Children with cochlear implants (CIs) are at elevated risk for delays in verbal working memory skills that may contribute to delayed speech and language abilities. Verbal working memory skills can be measured, in part, on speed of scanning for verbal memory units during retrieval and on subverbal verbal rehearsal speed, both of which are delayed in children with CIs. Recently, working memory skills and language abilities in children with CIs who have cochlear implants have been linked to language outcomes in children with CIs. Children with cochlear implants have normal working memory capacity and some speech-language skills in a sample of children with cochlear implants. At present, the following are the findings: some working memory training may improve underlying memory scanning and verbal rehearsal speed. In this study, measures of memory scanning speed (Digit Span speed duration) and verbal rehearsal speed (Sentence Repetition utterance length) were measured in a sample of 9 children with CIs before and after a Waiting (No-Treatment) Period, Treatment (Cogmed Working Memory Training) Period, and 1-Month Follow-Up (Post-Treatment) Period. Although scanning speed did not change during the Waiting Period, improvement in scanning speed was found for the Digit Backward task after the Treatment and Follow-Up periods, and verbal rehearsal speed improved following the Follow-Up period. Other comparisons for scanning speed and verbal rehearsal speed were in the expected direction but not significant. Study results extend prior findings of working memory training in children with CIs and suggest improvement not only in working memory capacity but also in two key cognitive processes that underlie working memory (scanning speed and verbal rehearsal speed).

Subjects
Subjects were 9 children between ages 7 and 15 years (mean=10.2 years; SD=2.2; 6 males, 3 females) who had undergone bilateral cochlear implantation by 6 years of age. All subjects between birth (mean unaided pure tone average for the frequencies 500, 1000, and 2000 Hz=60 dB HL; SD=9.2) and 9 years of age (mean=8.4 years; SD=2.8). Subjects were from English-speaking home environments with enrollment in kindergarten or first grade prior to or at the time of enrollment in the study. All had normal hearing and language skills (oral or total communication). Subjects were also required to have average or lower working memory skills based on a working memory assessment battery (see Kronenberger et al. for review, for other sample characteristics).

Procedure
Subjects attended an initial Screening Visit, followed by a 2-week Waiting Period during which no intervention took place. At the end of the Waiting period, subjects returned for a Pretreatment Visit, which was followed by a 5-week Treatment period during which all subjects completed the standard Cogmed Working Memory Training (Klingberg et al., 2005) at home. A minimum of 20 completed Cogmed training sessions was required to remain in the study. At the end of the Treatment period, subjects returned for a Post-Treatment Visit. Short-term follow-up data were collected one month after completion of Cogmed Working Memory Training at a Follow-Up Visit.

Measures

table:

<table>
<thead>
<tr>
<th>Measure</th>
<th>Follow-Up Period</th>
<th>Post-Treatment Period</th>
<th>Pre-Treatment Period</th>
<th>Pre-Treatment Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digits Forward Latency</td>
<td>359.4</td>
<td>581.8</td>
<td>86.7</td>
<td>359.4</td>
</tr>
<tr>
<td>Digits Backward Latency</td>
<td>173.8</td>
<td>1405.6</td>
<td>206.3</td>
<td>1547.6</td>
</tr>
<tr>
<td>Utterance Length</td>
<td>216.8</td>
<td>442.3</td>
<td>266.1</td>
<td>250.4</td>
</tr>
<tr>
<td>Faster</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Slower</td>
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For the following timing variables: Latency (time from end of the examiner’s utterance to response), Pause Duration (average pause time between digits in a DS item), and Utterance Length (duration of subject’s sentence response utterance). Two research assistants independently measured these timing values using a digitally controlled waveform editor. The final values were obtained by averaging values provided by the research assistants.

Data Analysis
All data were analyzed using the Statistical Package for the Social Sciences (SPSS). All reported effect sizes were calculated using Cohen’s d. Differences for each timing measure were calculated by subtracting the baseline mean from the mean at each of the following time periods: Pretreatment Visit, Post-Treatment Visit, 1-Month Follow-Up Visit, and 1-Month Follow-Up Visit. Pretreatment Visit was used as the baseline, and for NEPSY-SR, Visit 1 was used as the baseline. Negative difference scores reflect shorter/last durations at the end visit as compared to the baseline visit. One sample t-tests were used to compare the sample mean difference scores to a value of 0 (no change). Paired sample t-tests were used to detect differences in mean difference scores within the same subjects across each visit. For each timing measure, the sample showing improvement in the timing measures (i.e., negative difference scores) was used to calculate effect sizes (i.e., 50% chance of improvement). P-values were based on 1-tailed tests because all hypotheses were unidirectional (expectation of improvement in timing measures).

RESULTS

Background
Cochlear implantation (CI) restores some components of hearing to a subset of deaf children, resulting in significant speech and language benefits. However, deficits in verbal working memory are present in a large proportion of children with CIs and have detrimental effects on speech and language skills (Pisoni et al., 2006). Recently, Kronenberger et al. (under review) demonstrated improvement in working memory and sentence repetition skills in a sample of children with CIs after working memory training. Verbal working memory measures have good reliability and validity. However, some of the underlying mechanisms that might be responsible for that improvement. Specifically, these study results demonstrated that improvement in scanning speed during a verbal working memory task (reflected by improvement in Pause Durations during DB as well as improvement in verbal rehearsal speed during a sentence repetition task (reflected by improvement in Latency and Utterance Length)) immediately and one-month after completion of Cogmed Working Memory Training. However, the current study extends those findings by investigating some of the underlying mechanisms that might be responsible for that improvement. Specifically, it was hypothesized that the aforementioned improvement in scanning speed during a verbal working memory task (reflected by improvement in Pause Durations during DB) as well as improvement in verbal rehearsal speed during a sentence repetition task (reflected by improvement in Latency and Utterance Length) would be predicted by changes in working memory performance on other tasks and by changes in language performance on other tasks. The current study therefore aimed to examine the relationship between working memory performance on other tasks and changes in language performance on other tasks. The results of this study must be interpreted in light of some limitations, including small N and lack of a control group. Additional studies are planned with larger samples using blinded, placebo-controlled methods.

REFERENCES


