Cogmed Working Memory Training

– Research Evidence for the Improvement of

Working Memory and Attention

Summary

Working memory (WM) is a key cognitive ability, necessary for control of attention and academic performance. Cogmed Working Memory Training (CWMT) is a researched-based, systematic method for improving WM through computerized training. The improvements after CWMT transfers to non-trained WM tasks, an effect equivalent of about 2 years of normal childhood development. The effect on attention is documented in healthy adults as well as in patient groups, including long-term follow-up studies. In particular, the clinical research has documented improvement of the key inattentive symptoms in:

- **Children with ADHD**
- **Children who have received cancer treatment**
- **Adults after stroke**

Improvements in mathematics has been documented in several trials, but is larger in typically developing children than in children with WM impairments. There are now more than 120 studies of CWMT, by independent research groups around the world, which makes it the most well-researched, method of improving WM and attention.

What is Working Memory?

Working Memory (WM) is our ability to keep information online. We use WM to keep plans for what to do next, or to keep relevant information in mind when solving problems. WM is closely related to control of attention, and these abilities make use of partly the same regions the parietal and prefrontal cortex in the brain (Ikkai and Curtis, 2010), areas that are targeted by CWMT (Olesen et al., 2004). One way to put it is that we use WM to remember what to focus on.

All individuals vary in their WM capacity. A low WM can be hereditary, linked to environmental effects such as stress, or caused by injury to the brain. Many diagnoses and clinical conditions are associated with low WM and attention deficits, including ADHD, ADD, traumatic brain injury, premature birth, stroke and cancer treatment.

The results of an impaired WM are similar, independent of the cause: an inability to remember plans and instructions, inability to pay attention task at hand in everyday life which is often perceived as the individual being distracted. This is especially pronounced during mentally demanding situations. In children, WM deficits are associated with academic problems in both reading and mathematics.

Cogmed Improves Working Memory Capacity and Attention

Cogmed is based on research showing that WM capacity can be increased through training. This was originally shown in studies from the Karolinska Institute (Klingberg et al., 2002; Klingberg et al., 2005), and has now been replicated by independent research groups around the world. There are now more than 120 published studies of CWMT.

The key finding is that WM capacity is improved not only for the tasks that are part of the training program, but also for tasks that are dissimilar. For example, studies at Cambridge University, UK and Karolinska Institute, Sweden, show that CWMT improves the ability of children to remember and perform long and WM-demanding verbal instructions, a task that is highly relevant in daily life (Holmes et al., 2009a; Bergman-Nutley and Klingberg, 2014). Another example is transfer to a test battery (Automated WM Assessment) developed to specifically measure complex WM (Holmes et al., 2009b; Carlson-Green et al., 2017; Peers et al., 2020). A third example is improved ability to keep in mind, update and add digits (The Paced Auditory Serial Addition Task), a task not part of the training (Westerberg et al., 2007; Lundqvist et al., 2010; Brehmer et al., 2012). Taken together, this means that CWMT **training transfers to non-trained WM tasks.**

A summary of the improvements in 12 CWMT studies, found significant, long-lasting improvements in WM task performance, which was 0.7 standard deviations compared to the control groups (Spencer-Smith and Klingberg, 2015). This is larger than the effect of physical exercise on cognition (Verburgh et al., 2014), or of stimulant medication on WM capacity (Roberts et al., 2020).

Another way to illustrate the impact on cognition is to compare it to years of development. When children grow older, their WM improves with around 0.25 SD per year for a 10-year old child (Ullman et al., 2014). The 0.7 SD deviation **improvement from CWMT is comparable to at least 2 years of normal development**.

Because WM and attention are closely related (Lui and Tannock, 2007; Ikkai and Curtis, 2010), we would expect that improvement of WM would also lead to improvements in attention in neuropsychological tasks as well as in everyday life.

In a meta-analysis of 12 CWMT studies, improvement in attentive behavior in every-day life was documented independent of diagnosis and age, an effect that was retained at follow-up (Spencer-Smith and Klingberg, 2015). This includes a study in 100 healthy young and older adults with significant improvements documented with both neuropsychological tests and questions about attention problems in everyday life (Brehmer et al., 2012).

