Novel Learning Abilities After Traumatic Head Injury in Children

Nicole Hoffman
Adler School of Professional Psychology

Jacobus Donders
Mary Free Bed Hospital

Elizabeth H. Thompson
Adler School of Professional Psychology

The cognitive abilities of 69 children with traumatic head injury (THI) were evaluated with the California Verbal Learning Test-Children's Version (CVLT-C; Delis, Kramer, Kaplan, & Ober, 1994), the Children's Category Test (CCT; Boll, 1993), and the Wechsler Intelligence Scale for Children-Third Edition (WISC-III; Wechsler, 1991). Compared to children with mild to moderate injuries, children with severe THI demonstrated statistically significant impairments on the CVLT-C Total T-score as well as the WISC-III Processing Speed index, but findings for the CCT were less robust. Longer length of coma and male gender were associated with relatively poorer performance on the CVLT-C. Children with severe THI demonstrated difficulties with both capacity and speed of information processing, which could not be accounted for by attentional or general verbal knowledge factors. It is concluded that the combination of the CVLT-C and the WISC-III is useful in the evaluation of cognitive sequelae of THI but that findings from the CCT must be considered with some caution in this population. © 1999 National Academy of Neuropsychology. Published by Elsevier Science Ltd

Keywords: novel learning, head injury, children

It has been well-established that traumatic head injury (THI) may result in significant cognitive sequelae, such as reduced speed of information processing and impaired learning of new information and concepts, particularly with more severe injuries (Dalby & Obrzut, 1991; Donders & Kuldanek, 1998; Fletcher, Levin, & Butler, 1995). Until fairly recently, however, there were relatively few appropriately normed and standardized instruments to assess such abilities in children. The purpose of this investigation was to de-
termine the relative validity and clinical utility of a variety of these instruments in the context of neuropsychological assessment of children with THI, including the California Verbal Learning Test-Children’s Version (CVLT-C; Delis, Kramer, Kaplan, & Ober, 1994), the Children’s Category Test (CCT; Boll, 1993) and the Wechsler Intelligence Scale for Children-Third Edition (WISC-III; Wechsler, 1991).

The CVLT-C is a test of verbal learning that mimics the common task of remembering a grocery list. Its format offers the opportunity to evaluate both quantitative (e.g., number of items recalled) and qualitative (e.g., learning strategies) aspects of children’s memory. The validity of the CVLT-C in terms of sensitivity to THI has been demonstrated in several recent studies (Jaffe et al., 1993; Levin et al., 1994; Yeates, Blumenstein, Patterson, & Delis, 1995). Although the findings were variable with regard to a variety of learning style characteristics, most of these studies consistently found deficits in the amount of words that children could recall after time delays. The relatively more replicable findings with quantitative than with qualitative variables in this regard are consistent with recent findings in the CVLT-C standardization sample that suggested that quantitative variables, such as the number of words correctly or incorrectly recalled, were much more reliably associated with clearly defined theoretical constructs than qualitative variables, such as the degree to which words were reproduced in groups from the same semantic category or the region of the list (Donders, in press). In light of the well-known fact that THI tends to happen disproportionately more in boys than in girls (Dalby & Obrzut, 1991; Donders & Kuldanek, 1998), it is also noteworthy that recent evidence has suggested that girls tended to perform better than boys on most CVLT-C variables in the standardization sample (Kramer, Delis, Kaplan, O’Donnell, & Prifitera, 1997). This raises the possibility that demographic background may need to be considered in concert with neurological variables in the evaluation of the performance of children with THI on this test.

The CCT is an abbreviated measure of the children’s version of the Halstead Category Test (HCT), a widely used measure of complex conceptual learning processes that is known to be sensitive to cerebral impairment (Reitan & Wolfson, 1992a, 1992b). There have been few studies that have looked specifically at the CCT performance of children with acquired neurological impairment. However, the validity of the abbreviated format of the HCT that formed the basis for the CCT has been demonstrated in children with THI (Donders, 1996). Potential advantages of the CCT over the traditional HCT include reduced administration time and especially the fact that this instrument was normed on the same standardization sample as the CVLT-C, allowing for direct comparisons between the results from both instruments. Although both the CVLT-C and the CCT assess novel learning ability, recent research with the standardization sample of these instruments has demonstrated that they measure fairly different aspects of children’s cognition (sharing less than 15% of common variance at any age level), and that statistically significant differences between the standard scores of these two tests are not uncommon (Donders, 1998). Thus, inclusion of both of these tests in a neuropsychological test battery would likely provide a broader and nonredundant description of a child’s novel learning ability than choosing either test alone. To our knowledge, the specific pattern of performance of children with THI across the combination of the CVLT-C and CCT has not been evaluated previously.

