

## README FINAL DATA Working Memory and Dyslexia

The dataset contains all raw data and corresponding standard scores used for analyses considering the effect of Cogmed-working-memory training on reading and spelling in skills in children with dyslexia and low working memory. For a full description of the reading and spelling remediation program, the working memory-training, and all measures see below. The experiment design was a randomized controlled trial, using four moments of measurement for literacy skill and two moments of measurement for working memory skill, administered in a one-to-one assessment setting. Working memory skill was assessed just before working-memory training (T1) and after working-memory training (T1a). The pretest (T1) took place prior to all interventions. For reading and spelling skill, three follow-up measurements were administered after three (T2), six (T3), and nine (T4) months of reading and spelling remediation. In this document, the process of collecting data is described, followed by an overview and description of variables included in the data set.

### Context of the research

In this study, the potential benefits of working-memory training for children with dyslexia was investigated using Cogmed (see <http://www.cogmed.com/research>). The objective is to investigate to what extent Cogmed-working-memory training has a beneficial effect on the remediation process of children with dyslexia and low working-memory skills. Previous research has shown that working-memory skills can be boosted by a working-memory training (Söderqvist & Nutley, 2017). After all, Cogmed-working-memory training may enhance reading performance of children with dyslexia and low working-memory skills, as suggested by the following claim:

“A likely explanation to the findings indicating a growth in reading performance over time is that in those cases where an impaired working memory has been limiting performance in reading, effects are apparent in conjunction with the increases in working-memory capacity. However, for those where working memory has not acted as a bottleneck for applying current knowledge to performance, effects may not be evident immediately after training, but may emerge in the months following training as an increase in working-memory capacity enables more learning opportunities and more efficient practice” (Söderqvist & Nutley, 2017, p.16).

The main variables of interest were word decoding, text decoding, and spelling, because these skills are typically impaired in children with dyslexia. Working memory variables involved digit recall, backward-digit recall, and block recall. To limit design flaws, a treatment group (adaptive working memory-training), an active control group (fixed working memory-training), and a passive control group (passive working memory-control) were included. Also, to be able to detect delayed growth in performance discussed by Söderqvist and Nutley (2017), children were assessed on literacy-measures every three months during nine months of reading and spelling remediation.

### Data collection process

**How data were collected.** All assessments were conducted by doctoral school psychologists.

**Where data were collected.** Braams & Partners, a Dutch institute for the assessment and remediation of learning disorders.

**How participants were recruited.** Clients (i.e., participants) were registered for diagnosis and remediation by their parents (referred by their schools). If the pretest resulted in a severe singular dyslexia diagnosis, and parents wished to attend the reading and spelling remediation at Braams & Partners, parents were informed about the scientific research conducted at the institute. Before the child started the reading and spelling remediation program, they were asked permission for the use of their child's test scores and, if applicable, whether they were willing to participate in an additional preceding working memory-training. They were told that privacy was guaranteed. In case they wished not to join, their data were excluded. Less than 5% of selected participants refused to participate. In one case the working-memory training was aborted, because the child developed emotional problems during the training.

**Number of participants.** 62

**Inclusion criteria of participants.** Participants were selected according to a strict admission procedure prescribed by the so-called Protocol Dyslexie Diagnostiek en Behandeling [Protocol Dyslexia Diagnostics and Remediation] of Blomert (2006). This protocol has been accorded by the Dutch College of Health Insurance (College van Zorgverzekeringen) and was presented to the minister of Public health, Welfare, and Sports (Volksgezondheid, Welzijn en Sport). The criteria of the Dyslexia Protocol are: a) the participant attended or attends a Dutch primary school; b) the participant's results on a word-decoding test (i.e., Drie Minuten Toets, [Three Minute Test]; Jongen & Krom, 2009) are in the 10th percentile or participant's results on word-decoding tests are in the 16th percentile and results on spelling tests (Schaal Vorderingen Spellingvaardigheid [Scale for progress in spelling skills], see de Wijs, Kamphuis, Kleintjes, & Tomesen, 2010) are in the 10th percentile; c) the participant has received at least eight weeks of intensive and qualitative remediation, either individually or in a small group in the school, without showing significant improvement in reading and spelling (see criterion b); d) the participant does not suffer from another developmental disorder other than dyslexia, which entitles for payment otherwise.

