creyos

Condition-Based Research Guide

Research linking Creyos cognitive tasks to health conditions.

Quickly gain validated and powerful brain health insights.

Table of Contents

Section I

Background, Introduction, and Instructions

A - Index

Where to find what you're looking for.

B - Introduction

Using this guide

Many health conditions have cognitive symptoms. This guide summarizes research on the connection between key conditions and each Creyos cognitive task.

What this guide may be useful for:

- Finding research on the association between cognition and a particular health condition.
- Determining if a patient's cognitive deficits are typical of a diagnosis.
- Hypothesizing about which conditions or lifestyle factors to focus on in order to explain or treat specific cognitive deficits.
- Narrowing down a battery of tasks to the ones most likely to improve as a result of treating a known diagnosis.

Creyos recommends administering as many tasks as possible in order to gain a full picture of a patient's health, determine if deficits are specific to certain cognitive domains, and identify strengths as well as weaknesses. For example, when a patient has taken all of the Creyos cognitive tasks, then a clinician may note if the patient's weakest scores match up with areas typically impaired by a suspected diagnosis. A shorter battery may be appropriate, however, when more information is already known about the patient, or administering a longer battery is impractical.

This guide should *not* be solely relied upon for diagnosing a condition based on cognitive symptoms. Each individual's pattern of cognitive strengths and weaknesses is determined by multiple factors. Most conditions cannot be diagnosed based on cognitive deficits alone, and require additional patient information to be gathered, such as self-reported symptoms, patient interviews, physical tests, and direct observation.

Interpreting the research

Research is represented in tables linking each condition with each Creyos cognitive task.

A checkmark indicates that scientific studies have shown a difference between people diagnosed with the condition compared to people not diagnosed with the condition.

Additional details are included in the tables:

- **A green checkmark** ✔ indicates that individuals with the condition perform differently from controls on the Creyos task.
- **A blue checkmark** ✔ indicates that individuals with the condition perform differently from controls in the area of cognition measured by the Creyos task (but no research used the Creyos task specifically).
- **A blank entry with an X** ☒ indicates that there is research involving individuals with the condition, but they do not perform differently from controls in the area of cognition measured by the Creyos task.
- **A blank entry** ☐ indicates that no research could be found linking the condition with the area of cognition.

Footnotes provide clarification on some entries.

References supporting each entry are included in Section III below, which can also be reached by clicking on the name of a condition within a table. When possible, research focuses on meta-analyses and reviews aggregating results from multiple studies to confirm or rule out a connection between the condition and the area of cognition.

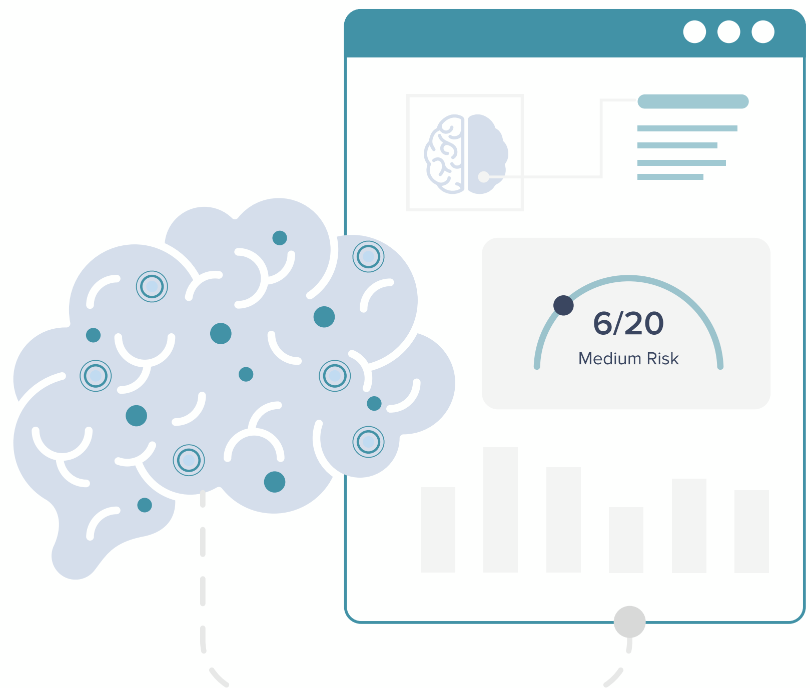
Many cognitive symptoms are also dependent on age, context, comorbidities, and other factors. The tables below can be thought of as the areas of cognition likely to be associated with a condition across a wide range of patients. Additional information to help interpret connections between each condition and cognition are included alongside the references in Section III.

Finding more information

For additional information on each cognitive task, including example everyday activities that may be affected by deficits, see Creyos Cognitive Task Descriptions and Example Activities.

Other resources that may complement this guide include:

- Creyos Health Report Interpretation Guide
- Creyos Brain Regions Guide
- Creyos Science Overview



Section II

Conditions, Disorders, and Protocols

C - Aging and Lifestyle

Condition	Digit Span	Double Trouble	Feature Match	Grammatical Reasoning	Monkey Ladder	Odd One Out	Paired Associates	Polygons	Rotations	Spatial Planning	Spatial Span	Token Search
Alzheimer's Disease (Early)	✓	✔	✔	✔	✔		✔	✔			✔	
Dementia (Non-Alzheimer's)	✓		✔		✓		✓	✔		✔	✓	
Menopause	✕	✓	✕		✕	✓	✓	✕	✕	✓	✕	✕
Mild Cognitive Impairment & Age-Related Decline	✓	✔	✔	✔	✔	✓	✔	✓	✔	✓	✔	✓
Sleep	✕	✔	✕	✔	✕	✔	✕	✔	✔	✔	✕	✔
Stress	✕	✓*	✓		✓*		✓*					✓*

✕ Not related with condition

☐ Unknown; insufficient research

✔ (green) Individuals with the condition perform differently from controls on the Creyos task

✓ (blue) Individuals with the condition perform differently from controls in the area of cognition measured by the Creyos task

* In some cases, milder stress can *improve* performance

D - Developmental Disorders

Condition	Digit Span	Double Trouble	Feature Match	Grammatical Reasoning	Monkey Ladder	Odd One Out	Paired Associates	Polygons	Rotations	Spatial Planning	Spatial Span	Token Search
Attention Deficit Hyperactivity Disorder	✔	✔	✔	✕	✓	✕		✕	✓	✔	✓	✔
Autism	✔*	✓		✓	✓	✔			✓*	✓		✓
Dyslexia	✔	✓		✓		✓						

✕ Not related with condition

☐ Unknown; insufficient research

✔ (green) Individuals with the condition perform differently from controls on the Creyos task

✓ (blue) Individuals with the condition perform differently from controls in the area of cognition measured by the Creyos task

* Patients with autism may score *higher* on this task, depending on factors such as sex and context

E - Diseases and Neurological Disorders

Condition	Digit Span	Double Trouble	Feature Match	Grammatical Reasoning	Monkey Ladder	Odd One Out	Paired Associates	Polygons	Rotations	Spatial Planning	Spatial Span	Token Search
COVID-19	✗	✓ (green)	✓ (green)	✓ (green)	✓ (green)	✗	✓ (green)	✓ (green)	✗	✗	✗	
Epilepsy		✓ (green)		✓ (blue)		✓ (green)						
Fibromyalgia	✗	✓ (blue)	✓ (blue)	✗	✓ (blue)		✗	✗	✓ (blue)	✗	✓ (blue)	✓ (blue)
Huntington's Disease		✓ (green)	✓ (green)							✓ (green)	✓ (green)	✓ (green)
Lyme Disease	✗	✗	✗	✗	✗		✗	✗			✗	✗
Multiple Sclerosis	✗	✓ (green)	✓ (blue)	✗	✓ (blue)		✓ (green)	✓ (blue)	✓ (blue)	✓ (green)	✗	✓ (green)
Parkinson's Disease		✓ (blue)	✓ (green)	✓ (blue)			✓ (green)	✓ (blue)		✓ (green)	✓ (green)	✓ (green)

✗ Not related with condition

☐ Unknown; insufficient research

✓ (green) Individuals with the condition perform differently from controls on the Creyos task

✓ (blue) Individuals with the condition perform differently from controls in the area of cognition measured by the Creyos task

F - Injury and Pain

Condition	Digit Span	Double Trouble	Feature Match	Grammatical Reasoning	Monkey Ladder	Odd One Out	Paired Associates	Polygons	Rotations	Spatial Planning	Spatial Span	Token Search
Brain Injury: Frontal Lobe		✓ (green)		✓ (blue)		✓ (blue)	✓ (green)			✓ (green)	✓ (green)	✓ (green)
Brain Injury: Temporal Lobe							✓ (green)					✓ (green)
Chronic Pain	✗	✓ (blue)	✓ (blue)		✓ (blue)	✗	✗	✓ (blue)	✗	✗	✗	✓ (blue)
Concussion		✓ (green)	✓ (blue)		✓ (green)	✓ (green)	✓ (green)			✓ (green)	✓ (green)	✓ (green)
Stroke		✓ (blue)		✓ (blue)	✓ (green)		✓ (green)	✓ (green)				✓ (green)

✗ Not related with condition

☐ Unknown; insufficient research

✓ (green) Individuals with the condition perform differently from controls on the Creyos task

✓ (blue) Individuals with the condition perform differently from controls in the area of cognition measured by the Creyos task

G - Mental Health and Addiction

Condition	Digit Span	Double Trouble	Feature Match	Grammatical Reasoning	Monkey Ladder	Odd One Out	Paired Associates	Polygons	Rotations	Spatial Planning	Spatial Span	Token Search
Addiction & Drug Abuse	✕	✓	✓		✓		✓	✓		✓		✓
Alcohol Abuse	✓	✓	✓				✓	✓			✓	✓
Anxiety	✕	✕	✕	✕	✔	✕	✕	✕	✕	✔	✔	✔
Bipolar Disorder	✓	✓	✕		✓	✓	✔	✓	✓	✓	✔	✓
Cannabis Abuse	✕	✓	✓				✓	✕		✓	✕	✓
Depression	✔	✔		✔		✓	✔			✔		✔
Post-Traumatic Stress Disorder	✔	✓		✓		✓						✓
Schizophrenia	✔	✓				✔				✔	✔	✔

✕ Not related with condition

☐ Unknown; insufficient research

✔ Individuals with the condition perform differently from controls on the Creyos task

✓ Individuals with the condition perform differently from controls in the area of cognition measured by the Creyos task

H - Situation-Specific Protocols

Condition	Digit Span	Double Trouble	Feature Match	Grammatical Reasoning	Monkey Ladder	Odd One Out	Paired Associates	Polygons	Rotations	Spatial Planning	Spatial Span	Token Search
Abbreviated Battery	✔	✕	✕	✔	✔	✔	✔	✕	✔	✕	✕	✕
Youth Battery	✔	✕	✔	✕	✔	✔	✔	✕	✔	✕	✔	✔

✕ Not included in battery

✔ Included in the battery

Section III

Additional Information and References

I - Additional Information and References

References supporting the connections between cognition and each condition are listed below, by condition, in alphabetical order. Notes about details, exceptions, or nuances related to each connection are also included.

Abbreviated Battery

The abbreviated battery contains tasks closely aligned with the short-term memory, reasoning, and verbal ability domains of cognition. It can be used when administering all 12 tasks is not practical, but a broad assessment of various domains of cognition is still needed. This set of tasks has been called the “CBS-6” in several scientific studies, where it has been used in patients where fatigue may be an issue, such as critical illness survivors, and found to be feasible to administer to these populations. Note that the abbreviated battery does not contain any attention-specific tasks.

- Honarmand, K., Malik, S., Wild, C., Gonzalez-Lara, L. E., McIntyre, C. W., Owen, A. M., & Slessarev, M. (2019). Feasibility of a web-based neurocognitive battery for assessing cognitive function in critical illness survivors. *PLOS ONE, 14,* e0215203. https://doi.org/10.1371/journal.pone.0215203
- Paleczny, S. G. (2023). Neuropsychological outcomes after cardiac surgery: A pilot feasibility study. *Electronic Thesis and Dissertation Repository, 9460.* https://ir.lib.uwo.ca/etd/9460

Addiction & Drug Abuse

Research focuses on the relationship between cognition and addiction, characteristics of people in treatment for addiction, chronic drug abuse and substance use disorder. In general, drug addiction may most commonly affect functions of inhibitory control, working memory and decision making. For alcoholism or cannabis use, see the separate entries in this guide. Self-report data can also be gathered to complement cognitive assessments using the Drug Abuse Screening Test (DAST-10), also available in Creyos Health.

