Working Memory Training Improves Cognitive Function in VLBW Preschoolers

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KEY WORDS
working memory training, preterm birth, VLBW children, cognition, intervention

ABBREVIATIONS
ADHD—attention-deficit/hyperactivity disorders
CI—confidence interval
ELBW—extremely low birth weight
FSIQ—full intelligence quotient
VLBW—very low birth weight

Dr. Grunewaldt coordinated and organized the study, collected data, conducted the analyses, drafted the initial manuscript, and approved the final manuscript as submitted; Dr. Laugen performed all neuropsychological examinations, contributed to the interpretation of data, critically reviewed and revised the manuscript and approved the final manuscript as submitted; Dr. Austeng performed the ophthalmological examinations, reviewed and critically revised the manuscript and approved the final manuscript as submitted; Dr. Brubakk contributed to the design of the study, critically reviewed and revised the manuscript and approved the final manuscript as submitted; and Mr. Skranes conceptualized and designed the study, contributed in the interpretation of data, critically reviewed and revised the manuscript, and approved the final manuscript as submitted.

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WHAT’S KNOWN ON THIS SUBJECT: Preterm born children have cognitive problems that include deficits in working memory. Computer-based working memory training has been reported to improve cognitive function in children.

WHAT THIS STUDY ADDS: A computer-based working memory training program designed for preschoolers seems effective in very low birth weight children, not only on working memory tasks, but also by having a generalizing effect regarding memory and learning.

abstract

BACKGROUND AND OBJECTIVE: Preterm born children perform poorer than term peers on tests of attention and executive functions including working memory tests. Our aim was to evaluate if preterm born preschoolers with very low birth weight (VLBW) would benefit from a computerized working memory training program and if the training would have a generalizing effect on memory, learning, attention, behavior, and anxiety.

METHODS: A prospective intervention study with a stepped wedge design where 20 VLBW preschoolers aged 5 to 6 years participated. The children trained with the Cogmed JM program for 10 to 15 minutes a day, 5 days a week over a 5-week period. Extensive neuropsychological assessment and parental questionnaires regarding behavior and anxiety were performed before and 4 weeks after intervention.

RESULTS: The children improved significantly on trained (mean Start Index 42.1 [SD 6.3]), mean Max Index 60.6 [SD 5.7]), and nontrained working memory tasks (Spatial Span backward, 2.3 [before] to 3.6 [after training] [confidence interval CI –2.2 to –0.4] and Spatial Span total score; 6.4–8.3 [CI –3.7 to –0.1]). A generalization effect was found on auditory attention (49.6–58.2 [CI –15.5 to –1.6]), phonological awareness (9.3–12.6 [CI –5.2 to –1.4]), visual (memory for faces 20.0–24.9 [CI –7.4 to –2.5]), as well as verbal memory (narrative memory, 12.9–17.5 [CI –7.1 to –2.0], and sentence repetition 15.7–17.7 [CI –3.3 to –0.7]).

CONCLUSION: This study shows that VLBW preschoolers benefit from a computerized working memory training program. We speculate that such training before starting school may prevent or reduce cognitive problems that impact educational achievement. Pediatrics 2013;131: e747–e754
During the past decades the medical treatment and survival of preterm born children has improved substantially, especially after the introduction of antenatal steroids and surfactant treatment.1,2 Despite the increased survival, the number of children with brain pathology and neuroimpairments is still very high, especially among the most immature children.3–5 Cognitive and behavioral deficits are reported to last into adolescence and early adulthood.6,7 Very preterm born children perform more poorly than term born peers on tests of attention and executive functions,8,9 and these skills are essential for a child’s ability to learn, to plan their actions, to solve problems and to develop language as well as mathematical skills.10 Deficits in these domains may therefore impact academic achievements,4,11 and intervention strategies to minimize the long-term cognitive impact of prematurity should be prioritized.

Working memory is defined as our ability to temporarily store and at the same time manipulate information “online” over short periods of time.12 Working memory is considered to be a prerequisite for other executive functions such as reasoning and planning and to predict intelligence and academic success.13,14 Impairment in working memory has been linked to learning disabilities15 and intervention strategies to minimize the long-term cognitive impact of prematurity should be prioritized.