The classroom teacher or remedial teacher at the school administered the tests described above and provided and evaluated the remediation program. Guidelines for the remediation program at school are accommodated for by the Protocol Leesproblemen en Dyslexie (Protocol Reading Difficulties and Dyslexia; Wentink & Verhoeven, 2003) and Protocol Leesproblemen en Dyslexie voor groep 5-8 (Protocol Reading Difficulties and Dyslexia for Grades 3 to 6; Wentink & Verhoeven, 2004).

The tests administered at the institute for learning disorders assessed whether criteria were met for severe dyslexia, and thus for reading and spelling remediation at the institute. The inclusion criteria were: 1) Intelligence quotient above 70 (based on recent or at most two year old WISC-III results); 2) participant's results on word decoding in the 10th percentile or participant's results on word decoding in the 15th percentile and results on spelling tests in the 10th percentile, 3) low scores (in the 10th percentile) on phonological processing tasks (two out of six measures) or, when phonological processing scores were above the 10th percentile, low scores on memory tasks for phonological stimuli (e.g., sounds and syllables).

On top of the severe-dyslexia criteria (which required persistent low scores on decoding and spelling tests), only children with low scores (i.e., more than one standard deviation below the mean) on a working-memory task (backward digit recall) were included.

**When data were collected.** The pretests took place in 2011, 2012, and 2013. Follow-up measures were administered after approximately three (follow-up 1), six (follow-up 2), and nine months (follow-up 3) of reading and spelling remediation.

**Reward for participation.** Participants did not receive any reward for participation.

### Additional information

**Sample size.** The experimental group consisted of 20 participants (10 girls and 10 boys), aged 7;5-12;0. The active control group consisted of 20 participants (10 girls and 10 boys), aged 7;5-11;4. The passive control group consisted of 22 participants (8 girls and 14 boys), aged 7;9-11;7.

**Randomization and masking.** Intelligence quotients (available for 53 participants) varied between 80 and 117 ( $M = 98.3$ ;  $SD = 9.6$ ). Participants, their parents, and reading specialists were not aware of the differences between groups.

#### **Intervention program.**

*Cogmed-working-memory-training programs.* The working memory-training consisted of the Cogmed-working-memory training program. In this study, the principle of adaptivity was only met for the adaptive working memory-training group (the consumer program of Cogmed-working-memory training is always adaptive). The principle of intensity was met for both the adaptive working memory-training group and the fixed working memory-training group. Also, the system of rewards for fulfilling the number of training sessions was used in both working memory-training groups.

The adaptive working memory-training group (treatment group) received a computer working-memory training (commercial software program named Cogmed RoboMemory) prior to reading and spelling remediation. The number of items to be remembered was adjusted to the performance of the participant. The fixed working memory-training group (active-control group) received a computer working-memory training in which the number of items to be remembered was fixed at three items per trial (software program provided by the publisher named Cogmed MegaMemory). Both working memory-training groups received an intake consult with the working memory trainer, 25 sessions of computerized working-memory training (during approximately 5 weeks, each session lasting 30-40 minutes), weekly phone consults with the working memory trainer, and a posttest. Participants received the software on a CD ROM and did the training sessions on their home computer. Parents were asked to supervise, observe, and coach their children during training sessions and a reward system was applied with a reward for every five fulfilled training sessions. Treatment fidelity was warranted by weekly phone consults with the working memory trainer. The working memory trainer checked the training results on an online interface that registered actions and results during all training sessions. During phone calls, progress and functioning were discussed with the child and the parent. The parent received information on how to coach their child in the next five sessions. Each session, both working memory-training groups had to perform eight out of thirteen working-memory tasks selected by the computer, which consisted of fifteen trials. The passive working memory-control group did not receive any training between the diagnostic phase and the reading and spelling remediation.