The WISC-III is one of the most common and well-researched tests of children’s cognitive abilities. It is well-known that overreliance on measures of psychometric intelligence should be avoided in the evaluation of children with THI because to a large extent such tests measure overlearned skills that are relatively robust to the effects of head trauma (Telzrow, 1987; Ylvisaker, Hartwick, Ross, & Nussbaum, 1994). However, the
WISC-III offers the opportunity to consider children’s performance in terms of specific factor index scores, some of which (especially Perceptual Organization and Processing Speed) have demonstrated excellent sensitivity to injury severity in children with THI (Donders, 1997). The factor structure of the WISC-III has also been validated in a recent study of children with THI (Donders & Warschauisky, 1996). Inclusion of the WISC-III along with the CVLT-C and CCT allows the clinician to evaluate some aspects of learning ability (e.g., speed of information processing) that are not addressed by the other two instruments. This may be important because it is known that children with THI tend to be particularly deficient on speeded tasks (e.g., Bawden, Knights, & Wingron, 1985; Chadwick, Rutter, Shaffer, & Shroot, 1981).

On the basis of previous research, it was hypothesized that (a) greater degree of injury severity in children with THI would be associated with relative impairments on the summary standard scores of the CVLT-C and the CCT, as well as the Perceptual Organization and Processing Speed indexes of the WISC-III, and that (b) demographic variables (especially male gender) would also be associated with relatively greater impairment on the CVLT-C.

**METHOD**

**Participants**

The 69 children for this investigation were selected from a 3-year series of consecutive referrals to a regional midwestern rehabilitation facility. Criteria for inclusion of potential participants in the study were (a) diagnosis of nonpenetrating THI as the result of an external force to the head, with alteration of consciousness; (b) age between 6.0 and 16.11 years; and (c) completion of the CCT, CVLT-C, and WISC-III within 1 year after injury. Only first evaluations, no repeat evaluations, were used in this study. Of 87 available potential participants who met these criteria, a total of 18 children were excluded for the following reasons: premorbid learning disability ($n = 6$), prior history of treatment for attention-deficit/hyperactivity disorder ($n = 4$) or other psychiatric condition ($n = 3$), prior head trauma ($n = 3$), injury sustained as the result of child abuse ($n = 1$), and insufficient cooperation ($n = 1$).

Injury severity was classified on the basis of a combination of the lowest score on the Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974) during the first 24 hours following injury (after the first 30 minutes, and measured postresuscitation when applicable) and findings on computed tomography (CT) or magnetic resonance imaging (MRI) scan, according to the criteria suggested by Williams, Levin, and Eisenberg (1990). Children with mild injuries had GCS scores $\geq 12$ and no evidence of intracranial pathology on CT/MRI scan. Children with moderate injuries had either GCS scores $9$ to $12$ ($n = 22$), or GCS scores $\geq 12$ but associated with evidence of intracranial lesion on CT/MRI scan ($n = 6$). In order to assure sufficient power for the statistical analyses, the children with mild and moderate injuries were combined to form a Minor Injury group ($n = 41$), to be compared with the Severe Injury group ($n = 28$). Children in the latter group all had GCS scores $< 9$, and all of these children had loss of consciousness of more than 30 minutes.

Length of coma was determined on the basis of the number of days until the child provided motor responses to verbal command (i.e., GCS Motor subscale of 6). Diffuse lesions were defined as evidence for edema, shear injury, or multifocal petechial hemorrhagic contusions. Focal lesions were coded according to the presence or absence of an intracranial discrete lesion along four nonexclusive, descriptive categories: in the left or right hemisphere, and anterior or posterior to the Rolanidic and Sylvian fissures.
Details regarding the characteristics of the final sample are presented in Table 1 for the complete sample and, separately, for the Minor and Severe subgroups. This sample was, for the most part, independent of a previous investigation where the focus was exclusively on performance on the WISC-III (Donders, 1997). Only 20 of the 69 participants in the current study had also been used in the previous one.

