

Title: Training of working memory in children with ADHD

PI: Torkel Klingberg, M.D., Ph.D.

Institution: Karolinska Institute

Published: Journal of Clinical & Experimental Neuropsychology, November 2002

Summary: This was the first published research on working memory training and included separate small sample studies of children with ADHD and healthy adults. A randomized-controlled design was used. Results indicated improvements on non-trained tasks of working memory as well as on several other neuropsychological tests. The study is important in that it is the first indication that working memory capacity can be increased with training. Limitations include the small sample size, the lack of behavioral measures, and no longer-term follow-up.

Reference: Klingberg T, Forssberg H, Westerberg H (2002) Training of working memory in children with ADHD. *J Clin Exp Neuropsych* 24:781-791.

Title: Computerized training of working memory in children with ADHD – A randomized, controlled, trial

PI: Torkel Klingberg, M.D., Ph.D.

Institution: Karolinska Institute

Published: Journal of American Academy of Child and Adolescent Psychiatry, February 2005

Summary: This was a randomized-controlled study of working memory training in 53 children diagnosed with ADHD, i.e., a replication of the 2002 study with a substantially larger sample. Results indicated significant gains in non-trained measures of working memory, non-verbal reasoning, and response inhibition. In addition, significant reductions in parent ratings of ADHD symptoms were found, although comparable reductions in teacher ratings were not evident. Gains evident immediately after the training ended were largely intact 3-months later.

Reference: Klingberg T, Fernell E, Olesen P, Johnson M, Gustafsson P, Dahlström K, Gillberg CG, Forssberg H, Westerberg H (2005) Computerized Training of Working Memory in Children with ADHD – a Randomized, Controlled, Trial. *J American Academy of Child and Adolescent Psychiatry* 44 (2):177-186.

PI: Lisa Thorell

Institution: Karolinska Institute

Published: Developmental Science, December 2008

Summary: This study examined the impact of visuo-spatial working memory training in 63 typically developing 4-5 year-old children. Participants were randomly assigned to working memory training or to a video game condition that controlled for simply working on a computer. Results indicated that working memory training yielded significant benefits in non-trained measures of attention and both verbal and visuo-spatial of working memory. Behavioral ratings were not collected, which is a study limitation. The study is important in that it suggests that visuo-spatial working memory training may enhance verbal and visuo-spatial working memory and attention in young children, functions that are critically important for academic success.

Reference: Thorell L B, Lindqvist S, Bergman S, Bohlin G, Klingberg T (2008) Training and transfer effects of executive functions in preschool children. *Developmental Science*, 11(6): 969–976.

Title: Adaptive training leads to sustained enhancement of poor working memory in children

PI: Joni Holmes, Ph.D.

Institution: University of York

Published: Developmental Science, April 2009

Summary: Forty-two children screened for working memory deficits were randomly assigned to high or low intensity training conditions. Children receiving high intensity working memory training (this is the standard training protocol) showed significant gains on several non-trained measures of working memory that remained evident at 6 months. They also showed improved on a 'real world' measure of listening skills. Furthermore, 6 months after training ended, significant gains in a measure of math achievement had emerged. The study is important because it was another independent replication of Cogmed training and the first to demonstrate that working memory training can produce gains on a standardized measure of academic achievement.

Reference: Holmes J, Gathercole S E, Dunning D L (2009) Adaptive training leads to sustained enhancement of poor working memory in children. *Developmental Science*, April, 2009.

Title: Working memory deficits can be overcome: Impacts of training and medication on working memory in children with ADHD

PI: Joni Holmes, Ph.D.

Institution: University of York

Published: Applied Cognitive Psychology, April 2009

Summary: This study examined the impact of medication treatment and Cogmed Working Memory Training on the working memory performance and IQ of 25 8-11-year old children with ADHD. Children's working memory performance was assessed 4 times – when they were off medication, when they were on medication, after completed 5-weeks of working memory training, and 6 months after training ended. IQ was measured at the first 3 time points. Results indicated that medication treatment improved performance on visuo-spatial working memory, but not on verbal short-term memory, visuo-spatial short-term memory, or verbal working memory. In contrast, working memory training led to significant gains on all 4 memory tasks and moved children's performance into the average range. No impact on IQ was found for either intervention. Follow-up data collected 6 months later indicated that training gains in working memory had persisted. The study is important because it demonstrates that working memory training leads to gains in this key function beyond any provided by medication and that these gains persist after training has ended.

