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**INTERVENTIONS FOR WORKING MEMORY DEFICITS**

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For individuals with impaired working memory a number of actions can be of help. Firstly, there are interventions designed to reduce the load on working memory, such as customized education. Secondly, there are interventions that aim at enhancing working memory, such as working memory training. These two types of interventions can often be a great complement to each other and it is important to bear in mind that what may have a positive effect for a certain person with working memory difficulties may not have positive effects for another.

*TABLE 1: EXAMPLES OF INTERVENTIONS AIMING AT COMPENSATING FOR WORKING MEMORY DEFICITS*

INTERVENTION	FOR WHOM?	READING TIPS/ARTICLES
Adapted pedagogy	All children with poor working memory	Gathercole, S. E., Alloway, T. P. (2008). Working Memory and Learning. A Practical Guide for Teachers. London: SAGE Publications.  <a href="http://www.york.ac.uk/res/wml/">www.york.ac.uk/res/wml/</a>
Special aids (e.g. calendar/organiser and weekly schedule)	Children and adults	Barkley, R. A., Benton, C. M. (2010). Taking Charge of Adult ADHD: New York. The Guilford Press.  <a href="http://www.ldonline.org">www.ldonline.org</a>
Parent training programs (e.g. COPE)	Parents who want tools to understand and handle their children's behaviour.	Cunningham, C. (2005). A large group community based family systems approach to parent training. In Attention-Deficit Hyperactivity Disorder. A Handbook for Diagnosis and Treatment. 2nd edition Ed. Barkley, R. New York: The Guilford Press.
Cognitive behavioural therapy for ADHD-symptoms	Adults diagnosed with ADHD	Safren, S. A, Perlman C. A, Sprich, S & Otto, M, W. (2005) Mastering your Adult ADHD – a Cognitive Behavioral Treatment Program. Oxford University Press*

\* The book is written for psychologists/therapists.

**TABLE 2: EXAMPLE OF INTERVENTIONS THAT CAN IMPROVE WORKING MEMORY AND/OR RELATED FUNCTIONS**

INTERVENTION	FOR WHO?	READING TIPS/ARTICLES
Medicine* (Methylphenidate and atomoxetine)	Children and adults diagnosed with ADHD	Information about ADHD and treatment can be found e.g. here:  <a href="http://www.helpguide.org">www.helpguide.org</a>  <a href="http://www.adhdnews.com">www.adhdnews.com</a>
Working memory training	Children and adults with poor working memory	Klingberg T, Fernell E, Olesen PJ, Johnson M, Gustafsson P, Dahlström K et al. Computerized training of working memory in children with ADHD – a randomized, controlled trial. <i>J Am Acad Child Adolesc Psychiatry</i> 2005;44(2):177-86.  Ivarsson, M., Strohmayer, S. (2010). Working memory training improves arithmetic skills and verbal working memory capacity in children with ADHD. Master’s thesis. Stockholm. Stockholm University.
Non-computerized training of attention and memory functions (e.g. SMART*)	Children with specific attention and memory difficulties	van't Hooft, I., Andersson, K., Bergman, B., Sejersen, T., von Wendt, L., Bartfai, A. (2007) A randomized controlled trial on children with acquired brain injuries reveals sustained favorable effects of cognitive training. <i>Neurorehabilitation</i> , 22, 109-116.

\*Does not primarily aim at enhancing working memory ability.

There are a number of other factors in addition to those mentioned above that profoundly affects one's ability to concentrate and one's working memory capacity, whether you have been diagnosed with ADHD or not, such as diet, sleep, exercise and stress.



*SLEEP CAN HAVE A BIG IMPACT ON OUR WORKING MEMORY CAPACITY*

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## RESEARCH AND EXPERIENCES OF WORKING MEMORY TRAINING

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The following sections presents an overview of research on working memory training and experiences of the computer programs in the Memory Quest series.

### RESEARCH ON WORKING MEMORY TRAINING

Research results from recent years indicate that the brain's plasticity and the effects of cognitive training are larger than has previously been believed. The previously dominant view of most researchers has been that cognitive training would lead to improved ability in the specific task alone and only in connection with the training of the specific task. In recent years, however, several different types of training that involve working memory have been shown to have transfer effects, i.e. effects on abilities other than those trained. Working memory training has resulted in improvements in e.g. problem-solving skills and mathematical ability. However, relatively little research has been conducted thus far regarding the long-term effects of working memory training. Studies have shown effects remaining up to one and half years after completion of training.