METHODS
Participants
In 2005–2006, a total of 79 VLBW children were admitted to the NICU, Trondheim University Hospital in Norway. Of 75 surviving infants, 11 children were too young to participate in the study (<5 years of age at study start). Other exclusion criteria were living in another region, severe cerebral palsy with totally impaired bilateral hand functions (Gross-Motor-Function-Classification-System level V), epilepsy, or blindness. According to these criteria, 29 (45%) children were excluded. A total of 35 children aged 5 to 6 years met the inclusion criteria and were invited to participate in the current study (Fig 1). Twenty-two children consented to participate, but 2 children did not show up for initial testing; hence, a total of 20 of the 35 eligible children (57%) participated in the intervention study. Mean birth weight was 1099 g (SD 311), mean gestational age was 28.8 weeks (SD 2.8), and mean age at intervention was 5.8 years (SD 0.5).

Nonresponders
The clinical characteristics of participants and nonresponders are described in Supplemental Table 6. Neonatal data and risk factors did not differ significantly, except for more use of antenatal steroids among participants.

Study Design
A Stepped Wedge randomized trial design was chosen to split the participants into 2 groups for sequential rollout of the intervention. The participants were randomly assigned to 2 equal groups; however, owing to familiar courses, 1 child had to switch training group to be able to complete the training. There were no significant differences in the clinical characteristics between the 2 groups at start of the study (Table 1). Both groups were tested with cognitive and neuropsychological tests at time point 1-T1 (Fig 2). Then the participants in group 1 started the training program, while those in group 2 waited. When group 1 had completed the training period, both groups were retested ~1 month after ended training in group 1 (time point 2-T2). Group 2 then started the working memory training. At last, group 2 was tested at time point 3-T3 ~1 month after ended training. Owing to the small study sample, we then combined the results from pre- and posttraining testing in both groups to look at training effects in the whole sample. However, we also looked at possible training effects by separate group analyses from T1 to T2 and for group 2 also from T2 to T3.

Intervention Program
The intervention program consisted of 7 working memory tasks presented in the software-based computer program Cogmed JM (www.cogmed.com). The working memory tasks are described in detail in the Supplemental Information. The participating families received a computer link, and the web-based software program was downloaded. A training period of 10 to 15
minutes, 5 days a week for 5 weeks was performed by the child. Three tasks were administered to the child each day. The exercises became more difficult as the child's skills improved, and the difficulty level of the training was adjusted by the software based on the child's performance. After each training, the parents uploaded the results to a secure Internet site. Once a week, the principal investigator contacted the family to give advice based on the uploaded results.

**Visual Acuity**

An experienced ophthalmologist assessed visual acuity in all children with Lea Symbols 15 Line Distance Chart before training.

**Socioeconomic Status**

Socioeconomic status was calculated according to the Hollingshead 2-factor index of social position (mean educational levels and current employment of both parents or from a single parent).25

**Neonatal Data and Additional Diagnoses**

Neonatal data and additional diagnoses were retrieved from the medical journals at the Trondheim University Hospital.

**Outcome Measures**

Effect on the trained tasks (included in the computer program) was assessed.