### Materials

The CVLT-C is an individually administered measure of a child’s ability to learn and remember verbally presented information. The same version is given to all children between the ages of 5 and 16 years. It contains two word lists that each contain 15 shopping...
items, including 5 words from each of 3 semantic categories. There are five trials of full presentation and immediate recall of the first list, followed by one-time presentation and immediate recall of the second list. Measures of free recall and semantically cued recall of the first list are obtained immediately after the interference trial with the second list, and again after a 20-minute delay. Finally, a recognition trial is presented in which the child is asked to identify the 15 items from the first list from a larger list containing distractor items. The total number of items that are correctly recalled over the first five trials involving immediate recall of the first list (CVLT-C Total) can be expressed as an age-normed $T$-score ($M = 50, SD = 10$), with higher scores reflecting better performance. Average internal consistency of this variable is .85, with an average standard error of measurement of 3.83, suggesting adequate reliability (Delis et al., 1994). Numerous other measures of quantitative (e.g., number of words) and qualitative (e.g., recall strategy) can be obtained from the CVLT-C, and these are expressed as age-normed $z$-scores ($M = 0, SD = 1$).

The CCT is an individually administered measure of a child’s ability to solve problems by means of developing and modifying strategies of responding to visual patterns and designs on the basis of feedback regarding the accuracy of responses. Level 1 of this test is given to children between the ages of 5 and 8 years and consists of 5 subtests and 80 items. Level 2 is given to children between the ages of 9 and 16 years and consists of 6 subtests and 83 items. On both levels, the child’s task on each but the last subtest is to identify the single conceptual rule underlying the comprising items. The last subtest on both levels requires the child to remember and reapply the conceptual rules from previous subtests. On both levels, the main variable is the total number of errors (CCT Total), which is converted into an age-normed $T$-score, similar to the CVLT-C Total score. Average internal consistency of this variable is .88 for Level 1, and .86 for Level 2; with average standard errors of measurement of 3.46 and 3.74, respectively; suggesting adequate reliability (Boll, 1993).

The WISC-III is an individually administered group of measures of psychometric intelligence. Although the traditional IQ scores are still provided by this instrument, the manual suggests that interpretation along four-factor index scores may be more accurate, and this has been confirmed in a recent study of children with THI (Donders & Warschausky, 1996). These factors scores include Verbal Comprehension (VC), Perceptual Organization (PO), Freedom from Distractibility (FD), and Processing Speed (PS). They are expressed as age-normed standard scores ($M = 100, SD = 15$). Average reliability coefficients for these factor index scores range from .85 to .94; with average standard errors of measurement ranging from 3.78 to 5.83; suggesting excellent reliability (Wechsler, 1991).

**Procedure**

The CVLT-C, CCT, and WISC-III were administered and scored according to standardized test procedures as part of neuropsychological evaluations that were requested by attending physicians during the rehabilitation of the children, when they were medically stable and when they could recall meaningful information from day to day. Differences between the Minor and Severe groups were evaluated by means of chi-square tests for discrete variables, and by means of analysis of variance (ANOVA) for continuous variables. For these purposes, some of the discrete variables were dichotomized in order to ensure sufficient numbers of participants in each cell for the statistical analyses. Specifically, for parental occupational status, the two highest subclassifications were com-
bined, as well as the two lowest ones. For injury circumstances, the distinction was whether or not the children were passengers in motor vehicle accidents.

RESULTS

There were no statistically significant differences between the Minor and Severe Injury groups in terms of the proportion of ethnic minorities, parental occupational status, injury circumstances, age, or interval between injury and psychometric assessment ($p > .10$ for all variables). There was a statistically not significant trend for the Severe group to have relatively more boys than girls, as compared to the Minor group, $\chi^2(1, N = 69) = 2.82, p < .10$ (see Table 1).

As an initial investigation of the criterion validity of the various psychometric measures, a multivariate analysis of variance (MANOVA) was performed to compare the Minor and Severe Injury groups on six global test summary variables: the $T$-scores for, respectively CVLT-C Total and CCT Total, as well as the VC, PO, FD, and PS indexes of the WISC-III. These data are presented in Table 2. There was a statistically significant main effect of groups, $F(6, 62) = 3.77, p < .005$. As post hoc comparisons, Bonferroni-corrected $t$-tests were performed with alpha set at $.008 (.05/6)$. The results indicated that the Minor group had statistically significant higher scores than the Severe group on CVLT-C Total, $t(67) = 3.82, p < .001$, and on WISC-III PS, $t(67) = 4.26, p < .0001$. Partial univariate effect sizes (.18 for CVLT-C Total and .21 for WISC-III PS) were moderate by conventional standards (Cohen, 1977; Stevens, 1992). The other group differences did not meet the a priori established level of statistical significance.