*Reading and spelling remediation.* The program was provided according to the recommendations of Blomert's (2006) Protocol Dyslexie Diagnostiek en Behandeling [Protocol Dyslexia Diagnostics and Remediation]. This 'best practice' remediation program is based at the premise that dyslexia as a specific-language-processing disorder is strongly associated with phonological skills. It targets both reading and spelling skills and links processing of speech sounds to processing of letters and words. The program consists of several modules manualized to the level of skills of the individual student, but protocolized by difficulty level in ascending order and based on letter-sound correspondence, regularities in orthography, and word structure. The level of difficulty is systematically increased by the program.

The children who participated in this study received instruction and practice once a week from a doctoral school psychologist at the institute for learning disorders for about 45 minutes with one of the parents attending. Instruction and practice (also manualized, based on a protocol) consisted of story reading (aloud), instruction on spelling categories, practicing word and sentence spelling, and coaching of the parent with homework assignments. Participants were asked to do homework assignments (reading and spelling exercises) together with their parents three to four times a week for about 30 minutes. Fidelity to homework assignments was a prerequisite for the remediation program: Children and parents who could not meet this criterion, were asked to use other opportunities to remediate reading and spelling. The length of the remediation program varied between 12 and 18 months (note that, for this study children were followed during the first nine months).

**Missing data.** Due to the clinical nature of the study, we had to deal with missing data. Participants sometimes happened to miss an assessment of one of the variables due to occasional circumstances; the number of participants therefore varied across analyses. Missing data are coded 999.

## Variables in data set

Concept	Names of variables in the dataset	Amount of variables per moment	Scale <sup>i</sup>	Note	Reference
Age	Age in months (T1_age_m)	1	0-144	months between birth and pretest	
Research group	Research group (rg)	1	3-5	3: Adaptive WMTG 4: Fixed WMTG 5: Passive WMCG	
Sex	Sex (sx)	1	1-2	1: male 2: female	
Grade	Education group (T1_eg)	1	3-8	Education group in primary school at pretest (group 3 corresponds to Grade 1)	
IQ	Total Intelligence Quotient WISC-III T1 (T1_wisc_tiq)	1	50-150		WISC-III: Wechsler, D. (2005). <i>WISC-III NL</i> . London: Harcourt Assessment.
Word decoding	Word decoding 1 T1 (T1_wd1_r; T1_wd1_d) Word decoding 2 T1 (T1_wd2_r; T1_wd2_d) Word decoding 3 T1 (T1_wd3_r; T1_wd3_d) Word decoding 4 T1 (T1_wd4_r; T1_wd4_c)	10	Raw score: 0-30 Total score: 0-90 Dae score: 0-60 <sup>ii</sup> C score: 0-9	_r: raw score _tot: sum of raw scores on word decoding 1, 2, and 3 _d: dae score _c: c-score T1: pre test T2: follow up after three months T3: follow up after six months T4: follow up after nine months	Word decoding 1-3: Jongen, I., & Krom, R. (2009). Drie Minuten Toets (DMT). [Three Minute Test]. Arnhem, the Netherlands: CITO. Word decoding 4: Brus, B. Th., & Voeten, M.J.M. (1972). <i>EenMinuutTest</i> . [One Minute Test] Nijmegen, the Netherlands: Berkhout.
	Word decoding 1 T2 (T2_wd1_r; T2_wd1_d) Word decoding 2 T2 (T2_wd2_r; T2_wd2_d) Word decoding 3 T2 (T2_wd3_r; T2_wd3_d) Word decoding 4 T2 (T2_wd4_r; T2_wd4_c)	10			