Reference: Holmes J, Gathercole S E, Place M, Dunning D L, Hilton K A, Ellito J G (2009) Working memory deficits can be overcome: Impacts of training and medication on working memory in children with ADHD. Applied Cognitive Psychology, July 2009.

Title: Computer Training of Working Memory for Children with ADHD: A School-Based Feasibility Pilot Study

PI: Enrico Mezzacappa, M.D.

Institution: Harvard University

Published: School Mental Health, February 2010

Summary: This study was conducted by researchers at Children's Hospital, Harvard University. 8 children from one school in a low SES environment, all qualified for free breakfast and lunch at school, trained with Cogmed RM at school for five weeks. After training they improved significantly on measures of verbal and visuo-spatial working memory and symptoms of ADHD as rated by teachers decreased. This study is important in that the training took place in a school setting.

Reference: Mezzacappa E, Buckner J (2010) Working Memory Training for Children with Attention Problems or Hyperactivity: A School-Based Pilot Study. School Mental Health.

Title: Effects of working memory training on reading in children with special needs

PI: Karin Dahlin

Institution: Stockholm University

Published: Reading and Writing, May 2010

Summary: This study examined the efficacy of Cogmed training in improving reading comprehension development in 57 Swedish children with special needs. The study showed specific improvements in reading comprehension. The researchers concluded that “the training of working memory may be useful for children with reading comprehension problems, special-education needs, and attention problems”. The researchers also concluded that screening for working memory deficits would be valuable for identifying those at risk to struggle academically.

Reference: Dahlin K (2010) Effects of working memory training on reading in children with special needs. Reading and Writing, May 2010.

Title: A Controlled Trial of Working Memory Training for Children and Adolescents with ADHD

PI: Steven Beck, Ph.D.

Institution: Ohio State University

Published: Journal of Clinical Child & Adolescent Psychology, November 2010

Summary: This study examined the efficacy of Cogmed training on 52 children with ADHD and other comorbid diagnoses. The children ranged in age from 7-17 and all attended a private school for children with ADHD and other learning disabilities. The researchers found significant improvement in ADHD symptoms and executive functions as well as inattention, organization, and working memory. This improvement was noted, in addition to various neuropsychological assessments, by rating scales filled out by both the parents and the teachers of the participants. The researchers concluded that Cogmed training may be effective in improving core cognitive deficits underlying ADHD and thus improve ADHD symptoms.

Reference: Beck S, Hanson C, Puffenberger S, Benninger K, Benninger W (2010) A Controlled Trial of Working Memory Training for Children and Adolescents with ADHD. Journal of Clinical Child & Adolescent Psychology, November 2010.

Title: A Controlled Trial of Working Memory Training for Children and Adolescents with ADHD

PI: Gro Løhaugen

Institution: St. Olav's University Hospital, Trondheim, Norway

Published: The Journal of Pediatrics, December 2010

Summary: This study examined the efficacy of Cogmed training on children and adolescents who were born preterm with extremely low birth weight (ELBW). These children usually have a working memory deficit which contributes to the problems they have later in life. The results showed that the children examined were able to improve non-trained working memory tasks following the program. They also found the training to generalize to verbal learning ability and that the results remained stable six months after training. The researchers concluded that Cogmed was an "effective intervention tool for improving memory and reducing core learning deficits in adolescents born at ELBW".

Reference: Løhaugen GC, Antonsen I, Håberg A, Gramstad A, Vik T, Brubakk AM, Skranes J (2010) A Controlled Trial of Working Memory Training for Children and Adolescents with ADHD. The Journal of Pediatrics, December 2010.

Title: Working Memory Training for Children with Cochlear Implants: A Pilot Study

PI: William Kronenberger, Ph.D.

Institution: Indiana University

Published: Journal of Speech, Language, and Hearing Research

Summary: This study investigated the efficacy of Cogmed training for improving memory and language skills in a sample of deaf children with cochlear implants (CIs). The study examined 9 children ages 7-15 and results showed significant improvement on measures of verbal and nonverbal working memory, parent-reported working memory behavior, and sentence repetition skills. The study included a six month follow up which showed a slight drop in working memory, but continued improvement in sentence repetition.

Reference: Kronenberger WG, Pisoni DB, Henning SC, Colson BG, Hazzard LM (2010) Working Memory Training for Children with Cochlear Implants: A Pilot Study. Journal of Speech, Language, and Hearing Research, December 2010.