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A Beneficial Effect of a Cogmed Working Memory Training on Intelligence Without an Improvement in Working Memory Capacity

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A Cogmed working memory training was done aimed to enhance intelligence in a group of adolescents at risk for school dropout and with below average IQ through an increase in working memory capacity. The adolescents came from poor families and 84% came from minority groups. The effect of the Cogmed working memory training was tested in a randomized control trial with a reading comprehension and a no-training control group. We took care that the amount of coaching to ensure treatment integrity was similar in both training groups. The trainings took five weeks but were followed two months later by a 1-week booster. Participants were 64 students (42 boys and 22 girls) with a mean age of 14,6 years (*SD* = 16.5 months). An intermediate-test was done after the 5 week training and a posttest at the end of the year, 3 months after the booster. Measures of working memory capacity were involved at pre-, intermediate and posttest. IQ and school achievement were included at pretest and posttest. We found short but no long-term effects on working memory capacity. Surprisingly, at posttest both trainings had an effect on IQ and school achievement in the absence of an increase in working memory capacity. We argue that these results might be due to more general aspects of these interventions, in particular the coaching and support that were provided to the students.

Keywords: working memory, intelligence, intervention, Cogmed, coaching

Working memory is one of the main fronto-executive functions for the control and regulation of behavior. It is a system of limited capacity for the temporary storage and processing of information (Baddeley, 1986). Working memory (WM) is particularly involved in a range of cognitive abilities including fluid intelligence (de Jong & Das-Smaal, 1995; Kyllonen & Christal, 1990; Shipstead, Harrison, & Engle, 2016), reading comprehension (Daneman & Carpenter, 1980; Oakhill & Cain, 2012; Peng et al., 2018) and arithmetic (Friso-van den Bos, van der Ven, Kroesbergen, & van Luit, 2013; Geary, Nicholas, Li, & Sun, 2017; Xenidou-Dervou et al., 2018). Impairments in working memory have often been observed in children with learning disabilities (Brandenburg et al., 2015; de Jong, 1998; Raghubar, Barnes, & Hecht, 2010) and with intellectual disabilities (Henry, 2001; Lanfranchi, Baddeley, Gathercole, & Vianello, 2012).

As WM is involved in so many (daily) cognitive activities, the training of WM seems highly attractive. Instead of training each cognitive ability separately, an increase in WM-capacity has the potential to improve performance in a range of cognitive abilities. The main idea is that training on WM-tasks improves the functioning of various areas in the prefrontal cortex, the neurological substrate underlying fronto-executive functions (Blair & Raver, 2015; Sun, 2018). As brain areas related to WM also underlie performance in other abil-

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ities, such as intelligence and school achievement, improvements on these cognitive abilities are to be expected as well (e.g., Klingberg, 2010).

Indeed, the first studies on the training of WM seemed highly promising reporting increases in WM-capacity as well as, for example, a rise of fluid intelligence and a decrease of symptoms related to Attention Hyperactivity Disorder (Holmes, Gathercole, & Dunning, 2009; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Klingberg, Forssberg, & Westerberg, 2002). Various studies also showed that WM-training affected the functioning of the prefrontal cortex (see for reviews Constantinidis & Klingberg, 2016; Klingberg, 2010). WM-training led to both increases and decreases of activity in the middle and superior frontal girus during WM-task performance (see for reviews Constantinidis & Klingberg, 2016; Klingberg, 2010). An increase in activity suggests a higher firing rate of the neurons in these areas whereas a decrease in activity could be the result of improved efficiency. In addition, several studies found stronger connectedness of frontal and parietal regions after WM-training (Constantinidis & Klingberg, 2016).

However, these first studies had a number of methodological shortcomings thereby casting doubts about the training effects that were found (Redick, Shipstead, Wiemers, Melby-Lervåg, & Hulme, 2015; Shipstead, Redick, & Engle, 2012). Often control groups were absent or no-contact control groups were involved instead of an active control group enabling for the control of training effects that are not tied to WM. In case of a control group, subjects were not always randomly assigned to the training and control conditions (e.g., Dahlin, 2011; Shipstead, Redick, & Engle, 2010). Furthermore, improvements in the functioning of prefrontal areas were mainly confined to WM-tasks, as other tasks were not included in these brain studies. Therefore, it is not clear whether increases in performance on other tasks, such as fluid intelligence, were due to a better functioning of brain areas involved in WM-performance.

Several meta-analyses have now shown that the effects of WM-training are mainly limited to an increase in performance on WM-tasks (Melby-Lervåg & Hulme, 2013; Melby-Lervåg, Redick, & Hulme, 2016; Sala & Gobet, 2017; Simons et al., 2016). That is WM-training is found to affect performance on tasks that are similar to the tasks used to train WM. Such effects are usually denoted as 'near-transfer' effects (Shipstead et al., 2010). The effects of training to cognitive abilities outside the domain of working memory, that is 'far-transfer' effects, tend to be negligible. But these meta-analyses have been debated by others arguing that WM-training has both near and far-transfer effects (Au et al., 2015; Bergman Nutley & Söderqvist, 2017; Peijnenborgh, Hurks, Aldenkamp, Vles, & Hendriksen, 2016).