- Carpenter, S. (2001, June 1). Cognition is central to drug addiction. *Monitor on Psychology, 32.* https://www.apa.org/monitor/jun01/cogcentral
- Dong, G., Zhou, H., & Zhao, X. (2011a). Male Internet addicts show impaired executive control ability: evidence from a color-word Stroop task. *Neuroscience Letters, 499,* 114-118. https://doi.org/10.1016/j.neulet.2011.05.047
- Dong, G., Huang, J., & Du, X. (2011b). Enhanced reward sensitivity and decreased loss sensitivity in Internet addicts: an fMRI study during a guessing task. *Journal of Psychiatric Research, 45,* 1525-1529. https://doi.org/10.1016/j.jpsychires.2011.06.017
- Haberstroh, C., Weider, S., Flemmen, G., Loe, H., Andersson, H. W., Hallgren, M., & Mosti, M. P. (2022). The effect of high-intensity interval training on cognitive function in patients with substance use disorder: Study protocol for a two-armed randomized controlled trial. *Frontiers in Sports and Active Living, 4,* 470. https://doi.org/10.3389/fspor.2022.954561
- Manning, V., Verdejo-Garcia, A., & Lubman, D. I. (2017). Neurocognitive impairment in addiction and opportunities for intervention. *Current Opinion in Behavioral Sciences, 13,* 40-45. https://doi.org/10.1016/j.cobeha.2016.10.003
- Ornstein, T. J., Iddon, J. L., Baldacchino, A. M., Sahakian, B. J., London, M., Everitt, B. J., & Robbins, T. W. (2000). Profiles of cognitive dysfunction in chronic amphetamine and heroin abusers. *Neuropsychopharmacology, 23,* 113-126. https://doi.org/10.1016/S0893-133X(00)00097-X
- Verdejo-García, A., Bechara, A., Recknor, E. C., & Perez-Garcia, M. (2006). Executive dysfunction in substance dependent individuals during drug use and abstinence: An examination of the behavioral, cognitive and emotional correlates of addiction. *Journal of the International Neuropsychological Society, 12,* 405-415. https://doi.org/10.1017/S1355617706060486

Alcoholism

Research focuses on cognitive effects of long-term alcohol abuse, overuse, and performance of those in treatment for alcoholism. Research indicates widespread effects on most aspects of core cognition, including memory, attention, and executive function. However, for many deficits, recovery may be possible with continued sobriety. Self-report data can also be gathered to complement cognitive assessments using the Alcohol Use Disorders Identification Test (AUDIT), also available in Creyos Health.

- Haberstroh, C., Weider, S., Flemmen, G., Loe, H., Andersson, H. W., Hallgren, M., & Mosti, M. P. (2022). The effect of high-intensity interval training on cognitive function in patients with substance use disorder: Study protocol for a two-armed randomized controlled trial. *Frontiers in Sports and Active Living, 4,* 470. https://doi.org/10.3389/fspor.2022.954561
- Kodituwakku, P. W., Handmaker, N. S., Cutler, S. K., Weathersby, E. K., & Handmaker, S. D. (1995). Specific impairments in self-regulation in children exposed to alcohol prenatally. *Alcoholism: Clinical and Experimental Research, 19,* 1558-1564. https://doi.org/10.1111/j.1530-0277.1995.tb01024.x
- Le Berre, A. P., Fama, R., & Sullivan, E. V. (2017). Executive functions, memory, and social cognitive deficits and recovery in chronic alcoholism: a critical review to inform future research. *Alcoholism: Clinical and Experimental Research, 41,* 1432-1443. https://doi.org/10.1111/acer.13431
- Oscar-Berman, M., Valmas, M. M., Sawyer, K. S., Ruiz, S. M., Luhar, R. B., & Gravitz, Z. R. (2014). Profiles of impaired, spared, and recovered neuropsychologic processes in alcoholism. *Handbook of Clinical Neurology, 125,* 183-210. https://doi.org/10.1016/B978-0-444-62619-6.00012-4
- Stavro, K., Pelletier, J., & Potvin, S. (2013). Widespread and sustained cognitive deficits in alcoholism: A meta-analysis. *Addiction Biology, 18,* 203-213. https://doi.org/10.1111/j.1369-1600.2011.00418.x
- Verdejo-García, A., Bechara, A., Recknor, E. C., & Perez-Garcia, M. (2006). Executive dysfunction in substance dependent individuals during drug use and abstinence: An examination of the behavioral, cognitive and emotional correlates of addiction. *Journal of the International Neuropsychological Society, 12,* 405-415. https://doi.org/10.1017/S1355617706060486

Alzheimer's Disease

Alzheimer's disease is sometimes seen as a problem with memory, but it can affect a wide variety of cognitive domains. Early signs of Alzheimer's disease may manifest as a decline in any domain, but the tasks listed here have demonstrated a clear association in studies. See separate entries on non-Alzheimer's dementia and mild cognitive impairment for related research. The Instrumental Activities of Daily Living (IADL) questionnaire, also available in Creyos Health, can be used to gather self-report or informant data that complement cognitive assessments when examining patients concerned with age-related cognitive decline.

- Ala, T. A., Hughes, L. F., Kyrouac, G. A., Ghobrial, M. W., & Elble, R. J. (2001). Pentagon copying is more impaired in dementia with Lewy bodies than in Alzheimer's disease. *Journal of Neurology, Neurosurgery & Psychiatry, 70,* 483-488. https://doi.org/10.1136/jnnp.70.4.483
- Belleville, S., Rouleau, N., & Van der Linden, M. (2006). Use of the Hayling task to measure inhibition of prepotent responses in normal aging and Alzheimer's disease. *Brain and Cognition, 62*, 113-119. https://doi.org/10.1016/j.bandc.2006.04.006
- Bélanger, S., Belleville, S., & Gauthier, S. (2010). Inhibition impairments in Alzheimer's disease, mild cognitive impairment and healthy aging: Effect of congruency proportion in a Stroop task. *Neuropsychologia, 48,* 581-590. https://doi.org/10.1016/j.neuropsychologia.2009.10.021
- Brodaty, H., Valenzuela, M., Fiatarone Singh, M. A., Sachdev, P. S., McNeil, J., Lautenschlager, N. T., Maeder, A., Jorm, L., Millard, M., Heffernan, M., Anstey, K. J., Ginige, J. A., Chau, T., San Jose, J. C., Welberry, H., Briggs, N., & Popovic, G. (2023). Maintain Your Brain: Outcomes of an online program to prevent cognitive decline with aging. *Alzheimer's & Dementia, 19,* e075183. https://doi.org/10.1002/alz.075183
- Ferreira, N., Owen, A., Mohan, A., Corbett, A., & Ballard, C. (2015). Associations between cognitively stimulating leisure activities, cognitive function and age-related cognitive decline. *International Journal of Geriatric Psychiatry, 30,* 422–430. https://doi.org/10.1002/gps.4155
- Gould, R. L., Arroyo, B., Brown, R. G., Owen, A. M., Bullmore, E. T., & Howard, R. J. (2006). Brain mechanisms of successful compensation during learning in Alzheimer disease. *Neurology, 67,* 1011–1017. https://doi.org/10.1212/01.wnl.0000237534.31734.1b
- Gould, R. L., Brown, R. G., Owen, A. M., Bullmore, E. T., & Howard, R. J. (2006). Task-induced deactivations during successful paired associates learning: An effect of age but not Alzheimer's disease. *NeuroImage, 31,* 818–831. https://doi.org/10.1016/j.neuroimage.2005.12.045
- Lange, K. W., Sahakian, B. J., Quinn, N. P., Marsden, C. D., & Robbins, T. W. (1995). Comparison of executive and visuospatial memory function in Huntington's disease and dementia of Alzheimer type matched for degree of dementia. *Journal of Neurology, Neurosurgery & Psychiatry, 58,* 598-606. https://doi.org/10.1136/jnnp.58.5.598
- Lupton, M. K., Gomez, L., Mitchell, B. L., Adsett, J., García-Marín, L. M., Renteria, M. E., McAloney, K., Ceslis, A., Thienel, R., Robinson, G., Breakspear, M., & Martin, N. G. (2023). Poorer online cognitive performance is associated with genetic risk for Alzheimer's disease and brain phenotypes in healthy mid-life and older adults. *Alzheimer's & Dementia, 19,* e078078. https://doi.org/10.1002/alz.078078

- Ozonoff, S., Cook, I., Coon, H., Dawson, G., Joseph, R.M., Klin, A., McMahon, W.M., Minshew, N., Munson, J.A., Pennington, B.F., Rogers, S.J., Spence, M.A., Tager-Flusberg, H., Volkmar, F.R., & Wrathall, D. (2004). Performance on Cambridge Neuropsychological Test Automated Battery subtests sensitive to frontal lobe function in people with autistic disorder: Evidence from the Collaborative Programs of Excellence in Autism network. *Journal of Autism and Developmental Disorders, 34,* 139-50. https://doi.org/10.1023/B:JADD.0000022605.81989.cc
- Sahakian, B. J., Morris, R. G., Evenden, J. L., Heald, A., Levy, R., Philpot, M., & Robbins, T. W. (1988). A comparative study of visuospatial memory and learning in Alzheimer-type dementia and Parkinson's disease. *Brain, 111,* 695-718. https://doi.org/10.1093/brain/111.3.695
- Sahgal, A., Galloway, P. H., McKeith, I. G., Lloyd, S., Cook, J. H., Ferrier, I. N., & Edwardson, J. A. (1992). Matching-to-sample deficits in patients with senile dementias of the Alzheimer and Lewy body types. *Archives of Neurology, 49,* 1043-1046. https://doi.org/10.1001/archneur.1992.00530340059019
- Sterning, A., Burns, A., & Owen, A. M. Thirty-five years of computerized cognitive assessment of aging—where are we now? *Diagnostics, 9,* 114. https://doi.org/10.3390%2Fdiagnostics9030114
- Thienel, R., Borne, L., Faucher, C., Robinson, G., Fripp, J., Giorgio, J., Martin, N. G., Breakspear, M., & Lupton, M. K. Can an online battery match in-person cognitive testing in predicting age-related cortical changes? *Alzheimer's & Dementia, 19,* e074476. https://doi.org/10.1002/alz.074476

Anxiety

Anxiety here refers to generalized anxiety disorder. For post-traumatic stress disorder or temporary high stress, see the separate entries in this guide. The relationship between anxiety and cognition can be subtle or context-dependent, but some areas of cognition do seem to be consistently impaired in individuals with high trait anxiety. Self-report data can also be gathered using the General Anxiety Disorder (GAD-7) questionnaire, also available in Creyos Health, to complement cognitive assessments.

- Afshari, B., Jafarian Dehkordi, F., Asgharnejad Farid, A. A., Aramfar, B., Balagabri, Z., Mohebi, M., Mardi, N., & Amiri, P. (2022). Study of the effects of cognitive behavioral therapy versus dialectical behavior therapy on executive function and reduction of symptoms in generalized anxiety disorder. *Trends in Psychiatry and Psychotherapy, 44.* https://doi.org/10.47626/2237-6089-2020-0156

- Borst, G., Standing, G., & Kosslyn, S. M. (2012). Fear and anxiety modulate mental rotation. *Journal of Cognitive Psychology, 24,* 665-671. https://doi.org/10.1080/20445911.2012.679924 Castaneda, A. E., Suvisaari, J., Marttunen, M., Perälä, J., Saarni, S. I., Aalto-Setälä, T., Lönnqvist, J., & Tuulio-Henriksson, A. (2011). Cognitive functioning in a population-based sample of young adults with anxiety disorders. *European Psychiatry, 26,* 346-353. https://doi.org/10.1016/j.eurpsy.2009.11.006
- Eysenck, M., Payne, S., & Derakshan, N. (2005). Trait anxiety, visuospatial processing, and working memory. *Cognition and Emotion, 19,* 1214-1228. https://doi.org/10.1080/02699930500260245
- Grillon, C., Robinson, O. J., O'Connell, K., Davis, A., Alvarez, G., Pine, D. S., & Ernst, M. (2017). Clinical anxiety promotes excessive response inhibition. *Psychological Medicine, 47,* 484–494. https://doi.org/10.1017/S0033291716002555
- Gulpers, B. J. A., Verhey, F. R. J., Eussen, S. J. P. M., Schram, M. T., de Galan, B. E., van Boxtel, M. P. J., Stehouwer, C. D. A., & Köhler, S. (2022). Anxiety and cognitive functioning in the Maastricht study: A cross-sectional population study. *Journal of Affective Disorders, 319,* 570–579. https://doi.org/10.1016/j.jad.2022.09.072
- Hadwin, J. A., Brogan, J., & Stevenson, J. (2005). State anxiety and working memory in children: A test of processing efficiency theory. *Educational Psychology, 25,* 379–393. https://doi.org/10.1080/01443410500041607
- Hampshire, A., Highfield, R., Parkin, B., & Owen, A.M. (2012). Fractionating human intelligence. *Neuron, 76,* 1225-1237. https://doi.org/10.1016/j.neuron.2012.06.022
- Kim, K. L., Christensen, R. E., Ruggieri, A., Schettini, E., Freeman, J. B., Garcia, A. M., Flessner, C., Stewart, E., Conelea, C., & Dickstein, D. P. (2019). Cognitive performance of youth with primary generalized anxiety disorder versus primary obsessive–compulsive disorder. *Depression and Anxiety, 36,* 130–140. https://doi.org/10.1002/da.22848
- Lapointe, M.-L. B., Blanchette, I., Duclos, M., Langlois, F., Provencher, M. D., & Tremblay, S. (2013). Attentional bias, distractibility and short-term memory in anxiety. *Anxiety, Stress, & Coping, 26,* 293–313. https://doi.org/10.1080/10615806.2012.687722
- Leonard, K., & Abramovitch, A. (2019). Cognitive functions in young adults with generalized anxiety disorder. *European Psychiatry, 56,* 1–7. https://doi.org/10.1016/j.eurpsy.2018.10.008
- MacLeod, C., & Donnellan, A. M. (1993). Individual differences in anxiety and the restriction of working memory capacity. *Personality and Individual Differences, 15,* 163–173. https://doi.org/10.1016/0191-8869(93)90023-V
- Markham, R., & Darke, S. (1991). The effects of anxiety on verbal and spatial task performance. *Australian Journal of Psychology, 43,* 107–111. https://doi.org/10.1080/00049539108259108
- Moran, T. P. (2016). Anxiety and working memory capacity: A meta-analysis and narrative review. *Psychological Bulletin, 142,* 831–864. https://doi.org/10.1037/bul0000051

