⁴⁻³³ , mild cognitive impairments ^{15,34} and mTBI ^{35,36}	Improvement in working memory
Impairments in <u>attention</u> and <u>inhibition</u> in ADHD ^{2,37} , aging ^{38,39} , Parkinson ⁴⁰⁻⁴² and patients with learning disability ^{43,44} , fall risk ^{11,42,45} , mild cognitive impairments ^{14,15,34,46-48} and mTBI ^{36,49,50}	Improvement in attention and task switching/inhibition
Deficits in <u>processing speed</u> in ADHD^{24,51-53}, aging^{21,38,54,55} and patients with learning disability²⁵ and mTBI ^{50,56,57}	Improvement in processing speed
Lower overall <u>cognitive ability</u> in ADHD ^{1,58-61} , aging ^{21,55,62,63} and patients with fall risk ¹³ and mTBI ⁶⁴	Brain plasticity and correlation to cognitive capacity
L	ADHD: Attention Deficit Hyperactivity Disorder

Click the reference numbers (e.g. $\frac{14,15}{\sqrt{5}}$) to view details of the specific literature

ADHD: Attention Deficit Hyperactivity Disorder **mTBI**: mild Traumatic Brain Injury





- 1. Children with ADHD exhibit impairments in executive function and Processing Speed in real-world activities as well as in neuropsychological testing. See Lawrence, V., et al., Executive function and ADHD: a comparison of children's performance during neuropsychological testing and real-world activities. J Atten Disord, 2004. 7(3): p. 137-49.
- 2. Groups with ADHD exhibit significant impairment on all EF tasks. See: Willcutt, E.G., et al., Validity of the executive function theory of attention-deficit/hyperactivity disorder: a meta-analytic review. Biol Psychiatry, 2005. 57(11): p. 1336-46.
- 3. Executive and visual attention measures significantly determine competence to drive in older individuals with early-stage cognitive decline. Whelihan, W.M., M.A. DiCarlo, and R.H. Paul, The relationship of neuropsychological functioning to driving competence in older persons with early cognitive decline. Arch Clin Neuropsychol, 2005. 20(2): p. 217-28.
- 4. Executive functioning is an important determinant of functional status in older populations. Grigsby, J., et al., Executive cognitive abilities and functional status among community-dwelling older persons in the San Luis Valley Health and Aging Study. J Am Geriatr Soc, 1998. 46(5): p. 590-6.
- 5. Impairment in executive function is associated with the development of dementia in patients with PD. Levy, G., et al., Memory and executive function impairment predict dementia in Parkinson's disease. Mov Disord, 2002. 17(6): p. 1221-6.
- 6. Patients with PD show deficits on measures of executive function. McKinlay, A., et al., Characteristics of executive function impairment in Parkinson's disease patients without dementia. J Int Neuropsychol Soc, 2010. 16(2): p. 268-77.
- 7. Consistent evidence for cognitive difficulties across five different Executive Function tests for patients with PD (metaanalysis). Kudlicka, A., L. Clare, and J.V. Hindle, Executive functions in Parkinson's disease: systematic review and meta-analysis. Mov Disord, 2011. 26(13): p. 2305-15.