In the current study we examined the effects of a Cogmed WM-training on intelligence and academic achievement in adolescents who were in the prevocational track of Dutch education and were regarded as at risk for school dropout. In Dutch education, the prevocational track starts at the end of primary education (Grade 6). Students in this track are among the 60% lowest performing students by the end of Grade 6 and most have a below average IQ. Only a minority of these students drops out of school, but the personal consequences are huge in terms of negative effects on income and health (e.g., Lansford, Dodge, Pettit, & Bates, 2016). Generally, the number of students from lower SES and minority families are overrepresented in lower educational tracks (e.g., van de Werfhorst & Mijs, 2010). Especially students from lower SES families tend to have less developed fronto-executive functions, including WM (Lawson, Hook, & Farah, 2018; Raver, Blair, & Willoughby, 2013). Studies also show a decreased surface area and different activation patterns of the prefrontal cortex in students from lower SES families (e.g., Merz, Wiltshire, & Noble, 2019; Noble et al., 2015). The training of working memory, being a generic approach, was deemed to be suited for these students as multiple factors contribute to the risk for dropout including lower SES and low overall school achievement (see for a review Ripamonti, 2018). In this study we used the Cogmed training program to enlarge WM-capacity.

As mentioned above, several methodological issues have been raised with regards to the proper design of studies on the effects of WM-training (Shipstead et al., 2012; Simons et al., 2016). Two issues are of particular relevance for the current study. One issue concerns the training in the control group. Effects in studies with a no-training control group leave open the possibility that the effects of the WM-training are mainly due to effects that are irrelevant to WM-capacity, such as a placebo-effect (Shipstead er al., 2012). Indeed, a meta-analysis on the effects of WM-training by Melby-Lervåg et al. (2016) nicely illustrates that the effects with trained control groups are far larger than with no-training control groups (but see Au, Buschkuehl, Duncan, & Jaeggi, 2016). However, it is not entirely straightforward how the training of the control group should be designed. In several studies the training control group was given a nonadaptive version of the WM-training (Chacko et al., 2014; Chooi & Thompson, 2012; Dunning, Holmes, & Gathercole, 2013; Holmes et al., 2009). Task difficulty in the control condition was kept constant instead of adjusting task difficulty as performance improved, as in the WM-training condition. The risk of such a passive control training is that students get bored and lose their motivation. Therefore, control conditions with active trainings are to be preferred. Such trainings have been focused on the improvement of for example mathematics (Gray et al., 2012), simple span (Harrison et al., 2013) or video game performance (Minear et al., 2016; Yang, Peng, Zhang, Zheng, & Mo, 2017).

A particular aspect of any intervention, and also of WM-training, concerns its implementation. It is important to ensure treatment fidelity, that is to safeguard that the intervention is implemented as intended (e.g., Fogarty et al., 2014). Especially the Cogmed WM-training involves a fair amount of coaching of the participants by certified coaches to ensure that the training is accomplished. Among other things, coaches monitor the performance of the participants and discuss problems with keeping up the daily training. Thereby, they help to keep the participants motivated and seem to assist in regulating the learning of the participant. Schwaighofer, Fischer, and Bühner (2015) show that supervision during a WM-learning session has a positive effect on training outcomes. However, during the Cogmed WM-training coaching continues outside the training sessions. Thus far, coaching as an integral part of a WM-training has been largely neglected (Diamond & Ling, 2016, but see Nelwan, Vissers, & Kroesbergen, 2018). Evidently, a proper control group needs to have an active treatment, but this should be accompanied by a similar amount of coaching as in the WM-training condition.

A second issue of particular relevance to this study is the inclusion of a booster training. As argued by Bergman Nutley and Söderqvist (2017) it might take some time before the effects of WM-training on far transfer measures become visible. However, the effects of WM-training on WM-capacity tend to decrease (Diamond & Ling, 2016; Sala & Gobet, 2017). Therefore, a short refreshment training to give WM-capacity an additional boost might be beneficial to enable far transfer (Diamond & Ling, 2016).

In sum, the current study aimed to evaluate the short and long-term near and far transfer effects of a Cogmed WM-training. The study has three particular features. First, participants were students in the lower track of secondary education and at risk for school dropout. We expected that the students in this group are characterized by an accumulation of risk factors, including lowered fronto-executive functioning, as multiple factors are known to contribute to the risk for school dropout. WM-training might be beneficial for this group, but at the same time warranting treatment fidelity might be a challenge. Second, the WM-training was compared to both a no-training and a training control group. The training in the control group involved a training in reading comprehension, in which, as the WM-training, the difficulty of the exercises was adapted to the level of the participants. The coaching during this training was closely modeled after the coaching provided during the WM-training. Finally, we included a booster, an extra training of one week which was done two to three months after the five week training that is standard in the Cogmed WM-training.

Method

Participants

Students came from the lower prevocational track of four schools for secondary education. In the Netherlands tracking starts after 6th grade. Dependent on their level of performance at the end of 6th grade, students pursue their education in the upper tracks, preparing for college or university, or the lower prevocational track. The latter track contains relatively more students from poor families and families with a non-Dutch background.

The mean age of the students was 14 years and 5.5 months with a standard deviation of 1 year and 4.5 months. There were 42 boys (65.6%) and 22 girls (34.4%) with 13 to 15 boys per condition. The overall majority of the students, 84%, were from families with an minority group background (17 to 19 per condition); 43% of the students was born outside the Netherlands. All children came from poor neighborhoods with an overall majority of low SES families.