- Nyberg, J., Henriksson, M., Wall, A., Vestberg, T., Westerlund, M., Walser, M., Eggertsen, R., Danielsson, L., Kuhn, H. G., Åberg, N. D., Waern, M., & Åberg, M. (2021). Anxiety severity and cognitive function in primary care patients with anxiety disorder: *A cross-sectional study. BMC Psychiatry, 21,* 617. https://doi.org/10.1186/s12888-021-03618-z
- Pacheco-Unguetti, A. P., Acosta, A., Callejas, A., & Lupiáñez, J. (2010). Attention and anxiety: Different attentional functioning under state and trait anxiety. *Psychological Science, 21,* 298–304. https://doi.org/10.1177/0956797609359624
- Unterrainer, J. M., Domschke, K., Rahm, B., Wiltink, J., Schulz, A., Pfeiffer, N., Lackner, K. J., Münzel, T., Wild, P. S., & Beutel, M. (2018). Subclinical levels of anxiety but not depression are associated with planning performance in a large population-based sample. *Psychological Medicine, 48,* 168–174. https://doi.org/10.1017/S0033291717002562
- Wetherell, J. L., Reynolds, C. A., Gatz, M., & Pedersen, N. L. (2002). Anxiety, cognitive performance, and cognitive decline in normal aging. T*he Journals of Gerontology: Series B, 57,* 246–255. https://doi.org/10.1093/geronb/57.3.P246
- Wild, C. J., Nichols, E. S., Battista, M. E., Stojanoski, B., & Owen, A. M. (2018). Dissociable effects of self-reported daily sleep duration on high-level cognitive abilities. *Sleep, 41,* zsy182. https://doi.org/10.1093/sleep/zsy182

Attention Deficit Hyperactivity Disorder (ADHD)

Attention deficits are a defining feature of ADHD, but aspects of executive function may also be impaired. Research on ADHD often focuses on children, but deficits may continue into adulthood. Creyos Health contains additional features to assist with assessing ADHD that go beyond overall cognitive task scores. Self-report data and questionnaires from parents or teachers can also be used to complement cognitive assessments. The Adult ADHD Self-Report Scale (ASRS), Strengths and Weaknesses of ADHD Symptoms and Normal Behavior Scale (SWAN), and Vanderbilt ADHD Diagnostic Rating Scale (VADRS) are also available in Creyos Health.

- Alderson, R. M., Kasper, L. J., Hudec, K. L., & Patros, C. H. G. (2013). Attention-deficit/hyperactivity disorder (ADHD) and working memory in adults: A meta-analytic review. *Neuropsychology, 27*, 287–302. https://doi.org/10.1037/a0032371
- Boonstra, A. M., Oosterlaan, J., Sergeant, J. A., & Buitelaar, J. K. (2005). Executive functioning in adult ADHD: A meta-analytic review. *Psychological Medicine, 35,* 1097-1108. https://doi.org/10.1017/S003329170500499X

- Borella, E., Ribaupierre, A., Cornoldi, C., & Chicherio, C. (2013). Beyond interference control impairment in ADHD: Evidence from increased intraindividual variability in the Color-Stroop test. *Child Neuropsychology, 19,* 495-515. https://doi.org/10.1080/09297049.2012.696603
- Feldman, J. S., & Huang-Pollock, C. (2021). A new spin on spatial cognition in ADHD: A diffusion model decomposition of mental rotation. *Journal of the International Neuropsychological Society, 27,* 472-483. https://doi.org/10.1017/S1355617720001198
- Homack, S., & Riccio, C. A. (2004). A meta-analysis of the sensitivity and specificity of the Stroop Color and Word Test with children. *Archives of Clinical Neuropsychology, 19,* 725-743. https://doi.org/10.1016/j.acn.2003.09.003
- Inoue, K., Nadaoka, T., Oiji, A., Morioka, Y., Totsuka, S., Kanbayashi, Y., & Hukui, T. (1998). Clinical evaluation of attention-deficit hyperactivity disorder by objective quantitative measures. *Child Psychiatry and Human Development, 28,* 179-188. https://doi.org/10.1023/A:1022885827086
- Jackson, R., & Wild, C. J. (2021). Effect of the Brain Balance Program® on cognitive performance in children and adolescents with developmental and attentional issues. J*ournal of Advances in Medicine and Medical Research, 33,* 27-41. https://doi.org/10.9734/jammr/2021/v33i630857
- Kempton, S., Vance, A., Maruff, P., Luk, E., Costin, J., & Pantelis, C. (1999). Executive function and attention deficit hyperactivity disorder: Stimulant medication and better executive function performance in children. *Psychological Medicine, 29,* 527-538. https://doi.org/10.1017/S0033291799008338
- Langley, K., Marshall, L., van den Bree, M., Thomas, H., Owen, M., O'Donovan, M., & Thapar, A. (2004). Association of the dopamine D4 receptor gene 7-repeat allele with neuropsychological test performance of children with ADHD. *American Journal of Psychiatry, 161,* 133-138. https://doi.org/10.1176/appi.ajp.161.1.133
- Lansbergen, M. M., Kenemans, J. L., & van Engeland, H. (2007). Stroop interference and attention-deficit/hyperactivity disorder: A review and meta-analysis. *Neuropsychology, 21,* 251–262. https://doi.org/10.1037/0894-4105.21.2.251
- Mehta, M. A., Owen, A. M., Sahakian, B. J., Mavaddat, N., Pickard, J. D., & Robbins, T. W. (2000). Methylphenidate enhances working memory by modulating discrete frontal and parietal lobe regions in the human brain. The Journal of *Neuroscience, 20,* RC65. https://doi.org/10.1523/jneurosci.20-06-j0004.2000
- Matsuura, N., Ishitobi, M., Arai, S., Kawamura, K., Asano, M., Inohara, K., ... & Kosaka, H. (2014). Distinguishing between autism spectrum disorder and attention deficit hyperactivity disorder by using behavioral checklists, cognitive assessments, and neuropsychological test battery. *Asian Journal of Psychiatry, 12,* 50-57. https://doi.org/10.1016/j.ajp.2014.06.011
- Patros, C. H. G., Tarle, S. J., Alderson, R. M., Lea, S. E., & Arrington, E. F. (2019). Planning deficits in children with attention-deficit/hyperactivity disorder (ADHD): A meta-analytic review of tower task performance. *Neuropsychology, 33,* 425-444. https://doi.org/10.1037/neu0000531

- Pocklington, B., & Maybery, M. (2006). Proportional slowing or disinhibition in ADHD? A Brinley plot meta-analysis of Stroop Color and Word Test performance. *International Journal of Disability, Development and Education, 53,* 67-91. https://doi.org/10.1080/10349120500510057
- Shallice, T., Marzocchi, G. M., Coser, S., Del Savio, M., Meuter, R. F., & Rumiati, R. I. (2002). Executive function profile of children with attention deficit hyperactivity disorder. *Developmental Neuropsychology, 21,* 43-71. https://doi.org/10.1207/S15326942DN2101_3
- Tirosh, E., Perets-Dubrovsky, S., Davidovitch, M., & Hocherman, S. (2006). Visuomotor tracking related to attention-deficit hyperactivity disorder (ADHD). *Journal of Child Neurology, 21,* 502-507. https://doi.org/10.1177/08830738060210062401
- van Ewijk, H., Heslenfeld, D. J., Luman, M., Rommelse, N. N., Hartman, C. A., Hoekstra, P., ... & Oosterlaan, J. (2014). Visuospatial working memory in ADHD patients, unaffected siblings, and healthy controls. *Journal of Attention Disorders, 18,* 369-378. https://doi.org/10.1177/1087054713482582

Autism

Consistent deficits and strengths in autistic patients can be difficult to identify, as individuals with autism spectrum disorders represent a heterogenous group. A wide range of verbal skills, social skills, and comorbidities (especially ADHD) can be found in people diagnosed with autism. Sex differences may also arise when comparing individuals with autism to typically developing controls —for example, mental rotation is typically higher in males, but this difference may not exist among autistic individuals. Similarly, some differences seen in younger individuals with autism may disappear when assessing older individuals. Therefore, the general connections with autism identified in this guide's table should be considered tentative links that may not apply to a specific patient. Self-report data can also be gathered using the Autism Spectrum Quotient (AQ) questionnaire, also available in Creyos Health, to complement cognitive assessments.

- Hayashi, M., Kato, M., Igarashi, K., & Kashima, H. (2008). Superior fluid intelligence in children with Asperger's disorder. *Brain and Cognition, 66,* 306-310. https://doi.org/10.1016/j.bandc.2007.09.008
- Hennessy, A. (2023). Identifying cognitive profiles in children with neurodevelopmental disorders using online cognitive testing. *Electronic Thesis and Dissertation Repository,* 9310. https://ir.lib.uwo.ca/etd/9310

- Hlavatá, P., Kašpárek, T., Linhartová, P., Ošlejšková, H., & Bareš, M. (2018). Autism, impulsivity and inhibition: A review of the literature. *Basal Ganglia, 14,* 44-53. https://doi.org/10.1016/j.baga.2018.10.002
- Jiang, Y.V., Capistrano, C.G., & Palm, B.E. (2014). Spatial working memory in children with high-functioning autism: intact configural processing but impaired capacity. *Journal of Abnormal Psychology, 123,* 248-57. https://doi.org/10.1037/a0035420
- Pickles, A., Anderson, D. K., & Lord, C. (2014). Heterogeneity and plasticity in the development of language: A 17-year follow-up of children referred early for possible autism. *Journal of Child Psychology and Psychiatry, 55,* 1354-1362. https://doi.org/10.1111/jcpp.12269
- Rohde, M. S., Georgescu, A. L., Vogeley, K., Fimmers, R., & Falter-Wagner, C. M. (2018). Absence of sex differences in mental rotation performance in autism spectrum disorder. *Autism, 22,* 855-865. https://doi.org/10.1177/1362361317714991
- Soulières, I., Dawson, M., Samson, F., Barbeau, E. B., Sahyoun, C. P., Strangman, G. E., ... & Mottron, L. (2009). Enhanced visual processing contributes to matrix reasoning in autism. *Human Brain Mapping, 30,* 4082-4107. https://doi.org/10.1002/hbm.20831
- Unterrainer, J. M., Rauh, R., Rahm, B., Hardt, J., Kaller, C. P., Klein, C., Paschke-Müller, M., & Biscaldi, M. (2015). Development of planning in children with high-functioning autism spectrum disorders and/or attention deficit/hyperactivity disorder. *Autism Research, 9,* 739-751. https://doi.org/10.1002/aur.1574
- Wang, Y., Zhang, Y. B., Liu, L. L., Cui, J. F., Wang, J., Shum, D. H. K., van Amelsvoort, T., & Chan, R. C. K. (2017). A meta-analysis of working memory impairments in autism spectrum disorders. *Neuropsychology Review, 27,* 46–61. https://doi.org/10.1007/s11065-016-9336-y
- Zapf, A.C., Glindemann, L.A., Vogeley, K., & Falter, C.M. (2015). Sex differences in mental rotation and how they add to the understanding of autism. *PLoS ONE, 10,* e0124628. https://doi.org/10.1371/journal.pone.0124628

Bipolar Disorder

Research on bipolar disorder was focused on patients in a euthymic state (i.e., a stable period). Cognitive deficits seen in bipolar disorder tend to be non-specific and/or heterogeneous, affecting multiple domains. The Mood Disorder Questionnaire (MDQ), also available in Creyos Health, can be used to gather self-report data that complement cognitive assessments.