- 8. Children with low levels of curriculum attainment showed marked impairments on measures of central executive function and of visuo-spatial memory in particular. Gathercole, S.E. and S.J. Pickering, Working memory deficits in children with low achievements in the national curriculum at 7 years of age. Br J Educ Psychol, 2000. 70 (Pt 2): p. 177-94.
- 9. Executive function impairment is consistently associated with increased fall risk. Muir, S.W., K. Gopaul, and M.M. Montero Odasso, The role of cognitive impairment in fall risk among older adults: a systematic review and meta-analysis. Age Ageing, 2012. 41(3): p. 299-308.
- 10. The risk of future falls of older adults was predicted by performance on EF and attention tests conducted 5 years earlier, indicating that screening EF will likely enhance fall risk assessment, and that treatment of EF may reduce fall risk. Mirelman, A., et al., Executive function and falls in older adults: new findings from a five-year prospective study link fall risk to cognition. PLoS One, 2012. 7(6): p. e40297.
- 11. Assessments of executive function and attention could be applied in the clinical setting as part of the process of identifying and understanding gait disorders and fall risk. Yogev-Seligmann, G., J.M. Hausdorff, and N. Giladi, The role of executive function and attention in gait. Mov Disord, 2008. 23(3): p. 329-42; quiz 472.
- 12. Among healthy older adults, individuals with poorer EF are more prone to falls. Herman, T., et al., Executive Control Deficits as a Prodrome to Falls in Healthy Older Adults: A Prospective Study Linking Thinking, Walking, and Falling. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 2010. 65A(10): p. 1086-1092.
- Executive Dysfunction Contributes to Fall Risk in AD. Sheridan, P.L. and J.M. Hausdorff, The role of higher-level cognitive function in gait: executive dysfunction contributes to fall risk in Alzheimer's disease. Dement Geriatr Cogn Disord, 2007. 24(2): p. 125-37.





- 14. Tests assessing new learning and attention/executive function seem to provide valuable information for screening and diagnosis of MCI and early AD. Arnaiz, E. and O. Almkvist, Neuropsychological features of mild cognitive impairment and preclinical Alzheimer's disease. Acta Neurol Scand Suppl, 2003. 179: p. 34-41.
- 15. MCI displays a stable pattern of deficits to attention, working memory, and executive function. The decline in simple sustained attention in and to divided attention may be early indicators of possible transition to dementia from MCI. Saunders, N.L. and M.J. Summers, Longitudinal deficits to attention, executive, and working memory in subtypes of mild cognitive impairment. Neuropsychology, 2011. 25(2): p. 237-48.
- 16. Multiple self-reported mTBI are associated with poorer performance on measures executive functioning. Belanger, H.G., E. Spiegel, and R.D. Vanderploeg, Neuropsychological performance following a history of multiple self-reported concussions: a meta-analysis. J Int Neuropsychol Soc, 2010. 16(2): p. 262-7.
- Scores for Full Scale IQ are significantly lower in ADHD than for healthy individuals. See: Frazier, T.W., H.A. Demaree, and E.A. Youngstrom, Meta-analysis of intellectual and neuropsychological test performance in attention-deficit/hyperactivity disorder. Neuropsychology, 2004. 18(3): p. 543-55.
- 18. Students with ADHD underachieve in the school situation in relation to their optimal cognitive capacity. See: Ek, U., et al., Academic performance of adolescents with ADHD and other behavioural and learning problems -a population-based longitudinal study. Acta Paediatr, 2011. 100(3): p. 402-6.
- 19. Working Memory measures show reductions with aging. Rhodes, M.G., Age-related differences in performance on the Wisconsin card sorting test: a meta-analytic review. Psychol Aging, 2004. 19(3): p. 482-94.



- 20. Verbal Working Memory span declines with aging. Bopp, K.L. and P. Verhaeghen, Aging and verbal memory span: a metaanalysis. J Gerontol B Psychol Sci Soc Sci, 2005. 60(5): p. P223-33.
- 21. Older adults experience significant deficits in Working Memory, and there is little doubt that speed of information processing is slowed with the effects of aging. Park, D.C., The basic mechanisms accounting for age-related decline in cognitive function, in Cognitive aging: A primer, D.C.P.N. Schwarz, Editor. 2000, Psychology Press: New York, NY, US. p. 3-21.
- 22. Working memory deficits in Parkinson's disease emerge, and subsequently progress, according to a defined sequence. Owen, A.M., et al., Spatial and non-spatial working memory at different stages of Parkinson's disease. Neuropsychologia, 1997. 35(4): p. 519-32.
- 23. Reduced working memory spans for patients with PD. Gabrieli JDE, et al., Reduced working memory span in Parkinson's disease: evidence for the role of a frontostriatal system in working and strategic memory. Neuropsychology, 1996.10(3): p.22-32.
- 24. Reading Disability is associated with significant deficits on measures of verbal working memory. Willcutt, E.G., et al., A comparison of the cognitive deficits in reading disability and attention-deficit/hyperactivity disorder. J Abnorm Psychol, 2001. 110(1): p. 157-72.
- 25. Children with Mathematical Learning Disability have deficits in working memory and speed of processing. Geary, D.C., et al., Cognitive mechanisms underlying achievement deficits in children with mathematical learning disability. Child Dev, 2007. 78(4): p. 1343-59.