Inclusion and Exclusion Criteria

The schools were asked to nominate students for the intervention that (a) are at risk for school drop-out or grade retention, (b) have minor or moderate attention or conduct problems and, (c) are suspected by their teachers to have a below average IQ. Exclusion criteria were severe conduct problems or social-emotional problems or a diagnosis according to the criteria of the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (*DSM–IV*). Schools only signed up students for the study if they and their parents were willing to participate. In all, 77 students were nominated.

Figure 1 shows the flow of the students through the study. Four of the nominated students had to be excluded. Two withdraw from the study before the pretest and two appeared to have a *DSM–IV* Diagnosis. Of the remaining 73 students, triplets were formed matched on sex, age, and familial background (minority group) and on IQ and reading comprehension at pretest. Next, children within each triplet were randomly assigned to the three conditions. During the Study 9 students, three per condition, were lost (see Figure 1). Posttest data were not available for seven of these students: two were expelled from school, two stopped with the WM training and three students in the control condition did not show up. In addition, we excluded two students with an IQ above 100 in the RC condition as their matched students in the WM and control condition had dropped out. As a result, all students had an IQ below 100.

Design

Children were randomly assigned to a Working memory training (WMt), a Reading Comprehension training (RCt) or a no-training control group (Nt). Figure 2 shows the timeline of

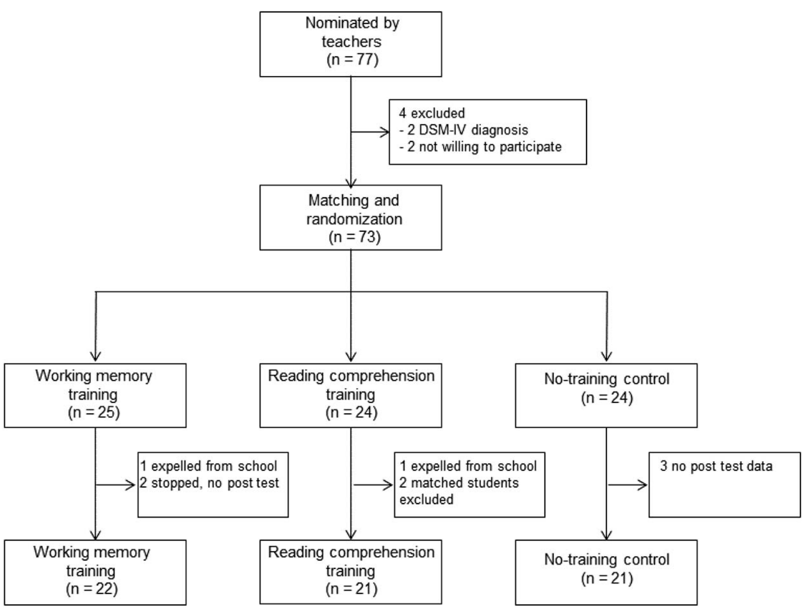

Figure 1. Flow of the students from nomination by teachers to final groups.

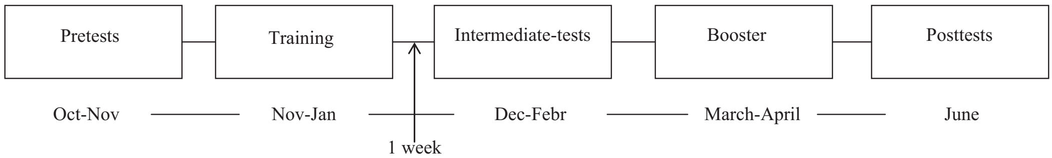

Figure 2. Timeline of the assessments, main training, and booster.

the trainings and the occasions of measurement. Both trainings took five weeks, which is standard for the Cogmed training. Students started with the training in November 2012 or in January 2013. An additional booster of one week was conducted in March-April 2013. Coaching was provided during the training and the booster. Children were tested before the training, one week after the training (intermediate-tests) and in June at the end of the school year (posttests).

Training

Each training, WMt or RCt, consisted of two parts: the standard training of five weeks and a booster of one weak two to three months later (see Figure 1). Both trainings were delivered through commercially available computer-based programs (WMt: Cogmed, www.cogmed.nl; RCt: Muiswerk, www.muiswerk.nl). These programs enable online feedback and adaptation of the difficulty of the task to the performance level of the student. RCt was closely modeled after the Cogmed WMt. Accordingly, during the standard training and the booster students trained 5 times a week for 45 min to one hour a day. In addition, coaching of the students (see below), which is an integral part of the Cogmed WMt, was also provided as part of RCt.

Working memory training. The Cogmed WMt has been described at length (e.g., Simons et al., 2016; see also www.cogmed.nl). In short, the training consists of 12 game-like span tasks covering the components of working memory. The tasks involve forward and backward span in the verbal and visuospatial domain with static and dynamic presentation. Task difficulty is adjusted on a trial-by-trial basis by increasing or decreasing the number of elements to be reproduced.