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**TABLE 1**

Clinical Characteristics of the Study Population

<table>
<thead>
<tr>
<th></th>
<th>Total n = 20, Mean (SD)</th>
<th>Group 1 n = 9, Mean (SD)</th>
<th>Group 2 n = 11, Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestational age, wk</td>
<td>28.8 (2.8)</td>
<td>29.4 (2.3)</td>
<td>28.2 (3.1)</td>
</tr>
<tr>
<td>Birth weight, g</td>
<td>1099 (311)</td>
<td>1212 (203)</td>
<td>1005 (360)</td>
</tr>
<tr>
<td>Male gender, n (%)</td>
<td>6 (30)</td>
<td>3 (33)</td>
<td>3 (27)</td>
</tr>
<tr>
<td>Multiple births, n (%)</td>
<td>2 (10)</td>
<td>0</td>
<td>2 (18)</td>
</tr>
<tr>
<td>Apgar 1 min</td>
<td>6.9 (2.7)</td>
<td>7.8 (1.6)</td>
<td>6.1 (5.2)</td>
</tr>
<tr>
<td>Apgar 5 min</td>
<td>8.7 (1.5)</td>
<td>9.1 (0.9)</td>
<td>8.4 (1.9)</td>
</tr>
<tr>
<td>Mechanical ventilation, days</td>
<td>9.7 (40)</td>
<td>0.3 (1.0)</td>
<td>17.4 (54.0)</td>
</tr>
<tr>
<td>CPAP, days</td>
<td>30.7 (31)</td>
<td>23.0 (19.4)</td>
<td>36.9 (38.8)</td>
</tr>
<tr>
<td>Intraventricular hemorrhage, grade 1</td>
<td>3 (15)</td>
<td>0</td>
<td>3 (27)</td>
</tr>
<tr>
<td>Intraventricular hemorrhage, grade 2</td>
<td>2 (10)</td>
<td>2 (22)</td>
<td>0</td>
</tr>
<tr>
<td>Septicemia, n (%)</td>
<td>2 (10)</td>
<td>0</td>
<td>2 (18)</td>
</tr>
<tr>
<td>Patent ductus arteriosus, n (%)</td>
<td>4 (20)</td>
<td>1 (11)</td>
<td>3 (27)</td>
</tr>
<tr>
<td>Indomethacin treatment, n (%)</td>
<td>1 (25)</td>
<td>0</td>
<td>2 (18)</td>
</tr>
<tr>
<td>Surgery, n (%)</td>
<td>2 (50)</td>
<td>1 (11)</td>
<td>1 (9)</td>
</tr>
<tr>
<td>BPD/O2, at GA 36 wk, n (%)</td>
<td>6 (50)</td>
<td>1 (11)</td>
<td>3 (45)</td>
</tr>
<tr>
<td>Cerebral palsy, n (%)</td>
<td>2 (10)</td>
<td>1 (11)</td>
<td>1 (9)</td>
</tr>
<tr>
<td>Maternal education, y</td>
<td>14.9 (1.0)</td>
<td>14.8 (0.7)</td>
<td>15.0 (1.3)</td>
</tr>
<tr>
<td>Single-parent household, n (%)</td>
<td>3 (15)</td>
<td>0</td>
<td>3 (27)</td>
</tr>
<tr>
<td>Socioeconomic status</td>
<td>3.8 (0.7)</td>
<td>3.6 (0.7)</td>
<td>4.0 (0.6)</td>
</tr>
<tr>
<td>Full IQ</td>
<td>93 (8)</td>
<td>95 (8)</td>
<td>92 (8)</td>
</tr>
<tr>
<td>Verbal IQ index</td>
<td>96 (10)</td>
<td>98 (7)</td>
<td>94 (11)</td>
</tr>
<tr>
<td>Performance IQ index</td>
<td>94 (8)</td>
<td>95 (8)</td>
<td>93 (8)</td>
</tr>
<tr>
<td>Processing speed IQ index</td>
<td>101 (10)</td>
<td>102 (8)</td>
<td>100 (12)</td>
</tr>
</tbody>
</table>

*Mann-Whitney U test, χ² test. CPAP, continuous positive airway pressure; BPD, bronchopulmonary dysplasia; GA, gestational age.*
through a training/improvement index provided by Cogmed. This showed the improvement achieved in each participant during training. Cogmed JM Start Index is based on the average performance on days 2 and 3 from 4 of the tasks in the program, whereas the Max Index is based on the average of the best 2 trials over the course of training. A Training/Improvement Index is then calculated by subtracting the Start Index from the Max Index.

The Wechsler Preschool and Primary Scale of Intelligence, third edition, was performed at time point T1 to assess general cognitive ability. The effects of training on nontrained working memory tasks were assessed with standard neuropsychological tests of verbal (Digit Span) and visual (Spatial Span board task) working memory. Generalization effects to functions like attention/executive, language, learning, and memory were assessed by subtests from the NEPSY (second edition). The Stepped Wedge design allowed for the analysis of any practice (test-retest) effect on the neuropsychological tests from T1 to T2 in the group with delayed training (group 2). Tests that showed significant improvements were excluded in the further analyses when evaluating training effect.