- 26. Compared to typically developing children, learning difficulty groups demonstrate deficits in verbal WM and numerical A Meta-Analysis of Working Memory Deficits in Children With Learning Difficulties. Peng, P. and D. Fuchs, A Meta-Analysis of Working Memory Deficits in Children With Learning Difficulties: Is There a Difference Between Verbal Domain and Numerical Domain? J Learn Disabil, 2016. 49(1): p. 3-20.
- 27. Inhibition and working memory tasks predicted math learning disabilities over and above the predictive value of preparatory mathematical abilities. Toll, S.W., et al., Executive functions as predictors of math learning disabilities. J Learn Disabil, 2011. 44(6): p. 521-32.
- 28. Spatial working memory difficulties predict nonverbal learning disabilities. Mammarella, I.C., D. Lucangeli, and C. Cornoldi, Spatial working memory and arithmetic deficits in children with nonverbal learning difficulties. J Learn Disabil, 2010. 43(5): p. 455-68.
- 29. There is extensive evidence that working memory is linked to key learning outcomes in literacy. Daneman, M. and P.A. Carpenter, Individual differences in working memory and reading. Journal of Verbal Learning and Verbal Behavior, 1980. 19(4): p. 450-466.
- 30. Children who have low measures on Working Memory measures are at risk of Serious Math Difficulties. Swanson, H.L. and M. Beebe-Frankenberger, The Relationship Between Working Memory and Mathematical Problem Solving in Children at Risk and Not at Risk for Serious Math Difficulties. Journal of Educational Psychology, 2004. 96(3): p. 471-491.
- 31. Measures of working-memory capacity are strongly related to performance in other complex cognitive tasks, such as reading comprehension, problem solving, and with measures of intelligence quotient. Conway, A.R., M.J. Kane, and R.W. Engle, Working memory capacity and its relation to general intelligence. Trends Cogn Sci, 2003. 7(12): p. 547-52.



- 32. A longitudinal study confirmed that a child's working memory at 5 years old is a better predictor of academic success than IQ. Alloway, T.P. and R.G. Alloway, Investigating the predictive roles of working memory and IQ in academic attainment. J Exp Child Psychol, 2010. 106(1): p. 20-9.
- 33. Children with very low scores on Working Memory measures display a range of serious learning challenges, including inattentiveness, distractibility, problem solving issues, and short attention spans. Alloway, T.P., et al., The cognitive and behavioral characteristics of children with low working memory. Child Dev, 2009. 80(2): p. 606-21.
- 34. MCI exhibits deficits in measures of Working Memory, Divided Attention and Inhibition, that increase with severity, and can be used to track MCI changes in AD at a preclinical stage. Belleville, S., H. Chertkow, and S. Gauthier, Working memory and control of attention in persons with Alzheimer's disease and mild cognitive impairment. Neuropsychology, 2007. 21(4): p. 458-69.
- 35. Working Memory focused interventions with mTBI participants revealed they were more likely to exhibit clinically significant improvement on measures of attention and reduction of self-reported attentional difficulties in their daily functioning. Cicerone, K.D., Remediation of "working attention" in mild traumatic brain injury. Brain Inj, 2002. 16(3): p. 185-95.
- 36. MTBI can have adverse long-term neuropsychological outcomes on subtle aspects of complex attention and working memory in veterans with an average of 8 years post selfreported mBTI injury. Vanderploeg, R.D., G. Curtiss, and H.G. Belanger, Long-term neuropsychological outcomes following mild traumatic brain injury. J Int Neuropsychol Soc, 2005. 11(3): p. 228-36.
- 37. Working Memory training has potential for treatment of ADHD. See: Klingberg, T., H. Forssberg, and H. Westerberg, Training of working memory in children with ADHD. J Clin Exp Neuropsychol, 2002. 24(6): p. 781-91.