- Bora, E., Hıdıroğlu, C., Özerdem, A., Kaçar, Ö. F., Sarısoy, G., Civil Arslan, F., Aydemir, Ö., Tas, Z. C., Vahip, S., Atalay, A., Atasoy, N., Ateşci, F., & Tümkaya, S. (2016). Executive dysfunction and cognitive subgroups in a large sample of euthymic patients with bipolar disorder. *European Neuropsychopharmacology, 26,* 1338-1347. https://doi.org/10.1016/j.euroneuro.2016.04.002
- Bourne, C., Aydemir, Ö., Balanzá-Martínez, V., Bora, E., Brissos, S., Cavanagh, J. T., Clark, L., Cubukcuoglu, Z., Dias, V. V., Dittmann, S., Ferrier, I. N., Fleck, D. E., Frangou, S., Gallagher, P., Jones, L., Kieseppä, T., Martínez-Aran, A., Melle, I., Moore, P. B., Mur, M., … Goodwin, G. M. (2013). Neuropsychological testing of cognitive impairment in euthymic bipolar disorder: an individual patient data meta-analysis. *Acta Psychiatrica Scandinavica, 128,* 149–162. https://doi.org/10.1111/acps.12133
- Canuto, A., Giannakopoulos, P., Moy, G., Rubio, M. M., Ebbing, K., Meiler-Mititelu, C., Herrmann, F. R., Gold, G., Delaloye, C., & Weber, K. (2010). Neurocognitive deficits and personality traits among euthymic patients with mood disorders in late life. *Journal of the Neurological Sciences, 299,* 24-29. https://doi.org/10.1016/j.jns.2010.08.045
- Chase, H. W., Fournier, J. C., Aslam, H., Stiffler, R., Almeida, J. R., Sahakian, B. J., & Phillips, M. L. (2018). Haste or speed? Alterations in the impact of incentive cues on task performance in remitted and depressed patients with bipolar disorder. *Frontiers in Psychiatry, 9.* https://doi.org/10.3389/fpsyt.2018.00396
- Chrobak, A., Jeziorko, S., Tereszko, A., Janeczko, W., Arciszewska, A., Siuda-Krzywicka, K., Starowicz-Filip, A., Siwek, M., & Dudek, D. (2018). Mental rotation task in bipolar disorder. *Psychiatria Polska, 52,* 807-817. https://doi.org/10.12740/pp/onlinefirst/79835
- Depp, C. A., Mausbach, B. T., Harmell, A. L., Savla, G. N., Bowie, C. R., Harvey, P. D., & Patterson, T. L. (2012). Meta-analysis of the association between cognitive abilities and everyday functioning in bipolar disorder. *Bipolar Disorders, 14,* 217-226. https://doi.org/10.1111/j.1399-5618.2012.01011.x
- Dickinson, T., Becerra, R., & Coombes, J. (2017). Executive functioning deficits among adults with bipolar disorder (types I and II): A systematic review and meta-analysis. *Journal of Affective Disorders, 218,* 407-427. https://doi.org/10.1016/j.jad.2017.04.010
- Frantom, L. V., Allen, D. N., & Cross, C. L. (2008). Neurocognitive endophenotypes for bipolar disorder. *Bipolar Disorders, 10,* 387-399. https://doi.org/10.1111/j.1399-5618.2007.00529.x
- Fu, L., Xiang, D., Xiao, J., Yao, L., Wang, Y., Xiao, L., Wang, H., Wang, G., & Liu, Z. (2018). Reduced prefrontal activation during the Tower of London and verbal fluency task in patients with bipolar depression: A multi-channel NIRS study. *Frontiers in Psychiatry, 9*. https://doi.org/10.3389/fpsyt.2018.00214
- Kurtz, M. M., & Gerraty, R. T. (2009). A meta-analytic investigation of neurocognitive deficits in bipolar illness: Profile and effects of clinical state. *Neuropsychology, 23,* 551–562. https://doi.org/10.1037/a0016277

- Robinson, L. J., Thompson, J. M., Gallagher, P., Goswami, U., Young, A. H., Ferrier, I. N., & Moore, P. B. (2006). A meta-analysis of cognitive deficits in euthymic patients with bipolar disorder. *Journal of Affective Disorders, 93,* 105-115. https://doi.org/10.1016/j.jad.2006.02.016
- Samamé, C., Martino, D. J., & Strejilevich, S. A. (2013). A quantitative review of neurocognition in euthymic late-life bipolar disorder. *Bipolar Disorders, 15,* 633-644. https://doi.org/10.1111/bdi.12077
- Samamé, C., Martino, D. J., & Strejilevich, S. A. (2014). Longitudinal course of cognitive deficits in bipolar disorder: A meta-analytic study. *Journal of Affective Disorders, 164,* 130-138. https://doi.org/10.1016/j.jad.2014.04.028
- Stefanopoulou, E., Manoharan, A., Landau, S., Geddes, J. R., Goodwin, G., & Frangou, S. (2009). Cognitive functioning in patients with affective disorders and schizophrenia: A meta-analysis. *International Review of Psychiatry, 21,* 336-356. https://doi.org/10.1080/09540260902962149
- Sweeney, J. A., Kmiec, J. A., & Kupfer, D. J. (2000). Neuropsychologic impairments in bipolar and unipolar mood disorders on the CANTAB neurocognitive battery. *Biological Psychiatry, 48,* 674-684. https://doi.org/10.1016/s0006-3223(00)00910-0
- Szmulewicz, A. G., Valerio, M. P., Smith, J. M., Samamé, C., Martino, D. J., & Strejilevich, S. A. (2017). Neuropsychological profiles of major depressive disorder and bipolar disorder during euthymia. A systematic literature review of comparative studies. *Psychiatry Research, 248,* 127-133. https://doi.org/10.1016/j.psychres.2016.12.031
- Torrent, C., Martínez-Arán, A., Daban, C., Sánchez-Moreno, J., Comes, M., Goikolea, J. M., Salamero, M., & Vieta, E. (2006). Cognitive impairment in bipolar II disorder. *British Journal of Psychiatry, 189,* 254-259. https://doi.org/10.1192/bjp.bp.105.017269
- Torres, I. J., Boudreau, V. G., & Yatham, L. N. (2007). Neuropsychological functioning in euthymic bipolar disorder: A meta-analysis. *Acta Psychiatrica Scandinavica, 116,* 17-26. https://doi.org/10.1111/j.1600-0447.2007.01055.x
- Yatham, L. N., Torres, I. J., Malhi, G. S., Frangou, S., Glahn, D. C., Bearden, C. E., Burdick, K. E., Martínez-Arán, A., Dittmann, S., Goldberg, J. F., Ozerdem, A., Aydemir, O., & Chengappa, K. N. (2010). The international society for bipolar disorders-battery for assessment of neurocognition (ISBD-BANC). *Bipolar Disorders, 12,* 351-363. https://doi.org/10.1111/j.1399-5618.2010.00830.x

Brain Injury: Frontal Lobe

Cognitive deficits due to brain injury can depend on the nature, severity, and location of the injury. Most of the Creyos cognitive tasks recruit frontal regions, and have been used to study the role of the frontal lobe in cognition. The Rivermead Post-Concussion Symptoms Questionnaire (RPQ) is also available in Creyos Health, and can be used to gather self-report data that complement cognitive assessments for patients with head injuries.

- Battista, M. (2022). *Creyos brain regions guide.* Creyos. https://creyos.com/assets/resources/creyos-health-brain-regions-guide.pdf
- Bor, D., Duncan, J., Lee, A. C., Parr, A., & Owen, A. M. (2006). Frontal lobe involvement in spatial span: Converging studies of normal and impaired function. *Neuropsychologia, 44,* 229-237. https://doi.org/10.1016/j.neuropsychologia.2005.05.010
- Kazazian, K., Norton, L., Laforge, G., Abdalmalak, A., Gofton, T. E., Debicki, D., Slessarev, M., Hollywood, S., St. Lawrence, K., & Owen, A. M. (2021). Improving diagnosis and prognosis in acute severe brain injury: a multimodal imaging protocol. *Frontiers in Neurology, 12.* https://doi.org/10.3389/fneur.2021.757219
- Mehta, M. A., Owen, A. M., Sahakian, B. J., Mavaddat, N., Pickard, J. D., & Robbins, T. W. (2000). Methylphenidate enhances working memory by modulating discrete frontal and parietal lobe regions in the human brain. *The Journal of Neuroscience, 20,* RC65. https://doi.org/10.1523/jneurosci.20-06-j0004.2000
- Owen, A. M., Downes, J. J., Sahakian, B. J., Polkey, C. E., & Robbins, T. W. (1990). Planning and spatial working memory following frontal lobe lesions in man. *Neuropsychologia, 28,* 1021-1034. https://doi.org/10.1016/0028-3932(90)90137-D
- Owen, A. M., James, M., Leigh, P. N., Summers, B. A., Marsden, C. D., Quinn, N. A., ... & Robbins, T. W. (1992). Fronto-striatal cognitive deficits at different stages of Parkinson's disease. *Brain, 115,* 1727-1751. https://doi.org/10.1093/brain/115.6.1727
- Owen, A. M., Morris, R. G., Sahakian, J. L., Polkey, C. E., Robbins, T. W., & Sahakian, B. J. (1996). Double dissociations of memory and executive functions in working memory task following frontal lobe excision, temporal lobe excisions or amygdala-hippocampectomy in man. *Brain, 119,* 1597–1615. https://doi.org/10.1093/brain/119.5.1597
- Owen, A. M., Roberts, A. C., Hodges, J. R., & Robbins, T. W. (1993). Contrasting mechanisms of impaired attentional set-shifting in patients with frontal lobe damage or Parkinson's disease. *Brain, 116,* 1159-1175. https://doi.org/10.1093/brain/116.5.1159
- Owen, A. M., Roberts, A. C., Polkey, C. E., Sahakian, B. J., & Robbins, T. W. (1991). Extra-dimensional versus intra-dimensional set shifting performance following frontal lobe excisions, temporal lobe excisions or amygdalo-hippocampectomy in man. *Neuropsychologia, 29,* 993-1006. https://doi.org/10.1016/0028-3932(91)90063-E
- Pantelis, C., Barnes, T. R., Nelson, H. E., Tanner, S., Weatherley, L., Owen, A. M., & Robbins, T. W. (1997). Frontal-striatal cognitive deficits in patients with chronic schizophrenia. *Brain, 120,* 1823-1843. https://doi.org/10.1093/brain/120.10.1823

- Vendrell, P., Junqué, C., Pujol, J., Jurado, M. A., Molet, J., & Grafman, J. (1995). The role of prefrontal regions in the Stroop task. *Neuropsychologia, 33,* 341-352. https://doi.org/10.1016/0028-3932(94)00116-7

Brain Injury: Temporal Lobe

Cognitive deficits due to brain injury can depend on the nature, severity, and location of the injury. While many of the Creyos cognitive tasks recruit frontal regions, temporal lobe injuries can affect different tasks or different aspects of each task. The Rivermead Post-Concussion Symptoms Questionnaire (RPQ) is also available in Creyos Health, and can be used to gather self-report data that complement cognitive assessments for patients with head injuries.

- Battista, M. (2022). *Creyos brain regions guide.* Creyos. https://creyos.com/assets/resources/creyos-health-brain-regions-guide.pdf
- Kazazian, K., Norton, L., Laforge, G., Abdalmalak, A., Gofton, T. E., Debicki, D., Slessarev, M., Hollywood, S., St. Lawrence, K., & Owen, A. M. (2021). Improving diagnosis and prognosis in acute severe brain injury: a multimodal imaging protocol. *Frontiers in Neurology, 12.* https://doi.org/10.3389/fneur.2021.757219
- Owen, A. M., Morris, R. G., Sahakian, J. L., Polkey, C. E., Robbins, T. W., & Sahakian, B. J. (1996). Double dissociations of memory and executive functions in working memory task following frontal lobe excision, temporal lobe excisions or amygdala-hippocampectomy in man. *Brain, 119,* 1597–1615. https://doi.org/10.1093/brain/119.5.1597
- Owen, A. M., Roberts, A. C., Polkey, C. E., Sahakian, B. J., & Robbins, T. W. (1991). Extra-dimensional versus intra-dimensional set shifting performance following frontal lobe excisions, temporal lobe excisions or amygdalo-hippocampectomy in man. *Neuropsychologia, 29,* 993-1006. https://doi.org/10.1016/0028-3932(91)90063-E

Cannabis Use

Research focuses on the effects of long-term, chronic cannabis use on cognitive function. Most studies have reported widespread effects on neurocognitive function, although some report no substantial relationship. Greater adverse effects may be associated with cannabis use in adolescence.