To assess any change in the child's behavioral, attention, and anxiety level before and after training, the parents completed 2 questionnaires: The ADHD Rating Scale-IV for assessing hyperactivity and inattention, and the Preschool Anxiety Scale to measure symptoms of different anxiety disorders.

**Ethics**

Written informed consent was obtained from the parents, and the study was approved by the Regional Committee of Medical Research Ethics (REK number 2011/532-7). The study was also registered at www.ClinicalTrials.gov (identifier NCT01518452).

**Statistical Analyses**

Statistical Package for Social Sciences, version 19 (IBM SPSS Statistics, IBM Corporation, Armonk, NY) was used for the statistical analyses. Differences in group means for normally distributed variables were compared with the Student t tests, whereas not normally distributed outcome measures were analyzed by using the Mann-Whitney U test. $X^2$ test was used as appropriate to compare differences in proportions between groups. Wilcoxon signed rank test for 2 related samples was used to compare scores at the different time points: T1 versus T2 (group 2) and pretraining versus postraining (groups 1 and 2). This test was also used to analyze changes in scores in separate group analysis from before to after training. Correlation analyses with the use of the Pearson correlation coefficient were performed to describe the relationship between the improvement index and IQ and total anxiety score, respectively. Two-tailed $P$ values of $\leq .05$ were considered to be statistically significant.

**RESULTS**

Clinical characteristics of the study population are listed in Table 1. No significant group differences were seen. Three children developed retinopathy of prematurity, and 1 child needed laser treatment during the neonatal period. However, all participating children had visual acuity $\geq 0.8$ tested binocularly; hence, none of the children had any problems performing the training. None of the children had a diagnosis of ADHD. All children completed the 25-day training period and were tested at all scheduled time points.

**General Cognitive Ability**

The VLBW children had mean full IQ (FSIQ) of 93 (SD 8) with a range of 80 to 112. Verbal IQ was 96 (SD 10), performance IQ was 94 (SD 8), and processing speed IQ was 101 (SD 10). None of the participants were cognitively disabled (FSIQ $< 70$) (Table 1). There was no significant correlation between mean FSIQ and improvement Index in the Cogmed program ($r = 0.02, P = .92$) (Supplemental Fig 3).
Practice (Test-Retest) Effects
In group 2 that was tested twice before training, a practice (test-retest) effect was found for the NEPSY subtasks Visual Attention Total Points and Statue and for the Digit Span Total score. These tasks were therefore excluded from further analysis in the combined group, but included in the separate group analysis.

Trained Working Memory Tasks
The children improved significantly \((P < .001)\) on trained working memory tasks measured in the Cogmed program. Mean Start Index was 42.1 (SD 6.3), mean Max Index was 60.6 (SD 5.7). The mean Improvement Index was 18.4 (range, 8–30). The 2 children with cerebral palsy had a mean Improvement Index of 20.0.

Nontrained Working Memory Tasks
After training, the VLBW children showed improvement on the Spatial Span tasks Number of Item Backward \((P = .01)\) and Total Correct Score \((P = .03)\) (Table 2). No significant changes were found for the Digit Span tests.

Attention/Executive and Language Function
After training, the children showed improvement on the attention and executive function tasks, auditory attention and response set \((P = .012)\). They also improved on phonological processing \((P = .004)\) and repetition of nonsense words \((P = .017)\) that are expressions of phonological awareness. Improvement was also found on tasks regarding visual (memory for faces, \(P = .001\)) as well as verbal memory and learning (narrative memory, \(P = .003\) and sentence repetition, \(P = .005\)) (Table 3).

ADHD Rating Scale
The children had normal scores on the ADHD rating scale before training. There were no significant effects on ADHD rating scale scores after training, but there was a slight reduction in hyperactivity/impulsivity scores after training \((P = .05)\). No change was seen in mean attention score before and after training (Table 4).

Preschool Anxiety Scale
The Preschool Anxiety Scale did not show any mean values in the clinical area before and after training. After training, the parents reported significant reduction in separation anxiety and total anxiety (Table 5). When performing correlation analyses nonsignificant correlations were found between Improvement Index and reduction in general anxiety (\(r = −0.14, P = .6\)) and reduction in physical injury fear (\(r = −0.12, P = .6\)) after training.