- 38. Motor vehicle accident rates are related to performance on information-processing measures of the switching of selective attention, divided and sustained attention. Parasuraman, R. and P.G. Nestor, Attention and driving skills in aging and Alzheimer's disease. Hum Factors, 1991. 33(5): p. 539-57.
- **39.** Specific aging related deficits for dual-task performance and global task-switching. Verhaeghen, P. and J. Cerella, Aging, executive control, and attention: a review of meta-analyses. Neurosci Biobehav Rev, 2002. 26(7): p. 849-57.
- 40. Patients with Parkinson's disease show impaired internal attentional control. Brown, R.G. and C.D. Marsden, Internal versus external cues and the control of attention in Parkinson's disease. Brain, 1988. 111 (Pt 2): p. 323-45.
- 41. PD patients as compared with normal controls are more likely to show deficits in selective attention. Maddox, W.T., et al., Visual selective attention deficits in patients with Parkinson's disease: A quantitative model-based approach. Neuropsychology, 1996. 10(2): p. 197-218.
- 42. Reduced power of attention is associated with increased fall frequency in PD. Allcock, L.M., et al., Impaired attention predicts falling in Parkinson's disease. Parkinsonism Relat Disord, 2009. 15(2): p. 110-5.
- 43. Children with Specific Language Impairment exhibit poorer performance than their peers on sustained selective attention tasks. Spaulding, T.J., E. Plante, and R. Vance, Sustained selective attention skills of preschool children with specific language impairment: evidence for separate attentional capacities. J Speech Lang Hear Res, 2008. 51(1): p. 16-34.
- 44. Sustained attention deficits are consistently found in children with Language Impairments in both auditory and visual modalities. Ebert, K.D. and K. Kohnert, Sustained attention in children with primary language impairment: a meta-analysis. J Speech Lang Hear Res, 2011. 54(5): p. 1372-84.



- **45.** Sustained and divided attention deficits in stroke patients correlate with functional impairments and falling. Hyndman, D. and A. Ashburn, People with stroke living in the community: Attention deficits, balance, ADL ability and falls. Disabil Rehabil, 2003. 25(15): p. 817-22.
- 46. Evidence for impaired focussed attention in patients with MCI and AD. Levinoff, E.J., D. Saumier, and H. Chertkow, Focused attention deficits in patients with Alzheimer's disease and mild cognitive impairment. Brain Cogn, 2005. 57(2): p. 127-30.
- 47. Attentional deficiencies are found in both MCI and AD patients. Alescio-Lautier, B., et al., Visual and visuospatial short-term memory in mild cognitive impairment and Alzheimer disease: role of attention. Neuropsychologia, 2007. 45(8): p. 1948-60.
- 48. MCI subjects show impaired top-down attentional control. Perry, R.J. and J.R. Hodges, Dissociation between top-down attentional control and the time course of visual attention as measured by attentional dwell time in patients with mild cognitive impairment. Eur J Neurosci, 2003. 18(2): p. 221-6.
- 49. Attention measures may be the most sensitive indicators of dysfunction associated with Post-concussion Syndrome. Processing Speed measures were shown to have strong positive predictive value. Cicerone, K.D. and J. Azulay, Diagnostic utility of attention measures in postconcussion syndrome. Clin Neuropsychol, 2002. 16(3): p. 280-9.
- 50. mTBI patients performed significantly more poorly in information processing and divided attention, sustained attention, immediately post-injury. Information processing and divided attention of remained moderately impaired at 1-3 months, while sustained attention remained significantly impaired over the 3-month period. Kwok, F.Y., et al., Changes of cognitive functioning following mild traumatic brain injury over a 3-month period. Brain Inj, 2008. 22(10): p. 740-51.