Reading comprehension training. We used two programs from Muiswerk (www.muiswerk.nl), Reading comprehension (Begrijpend Lezen 1JV) and Study skills (Studievaardigheden). Both programs aim to provide the students with tools to understand texts through practice of the various components of text comprehension. The training always started with the Reading Comprehension program. Students got instruction and practice in finding the main goal of a text and its main topics, list the chronology of topics and in making local and global inferences. The Study Skills program was similar, detecting the main topic of a text, making a graph of the text, making inferences, but also concerned supplementary skills as the use of a dictionary, understanding a table of content, differences between opinions and facts, and the reading of tables and graphs.

The programs consisted of modules that increased in difficulty. Each module was preceded and ended by a test. If the test was passed, the student could proceed to the next module.

Coaching. In principle the Cogmed training of WM is done at home by the student with guidance by a parent or other member of the family. But each student is also assigned to a coach. The coaching of student and parent is, according to the Cogmed manual, an essential part of the Cogmed training of WM (Gerrits, van der Zwaag, Gerrits-Entken, & van Berkel, 2012). It keeps participants motivated to practice and ensures treatment integrity. The current study involved five female coaches of Dutch origin with ages ranging from 21 to 46 years. The coaches were attending or had completed a master in clinical developmental psychology. The coaches did a two-day Cogmed training program (at that time provided by Beter Brein, www.beterbrein.nl, in collaboration with Pearson, the publisher of the Cogmed program). The coaches also completed the Cogmed training.

Following the Cogmed coaching protocol, the training (WMt or RCt) started with an intake with the student and the parent in which the coach showed how the computer program works, explored the goals of the student, explained the importance of a motivating role of the parent and answered questions. During the five week training the coach closely followed the achievement of the student through the information provided by the computer program that continuously tracked the performance on the exercises done by the student. Once a week the coach discussed the students' achievements with student and parent, provided guidance with respect to problems in keeping the student motivated to practice sufficiently, and considered possibilities to improve performance. The coach also sended at least once a week a text message by cell phone to inquire how the student is doing and to keep the student motivated to do the exercises.

Unfortunately, the coaching prescribed in the Cogmed protocol was not sufficient for 80% of these students from poor minority families and at risk for school dropout. First, some students did not have regular access to a computer at home. Second, for various reasons most parents could not provide sufficient support. One reason was that parents did not speak the Dutch language. They were not able to understand the printed instructions on the screen during the training and it was also impossible to communicate what was expected from them during the training sessions with their child. Moreover, some parents could not find the time to guide their child during the training sessions, for example because they had so many children. Therefore, the protocol was extended and coaching was intensified if deemed necessary by the coach. Extension involved training at school. Intensification of the coaching included extra contact of the coach with the student and the parent, help of the school mentor of the student and/or the second author and supervised practice at school. We distinguished two main categories of extra coaching. One category, 40.5% of the students, had extra contact with the coach, that is more than once a week, and had a variable amount of unsupervised training at school. The other category, 38.1% of the students, had a lot of extra contact with the coach and did the training at school with a variable amount of supervision. A chi-square test indicated that there were no significant differences between the WMt and RCt in these types of coaching.

The booster, a 1-week follow-up refreshment training, was done at school in groups. The booster training was supervised by one or two coaches.

Instruments

Working memory. WM was measured with a variety of simple and complex span tasks. Simple span tasks involved digit span, word span and visuospatial span. The complex span tasks measured listening span, reading span, counting span, computation span and backward visuospatial span. We also considered the learning on the training tasks during the WMt.

Improvement index. The Cogmed computer program of the WMt automatically provides an improvement index capturing overall progress on the training tasks. The index is derived from the starting level (mean performance over the second and the third day) and the end level (mean performance over the two best training days). The start and the max index were used to test for the increase in performance during learning.

Digits span. Students were required to recall series of two to nine digits. There were three series per list length. The digits for a series were randomly selected from the digits 1 to 9. Each digit was included only once in a series. The digits of a series were orally presented by the test assistant with a speed of one digit per second. The test was stopped if the student failed on three series of the same list length. The score on the test was the total number correct. The maximum score on the test was 24.

Word span. The task is identical to the digit span task except that words are used instead of digits. The words were nine one-syllable high frequent nouns. The maximum score on the test was 24.

Visuospatial span forward. We used the subtest Spatial Span of the Wechsler Nonverbal Scale of Ability (Wechsler & Naglieri, 2008). The tasks consisted of 10 square blue blocks which were randomly placed on a white board. On each trial the test assistant tapped a series of blocks with a speed of one per second. The blocks in a series were tapped only one time. The task of the student was to tap the series of blocks in the same order. The number of blocks tapped in a series increased from two to nine.

For each number of blocks (series length), two series were given, making a total of 16 series. The score was the total number of series that were reproduced in the correct order. The testing was stopped, when the student failed to reproduce two series with the same number of blocks correctly. The maximum score on the test was 18.

Listening span. This particular task was designed by Muijselaar et al. (2017). Series of sentences were presented verbally by a test assistant. After each sentence, the student had to judge whether the sentence was correct or incorrect and remember the last word. After all sentences were presented, the student had to recall the last words of all sentences in the order of presentation. The sentences contained three to seven monosyllabic words. The words to be recalled were selected from a list of words that were commonly known by 6-year-old children (Schaerlaekens, Kohnstamm, & Lejaegere, 1999). The series had a list length of two to five sentences, with four series per list length. The task was stopped if a student failed on all four items of the same list length. Two example items with a list length of respectively one and two items were given before the start of the test. The score was the number of items recalled correctly.