Separate Group Analyses
The results of the separate group analysis, which are presented in the Supplemental Information, supported the combined group results.

DISCUSSION
This study is the first to investigate the effect of computerized working memory training in a group of preterm born VLBW preschoolers. The main findings were that the VLBW preschoolers improved significantly on trained and nontrained working memory tasks, and transfer effects were observed as improvement on auditory attention, phonological awareness, and visual as well as verbal memory.

Strengths and Limitations
Strength of this study was the compliance of the participating children and their families during the study period. All 20 children completed the whole training program of 25 days, and there were no dropouts during the follow-up examinations. Further strength was the comprehensive neuropsychological assessment performed in all children by a neuropsychologist who was blinded to the group randomization. A possible limitation of this study might be selection bias of the participating children. However, when comparing participants and nonresponders the 2 groups seemed comparable (Supplemental Table 6). A possible confounder is the fact that we cannot exclude the positive effect highly motivated parents and children have on training and test results. We did not include a healthy term born control group in this study, because several studies confirm the positive effect of working memory training in different clinical conditions.

TABLE 2 Training Effects on Nontrained Visual and Verbal Working Memory Tasks

<table>
<thead>
<tr>
<th></th>
<th>Pretraining</th>
<th>Posttraining</th>
<th>Effect Size, (\chi^2)</th>
<th>95% CI of the Difference</th>
<th>(P)</th>
<th>Children With Improvement, %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spatial span</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward</td>
<td>4.2 (1.6)</td>
<td>4.7 (2.3)</td>
<td>0.05</td>
<td>(−1.7 to 0.6)</td>
<td>.27</td>
<td>55</td>
</tr>
<tr>
<td>Backward</td>
<td>2.3 (1.6)</td>
<td>3.6 (2.2)</td>
<td>0.34</td>
<td>(−2.2 to −0.4)</td>
<td>.01</td>
<td>70</td>
</tr>
<tr>
<td>Total</td>
<td>6.4 (5.0)</td>
<td>8.3 (4.2)</td>
<td>0.20</td>
<td>(−3.7 to −0.1)</td>
<td>.03</td>
<td>75</td>
</tr>
<tr>
<td><strong>Digit span</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward</td>
<td>5.5 (1.5)</td>
<td>5.5 (1.5)</td>
<td>0.001</td>
<td>(−0.6 to 0.5)</td>
<td>.93</td>
<td>40</td>
</tr>
<tr>
<td>Backward</td>
<td>1.25 (1.4)</td>
<td>1.7 (1.1)</td>
<td>0.13</td>
<td>(−0.9 to 0.1)</td>
<td>.10</td>
<td>35</td>
</tr>
</tbody>
</table>

Wilcoxon signed rank test for 2 related samples.
and healthy control groups including preschoolers. It would have been interesting to include a matched preterm born VLBW group acting as a control group that did not train. However, for ethical reasons, we had to offer the program to all participants.

None of the participants in this study had severe brain injury, and all of them obtained IQ scores within normal levels. No correlation was seen between Improvement Index and FSIQ (Supplemental Fig 3). This may indicate that effects of training are independent of IQ level, which is promising, because many VLBW children will have below-average IQs. This result is also supported by the findings in our study of working memory training in ELBW adolescents, in whom those with low IQ benefitted as well as those with normal IQ.

All participating children improved on trained working memory tasks delivered through the computer program. As far as we know, no studies report a specific value for the Improvement Index in the Cogmed JM version for preschool-aged children. We found a mean value of 18.4 with a range of 8 to 30. However, in studies where the Cogmed RM version was used, children with ADHD had mean Improvement Index of 28 (SD 12) (Cogmed America Inc 2009), and the study of ELBW adolescents reported mean Improvement Index of 32.7 (SD10.2). The lower Improvement Index found in the current study may reflect less strenuous training, simpler tasks, and the shorter training period per day for the preschoolers.

Studies in healthy preschool-aged children have shown that working memory training leads to significant improvement also on nontrained working memory tasks, as well as showing transfer effects on auditory and visual attention. The results in our group of VLBW children are consistent with these findings. Seventy-five percent of the children improved significantly on visual (Spatial Span), but not on verbal (Digit Span) working memory tasks (Table 2). Although other studies have shown improvement also on verbal working memory tasks like Digit Span after completed training at school age, we did not find this in our preschoolers. The reason may be that the preschool version of the Cogmed program does not include verbal working memory tasks.