- Becker, M. P., Collins, P. F., & Luciana, M. (2014). Neurocognition in college-aged daily marijuana users. *Journal of Clinical and Experimental Neuropsychology, 36, 379-398.* https://doi.org/10.1080/13803395.2014.893996
- Dellazizzo, L., Potvin, S., Giguère, S., & Dumais, A. (2022). Evidence on the acute and residual neurocognitive effects of cannabis use in adolescents and adults: A systematic meta-review of meta-analyses. *Addiction, 117,* 1857-1870. https://doi.org/10.1111/add.15764
- Figueiredo, P. R., Tolomeo, S., Steele, J. D., & Baldacchino, A. (2020). Neurocognitive consequences of chronic cannabis use: A systematic review and meta-analysis. *Neuroscience & Biobehavioral Reviews, 108,* 358-369. https://doi.org/10.1016/j.neubiorev.2019.10.014
- Ganzer, F., Bröning, S., Kraft, S., Sack, P. M., & Thomasius, R. (2016). Weighing the evidence: A systematic review on long-term neurocognitive effects of cannabis use in abstinent adolescents and adults. *Neuropsychology Review, 26,* 186-222. https://doi.org/10.1007/s11065-016-9316-2
- Harvey, M. A., Sellman, J. D., Porter, R. J., & Frampton, C. M. (2007). The relationship between non-acute adolescent cannabis use and cognition. *Drug and Alcohol Review, 26,* 309-319. https://doi.org/10.1080/09595230701247772
- Lawn, W., Fernandez-Vinson, N., Mokrysz, C., Hogg, G., Lees, R., Trinci, K., ... & Curran, H. V. (2022). The CannTeen study: Verbal episodic memory, spatial working memory, and response inhibition in adolescent and adult cannabis users and age-matched controls. *Psychopharmacology, 239,* 1629-1641. https://doi.org/10.1007/s00213-022-06143-3
- Solowij, N., & Battisti, R. (2008). The chronic effects of cannabis on memory in humans: A review. *Current Drug Abuse Reviews, 1,* 81-98. https://doi.org/10.2174/1874473710801010081
- Solowij, N., & Pesa, N. (2010). Cognitive abnormalities and cannabis use. *Brazilian Journal of Psychiatry, 32,* 531-540. https://doi.org/10.1590/S1516-44462010000500006

Chronic Pain

The relationship between pain and cognition can be complex. Chronic pain may have a variety of causes, but pain is often considered a disease in itself. Where possible, this summary focuses on the direct cognitive effects of chronic pain, rather than related factors such as medication side effects. However, medication effects cannot be ruled out in every study.

- Attal, N., Masselin-Dubois, A., Martinez, V., Jayr, C., Albi, A., Fermanian, J., Bouhassira, D., & Baudic, S. (2014). Does cognitive functioning predict chronic pain? Results from a prospective surgical cohort. *Brain: A Journal of Neurology, 137,* 904–917. https://doi.org/10.1093/brain/awt354

- Berryman, C., Stanton, T. R., Bowering, K. J., Tabor, A., McFarlane, A., & Moseley, G. L. (2014). Do people with chronic pain have impaired executive function? A meta-analytical review. *Clinical Psychology Review, 34,* 563-579. https://doi.org/10.1016/j.cpr.2014.08.003
- Corti, E. J., Gasson, N., & Loftus, A. M. (2021). Cognitive profile and mild cognitive impairment in people with chronic lower back pain. *Brain and Cognition, 151,* 105737. https://doi.org/10.1016/j.bandc.2021.105737
- Coslett, H. B., Medina, J., Kliot, D., & Burkey, A. (2010). Mental motor imagery and chronic pain: The foot laterality task. *Journal of the International Neuropsychological Society, 16,* 603-612. https://doi.org/10.1017/s1355617710000299
- Dick, B. D., & Rashiq, S. (2007). Disruption of attention and working memory traces in individuals with chronic pain. *Anesthesia & Analgesia, 104,* 1223-1229. https://doi.org/10.1213/01.ane.0000263280.49786.f5
- Gunnarsson, H., & Agerström, J. (2021). Is clinical, musculoskeletal pain associated with poorer logical reasoning? *Pain Reports, 6*. https://doi.org/10.1097/PR9.0000000000000929
- Iezzi, T., Duckworth, M. P., Vuong, L. N., Archibald, Y. M., & Klinck, A. (2004). Predictors of neurocognitive performance in chronic pain patients. *International Journal of Behavioral Medicine, 11,* 56-61. https://doi.org/10.1207/s15327558ijbm1101_7
- Jacobsen, H. B., Brun, A., Stubhaug, A., & Reme, S. E. (2023). Stress specifically deteriorates working memory in peripheral neuropathic pain and fibromyalgia. *Brain Communications, 5,* fcad194. https://doi.org/10.1093/braincomms/fcad194
- Mazza, S., Frot, M., & Rey, A. E. (2018). A comprehensive literature review of chronic pain and memory. *Progress in Neuro-Psychopharmacology and Biological Psychiatry, 87,* 183-192. https://doi.org/10.1016/j.pnpbp.2017.08.006
- McCracken, L. M., & Iverson, G. L. (2001). Predicting complaints of impaired cognitive functioning in patients with chronic pain. *Journal of Pain and Symptom Management, 21,* 392-396. https://doi.org/10.1016/s0885-3924(01)00267-6
- Nadar, M. S., Jasem, Z., & Manee, F. S. (2016). The cognitive functions in adults with chronic pain: A comparative study. *Pain Research and Management, 2016,* 1-8. https://doi.org/10.1155/2016/5719380
- Pickering, G., Pereira, B., Clère, F., Sorel, M., De Montgazon, G., Navez, M., Picard, P., Roux, D., Morel, V., Salimani, R., Adda, M., Legout, V., & Dubray, C. (2013). Cognitive function in older patients with Postherpetic neuralgia. *Pain Practice, 14,* E1-E7. https://doi.org/10.1111/papr.12079
- Rathbone, M., Parkinson, W., Rehman, Y., Jiang, S., Bhandari, M., & Kumbhare, D. (2016). Magnitude and variability of effect sizes for the associations between chronic pain and cognitive test performances: A meta-analysis. *British Journal of Pain, 10,* 141-155. https://doi.org/10.1177/2049463716642600

- Rouch, I., Edjolo, A., Laurent, B., Pongan, E., Dartigues, J., & Amieva, H. (2020). Association between chronic pain and long-term cognitive decline in a population-based cohort of elderly participants. *Pain, 162*, 552-560. https://doi.org/10.1097/j.pain.0000000000002047
- Schiltenwolf, M., Akbar, M., Hug, A., Pfüller, U., Gantz, S., Neubauer, E., Flor, H., & Wang, H. (2014). Evidence of specific cognitive deficits in patients with chronic low back pain under long-term substitution treatment of opioids. *Pain Physician, 17,* 9–20.
- Shuchang, H., Mingwei, H., Hongxiao, J., Si, W., Xing, Y., Antonius, D., & Opler, M. G. (2011). Emotional and neurobehavioural status in chronic pain patients. *Pain Research and Management, 16,* 41-43. https://doi.org/10.1155/2011/825636

Concussion

Cognitive deficits due to brain injury can depend on the nature, severity, and location of the injury, especially when examining acute or short-term effects. Long-term effects tend to be more subtle, but can be detected in some cognitive tasks, such as the Creyos Double Trouble measure of response inhibition. The Rivermead Post-Concussion Symptoms Questionnaire (RPQ) is also available in Creyos Health, and can be used to gather self-report data that complement cognitive assessments.

- Bleiberg, J., Cernich, A., Cameron, K., Sun, W., Peck, K., Ecklund, J., Reeves, D., Uhorchak, J., Sparling, M., & Warden, D. (2004). Duration of cognitive impairment after sports concussion. *Neurosurgery, 54,* 1073-1078. http://dx.doi.org/10.1227/01.NEU.0000118820.33396.6A
- Brewer-Deluce, D., Wilson, T. D., & Owen, A. M. (2018). Cognitive function in varsity football athletes is maintained in the absence of concussion. *The FASEB Journal, 31,* 745.7. https://doi.org/10.1096/fasebj.31.1_supplement.745.7
- Esopenko, C., Chow, T.W., Tartaglia, M.C., Bacopulos, A., Kumar, P., Binns, M. A., Kennedy, J. L., Muller, D. J., & Levine, B. (2017). Cognitive and psychosocial function in retired professional hockey players. *Journal of Neurology, Neurosurgery & Psychiatry, 88,* 512-519. https://doi.org/10.1136/jnnp-2016-315260
- Feddermann-Demont, N., Echemendia, R.J., Schneider, K.J., Solomon, G. S., Hayden, K. A., Turner, M., Dvorak, J., Straumann, D., & Tarnutzer, A. A. (2017). What domains of clinical function should be assessed after sport-related concussion? A systematic review. *British Journal of Sports Medicine, 51,* 903-918. https://doi.org/10.1136/bjsports-2016-097403

- Karr, J. E., Areshenkoff, C. N., & Garcia-Barrera, M. A. (2014). The neuropsychological outcomes of concussion: A systematic review of meta-analyses on the cognitive sequelae of mild traumatic brain injury. *Neuropsychology, 28,* 321–336. https://doi.org/10.1037/neu0000037
- Stafford, C. A., Stojanoski, B., Wild, C. J., Brewer-Deluce, D., Wilson, T. D., & Owen, A. M. (2020). Concussion-related deficits in the general population predict impairments in varsity footballers. *Journal of Neurology, 267,* 1970-1979. https://doi.org/10.1007/s00415-020-09749-9

COVID-19

Results focus on the long term effects of a previous COVID infection, known as post-COVID or long COVID. The COVID-19 pandemic is recent, ongoing, and evolving as of the time of this writing, so all research must be considered early results that may change with further research.

- Becker, J. H., Lin, J. J., Doernberg, M., Stone, K., Navis, A., Festa, J. R., & Wisnivesky, J. P. (2021). Assessment of cognitive function in patients after COVID-19 infection. *JAMA Network Open, 4,* e2130645. https://doi.org/10.1001/jamanetworkopen.2021.30645
- Bonizzato, S., Ghiggia, A., Ferraro, F., & Galante, E. (2021). Cognitive, behavioral, and psychological manifestations of COVID-19 in post-acute rehabilitation setting: Preliminary data of an observational study. *Neurological Sciences, 43,* 51-58. https://doi.org/10.1007/s10072-021-05653-w
- Hampshire, A., Trender, W., Chamberlain, S. R., Jolly, A. E., Grant, J. E., Patrick, F., Mazibuko, N., Williams, S. C., Barnby, J. M., Hellyer, P., & Mehta, M. A. (2021). Cognitive deficits in people who have recovered from COVID-19. *EClinicalMedicine, 39,* 101044. https://doi.org/10.1016/j.eclinm.2021.101044
- Mattioli, F., Stampatori, C., Righetti, F., Sala, E., Tomasi, C., & De Palma, G. (2021). Neurological and cognitive sequelae of COVID-19: A four month follow-up. *Journal of Neurology, 268,* 4422-4428. https://doi.org/10.1007/s00415-021-10579-6
- Ortelli, P., Ferrazzoli, D., Sebastianelli, L., Engl, M., Romanello, R., Nardone, R., Bonini, I., Koch, G., Saltuari, L., Quartarone, A., Oliviero, A., Kofler, M., & Versace, V. (2021). Neuropsychological and neurophysiological correlates of fatigue in post-acute patients with neurological manifestations of COVID-19: Insights into a challenging symptom. *Journal of the Neurological Sciences, 420,* 117271. https://doi.org/10.1016/j.jns.2020.117271

- Perrottelli, A., Sansone, N., Giordano, G. M., Caporusso, E., Giuliani, L., Melillo, A., Pezzella, P., Bucci, P., Mucci, A., & Galderisi, S. (2022). Cognitive impairment after post-acute COVID-19 infection: A systematic review of the literature. *Journal of Personalized Medicine, 12,* 2070. https://doi.org/10.3390/jpm12122070
- Rivera, D., Mortazavi, M., Seitz, T., Marx, T., Streeter, L., Samsam, L., & Lawson, S. (2023). Computerized cognitive testing in Long COVID patients with prolonged symptoms of brain fog and cognitive impairment. *Clinical Journal of Sport Medicine, 33,* 303-304.
- Wild, C., Norton, L., Menon, D., Ripsman, D., Swartz, R., & Owen, A. (2022). Disentangling the cognitive, physical, and mental health sequelae of COVID-19. *Cell Reports Medicine, 3,* 100750. https://doi.org/10.1016/j.xcrm.2022.100750

Dementia (Non-Alzheimer's)

This research focuses on non-Alzheimer's dementia—primarily Lewy body dementia. See separate entries on Alzheimer's and mild cognitive impairment for related research. The Instrumental Activities of Daily Living (IADL) questionnaire, also available in Creyos Health, can be used to gather self-report or informant data that complements cognitive assessments when examining patients concerned with age-related cognitive decline.

- Ala, T. A., Hughes, L. F., Kyrouac, G. A., Ghobrial, M. W., & Elble, R. J. (2001). Pentagon copying is more impaired in dementia with Lewy bodies than in Alzheimer's disease. *Journal of Neurology, Neurosurgery & Psychiatry, 70,* 483-488. https://doi.org/10.1136/jnnp.70.4.483
- Ferreira, N., Owen, A., Mohan, A., Corbett, A., & Ballard, C. (2015). Associations between cognitively stimulating leisure activities, cognitive function and age-related cognitive decline. *International Journal of Geriatric Psychiatry, 30,* 422–430. https://doi.org/10.1002/gps.4155
- Gould, R. L., Brown, R. G., Owen, A. M., Bullmore, E. T., & Howard, R. J. (2006). Task-induced deactivations during successful paired associates learning: An effect of age but not Alzheimer's disease. *NeuroImage, 31,* 818–831. https://doi.org/10.1016/j.neuroimage.2005.12.045
- Sahgal, A., Galloway, P. H., McKeith, I. G., Lloyd, S., Cook, J. H., Ferrier, I. N., & Edwardson, J. A. (1992). Matching-to-sample deficits in patients with senile dementias of the Alzheimer and Lewy body types. *Archives of Neurology, 49,* 1043-1046. https://doi.org/10.1001/archneur.1992.00530340059019

Depression

Depression is linked with several areas of cognition. Research has shown that not only does depression lead to cognitive deficits, but cognitive deficits may be a risk factor for depression as well. The Patient Health Questionnaire (PHQ-9), also available in Creyos Health, can be used to gather self-report data about depressive symptoms that complement cognitive assessments.