Reading span. In this task students were required to read series of sentences aloud (Muijselaar et al., 2017). After each sentence the student had to indicate whether the sentence was correct and then the test assistant provided a word that had to be remembered. When all sentences were read, the student was required to recall all the words given by the test assistant in the correct order. The words to be recalled were monosyllabic words and commonly known by 6-year-old children (Schaerlaekens et al., 1999). The sentences contained three to seven words. The series had a list length of two to five sentences and there were four items per list length. The task was stopped when a child failed on all four items of the same list length. Before the start of the test, two example items with list lengths of one and two items were provided. The score was the number of items recalled correctly.

Counting span. Each item consists of a series of pages with prints of 1–15 red and 10–30 white diamonds. At each page, the student had to count aloud the number of red diamonds and remember the result. After all pages in a series were done, the student had to recall the numbers of red diamonds in the correct order. The number of pages, list length, per series increased from two to seven. The number of red and white diamonds increased when the list length became larger. There were four items per list length. The test was stopped if two subsequent items of a given list length were incorrect. There were two items for practice. The score was the number of items recalled correctly.

Visuospatial span backward. This task is the same as the visuospatial span forward (see above) except that the student had to tap the series of blocks in the reverse order as they were tapped by the test assistant.

Intelligence. Four subtests of the Dutch version of the Wechsler Intelligence Scale for Children third edition (WISC–III-NL; Kortet al., 2005) were used to estimate IQ (Grégoire, 2000; Kaufman, Kaufman, Balgopal, & McLean, 1996). The subtests were Vocabulary, Similarities, Block design and Picture arrangement. The scaled scores of the subtests were added and the table provided by Grégoire (2000, p. 439) was used to estimate the Full Scale IQ. Two children, both in WMt condition, were about 17 years and too old for the WISC–III-NL. Their IQ was assessed with the complete Dutch version of the Wechsler Nonverbal Scale of Ability (WNV-NL, Wechsler & Naglieri, 2008).

School achievement. We used standard tests to measure achievement in word reading and decoding fluency, and calculation speed. A test for reading comprehension was administered at pretest only to match the triplets (see Participants).

Reading. The One Minute Word Reading Test (Eén Minuut Test; Brus & Voeten, 1995) consists of a list of words of increasing difficulty. The number of syllables per word increases from one to five. A similar test with 116 nonwords was used for decoding fluency (de Klepel; van den Bos, lutje Spelberg, Scheepstra, & de Vries, 1994). On the word reading test the students were asked to read as many words correctly in one minute; on the nonword reading test the student was allotted two minutes. The score was the number of words read correctly in one minute and nonwords read correctly in two minutes.

Calculation. Calculation speed was measured with the Tempo Test Arithmetic (de Vos, 1992). The test consists of five columns of arithmetic problems with one and double digit numbers. Each of the first four columns consists of 40 problems with a single operation, subsequently addition, subtraction, multiplication and division. In the fifth column the operation differs per problem. Within each column the problems increase in difficulty. Per problem the student had to do the computation by heart and write down the answer. For each column the student was asked to solve as many problems in 1 min. The total score was the number of problems solved over all columns. The maximum score was 200.

Reading comprehension. This ability was assessed by the Achievement Test for Reading Comprehension (Schoolvaardigheidstoets Begrijpend Lezen; de Vos, 2012).

Procedure

All measures were administered at pretest and at posttest. At the intermediate-test, one week after the standard training, we administered only a number of simple and complex span tasks to determine the effects of the training on working memory, the target ability of the WM-training. The simple span task was digit span, the complex span tasks were listening and counting span. The tests were administered by the coaches employed in the trainings. Care was taken that a student was not tested by his or her coach.

Statistical Analysis

Our main analyses were analysis of variance (ANOVA) for Repeated Measures with training condition as a between subjects factor and time (pretest, intermediate-test or posttest) as a within subjects factor. This analysis was followed by two planned condition by time contrasts. In the first contrast, denoted as the *training* contrast, we compared the increase in performance from pretest to intermediate- or posttest between the training conditions (WMt plus RCt) and the control condition. The second contrast, the *training type* contrast, concerned a comparison of the two training conditions. Because these planned contrasts are orthogonal, there is no need to adjust the significance level (Tabachnick & Fidel, 2007). To keep the number of statistical tests as low as possible, we conducted multivariate analyses whenever appropriate. In the multivariate analyses the two contrasts (training vs. control condition and WMt vs. RCt condition) were specified as multivariate contrasts. The univariate contrasts were only considered if the multivariate contrast was significant.

Results

The WMt and RCt involved 25 sessions in five weeks. In both training conditions the mean number of sessions (Msess) completed approached the maximum (Msess = 24.23 [SD = 2.09] for the WMt and Msess = 24.76 [SD = 2.14] for the RCt). Treatment integrity in the one week booster was lower. The maximum number of sessions during the booster was five. Students on average completed 75% of the sessions (Msess = 3.55 [SD = 2.13] and Msess = 3.90 [SD = 2.05] in the WMt and the RCt, respectively). In both training conditions approximately 70% of the students completed all sessions of the booster whereas about 20% of the students did not show up at all.