In our study, 70% to 80% of the children improved significantly on auditory attention, phonological processing, and repetition of nonsense words assessing phonological awareness. Phonological awareness plays a central role in the prereading linguistic ability and is also important for developing mathematical skills. Recent studies show that working memory training in children at school age increases the reading comprehension, and a positive training effect regarding phonological awareness could therefore be a valuable support for learning to read in preterm born children. In the VLBW preschoolers, working memory training improved visual as well as verbal memory and learning, which was also found in our study with ELBW adolescents. These are all tasks that are similar to what is presented in the school environment, and we speculate that preschool training may therefore have positive effect on later academic ability and school performance.

Studies performed in school-aged children show that working memory training reduces hyperactivity and improves attention. In our study, we found a slight improvement in hyperactivity/impulsivity, but no change on attention. One reason for this discrepancy might be the longer training time (~45–50 minutes a day) in the

### TABLE 3 Training Effects on Attention and Language Tasks from NEPSY

<table>
<thead>
<tr>
<th></th>
<th>Pretraining Mean (SD) n = 20</th>
<th>Posttraining Mean (SD) n = 20</th>
<th>Effect Size, $\eta^2$</th>
<th>95% CI</th>
<th>$P$</th>
<th>Children With Improvement, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual attention total time</td>
<td>233.5 (41.0)</td>
<td>212.6 (44.3)</td>
<td>0.16</td>
<td>(−2.0 to 43.8)</td>
<td>.12</td>
<td>30</td>
</tr>
<tr>
<td>Auditory attention and response set</td>
<td>49.6 (28.5)</td>
<td>58.2 (30.4)</td>
<td>0.26</td>
<td>(−15.5 to −1.6)</td>
<td>.01</td>
<td>75</td>
</tr>
<tr>
<td>Phonological processing</td>
<td>9.3 (5.5)</td>
<td>12.6 (4.7)</td>
<td>0.42</td>
<td>(−5.2 to −1.4)</td>
<td>.00</td>
<td>80</td>
</tr>
<tr>
<td>Comprehension of instructions</td>
<td>17.3 (2.8)</td>
<td>18.4 (2.8)</td>
<td>0.12</td>
<td>(−2.4 to 0.3)</td>
<td>.11</td>
<td>60</td>
</tr>
<tr>
<td>Repetition of nonsense words</td>
<td>28.9 (8.1)</td>
<td>34.5 (10.7)</td>
<td>0.25</td>
<td>(−10.4 to −0.9)</td>
<td>.02</td>
<td>70</td>
</tr>
<tr>
<td>Memory for faces</td>
<td>20.0 (6.2)</td>
<td>24.9 (5.7)</td>
<td>0.49</td>
<td>(−7.4 to −2.5)</td>
<td>.00</td>
<td>80</td>
</tr>
<tr>
<td>Narrative memory</td>
<td>12.9 (5.0)</td>
<td>17.5 (5.9)</td>
<td>0.43</td>
<td>(−7.1 to −2.0)</td>
<td>.00</td>
<td>75</td>
</tr>
<tr>
<td>Sentence repetition</td>
<td>15.7 (4.3)</td>
<td>17.7 (4.1)</td>
<td>0.35</td>
<td>(−3.3 to −0.7)</td>
<td>.01</td>
<td>75</td>
</tr>
</tbody>
</table>

Wilcoxon signed rank test for 2 related samples.