Pearson product-moment correlations between the psychometric variables and length of coma were calculated next. Because such correlations for the various WISC-III indexes have been reported previously (Donders, 1997), the primary interest of this investigation concerned the CCT and CVLT-C $T$-scores. CVLT-C Total had a strong inverse relationship with length of coma, $r = -.52, p < .0001$ (accounting for approximately 27% of the variance in coma duration), but the relationship CCT Total and length of coma only approached statistical significance, $r = -.23, p < .10$ (accounting for only

### Table 2

<table>
<thead>
<tr>
<th>Measure</th>
<th>Severe</th>
<th>Minor</th>
<th>df</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVLT-C Total</td>
<td>41.43 (12.66)</td>
<td>52.10 (10.47)</td>
<td>1.67</td>
<td>14.57</td>
</tr>
<tr>
<td>CCT Total</td>
<td>45.00 (8.39)</td>
<td>50.61 (10.33)</td>
<td>1.67</td>
<td>5.68</td>
</tr>
<tr>
<td>WISC-III VC</td>
<td>89.29 (16.03)</td>
<td>93.81 (14.48)</td>
<td>1.67</td>
<td>4.49</td>
</tr>
<tr>
<td>WISC-III PO</td>
<td>86.29 (17.93)</td>
<td>96.46 (16.82)</td>
<td>1.67</td>
<td>4.69</td>
</tr>
<tr>
<td>WISC-III FD</td>
<td>91.93 (13.46)</td>
<td>100.29 (13.95)</td>
<td>1.67</td>
<td>6.15</td>
</tr>
<tr>
<td>WISC-III PS</td>
<td>79.11 (16.06)</td>
<td>94.98 (14.60)</td>
<td>1.67</td>
<td>18.13</td>
</tr>
</tbody>
</table>

CVLT-C = California Verbal Learning Test—Children’s Version ($M = 50, SD = 10$); CCT = Children’s Category Test ($M = 50, SD = 10$); WISC-III = Wechsler Intelligence Scale for Children—Third Edition ($M = 100, SD = 15$); VC = Verbal Comprehension; PO = Perceptual Organization; FD = Freedom from Distractibility.

aMinor > severe, $p < .008$. 
about 5% of the variance in coma duration). Of interest is also the fact that CVLT-C Total correlated more strongly with WISC-III PS ($r = .68, p < .0001$) than with any other WISC-III factor index score, including VC ($r = .45, p < .001$), PO ($r = .56, p < .0001$), and FD ($r = .49, p < .0001$).

The degree to which performance on the CVLT-C Total $T$-score could be predicted on the basis of other variables was also evaluated. Stepwise regression analysis (SRA) with backward elimination of variables was used for this purpose. In order to ensure acceptable participant to variable ratios, two separate initial SRAs were first performed; one including demographic variables (gender, ethnicity, parental occupational status, and accident circumstances), and one including neurological injury variables that could be measured independently of length of coma (diffuse lesions, focal lesions, skull fractures, and seizures). These initial SRAs resulted in two preliminary regression models. Only those variables that had remained in these two preliminary models were then included in a final SRA to arrive at one overall best regression model to predict the CVLT-C Total $T$-score. Because this entire process involved three analyses, alpha for retention of variables in the final model was set a priori at .017 (.05/3). Gender remained as the single statistically significant predictor in this final regression model, $F(1, 67) = 10.33, p < .005$, explaining 14% of the variance in CVLT-C Total, with girls tending to outperform boys on this variable.

Because of the fact that the CVLT-C Total $T$-score is a summary index that does not provide details about various aspects of recall, it was decided to follow up the statistically significant findings for this variable with a separate MANOVA, again using injury severity groups as the independent variable but using various CVLT-C $z$-scores as the dependent variables. The purpose was to determine which aspects of memory, as assessed by the CVLT-C, best discriminated between the two groups. For this analysis, CVLT-C indexes were chosen on the basis of the results of a recent study involving confirmatory factor analysis of a subgroup of variables in the CVLT-C standardization sample that had acceptable sampling distribution characteristics and that were not linearly dependent of each other (Donders, in press). Five factors were identified in that investigation: Attention Span (variables list A trial 1, list B, and middle region recall), Learning Efficiency (variables list A trial 5, semantic clustering, and recall consistency), Free Delayed Recall (variables short delay free recall and long delay free recall), Cued Delayed Recall (variables short delay cued recall, long delay cued recall, and recognition hits), and Inaccurate Recall (variables total intrusions and recognition false positives). For the current purposes, two variables were selected to represent each of these five factors. All of these variables had relatively high ($>.50$) factor loadings in the original study.