- Beats, B. C., Sahakian, B. J., & Levy, R. (1996). Cognitive performance in tests sensitive to frontal lobe dysfunction in the elderly depressed. *Psychological Medicine, 26,* 591-603. https://doi.org/10.1017/S0033291700035662
- Desai, R., Charlesworth, G. M., Brooker, H. J., Potts, H. W., Corbett, A., Aarsland, D., & Ballard, C. G. (2020). Temporal relationship between depressive symptoms and cognition in mid and late life: a longitudinal cohort study. *Journal of the American Medical Directors Association, 21,* 1108-1113. https://doi.org/10.1016/j.jamda.2020.01.106
- Eraydin, I. E., Mueller, C., Corbett, A., Ballard, C., Brooker, H., Wesnes, K., ... & Huntley, J. (2019). Investigating the relationship between age of onset of depressive disorder and cognitive function. *International Journal of Geriatric Psychiatry, 34,* 38-46. https://doi.org/10.1002/gps.4979
- Lopez, M., Mayer, D., Breach, C., Walton, I., Karim, S., & Khan, K. (2023). Cognitive functioning as an outcome measure in therapy. *EMDR Therapy Quarterly, 5.* https://etq.emdrassociation.org.uk/paper/cognitive-functioning-as-an-outcome-measure-in-therapy/

Dyslexia

People with dyslexia may struggle with executive function tasks not directly related to reading. Most research on dyslexia involves children.

- Faccioli, C., Peru, A., Rubini, E., & Tassinari, G. (2008). Poor readers but compelled to read: Stroop effects in developmental dyslexia. *Child Neuropsychology, 14,* 277-283. https://doi.org/10.1080/09297040701290040
- Gray, S. (2006). The relationship between phonological memory, receptive vocabulary, and fast mapping in young children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 49,* 955-969. https://doi.org/10.1044/1092-4388(2006/069)
- Hatcher, J., Snowling, M. J., & Griffiths, Y. M. (2010). Cognitive assessment of dyslexic students in higher education. *British Journal of Educational Psychology, 72,* 119-133. https://doi.org/10.1348/000709902158801

- Helland, T., & Asbj rnsen, A. (2004). Digit span in dyslexia: Variations according to language comprehension and mathematics skills. *Journal of Clinical and Experimental Neuropsychology, 26,* 31-42. https://doi.org/10.1076/jcen.26.1.31.23935
- Reiter, A., Tucha, O., & Lange, K. W. (2004). Executive functions in children with dyslexia. *Dyslexia, 11,* 116-131. https://doi.org/10.1002/dys.289

Epilepsy

Cognitive profiles in people with epilepsy differ by patient, so links identified here are tentative. Chronic epilepsy appears to impair cognition, but the nature of impairments may depend on the areas of the brain affected, as well as reorganization, behavioral compensation, and surgery.

- Berg, A. T. (2011). Epilepsy, cognition, and behavior: The clinical picture. *Epilepsia, 52,* 7-12. https://doi.org/10.1111/j.1528-1167.2010.02905.x
- Elger, C. E., Helmstaedter, C., & Kurthen, M. (2004). Chronic epilepsy and cognition. *The Lancet Neurology, 3,* 663-672. https://doi.org/10.1016/S1474-4422(04)00906-8
- Loughman, A., Bowden, S.C., & D'Souza, W. (2014). Cognitive functioning in idiopathic generalised epilepsies: a systematic review and meta-analysis. *Neuroscience and Biobehavioral Reviews, 43,* 20-34. https://doi.org/10.1016/j.neubiorev.2014.02.012

Fibromyalgia

Research on fibromyalgia and cognition is often inconsistent, but some domains do seem to be consistently impaired in patients. Pain is a defining feature of fibromyalgia, so there is overlap with the entry on chronic pain, but fibromyalgia may have unique cognitive symptoms. Note that most research involved female participants, as fibromyalgia is much more common in women than in men.

- Bell, T., Trost, Z., Buelow, M. T., Clay, O., Younger, J., Moore, D., & Crowe, M. (2018). Meta-analysis of cognitive performance in fibromyalgia. *Journal of Clinical and Experimental Neuropsychology, 40,* 698-714. https://doi.org/10.1080/13803395.2017.1422699

- Bell, T., Trost, Z., Buelow, M. T., Clay, O., Younger, J., Moore, D., & Crowe, M. (2018). Meta-analysis of cognitive performance in fibromyalgia. *Journal of Clinical and Experimental Neuropsychology, 40,* 698-714. https://doi.org/10.1080/13803395.2017.1422699
- Berryman, C., Stanton, T. R., Bowering, J. K., Tabor, A., McFarlane, A., & Moseley, L. G. (2013). Evidence for working memory deficits in chronic pain: A systematic review and meta-analysis. *Pain, 154,* 1181-1196. https://doi.org/10.1016/j.pain.2013.03.002
- Cherry, B. J., Zettel-Watson, L., Shimizu, R., Roberson, I., Rutledge, D. N., & Jones, C. J. (2012). Cognitive performance in women aged 50 years and older with and without fibromyalgia. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 69,* 199-208. https://doi.org/10.1093/geronb/gbs122
- Di Tella, M., Castelli, L., Colonna, F., Fusaro, E., Torta, R., Ardito, R. B., & Adenzato, M. (2015). Theory of mind and emotional functioning in fibromyalgia syndrome: An investigation of the relationship between social cognition and executive function. *Plos One, 10,* e0116542. https://doi.org/10.1371/journal.pone.0116542
- Ferrera, D., Gómez-Esquer, F., Peláez, I., Barjola, P., Fernandes-Magalhaes, R., Carpio, A., De Lahoz, M. E., Díaz-Gil, G., & Mercado, F. (2020). Effects of COMT genotypes on working memory performance in fibromyalgia patients. *Journal of Clinical Medicine, 9,* 2479. https://doi.org/10.3390/jcm9082479
- Higgins, D. M., Martin, A. M., Baker, D. G., Vasterling, J. J., & Risbrough, V. (2018). The relationship between chronic pain and neurocognitive function. *The Clinical Journal of Pain, 34,* 262-275. https://doi.org/10.1097/ajp.0000000000000536
- Jacobsen, H. B., Brun, A., Stubhaug, A., & Reme, S. E. (2023). Stress specifically deteriorates working memory in peripheral neuropathic pain and fibromyalgia. *Brain Communications, 5,* fcad194. https://doi.org/10.1093/braincomms/fcad194
- Johnson, C., & Grant, J. (2016). The influence of Mitoq on symptoms and cognition in fibromyalgia, myalgic encephalomyelitis and chronic fatigue. *Mendus.* https://doi.org/10.13140/RG.2.1.2329.8805
- Rathbone, M., Parkinson, W., Rehman, Y., Jiang, S., Bhandari, M., & Kumbhare, D. (2016). Magnitude and variability of effect sizes for the associations between chronic pain and cognitive test performances: A meta-analysis. *British Journal of Pain, 10,* 141-155. https://doi.org/10.1177/2049463716642600
- Riquelme-Aguado, V., Gil-Crujera, A., Fernández-Carnero, J., Cuenca-Martínez, F., Klett, G. B., & Esquer, F. G. (2023). The influence of emotional and cognitive factors on limb laterality discrimination in women with Fibromyalgia syndrome: A cross-sectional study secondary analysis. *Applied Sciences, 13,* 1894. https://doi.org/10.3390/app13031894

- Roldán-Tapia, L., Cánovas-López, R., Cimadevilla, J., & Valverde, M. (2007). Cognition and perception deficits in fibromyalgia and rheumatoid arthritis. *Reumatología Clínica (English Edition), 3,* 101-109. https://doi.org/10.1016/s2173-5743(07)70224-1
- Veldhuijzen, D. S., Sondaal, S. F., & Oosterman, J. M. (2012). Intact cognitive inhibition in patients with fibromyalgia but evidence of declined processing speed. *The Journal of Pain, 13,* 507-515. https://doi.org/10.1016/j.jpain.2012.02.011

Huntington's Disease

Early versions of the Creyos tasks were used to identify specific deficits in patients with Huntington's disease.

- Lange, K. W., Sahakian, B. J., Quinn, N. P., Marsden, C. D., & Robbins, T. W. (1995). Comparison of executive and visuospatial memory function in Huntington's disease and dementia of Alzheimer type matched for degree of dementia. *Journal of Neurology, Neurosurgery & Psychiatry,* 58, 598-606. https://doi.org/10.1136/jnnp.58.5.598
- Lawrence, A. D., Sahakian, B. J., Hodges, J. R., Rosser, A. E., Lange, K. W., & Robbins, T. W. (1996). Executive and mnemonic functions in early Huntington's disease. *Brain, 119,* 1633-1645. https://doi.org/10.1093/brain/119.5.1633
- Swerdlow, N. R., Paulsen, J., Braff, D. L., Butters, N., Geyer, M. A., & Swenson, M. R. (1995). Impaired prepulse inhibition of acoustic and tactile startle response in patients with Huntington's disease. *Journal of Neurology, Neurosurgery & Psychiatry, 58,* 192-200. https://doi.org/10.1136/jnnp.58.2.192

Lyme Disease

Lyme has been considered a neuropsychiatric condition, and recommended to be considered as part of mental health evaluations (Fallon & Neilds 1994). However, objective cognitive impairments can be inconsistent, with only a few areas of cognition verified to be impaired in patients with Lyme disease.

- Bechtold, K. T., Rebman, A. W., Crowder, L. A., Johnson-Greene, D., & Aucott, J. N. (2017). Standardized symptom measurement of individuals with early Lyme disease over time. *Archives of Clinical Neuropsychology, 32,* 129-141. https://doi.org/10.1093/arclin/acw098
- Berende, A., Agelink van Rentergem, J., Evers, A. W., Ter Hofstede, H. J., Vos, F. J., Kullberg, B. J., & Kessels, R. P. (2019). Cognitive impairments in patients with persistent symptoms attributed to Lyme disease. *BMC Infectious Diseases, 19,* 1-6. https://doi.org/10.1186/s12879-019-4452-y

- Kaplan, R. F., Trevino, R. P., Johnson, G. M., Levy, L., Dornbush, R., Hu, L. T., ... & Klempner, M. S. (2003). Cognitive function in post-treatment Lyme disease Do additional antibiotics help? *Neurology, 60,* 1916-1922. https://doi.org/10.1212/01.WNL.0000068030.26992.25
- Keilp, J. G., Corbera, K., Gorlyn, M., Oquendo, M. A., Mann, J. J., & Fallon, B. A. (2018). Neurocognition in post-treatment Lyme disease and major depressive disorder. *Archives of Clinical Neuropsychology, 34,* 466-480. https://doi.org/10.1093/arclin/acy083
- Keilp, J. G., Corbera, K., Slavov, I., Taylor, M. J., Sackeim, H. A., & Fallon, B. A. (2006). WAIS-III and WMS-III performance in chronic Lyme disease. *Journal of the International Neuropsychological Society, 12,* 119-129. https://doi.org/10.1017/S1355617706060231
- Shadick, N. A., Phillips, C. B., Logigian, E. L., Steere, A. C., Kaplan, R. F., Berardi, V. P., ... & Liang, M. H. (1994). The long-term clinical outcomes of Lyme disease: A population-based retrospective cohort study. *Annals of Internal Medicine, 121,* 560-567. https://doi.org/10.7326/0003-4819-121-8-199410150-00002
- Vázquez, M., Sparrow, S. S., & Shapiro, E. D. (2003). Long-term neuropsychologic and health outcomes of children with facial nerve palsy attributable to Lyme disease. *Pediatrics, 112,* e93-e97. https://doi.org/10.1542/peds.112.2.e93
- Zotter, S., Koch, J., Schlachter, K., Katzensteiner, S., Dorninger, L., Brunner, J., Baumann, M., Wolf-Magele, A., Schmid, H., Ulmer, H., Hagspiel, S., & Rostasy, K. (2013). Neuropsychological profile of children after an episode of neuroborreliosis. *Neuropediatrics, 44,* 346–353. https://doi.org/10.1055/s-0033-1349724

Menopause

The relationships between menopause and cognitive function are generally poorly understood. Reviews tend to find that menopause itself has subtle or temporary effects on cognition, and no consistent relationship with the risk for dementia (Pertesi et al., 2019). Similarly, hormone replacement therapy (HRT) tends to improve performance in some areas of cognition, but results may be inconsistent.