Data of six students were missing on the intermediate-test, three in the WMt and three in the RCt condition. However, the groups still performed similar on the matching variables, that is age, IQ and reading comprehension. Data at posttest were complete.

All variables were approximately normally distributed with skewness lower than one. There was one student with an outlier score, more than 3.3 SD above the mean of the group, on Listening span. However, we did not remove this student as the results did not change when the student was omitted. The means and standard deviations per training group on pretests, intermediate- and posttests are presented in Tables 1 and 2.

Performance During the WMt

The Improvement Index provided by the Cogmed program increased significantly during the WMt, $t(21) = 12.809$, $p < .001$ (start M = 81.77 [SD = 14.233], end M = 108.14 [SD = 17.654]). As compared to the start of the standard WM training, there was also a significant increase during the Booster, $t(16) = 2.546$, $p =$

Table 1
Means (M) and Standard Deviations (SD) per Intervention Condition on the Measures of Simple and Complex Span at Pretest (t0), Intermediate-Test (t1), and Posttest (t2)

Variable	WMt *M*	WMt *SD*	RCt *M*	RCt *SD*	Nt *M*	Nt *SD*
Age t0	14;6	1;5	14;6	1;6	14;5	1;4
Reading comprehension t1	28.15	6.17	27.17	4.00	27.40	5.02
Simple span						
Digits						
t0	12.73	2.21	12.10	1.95	13.05	2.06
t1	13.93	3.12	11.44	2.36	13.00	3.02
t2	14.18	2.28	12.05	1.80	13.19	1.81
Words						
t0	11.41	2.65	9.76	1.41	10.76	2.23
t2	11.77	3.05	10.14	1.46	11.33	1.77
Visuo-spatial						
t0	7.91	1.51	7.67	2.27	7.57	2.36
t2	9.09	2.11	7.67	2.008	8.00	1.90
Complex span						
Listening						
t0	5.86	2.59	5.38	1.80	6.67	2.48
t1	8.05	3.17	6.72	1.97	7.00	2.35
t2	8.32	2.77	7.76	2.61	8.57	2.84
Reading						
t0	7.27	1.91	6.24	2.00	7.48	2.62
t2	9.18	2.20	7.95	2.38	9.29	2.61
Counting						
t0	8.18	2.63	7.38	3.35	9.52	3.25
t1	9.32	3.18	8.06	3.96	9.43	3.47
t2	10.91	3.16	11.81	5.94	12.05	5.21
Visuo-spatial						
t0	7.18	2.13	7.00	1.98	6.71	1.82
t2	8.14	1.49	7.19	1.40	7.48	1.78

Note. WMt = working memory training; RCt = reading comprehension training; Nt = no-training control.

.022 (start $M = 79.76$ [$SD = 10.88$], end $M = 87.65$ [$SD = 15.823$]). Note that five students did not do the booster, but that the starting level of the complete group was very similar to the starting level of the group that did the booster. Note also that the end level after the one week booster was smaller than the level after the standard five week training.

Near Transfer Effects at the Intermediate-Test

The intermediate-test was administered directly after the standard five week training and aimed to test the near transfer effects of the training on measures of WM. The repeated ANOVA for digit span, the measure of simple span, did not show a significant effect of Time, $F < 1$. Subsequent tests showed that the training contrast was not significant, $F < 1$. However, the training type contrast was significant, $F(1, 55) = 5.342$, $p = .025$, $\eta_p^2 = .089$, indicating that the increase in digit span performance from pretest to the intermediate-test was larger in the WMt condition than in the RCt condition.

A multivariate ANOVA for repeated measures was conducted with listening and counting span as dependent variables. We found a significant effect of Time, $F(1, 55) = 9.018$, $p < .01$, $\eta_p^2 = .141$, and a significant (multivariate) training contrast, $F(2, 55) = 5.014$, $p = .01$, $\eta_p^2 = .157$. The univariate contrasts showed that the increase in Listening span was larger in the training groups, $F(1, 55) = 10.157$, $p < .01$, $\eta_p^2 = .156$, whereas there were no differences among the groups in the increase of Counting

Table 2
Means and Standard Deviations per Intervention Condition on the Measures of Intelligence and School Achievement at Pretest (t0), Intermediate-Test (t1), and Posttest (t2)

Variable	WMt *M*	WMt *SD*	RCt *M*	RCt *SD*	Nt *M*	Nt *SD*
Intelligence						
Total IQ						
t0	80.77	9.08	79.52	9.34	78.05	7.48
t2	91.05	12.39	89.76	13.45	81.43	6.71
Vocabulary						
t0	7.10	1.71	5.57	2.16	5.67	2.24
t2	7.89	2.69	6.67	2.31	6.00	1.87
Similarities						
t0	8.05	2.56	7.95	2.09	7.19	2.06
t2	9.63	3.48	9.38	2.82	7.57	1.66
Block design						
t0	5.80	2.24	6.05	3.07	6.19	1.81
t2	6.68	2.16	7.29	2.90	6.48	2.82
Picture arrangement						
t0	6.95	2.59	7.76	1.70	7.33	2.67
t2	9.00	2.77	10.24	2.77	8.43	1.96
School Achievement						
Word reading						
t0	75.45	16.22	63.24	16.86	66.48	17.22
t2	82.59	14.59	70.62	17.22	67.86	15.97
Nonword reading						
t0	72.23	19.58	59.14	17.37	65.10	21.49
t2	76.64	21.26	64.43	23.18	63.57	27.54
Calculation						
t0	106.09	29.05	100.71	26.19	102.62	32.93
t2	107.23	28.92	106.29	25.60	102.76	33.79

Note. WMt = working memory training; RCt = reading comprehension training; Nt = no-training control.

span, $F < 1$. The training type contrast was not significant, $F(2, 55) = 2.103$, ns.