The mean effect size of this improvement (d = 0.4) is stronger than, for example, the effects of SSRI on depression (Kirsch et al., 2008).

Cogmed WM Training Improves Attention in Children with ADHD

Clinical studies has mainly been focused on ADHD. Table 1 summarizes six published studies (Klingberg et al., 2005; Gropper and Tannock, 2009; Beck et al., 2010; Green et al., 2012; Egeland et al., 2013; Bigorra et al., 2015), documenting how CWMT improves attention in ADHD, compared to control groups. Five studies are from children, one from adults. The questions used for estimating attention are similar or identical to those used to diagnose inattention problems, in school and at home, in ADHD. This means that **CWMT transfers to better attention in everyday life in children with ADHD.** One of the largest studies, by Bigorra and collaborators, from the University Hospital in Barcelona, concluded:

> *"CWMT had a significant impact on ADHD deficits by achieving long-term far-transfer effects."*

Study	N	Age	Ctrl group	Inattention sx
Klingberg, et al. (2005)	53	7-12	Active	DSM-IV inatt d = 0.7
Beck, et al. (2010)	52	7-17	Wait-list	DSM-IV d = 0.76
Green et al. (2012)	26	7-14	Active	RAST off-task d = 1.2
Egeland 2013	67	10-12	Wait-list	ARS attention d = 0.5 (par) 0.4 (teach) ns
Gropper et al. (2014)	62	19-52	Wait-list	ASRS d = 0.42
Bigorra et al. (2015)	66	7-12	Active	ADHD composite score d = 0.39 (par) 0.69 (teach)

Table 1. Controlled studies showing improved attention in children with ADHD. DSM-IV = diagnostic questions of inattention symptoms from the Diagnostic and Statistical Manual, version 4; RAST=restricted academic setting task.

There has been one larger study that did not find a similar effect (Chacko et al., 2014). This study included children from low SES regions, where a majority had Oppositional Defiant Disorder. Therefore, we do not recommend CWMT if ODD is part of the problem. CWMT is more likely to succeed in individuals where the deficit in WM and attention is the main problem.

Cogmed Enhances Working Memory and Attention in Children Treated for Cancer

Children who has been treated with cytostatic and/or radiation therapy towards the brain suffer cognitive problems due to the effect of treatment on the growing brain. Impaired working memory is a key component, associated with inattention and lower academic performance.

A series of studies from George Washington University School of Medicine, Washington and St Jude Children's Research Hospital, Memphis has evaluated CWMT in controlled studies and found significant, long-lasting improvements in WM and attention, including cognitive symptoms in everyday life (Hardy et al., 2013; Conklin et al., 2015; Carlson-Green et al., 2017; Conklin et al., 2017) (Table 2). In addition, they noted significant improvements in learning. Dr. Heather Conklin et al (2015) concluded their research paper:

"Study findings show computerized cognitive training is feasible and efficacious for childhood cancer survivors, with evidence for training-related neuroplasticity."

Study	N	Age	Ctrl group	Inattention sx	Other behavior	Cognition
Hardy 2012	20	8-16	Active Randomized	CPRS-3 inatt. d = 0.4	CPRS-3 Learning d = 0.8	WRAML2 d = 0.9
Conklin 2015	68	10-14	Waitlist Randomized	CPRS inatt d = 0.7	CPRS-3 Exec funct d = 0.8	WISC d = 0.8
Conklin 2017	62	10-14	Waitlist Randomized	CPRS. Effects maintained at 6 m	Effects maintained at 6 m.	Effects maintained at 6 m.
Carlsson-Green 2017	20	8-18	No ctrl group	CBCL 6 m. after intervention	BRIEF p<0.01 6 m. after intervention	AWMA WJ-III math

Table 2. Studies of pediatric cancer. CPRS = Conner's Parents Rating Scale.

Cogmed Enhances Working Memory and Attention in Stroke Patients

Stroke often results in cognitive problems, where impaired WM is a key component. A series of studies has documented how CWMT improves cognitive performance in stroke patients, including up to 6 months follow-up measures (Westerberg et al., 2007; Lundqvist et al., 2010; Johansson and Tornmalm, 2012; Akerlund et al., 2013; Bjorkdahl et al., 2013; Peers et al., 2020). Åkerlund and collegues, from Department of Rehabilitation Medicine, Sahlgrenska University Hospital, Gothenburg, Sweden, concluded:

"Results indicated that computerized WM training can improve working memory,cognition and psychological health."