- Duff, S. J., & Hampson, E. (2000). A beneficial effect of estrogen on working memory in postmenopausal women taking hormone replacement therapy. *Hormones and Behavior, 38*, 262-276. https://doi.org/10.1006/hbeh.2000.1625
- Georgakis, M. K., Beskou-Kontou, T., Theodoridis, I., Skalkidou, A., & Petridou, E. T. (2019). Surgical menopause in association with cognitive function and risk of dementia: A systematic review and meta-analysis. *Psychoneuroendocrinology, 106,* 9-19. https://doi.org/10.1016/j.psyneuen.2019.03.013

- Hogervorst, E., & Bandelow, S. (2010). Sex steroids to maintain cognitive function in women after the menopause: A meta-analyses of treatment trials. *Maturitas, 66,* 56-71. https://doi.org/10.1016/j.maturitas.2010.02.005
- Hogervorst, E., Williams, J., Budge, M., Riedel, W., & Jolles, J. (2000). The nature of the effect of female gonadal hormone replacement therapy on cognitive function in post-menopausal women: A meta-analysis. *Neuroscience, 101,* 485-512. https://doi.org/10.1016/S0306-4522(00)00410-3
- Lee, K. S., Jung, M. S., Kim, M., Cha, K., & Chung, E. (2020). Impact of cognitive aging on health-related quality of life in menopausal women. *Osong Public Health and Research Perspectives, 11,* 185-193. https://doi.org/10.24171/j.phrp.2020.11.4.07
- Maki, P. M., & Weber, M. T. (2021). A research primer for studies of cognitive changes across the menopause transition. *Climacteric, 24,* 382-388. https://doi.org/10.1080/13697137.2021.1905625
- Rice, K., & Morse, C. (2003). Measuring cognition in menopause research: A review of test use. *Climacteric, 6,* 2-22. https://doi.org/10.1080/cmt.6.1.2.22

Mild Cognitive Impairment (MCI) & Age-Related Decline

Performance on almost all cognitive tasks consistently declines after middle age, and may assist in identifying early or mild impairment in multiple domains. Creyos Health contains additional features for identifying MCI according to established diagnostic guidelines. See the entries for Alzheimer's disease and non-Alzheimer's dementia for related references. The Instrumental Activities of Daily Living (IADL) questionnaire, also available in Creyos Health, can be used to gather self-report or informant data that complement cognitive assessments when examining patients concerned with age-related cognitive decline.

- Ala, T. A., Hughes, L. F., Kyrouac, G. A., Ghobrial, M. W., & Elble, R. J. (2001). Pentagon copying is more impaired in dementia with Lewy bodies than in Alzheimer's disease. *Journal of Neurology, Neurosurgery & Psychiatry, 70,* 483-488. https://doi.org/10.1136/jnnp.70.4.483
- Beats, B. C., Sahakian, B. J., & Levy, R. (1996). Cognitive performance in tests sensitive to frontal lobe dysfunction in the elderly depressed. *Psychological Medicine, 26,* 591-603. https://doi.org/10.1017/S0033291700035662
- Bélanger, S., Belleville, S., & Gauthier, S. (2010). Inhibition impairments in Alzheimer's disease, mild cognitive impairment and healthy aging: Effect of congruency proportion in a Stroop task. *Neuropsychologia, 48,* 581-590. https://doi.org/10.1016/j.neuropsychologia.2009.10.021

- Belleville, S., Rouleau, N., & Van der Linden, M. (2006). Use of the Hayling task to measure inhibition of prepotent responses in normal aging and Alzheimer's disease. *Brain and Cognition, 62,* 113-119. https://doi.org/10.1016/j.bandc.2006.04.006
- Brodaty, H., Valenzuela, M., Fiatarone Singh, M. A., Sachdev, P. S., McNeil, J., Lautenschlager, N. T., Maeder, A., Jorm, L., Millard, M., Heffernan, M., Anstey, K. J., Ginige, J. A., Chau, T., San Jose, J. C., Welberry, H., Briggs, N., & Popovic, G. (2023). Maintain Your Brain: Outcomes of an online program to prevent cognitive decline with aging. *Alzheimer's & Dementia, 19,* e075183. https://doi.org/10.1002/alz.075183
- Ferreira, N., Owen, A., Mohan, A., Corbett, A., & Ballard, C. (2015). Associations between cognitively stimulating leisure activities, cognitive function and age-related cognitive decline. *International Journal of Geriatric Psychiatry, 30,* 422–430. https://doi.org/10.1002/gps.4155
- Gould, R. L., Brown, R. G., Owen, A. M., Bullmore, E. T., & Howard, R. J. (2006). Task-induced deactivations during successful paired associates learning: An effect of age but not Alzheimer's disease. *NeuroImage, 31,* 818–831. https://doi.org/10.1016/j.neuroimage.2005.12.045
- Gould, R. L., Arroyo, B., Brown, R. G., Owen, A. M., Bullmore, E. T., & Howard, R. J. (2006). Brain mechanisms of successful compensation during learning in Alzheimer disease. *Neurology, 67,* 1011–1017. https://doi.org/10.1212/01.wnl.0000237534.31734.1b
- Hampshire, A., Highfield, R., Parkin, B., & Owen, A.M. (2012). Fractionating human intelligence. *Neuron, 76,* 1225-1237. https://doi.org/10.1016/j.neuron.2012.06.022
- Levine, B., Bacopulos, A., Anderson, N. D., Black, S. E., Davidson, P. S. R., Fitneva, S. A., McAndrews, M. P., Spaniel, J., Jeyakumar, N., Abdi, H., Beaton, D., Owen, A. M., & Hampshire, A. (2013). Validation of a novel computerized test battery for automated testing. *Canadian Stroke Congress Conference, 44.*
- Lupton, M. K., Gomez, L., Mitchell, B. L., Adsett, J., García-Marín, L. M., Renteria, M. E., McAloney, K., Ceslis, A., Thienel, R., Robinson, G., Breakspear, M., & Martin, N. G. (2023). Poorer online cognitive performance is associated with genetic risk for Alzheimer's disease and brain phenotypes in healthy mid-life and older adults. *Alzheimer's & Dementia, 19,* e078078. https://doi.org/10.1002/alz.078078
- Nichols, E. S., Wild, C. J., Owen, A. M., & Soddu, A. (2021). Cognition across the lifespan: Investigating age, sex, and other sociodemographic influences. *Behavioral Sciences, 11,* 51. https://doi.org/10.3390/bs11040051
- Sterning, A., Burns, A., & Owen, A. M. Thirty-five years of computerized cognitive assessment of aging—where are we now? *Diagnostics, 9,* 114. https://doi.org/10.3390%2Fdiagnostics9030114
- Thienel, R., Borne, L., Faucher, C., Robinson, G., Fripp, J., Giorgio, J., Martin, N. G., Breakspear, M., & Lupton, M. K. Can an online battery match in-person cognitive testing in predicting age-related cortical changes? *Alzheimer's & Dementia, 19,* e074476. https://doi.org/10.1002/alz.074476

Multiple Sclerosis

Multiple Sclerosis (MS) patients may show consistent impairment on some domains of cognition such as response inhibition, memory, and processing speed. However, it may be the case that this impaired performance reflects slower task performance and therefore a reduced amount of item completion within a set amount of time. The subtype of MS may also affect the presence or severity of impairment.

- Denney, D., Sworowski, L., & Lynch, S. (2005). Cognitive impairment in three subtypes of multiple sclerosis. *Archives of Clinical Neuropsychology, 20,* 967-981. https://doi.org/10.1016/j.acn.2005.04.012
- DeSousa, E. A., Albert, R. H., & Kalman, B. (2002). Cognitive impairments in multiple sclerosis: a review. *American Journal of Alzheimer's Disease & Other Dementias, 17,* 23-29. https://doi.org/10.1177/153331750201700
- Foong, J., Rozewicz, L., Chong, W. K., Thompson, A. J., Miller, D. H., & Ron, M. A. (2000). A comparison of neuropsychological deficits in primary and secondary progressive multiple sclerosis. *Journal of Neurology, 247,* 97-101. https://doi.org/10.1007/pl00007804
- Gholami, M., Nami, M., Shamsi, F., Jaberi, K. R., Kateb, B., & Rahimi Jaberi, A. (2021). Effects of transcranial direct current stimulation on cognitive dysfunction in multiple sclerosis. *Neurophysiologie Clinique, 51,* 319-328. https://doi.org/10.1016/j.neucli.2021.05.003
- Giedraitiene, N., & Kaubrys, G. (2019). Distinctive pattern of cognitive disorders during multiple sclerosis relapse and recovery based on computerized CANTAB tests. *Frontiers in Neurology, 10.* https://doi.org/10.3389/fneur.2019.00572
- Matias-Guiu, J. A., Cortés-Martínez, A., Valles-Salgado, M., Oreja-Guevara, C., Pytel, V., Montero, P., ... & Matias-Guiu, J. (2017). Functional components of cognitive impairment in multiple sclerosis: a cross-sectional investigation. *Frontiers in Neurology, 8.* https://doi.org/10.3389/fneur.2017.00643
- Prakash, R., Snook, E., Lewis, J., Motl, R., & Kramer, A. (2008). Cognitive impairments in relapsing-remitting multiple sclerosis: A meta-analysis. *Multiple Sclerosis Journal, 14,* 1250-1261. https://doi.org/10.1177/1352458508095004
- Rao, S. M. (2004). Cognitive function in patients with multiple sclerosis: Impairment and treatment. International *Journal of MS Care, 6,* 9-22. https://doi.org/10.7224/1537-2073-6.1.9
- Renauld, S., Mohamed-Saïd, L., & Macoir, J. (2016). Language disorders in multiple sclerosis: A systematic review. *Multiple Sclerosis and Related Disorders, 10,* 103-111. https://doi.org/10.1016/j.msard.2016.09.005

- Wachowius, U., Talley, M., Silver, N., Heinze, H., & Sailer, M. (2005). Cognitive impairment in primary and secondary progressive multiple sclerosis. *Journal of Clinical and Experimental Neuropsychology, 27,* 65-77. https://doi.org/10.1080/138033990513645

Parkinson's Disease

Early versions of Creyos tasks were used to quantify specific cognitive deficits due to Parkinson's disease. Research has shown that impairments due to Parkinson's can be detected using cognitive tasks, even when traditional pen and paper screening tasks are within a normal range.

- Hosseini, M., Borhani-Haghighi, A., Petramfar, P., Foroughi, A. A., Ostovan, V. R., & Nami, M. (2023). Evaluating cognitive impairment in the early stages of Parkinson's disease using the Cambridge brain sciences-cognitive platform. *Clinical Neurology and Neurosurgery, 232,* 107866. https://doi.org/10.1016/j.clineuro.2023.107866
- Lázaro-Figueroa, A., Reyes-Pérez, P., Orelos-Figaredo, E., [...], Ruiz-Contreras, A. E., & The Latin American Research Consortium on the Genetics of Parkinson's Disease (LARGE-PD). (2023). MEX-PD: A national network for the epidemiological & genetic research on Parkinson's disease. *medRxiv, 2023.08.28.23294700.* https://doi.org/10.1101/2023.08.28.23294700
- Lewis, S. J. G., Dove, A., Robbins, T. W., Barker, R. A., & Owen, A. M. (2003). Cognitive impairments in early Parkinson's disease are accompanied by reductions in activity in frontostriatal neural circuitry. *The Journal of Neuroscience, 23,* 6351-6356. https://doi.org/10.1523/jneurosci.23-15-06351.2003
- Owen, A. M., Beksinska, M., James, M., Leigh, P. N., Summers, B. A., Marsden, C. D., ... & Robbins, T. W. (1993). Visuospatial memory deficits at different stages of Parkinson's disease. *Neuropsychologia, 31,* 627-644. https://doi.org/10.1016/0028-3932(93)90135-M
- Owen, A. M., James, M., Leigh, P. N., Summers, B. A., Marsden, C. D., Quinn, N. A., ... & Robbins, T. W. (1992). Fronto-striatal cognitive deficits at different stages of Parkinson's disease. *Brain, 115,* 1727-1751. https://doi.org/10.1093/brain/115.6.1727
- Owen, A. M., Roberts, A. C., Hodges, J. R., & Robbins, T. W. (1993). Contrasting mechanisms of impaired attentional set-shifting in patients with frontal lobe damage or Parkinson's disease. *Brain, 116,* 1159-1175. https://doi.org/10.1093/brain/116.5.1159

- Sahakian, B. J., Morris, R. G., Evenden, J. L., Heald, A., Levy, R., Philpot, M., & Robbins, T. W. (1988). A comparative study of visuospatial memory and learning in Alzheimer-type dementia and Parkinson's disease. *Brain, 111,* 695-718. https://doi.org/10.1093/brain/111.3.695

Post-Traumatic Stress Disorder (PTSD)

Although some cognitive tasks have been linked with PTSD, the pattern of deficits can be highly specific to each individual. See the stress entry for more general relationships with high stress.