Near Transfer Effects at the Posttest

The posttest was administered 5–6 months after the training and about 2 months after the booster. We analyzed the differences in increase in simple and complex performance from pretest to posttest.

A multivariate ANOVA for repeated measures was done on all simple span tasks, that is Word, Digit and Visuospatial span forward. The effect of Time was significant, $F(1, 61) = 10.017$, $p < .01$, $\eta_p^2 = .141$. The training contrast was not significant, $F < 1$, but we did find a significant multivariate training type contrast, $F(3, 59) = 3.903$, $p = .013$, $\eta_p^2 = .166$. The univariate contrasts showed that the larger increase in simple span in the WMt group was mainly driven by Digit span, $F(1, 61) = 8.172$, $p < .01$, $\eta_p^2 = .118$. The univariate contrasts for Word and Visuospatial span were not significant.

The multivariate ANOVA for complex span involved Listening, Reading, and Counting span, and Visuospatial span backward. We found a significant effect of Time, $F(1, 61) = 96.013$, $p < .001$, $\eta_p^2 = .611$, but neither the multivariate training contrast nor the training type contrast were significant (both Fs < 1).

Far Transfer Effects at Posttest

Far transfer concerned the effects of the trainings on IQ and achievement at posttest. An ANOVA for repeated measures showed a significant effect for Time, $F(1, 61) = 65.942$, $p < .001$, $\eta_p^2 = .519$. The training contrast was significant, $F(1, 61) = 10.835$, $p < .01$, $\eta_p^2 = .151$, the training type contrast was not, $F < 1$. Thus, the increase in mean IQ from pretest to the posttest was significantly larger in the training groups than in the Nt group. To examine the robustness of the training effects on the increase in IQ, we deleted the three students whose IQ was estimated with the WNV. The results of this analysis were virtually the same as the results for the complete group.

With respect to school achievement, we computed one reading score because the correlation between word and nonword reading at pretest was 0.82 ($p < .01$). The reading score at pretest was the average of the z-scores on the two word and nonword reading tests. To preserve growth effects the posttest scores were standardized on the basis of the means and standard deviations at pretest and then averaged. The Multivariate ANOVA for repeated measures with word reading and calculation as dependent variables showed a significant increase in school achievement from pretest to posttest, $F(1, 61) = 14.187$, $p < .01$, $\eta_p^2 = .189$. The multivariate training contrast was significant, $F(2, 60) = 3.342$, $p = .042$, $\eta_p^2 = .100$. The univariate contrasts showed that the training groups had a significantly higher increase in word/nonword reading speed, $F(1, 61) = 5.644$, $p = .021$, $\eta_p^2 = .085$, whereas there was no significant difference in the increase in calculation speed. The training type contrast, testing for the difference between the training groups, was not significant, $F(2, 60) = 1.184$, ns.

Discussion

We evaluated whether a Cogmed WM-training could improve WM-functioning, intelligence and school achievement in adolescents in the lower track of Dutch education at risk for school dropout. All students had below average IQ and the overall majority of the students came from minority families and poor neighborhoods. The outcomes of the WM-training were compared to a group of students who participated in a program aimed to foster reading comprehension and to a no-training control group. The trainings consisted of a five week training, the standard period for a Cogmed WM-training, and an additional one week booster.

We found small but significant effects of the WM-training on near transfer measures directly after the standard WM-training. On digit span, our measure of simple span, the WM-training group improved more than the control groups. For complex span, reflecting WM-capacity, the overall increase was larger in the WM-training group than in the no-training control group, although this effect was most pronounced on the listening span task. Unexpectedly, complex span performance also improved in the RC-training group. Reading comprehension also depends on WM-capacity and therefore, it can be argued that the RC-training also enhanced WM-capacity. Note that the overall improvement in complex span performance was most pronounced on the listening span task and almost absent in the counting span task. The listening span task requires both WM-capacity and language comprehension. An alternative possibility is that the short term increase in listening span is due to an improvement in language comprehension in the RC condition and a larger WM-capacity in the WM-training condition.

The effect of WM-training on digit span was still observed at posttest at the end of the year, that is 4 to 5 months after the standard WM-training and two months after the Booster. The initial effects on the complex span tasks in both training groups had disappeared by then. A similar isolated long term effect on digit span has been reported by van der Donk, Hiemstra-Beernink, Tjeenk-Kalff, van der Leij, and Lindauer (2015). Because of the absence of long term effects on the complex span tasks, we have to conclude that the WM-training did not increase the target skill of the training, that is WM-capacity.