Study	N	Age	Ctrl group	Inattention	Other	Followup
Westerberg,et al (2007)	18	34-65	Wait-list, rnd	CFQ	PASAT, Ruff, WM	
Lundqvist et al. (2010)	21	20-65	Wait-list, rnd, xo	Occupational perf	PASAT, list span	4,20 w
Johansson et al. (2012)	18	17-64	No ctrl gr	CFQ, occup perf		6 month
Åkerlund et al. (2013)	47	22-63	Wait-list, rnd, xo	Psychological health	BNIS cog test	6, 18 w
Björkdahl et al. (2013)	47	22-63	Wait-list, rnd, xo	Cognitive question	Digit-span	6, 18 w
Peers et al. (2018)	23	28-74	Wait-list, rnd, xo	Core symptoms	AWMA, TVA	No follow

Table 3. Studies of adult stroke patients. CFQ = Cognitive Failure Questionnaire. PASAT = Paced Auditory Serial Addition, Task. AWMA = Automated WM Assessment.

Potential Relevance of CWMT for Academic Performance in Typically Developing Children

WM capacity is highly correlated with performance in mathematics and reading. But, in contrast to attention, these abilities are dependent on many other factors, including knowledge stored in long-term memory. It is therefore likely that they are more difficult to improve through WM training than attention.

There are several studies documenting improvements in mathematical performance after CWMT, the two largest being a study of 155 children with self-perceived WM and attention problems and 304 control children (Bergman-Nutley and Klingberg, 2014). Here, repeated tests of arithmetics in both groups showed a gradual improvement during the course of training compared to the control group.

A study of 572 typically developing children, randomized to training or teaching as usual, Berger et al. (Berger, 2020) found that mathematical improvement (geometry) directly after training, were modest (effect size 0.2), but when children were followed up with a test one year after intervention, the difference between intervention and control group had increased to 0.4, which is equivalent of about half a year of normal improvement in primary school and 1 year of improvement in secondary school. Berger et al. note that the improvement in mathematics after training is about twice as large improvement as seen after reducing number of students in each classroom.

There is also a study on failing to find improvements in mathematics (Roberts et al., 2016) which included children who were selected based on their low-WM (15th percentile). At this stage, a plausible hypothesis is that improvements in mathematics after CWMT is smaller than that of the effect on inattention, develops gradually and depends on the child's WM capacity, where the typical population gain more than children with low WM. Children with low WM likely will demand about twice as much training to have the same gains in mathematics as children with a typical WM capacity.

Berger and colleagues, from University of Meinz and Zurich, conclude their paper:

> *"We find not only substantial near transfer effects on WM capacity that emerge right after the five-week training period and last throughout all evaluation waves; we also find far transfer effects on several important skills—geometry, reading ability, a measure of fluid IQ, children's ability to inhibit pre-potent impulses, and teacher-rated self-regulation ability"*

> *"Moreover, these far-transfer effects emerge over time and only become fully visible after 12-13 months. Finally, we document that 3–4 years after the intervention, the children who received training have a roughly 16 percentage points higher probability of entering the academic track in secondary school."*

Methodological notes on effect sizes and power

In a meta-analysis of CWMT on ratings of attention an average effect size of 0.4 was found (Spencer-Smith and Klingberg, 2015). Assuming that this is representative a study needs to include at least 200 subjects (100 training and 100 control) to have adequate statistical power (>80% chance of finding an effect). Studies with 60 subjects (30 in each group) has a statistical power of around 0.35, i.e. we would expect that around 6-7 out of 10 studies do not find a p-value less than 0.05 even if the training effect is real. To have adequate power to detect an effect size of 0.3, around 350 subjects (175 in each group) is needed. Looking back at the last 20 years of studies about cognitive interventions, we can observe that most studies have been underpowered.

Research on the benefits of cognitive training, including CWMT, will continue for several years. But CWMT is at this point the most well researched training method in for improving WM and attention.

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