- Brandes, D., Ben-Schachar, G., Gilboa, A., Bonne, O., Freedman, S., & Shalev, A. Y. (2002). PTSD symptoms and cognitive performance in recent trauma survivors. *Psychiatry Research, 110,* 231–238. https://doi.org/10.1016/s0165-1781(02)00125-7
- Clouston, S. A. P., Pietrzak, R. H., Kotov, R., Richards, M., Spiro III, A., Scott, S. B., Deri, Y., Mukherjee, S., Stewart, C., Bromet, E. J., & Luft, B. J. (2017). Traumatic exposures, posttraumatic stress disorder, and cognitive functioning in World Trade Center responders. *Alzheimer's & Dementia: Translational Research & Clinical Interventions, 3,* 593-602. https://doi.org/10.1016/j.trci.2017.09.001
- Levy-Gigi, E., Richter-Levin, G., & Kéri, S. (2014). The hidden price of repeated traumatic exposure: Different cognitive deficits in different first-responders. *Frontiers in Behavioral Neuroscience, 8.* https://doi.org/10.3389/fnbeh.2014.00281
- Millman, H., Andrews, K., Harricharan, S., Goegan, S., Sanger, B., Beech, I., O'Connor, C., Lanius, R., & McKinnon, M. (2022). Public safety personnel feedback from a remote trial of Goal Management Training for post-traumatic stress during Covid-19. *Journal of Community Safety and Well-Being, 7,* 27–31. https://doi.org/10.35502/jcswb.229
- Tian, F., Yennu, A., Smith-Osborne, A., Gonzalez-Lima, F., North, C. S., & Liu, H. (2014). Prefrontal responses to digit span memory phases in patients with post-traumatic stress disorder (PTSD): A functional near infrared spectroscopy study. *NeuroImage: Clinical, 4,* 808-819. https://doi.org/10.1016/j.nicl.2014.05.005

Schizophrenia

Cognitive impairment is closely linked with schizophrenia, and may even act as an early warning sign of a diagnosis. Specific areas have been shown to be impaired in patients with schizophrenia, but some researchers propose that impairments are global, affecting many or most domains of cognition.

- Conklin, H. M., Curtis, C. E., Katsanis, J., & Iacono, W. G. (2000). Verbal working memory impairment in schizophrenia patients and their first-degree relatives: evidence from the digit span task. *American Journal of Psychiatry, 157,* 275-277. https://doi.org/10.1176/appi.ajp.157.2.275
- Elvevag, B., & Goldberg, T. E. (2000). Cognitive impairment in schizophrenia is the core of the disorder. *Critical Reviews in Neurobiology, 14.* https://doi.org/10.1615/CritRevNeurobiol.v14.i1.10
- Jonas, K., Lian, W., Callahan, J., Ruggero, C. J., Clouston, S., Reichenberg, A., Carlson, G. A., Bromet, E. J., & Kotov, R. (2022). The course of general cognitive ability in individuals with psychotic disorders. *JAMA Psychiatry, 79,* 659-666. https://doi.org/10.1001/jamapsychiatry.2022.1142
- Keefe, R. S. E., & Fenton, W. S. (2007). How should DSM-V criteria for schizophrenia include cognitive impairment? *Schizophrenia Bulletin, 33,* 912-920. https://doi.org/10.1093/schbul/sbm046
- Keefe, R. S. E., & Harvey, P. D. (2012). Cognitive impairment in schizophrenia. In M. Geyer & G. Gross (Eds.), *Handbook of experimental pharmacology: Novel antischizophrenia treatments (Vol. 213).* Springer. https://doi.org/10.1007/978-3-642-25758-2_2
- Pantelis, C., Barnes, T. R., Nelson, H. E., Tanner, S., Weatherley, L., Owen, A. M., & Robbins, T. W. (1997). Frontal-striatal cognitive deficits in patients with chronic schizophrenia. *Brain, 120,* 1823-1843. https://doi.org/10.1093/brain/120.10.1823
- Schaefer, J., Giangrande, E., Weinberger, D. R., & Dickinson, D. (2013). The global cognitive impairment in schizophrenia: Consistent over decades and around the world. *Schizophrenia Research, 150,* 42–50. https://doi.org/10.1016/j.schres.2013.07.009

Sleep

Research suggests a relationship between sleep and cognition, outlined primarily in a large-scale study that found cognitive performance measured by the Creyos battery was lower in individuals deviating from 7-8 hours of sleep per night (Wild et al., 2018).

- Dewald-Kaufmann, J. F., Oort, F. J., & Meijer, A. M. (2013). The effects of sleep extension on sleep and cognitive performance in adolescents with chronic sleep reduction: An experimental study. *Sleep Medicine, 14,* 510-517. https://doi.org/10.1016/j.sleep.2013.01.012
- Fang, Z., Ray, L. B., Houldin, E., Smith, D., Owen, A. M., & Fogel, S. M. (2020). Sleep spindle-dependent functional connectivity correlates with cognitive abilities. *Journal of Cognitive Neuroscience, 32,* 446-466. https://doi.org/10.1162/jocn_a_01488

- Fang, Z., Smith, D. M., Houldin, E., Ray, L., Owen, A. M., & Fogel, S. (2022). The relationship between cognitive ability and BOLD activation across sleep–wake states. Brain Imaging and Behavior, 16, 305-315. https://doi.org/10.1007/s11682-021-00504-w
- García, A., Del Angel, J., Borrani, J., Ramirez, C., & Valdez, P. (2021). Sleep deprivation effects on basic cognitive processes: Which components of attention, working memory, and executive functions are more susceptible to the lack of sleep? *Sleep Science, 14,* 107. https://doi.org/10.5935/1984-0063.20200049
- Gobin, C. M., Banks, J. B., Fins, A. I., & Tartar, J. L. (2015). Poor sleep quality is associated with a negative cognitive bias and decreased sustained attention. *Journal of Sleep Research, 24,* 535-542. https://doi.org/10.1111/jsr.12302
- Smith, D., Fang, Z., Thompson, K., & Fogel, S. (2020). Sleep and individual differences in intellectual abilities. *Current Opinion in Behavioral Sciences, 33,* 126-131. https://doi.org/10.1016/j.cobeha.2020.02.011
- van den Berg, N. H., Benoit, A., Toor, B., & Fogel, S. (2019). Sleep stages and neural oscillations: A window into sleep's role in memory consolidation and cognitive abilities. *Handbook of Behavioral Neuroscience, 30,* 455-470. https://doi.org/10.1016/B978-0-12-813743-7.00030-X
- Wild, C. J., Nichols, E. S., Battista, M. E., Stojanoski, B., & Owen, A. M. (2018). Dissociable effects of self-reported daily sleep duration on high-level cognitive abilities. *Sleep, 41,* zsy182. https://doi.org/10.1093/sleep/zsy182

Stress

It is important to distinguish multiple aspects of stress, including (1) acute stress (short-term or induced in a lab setting), (2) perceived stress (everyday life stressors), and (3) chronic stress (long-term), as the effect of stress on cognition depends on the type of stress endured. For example, acute high stress may impair response inhibition or working memory; however, milder forms of stress may actually improve task performance and some aspects of memory in certain situations. Long-term perceived stress may also impair aspects of memory such as episodic and spatial working memory, although effects are context- and patient-dependent. For PTSD, see the separate entry in this guide. The Perceived Stress Scale (PSS) questionnaire, also available in Creyos Health, can be used to gather self-report data that complement cognitive assessments.

- Alomari, R. A., Fernandez, M., Banks, J. B., Acosta, J., & Tartar, J. L. (2015). Acute stress dysregulates the LPP ERP response to emotional pictures and impairs sustained attention: Time-sensitive effects. *Brain Sciences, 5,* 201-219. https://doi.org/10.3390/brainsci5020201
- Henderson, R. K., Snyder, H. R., Gupta, T., & Banich, M. T. (2012). When does stress help or harm? The effects of stress controllability and subjective stress response on Stroop performance. *Frontiers in Psychology, 3,* 179. https://doi.org/10.3389/fpsyg.2012.00179
- Hoffman, R., & Al'Absi, M. (2004). The effect of acute stress on subsequent neuropsychological test performance (2003). *Archives of Clinical Neuropsychology, 19,* 497-506. https://doi.org/10.1016/j.acn.2003.07.005
- Human, R., Thomas, K. G., Dreyer, A., Amod, A. R., Wolf, P. S., & Jacobs, W. J. (2013). Acute psychosocial stress enhances visuospatial memory in healthy males. *South African Journal of Psychology, 43,* 300-313. https://doi.org/10.1177/0081246313496913
- Lewis, R. S., Nikolova, A., Chang, D. J., & Weekes, N. Y. (2008). Examination stress and components of working memory. *Stress, 11,* 108-114. https://doi.org/10.1080/10253890701535160
- Payne, J., Jackson, E., Ryan, L., Hoscheidt, S., Jacobs, J., & Nadel, L. (2006). The impact of stress on neutral and emotional aspects of episodic memory. *Memory, 14,* 1-16. https://doi.org/10.1080/09658210500139176
- Romero-Martínez, Á., Hidalgo-Moreno, G., & Moya-Albiol, L. (2020). Neuropsychological consequences of chronic stress: The case of informal caregivers. *Aging & Mental Health, 24,* 259-271. https://doi.org/10.1080/13607863.2018.1537360
- Shields, G. S., Sazma, M. A., McCullough, A. M., & Yonelinas, A. P. (2017). The effects of acute stress on episodic memory: A meta-analysis and integrative review. *Psychological Bulletin, 143,* 636-675. https://doi.org/10.1037/bul0000100
- Tschanz, J. T., Pfister, R., Wanzek, J., Corcoran, C., Smith, K., Tschanz, B. T., ... & Norton, M. C. (2013). Stressful life events and cognitive decline in late life: Moderation by education and age. The Cache County Study. International *Journal of Geriatric Psychiatry, 28,* 821-830. https://doi.org/10.1002/gps.3888
- Turner, A. D., James, B. D., Capuano, A. W., Aggarwal, N. T., & Barnes, L. L. (2017). Perceived stress and cognitive decline in different cognitive domains in a cohort of older African Americans. *The American Journal of Geriatric Psychiatry, 25,* 25-34. https://doi.org/10.1016/j.jagp.2016.10.003
- Vedhara, K., Hyde, J., Gilchrist, I. D., Tytherleigh, M., & Plummer, S. (2000). Acute stress, memory, attention and cortisol. *Psychoneuroendocrinology, 25,* 535-549. https://doi.org/10.1016/S0306-4530(00)00008-1

Stroke

Stroke often leads to cognitive symptoms. The nature of impairments may depend on the type of stroke, the parts of the brain affected, severity, and other symptoms experienced (such as spatial neglect). See sections on brain injury and concussion for additional information about impairments directly attributable to brain damage.

- Ganesh, A., & Barber, P. A. (2022). The cognitive sequelae of transient ischemic attacks—recent insights and future directions. *Journal of Clinical Medicine, 11,* 2637. https://doi.org/10.3390/jcm11092637
- Lee, B. H., Kim, E. J., Ku, B. D., Choi, K. M., Seo, S. W., Kim, G. M., ... & Na, D. L. (2008). Cognitive impairments in patients with hemispatial neglect from acute right hemisphere stroke. *Cognitive and Behavioral Neurology, 21,* 73-76. https://doi.org/10.1097/WNN.0b013e3181772101
- Madureira, S., Guerreiro, M., & Ferro, J. M. (2001). Dementia and cognitive impairment three months after stroke. *European Journal of Neurology, 8,* 621-627. https://doi.org/10.1046/j.1468-1331.2001.00332.x
- Schmidt, W. P., Roesler, A., Kretzschmar, K., Ladwig, K. H., Junker, R., & Berger, K. (2004). Functional and cognitive consequences of silent stroke discovered using brain magnetic resonance imaging in an elderly population. *Journal of the American Geriatrics Society, 52,* 1045-1050. https://doi.org/10.1111/j.1532-5415.2004.52300.x

Youth Battery

The tasks included in the youth battery are most appropriate for younger children. In a study with children aged 4 to 11 with and without neurodevelopmental disorders, these tasks were well received by most children. Younger children (4-6) may require additional explanation of the rules and a demonstration of how to input their answers. Children may also be susceptible to losing focus over time, so shorter batches of 4 to 6 tasks at a time are recommended.

- De Waelle, S., Laureys, F., Lenoir, M., Bennett, S. J., & Deconinck, F. J. A. (2021). Children involved in team sports show superior executive function compared to their peers involved in self-paced sports. *Children, 8,* 264. https://doi.org/10.3390/children8040264

- Jackson, R., & Wild, C. J. (2021). Effect of the Brain Balance Program® on cognitive performance in children and adolescents with developmental and attentional issues. *Journal of Advances in Medicine and Medical Research, 33,* 27-41. https://doi.org/10.9734/jammr/2021/v33i630857
- Laureys, F., Collins, D., Deconinck, F. J. A., & Lenoir, M. (2023). Executive functions and psycho-behavioural skills in artistic gymnasts: Age, developmental stage and sex-related differences. *International Journal of Sport and Exercise Psychology.* https://doi.org/10.1080/1612197X.2023.2180069