#### "THE RIGHT AMOUNT OF RESISTANCE"

In a randomized controlled trial by Torkel Klingberg et.al. at the Karolinska Institute (2005) the effects of working memory training for children 7-12 years with ADHD were explored. Children in both treatment and control group trained for about 40 minutes a day, five days a week, for a total of five weeks. In the treatment group the difficulty of the working memory training was adapted automatically based on the children's performance, while the control group performed working memory exercises with a constant low level of difficulty.

The study showed that the treatment group significantly improved their performance, in comparison with the control group, on tests measuring verbal and visual working memory, response inhibition and problem solving. A very interesting finding in this study was the importance of difficulty adjustment for the training to have an effect. We can make a very simplified analogy with the exercise of our muscles in the body. If we do weight lifting in order to get enhanced strength in the biceps and for stronger arms it is not enough that we use a machine to exercise and that we do it regularly. It

also requires that we use the right weights and that we gradually increase the resistance/weight if we want the muscles to continue to grow.

### "THE RIGHT TOOLS"

In a recent study Lisa Thorell et.al. (2009) compared inhibition training (exercises to reduce impulsivity), with working memory training for pre-school children who were 4-5 years old. Inhibition training consisted of several types of exercises. In two of the exercises the task was to provide an answer for a certain type of stimulus (fruit) and to refrain from giving answers when other stimuli such as animals were presented. In two further exercises the task was to give an answer as quickly as possible when a fruit was shown, but not if a stop signal appeared immediately after. In the last exercise a number of arrows were shown in a row and the children's task was to press the arrow on the keyboard corresponding to the direction of the arrow that was presented in the middle. In both the inhibition and the memory training groups the level of difficulty of the exercises was adapted based on the performance of the children.

The results showed that working memory training led to improvements in working memory tests (including non-verbal trained) and attention. No improvement was seen, however, as a result of inhibition training. Returning to the analogy of weight lifting, this study showed that it is not just about work out over time and with the right weight but also that it must be a "machine" that involves the correct muscles if we want to have an effect.

### "SUFFICIENT TIME"

In a study from 2008 led by the Swiss researcher Susanne Jaeggi it was shown that working memory training can improve adults' performance on intelligence tests. The study also showed that the improvement on the tests appears to depend on the "dose", i.e. more days (19 days) of working memory training resulted in greater improvements in intelligence tests than fewer (8 days). If we return to the weight lifting analogy once again, this study showed that it is not just about using the right tool and right weights, but also the need to train a sufficient number of times to get the best results possible.



## EXPERIENCES OF MEMORY QUEST

As developers of the Memory Quest software we have been active in the two biggest evaluations of the software that have been made so far. Brief summaries of the evaluations are found in the next section.

### SMALLER GROUP, BETTER EFFECT

During the autumn of 2007 and spring of 2008 an evaluation of Memory Games Junior (a predecessor to Memory Quest) was made on 55 school children who were 7-9 years old. The children in the study were randomly divided into control and training groups with performance evaluated with Raven's Matrices, a non-verbal intelligence test. The children in the exercise group trained with Memory Games for about 5 weeks in groups of varying size (between 2 and 8 children).

The evaluation showed that the training group significantly improved their performance, in comparison with the control group, on verbal and spatial working memory tests. The evaluation also revealed that the children who trained in pairs improved more than those who trained in larger groups. The study indicated that training with Memory Games seems to work better when fewer children train at the same time with a single coach, for the explored age group.

## IMPROVED ARITHMETIC SKILLS

From autumn 2009 to spring 2010 we carried out an evaluation of Memory Games Senior (a predecessor to Memory Quest) on 21 children 6-10 years of age with ADHD. The children in the study were randomly divided into either a control or training group. All children trained for at least 20 days with a computer program at home, with their parents as coaches (children in the control group used a reading training program). Before and after the start of training the children were tested on various aspects of working memory. The children were also assessed with a series of tests measuring academic skills such as arithmetic and word decoding. Finally, a rating scale was used where the parents of the children were to assess the presence of ADHD symptoms in their children.

The children in the exercise group significantly improved their performance, in comparison with the control group, on tests measuring verbal working memory and arithmetic skills. In addition, parents rated a significant reduction in ADHD symptoms, both in terms of attention difficulties and hyperactivity/impulsivity. The decrease was not significantly greater in the exercise group than in the control group.

To summarize the evaluation indicated that training with Memory Games had a positive effect on mathematical ability and working memory capacity in children with ADHD.