- 51. Notable impairment in attention and behavioral inhibition for individuals with ADHD. See: Hervey, A.S., J.N. Epstein, and J.F. Curry, Neuropsychology of adults with attention-deficit/hyperactivity disorder: a meta-analytic review. Neuropsychology, 2004. 18(3): p. 485-503.
- 52. Patients with ADHD have consistent functional abnormalities in anterior cingulate cortex for inhibition and dorsolateral prefrontal cortex, parietal, and cerebellar areas for attention. See: Hart, H., et al., Meta-analysis of functional magnetic resonance imaging studies of inhibition and attention in attention-deficit/hyperactivity disorder: exploring task-specific, stimulant medication, and age effects. JAMA Psychiatry, 2013. 70(2): p. 185-98.
- 53. Deficits in brain networks for response inhibition for children with ADHD. See: Booth, J.R., et al., Larger deficits in brain networks for response inhibition than for visual selective attention in attention deficit hyperactivity disorder (ADHD). J Child Psychol Psychiatry, 2005. 46(1): p. 94-111.
- 54. Processing speed declines with aging, which in turn may strongly influence for most types cognitive impairments associated with aging. Salthouse, T.A., The processing-speed theory of adult age differences in cognition. Psychol Rev, 1996. 103(3): p. 403-28.
- 55. Adult age-related differences in cognitive functioning are attributable to reductions in the simultaneous storage and processing of information. Salthouse, T.A., Working memory as a processing resource in cognitive aging. Developmental Review, 1990. 10(1): p. 101-124.
- 56. Decline in processing speeds are much greater for patients with MTBI. Cicerone, K.D., Attention deficits and dual task demands after mild traumatic brain injury. Brain Inj, 1996. 10(2): p. 79-89.



- 57. Reduced speed of processing functioning was the main cognitive deficit found in individuals assessed more than 3 months post-mTBI injury. Frencham, K.A., A.M. Fox, and M.T. Maybery, Neuropsychological studies of mild traumatic brain injury: a meta-analytic review of research since 1995. J Clin Exp Neuropsychol, 2005. 27(3): p. 334-51.
- 58. Processing Speed deficits exists in children with both Reading Disability and ADHD. See: Shanahan, M.A., et al., Processing speed deficits in attention deficit/hyperactivity disorder and reading disability. J Abnorm Child Psychol, 2006. 34(5): p. 585-602.
- 59. ADHD Children perform poorly on measures of information Processing Speed. See: Weiler, M.D., et al., Processing speed in children with attention deficit/hyperactivity disorder, inattentive type. Child Neuropsychol, 2000. 6(3): p. 218-34.
- 60. Slower Processing Speed in adults with ADHD. See: Holdnack, J.A., et al., Speed of processing and verbal learning deficits in adults diagnosed with attention deficit disorder. Neuropsychiatry, Neuropsychology and Behavioral Neurology, 1995. 8(4): p. 282-292.
- 61. At a young age, children at risk of ADHD show specific information-processing deficits. See: Kalff, A.C., et al., Speed, speed variability, and accuracy of information processing in 5 to 6-year-old children at risk of ADHD. J Int Neuropsychol Soc, 2005. 11(2): p. 173-83.
- 62. There is considerable evidence that older adults have difficulty inhibiting irrelevant information in working memory. Park, D.C., et al., Cerebral aging: integration of brain and behavioral models of cognitive function. Dialogues Clin Neurosci, 2001. 3(3): p. 151-65.
- 63. From early adulthood, there are declines in mental domains such as processing speed, reasoning, memory and executive functions. Deary, I.J., et al., Age-associated cognitive decline. Br Med Bull, 2009. 92: p. 135-52.



www.NeuroTracker.net 🕥

64. One of the major functional deficits found in 21 studies of sports concussion was global cognitive functioning. Participants with a history of prior head injury appeared to inflate the effect. Belanger, H.G. and R.D. Vanderploeg, The neuropsychological impact of sports-related concussion: a meta-analysis. J Int Neuropsychol Soc, 2005. 11(4): p. 345-57.