Therefore it is surprising that we observed a large effect of both trainings on IQ ($d = 0.80$) and a smaller effect on school achievement, in particular word reading ($d = {\sim}0.33$), at the time that an increase in WM-capacity could no longer be traced. Especially the effect on IQ in both training conditions seems too large to dismiss as a chance finding. Moreover, this pattern of effects of a WM-training is not unprecedented. For example Jaeggi et al. (2008) found that the increase in fluid intelligence after their WM-training could not be accounted for by an improvement in WM-capacity and Jaeggi et al. (2010) reported an increase in matrix reasoning after a WM-training without a concomitant effect on operation span, their near transfer measure of WM-capacity. However, such a pattern of findings is clearly at odds with the theory that underlies the presumed effect of the training of

WM (e.g., Melby-Lervåg & Hulme, 2013). The far transfer effects in the current study cannot be due to an increase in WM-capacity, the target of the WM-training. We consider a number of possibilities that might account for the finding of far transfer in the absence of near transfer effects.

First, we should acknowledge that posttests were administered by the coaches. Although a coach never tested her own student, we cannot exclude the possibility that (some) coaches might have been aware of the training condition of the student. As a result, coaches might have been more lenient in the scoring of the various intelligence tests. If this were the case, we should have found the largest effect on the vocabulary subtest that requires more judgment in scoring. However, we found similar effects of both training conditions on all subtests. Alternatively, the test assistants might have unknowingly stimulated the performance of the students in both training conditions during testing as compared to the students in the no-training control condition. However, if the test assistants really pushed the limits of students in the training conditions, then it seems hard to understand why this did not affect performance on the complex span tasks. In all, it seems unlikely that the far transfer effects are, at least entirely, due to the influence of the test assistants during the posttests.

A more likely explanation for the far transfer effects is to be found in the common features of both trainings. As a start it is important to realize that the students in the current study were at risk for school dropout and grade retention, had a below average IQ and probably had overall low school performance. As a result these students are likely to have experienced repeated failures. The adaptive nature of the training might have given them some experience of success and thereby could have raised their feelings of competence (B. Spinath, F. Spinath, Spinath, Harlaar, & Plomin, 2006; Schneider, Lotz, & Sparfeldt, 2018). In addition, coaching was given during both trainings. The coaching was much more intensive than normally provided during a WM-training. This was necessary because most students were unable to work independently, most parents appeared not to be available to supervise the training sessions, and some households did not have a computer. It is noteworthy that the standard Cogmed coaching in this group of students with multiple problems and from poor neighborhoods would not have been sufficient to warrant treatment fidelity.

The extended coaching included two elements. One was the amount of supervision during the training sessions. A meta-analysis by Schwaighofer et al. (2015) showed that monitoring and guiding the efforts of the participants during the WM-training tasks has a beneficial effect on near transfer but not on far transfer. More recently, however, Nelwan et al. (2018) reported some effects of the amount of coaching on far transfer. They compared two groups of children with math and attention difficulties that received an eight week WM-training. The groups differed in the number of times that the children were visited (four vs. 8 times). During these visits the children received feedback about their performance, reflected on their task strategies and were explicitly praised for their achievements. Nelwan et al. (2018) found small effects on math achievement in the group that had the most intensive coaching.

The second, and probably more important, element of the coaching concerned the continuous motivation of the students to accomplish the aimed number of training sessions and discuss solutions with the students to do so. Such solutions involved goal setting, planning and convincing students of the importance of persistence. These kinds of strategies belong to the broader process of self-regulation described by Zimmerman (2000) as ‘self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals’ (p. 14). Fronto-executive functions are only part of this broader conception of self-regulation, the part where execution of tasks is at stake. However, self-regulation also entails strategies that help in organizing and structuring task behavior *before* the task is started and also concern reflection *after* the task has been done. Such strategies are usually regarded to support fronto-executive functions and to improve self-regulation (Zimmerman, 2000). The current results thus suggest that the problems in fronto-executive functions often found in students from lower SES families as the students in the current study (e.g., M. Kia-Keating, Nylund-Gibson, B. Kia-Keating, Schock, & Grimm et al., 2018; Raver et al., 2013), as such have not been affected by the trainings. In fact, it seems overly optimistic that long-term structural and functional changes in the prefrontal cortex can be established by 25–30 hr of training with WM-tasks without altering the living conditions of these families that are responsible for the fronto-executive problems of these children in the first place (e.g., Kolb, Harker, & Gibb, 2017). Instead, it seems more likely that coaching can support the broader process of self-regulation. An improvement in self-regulation might be more visible on an intelligence test than on a working memory task. In the latter task, items are very short, whereas the various intelligence subtest provide much more possibilities for persistence, goal setting, reflection and trying different strategies to solve an item.

Overall the results of the current study, as of many other studies, do not support the hypothesis that WM-training influences WM-capacity which in turn leads to an increase in IQ and school achievement. Instead, we found that both our WM and RC-training affected IQ and reading in the absence of an increase in WM-capacity. We suggest that this pattern of findings might be explained by the common elements of these trainings, in particular the extensive amount of coaching. For students from lower SES minority families coaching with an emphasize on self-regulatory strategies, might be more beneficial to improve task performance than a focus on the improvement of fronto-executive functions. Evidently, the findings of the current study cannot be used as evidence for the role of coaching. However, they do suggest that it is worthwhile to examine whether intensive coaching is a viable way to improve IQ and school achievement in lower SES multiproblem students.

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