	Word decoding 1 T3 (T3_wd1_r; T3_wd1_d) Word decoding 2 T3 (T3_wd2_r; T3_wd2_d) Word decoding 3 T3 (T3_wd3_r; T3_wd3_d) Word decoding 4 T3 (T3_wd4_r; T3_wd4_c)	10			
	Word decoding 1 T4 (T4_wd1_r; T4_wd1_d) Word decoding 2 T4 (T4_wd2_r; T4_wd2_d) Word decoding 3 T4 (T4_wd3_r; T4_wd3_d) Word decoding 4 T4 (T4_wd4_r; T4_wd4_c)	10			
Text decoding	Text decoding T1 (T1_td_t)	1	48-290	Time in seconds, needed to read the 3A card of AVI. T1: pre test T2: follow up after three months T3: follow up after six months T4: follow up after nine months	Visser, J., Van Laarhoven, A., & Ter Beek, A. (1996). AVI toetspakket. [AVI test package]. 's-Hertogenbosch, the Netherlands: KPC.
	Text decoding T2 (T2_td_t)	1			
	Text decoding T3 (T3_td_t)	1			
	Text decoding T4 (T4_td_t)	1			
Spelling	Word spelling T1 (T1_ws_r;T1_ ws_d)	2	Raw score: 0-30 Dae score: 0-60 <sup>ii</sup>	_r: raw score _d: dae score T1: pre test T2: follow up after three months T3: follow up after six months T4: follow up after nine months	Geelhoed, J., & Reitsma, P. (2004). PI- dictee. [PI-dictation]. Amsterdam, the Netherlands: Harcourt Test publishers.
	Word spelling T2 (T2_ws_r; T2_ws_d)	2			
	Word spelling T3 (T3_ws_r; T3_ws_d)	2			
	Word spelling T4 (T4_ws_r;T4_ ws_d)	2			

Digit recall	Digit recall raw score (T1_dr_r; T1_dr_s)	2	raw score: 0-54 standard score: 50-150	_r: raw score _s: standard score (quotient score)	Pickering, S., & Gathercole, S. (2001). <i>Working memory test battery for children (WMTB-C)</i> . London: The Psychological Corporation Limited.
	Digit recall raw score (T1a_dr_r; T1a_dr_s)	2			
Backward digit recall	Backward digit recall raw score (T1_bdr_r; T1_bdr_s)	2	raw score: 0-36 standard score: 50-150	_r: raw score _s: standard score (quotient score)	Pickering, S., & Gathercole, S. (2001). <i>Working memory test battery for children (WMTB-C)</i> . London: The Psychological Corporation Limited.
	Backward digit recall raw score (T1a_bdr_r; T1a_bdr_s)	2			
Block recall	Block recall raw score (T1_br_r; T1_br_s)	2	raw score: 0-54 standard score: 50-150	_r: raw score _s: standard score (quotient score)	Pickering, S., & Gathercole, S. (2001). <i>Working memory test battery for children (WMTB-C)</i> . London: The Psychological Corporation Limited.
	Block recall raw score (T1a_br_r; T1a_br_s)	2			

## References

- Blomert, L. (2006). Protocol dyslexie diagnostiek en behandeling. [Protocol dyslexia diagnostics and remediation]. Retrieved from <http://www.onvz.nl/ONVZ/documenten/2012/protocol-dyslexie-diagnose-behandeling-12-2006.pdf>
- de Wijs, A., Kamphuis, F., Kleintjes, F., & Tomesen, M. (2010). Wetenschappelijke verantwoording spelling voor groep 3 tot en met 6. [Scientific background spelling for Grade 1 through 4]. Retrieved from <http://toetswijzer.kennisnet.nl/html/tg/16.pdf>
- Jongen, I., & Krom, R. (2009). Drie Minuten Toets (DMT). [Three Minute Test]. Arnhem, the Netherlands: CITO.
- Söderqvist, S., & Nutley, S. (2017). Cogmed working-memory training. Claims & evidence - Extended version v4. Retrieved on August 20, 2017 from <http://www.cogmed.com/wp-content/uploads/CogmedClaimsEvidence.pdf>
- Wentink, H., & Verhoeven, L. (2003). *Protocol leesproblemen en dyslexie*. [Protocol reading difficulties and dyslexia]. Nijmegen, the Netherlands: Expertisecentrum Nederlands.
- Wentink, H., & Verhoeven, L. (2004). *Protocol leesproblemen en dyslexie voor groep 5-8*. [Protocol reading difficulties and dyslexia for Grades 3 to 6]. Nijmegen, the Netherlands: Expertisecentrum Nederlands.

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<sup>i</sup> missing variables are indicated by 999

<sup>ii</sup> Dae-score stands for didactic age equivalent. It is based on didactic age of a student (number of months in school, counted from grade 1, each grade including 10 months). "Dae-score" indicates the didactic age in a particular subject corresponding with the reading/spelling level, expressed in months.