### TABLE 4 ADHD Rating Scale Before and After Training

<table>
<thead>
<tr>
<th></th>
<th>Pretraining Mean (SD) n = 20</th>
<th>Posttraining Mean (SD) n = 20</th>
<th>Effect Size, $\eta^2$</th>
<th>95% CI</th>
<th>$P$</th>
<th>Children With Improvement, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inattention</td>
<td>6.5 (4.3)</td>
<td>5.8 (4.5)</td>
<td>0.03</td>
<td>(−1.2 to 2.6)</td>
<td>.31</td>
<td>55</td>
</tr>
<tr>
<td>Hyperactivity/ impulsivity</td>
<td>6.7 (4.5)</td>
<td>5.2 (4.2)</td>
<td>0.17</td>
<td>(−0.1 to 3.1)</td>
<td>.05</td>
<td>50</td>
</tr>
<tr>
<td>Total score</td>
<td>13.2 (9.1)</td>
<td>11.0 (7.7)</td>
<td>0.11</td>
<td>(−0.8 to 5.2)</td>
<td>.18</td>
<td>60</td>
</tr>
</tbody>
</table>

Wilcoxon signed rank test for 2 related samples.
Cogmed RM version for schoolchildren, whereas the preschoolers only train for 10 to 15 minutes a day. In addition, the children in our study had normal behavioral scores before training, which certainly causes limitations for improvement effects by training. Larger studies including VLBW preschoolers with clinical ADHD scores at pretraining may reveal whether working memory training will reduce such scores.

Studies report increased risk of anxiety disorders in preterm born children at school age,33,34 and behavioral problems including anxiety have been reported in preterm children as early as 3 to 5 years of age.35 In our study, none of the participating children had anxiety symptoms in the clinical range before training. However, after training, there was a significant decrease in separation anxiety and anxiety total score. One explanation for this may be natural development with increased maturity leading to less separation anxiety. We also speculate that increased working memory capacity may enable the child to understand more complex explanations providing a better understanding of the world. Owing to the small number of participants and the lack of significant correlation between improvement index and total anxiety score, additional studies will be needed to answer whether working memory training reduces anxiety in VLBW preschoolers.

**Clinical Implications**

Our study shows that computerized working memory training in a group of VLBW children at ages 5 to 6 years has a beneficial effect on trained and non-trained visual working memory tasks as well as generalizing effects on visual and verbal learning and memory functions. The study indicates that working memory training may be an effective intervention to be considered for use in preterm born children before they start school. We speculate that this may prevent or reduce cognitive problems that impact educational achievement and possibly also social function in these children. However, larger studies are needed to confirm our findings before a general recommendation of working memory training as an interventional tool for preterm born children at pre-school age should be given.

**REFERENCES**


**TABLE 5 Preschool Anxiety Scale (T scores) Before and After Training**

<table>
<thead>
<tr>
<th></th>
<th>Pretraining Mean (SD) n = 20</th>
<th>Posttraining Mean (SD) n = 20</th>
<th>Effect Size, $\eta^2$</th>
<th>95% CI of the Difference</th>
<th>$P$</th>
<th>Children With Improvement, %</th>
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<tbody>
<tr>
<td>Obsessive compulsive disorder</td>
<td>48.3 (10.1)</td>
<td>46.0 (7.7)</td>
<td>0.07</td>
<td>(−1.6 to 6.1)</td>
<td>.18</td>
<td>45</td>
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<tr>
<td>Social anxiety</td>
<td>48.4 (9.8)</td>
<td>48.0 (7.7)</td>
<td>0.05</td>
<td>(−1.5 to 4.3)</td>
<td>.40</td>
<td>60</td>
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<td>Separation anxiety</td>
<td>51.3 (13.6)</td>
<td>48.2 (10.3)</td>
<td>0.25</td>
<td>(0.5 to 5.7)</td>
<td>.05</td>
<td>55</td>
</tr>
<tr>
<td>Physical injury fears</td>
<td>48.6 (9.3)</td>
<td>46.9 (7.7)</td>
<td>0.15</td>
<td>(−0.2 to 3.6)</td>
<td>.08</td>
<td>45</td>
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<tr>
<td>Generalized anxiety</td>
<td>51.2 (13.5)</td>
<td>48.9 (10.9)</td>
<td>0.09</td>
<td>(−1.2 to 5.8)</td>
<td>.17</td>
<td>40</td>
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<tr>
<td>Total score</td>
<td>50.0 (12.5)</td>
<td>47.1 (9.2)</td>
<td>0.22</td>
<td>(0.3 to 5.5)</td>
<td>.02</td>
<td>65</td>
</tr>
</tbody>
</table>

Wilcoxon signed rank test for 2 related samples.


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