The specific CVLT-C variables selected for this investigation included the following: the total number of words correctly recalled on the first trial of the first (A1) and second (B) lists, representing the Attention Span factor; the total number of words correctly recalled on the final trial of the first list (A5) and the percentage of correct words consistently recalled across consecutive presentations of the first list (CONS), representing the Learning Efficiency factor; the total number of words correctly recalled on the short (SDFR) and long (LDFR) delay free recall trials, representing the Free Delayed Recall factor; the total number of words correctly recalled on the long delay cued recall trial (LDCR) and the number of hits during the recognition trial (HITS), representing the Cued Delayed Recall factor; and the total number of intrusions (words provided by the child that were not part of the list) across the test (INTR) and the total number of false positives during the recognition trial (FPOS), representing the Inaccurate Recall factor. For most of these variables, higher $z$-scores reflect better performance; with the excep-
tion of INTR and FPOS, for which higher z-scores reflect poorer performance. The results are presented in Table 3.

There was again a statistically significant main effect of groups, $F(10, 58) = 3.21, p < .005$. For post hoc comparisons, alpha was adjusted to .005 (.05/10). The results indicated that the Minor group had statistically significant higher scores than the Severe group on the following CVLT-C variables: A5, $t(67) = 3.30, p < .005$; SDFR, $t(67) = 4.75, p < .0001$; LDFR, $t(67) = 5.03, p < .0001$; and LDCR, $t(67) = 5.25, p < .0001$. In contrast, the Severe group had statistically significant higher scores on the variable FPOS than the Minor group, $t(67) = 3.92, p < .001$. Partial univariate effect sizes, ranging from a low of .14 for A5 to a high of .29 for LDCR, were moderate for these variables. The group differences on the other CVLT-C variables did not meet the a priori established level of statistical significance.

### DISCUSSION

The purpose of this investigation was to examine the relative validity and clinical utility of the combined use of the CVLT-C, CCT, and WISC-III in a sample of children with THI. Overall, the findings support the use of the CVLT-C and WISC-III in this context, but suggest that results from the CCT may need to be used with some caution.

Hypothesis 1 received partial support. The standard scores on the CVLT-C Total and WISC-III PS indexes demonstrated statistically significant inverse relationships with measures of injury severity (GCS and length of coma). This is consistent with previous research involving the CVLT-C (Levin et al., 1994) and the WISC-III (Donders, 1997). These findings confirm that severe THI is associated with significant deficits in overall efficacies of verbal memory and speed of information processing (Dalby & Obrzut, 1991; Donders & Kuldanek, 1998; Fletcher et al., 1995). CVLT-C Total and WISC-III PS may provide important complementary information to the clinician in this respect. At the same time, the differences between the two injury severity groups on CCT Total and WISC-III PO fell short of the a priori specified levels of statistical significance, even

---

**TABLE 3**

CVLT-C z-Scores of Severe ($n = 28$) and Minor ($n = 41$) Injury Groups, and Univariate Statistics

<table>
<thead>
<tr>
<th>Sample Group</th>
<th>Severe</th>
<th>Minor</th>
<th>df</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure</td>
<td>$M$ ($SD$)</td>
<td>$M$ ($SD$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>List A, Trial 1</td>
<td>-.38 (.97)</td>
<td>.22 (1.05)</td>
<td>1.67</td>
<td>5.68</td>
</tr>
<tr>
<td>List A, Trial 5</td>
<td>-.82 (1.52)</td>
<td>.17 (.99)</td>
<td>1.67</td>
<td>10.87</td>
</tr>
<tr>
<td>Recall consistency</td>
<td>-.23 (1.02)</td>
<td>.21 (.87)</td>
<td>1.67</td>
<td>3.67</td>
</tr>
<tr>
<td>List B</td>
<td>-.71 (1.06)</td>
<td>-.17 (.97)</td>
<td>1.67</td>
<td>4.88</td>
</tr>
<tr>
<td>Short Delay Free Recall</td>
<td>-.12 (1.41)</td>
<td>.10 (1.29)</td>
<td>1.67</td>
<td>22.55</td>
</tr>
<tr>
<td>Long Delay Free Recall</td>
<td>-.12 (1.35)</td>
<td>.12 (1.55)</td>
<td>1.67</td>
<td>25.29</td>
</tr>
<tr>
<td>Long Delay Cued Recall</td>
<td>-.14 (1.42)</td>
<td>.10 (.98)</td>
<td>1.67</td>
<td>27.52</td>
</tr>
<tr>
<td>Total intrusions</td>
<td>.70 (1.61)</td>
<td>-.12 (.93)</td>
<td>1.67</td>
<td>7.17</td>
</tr>
<tr>
<td>Recognition hits</td>
<td>-.38 (1.53)</td>
<td>.12 (.59)</td>
<td>1.67</td>
<td>3.57</td>
</tr>
<tr>
<td>Recognition false positives</td>
<td>.71 (1.56)</td>
<td>-.38 (.58)</td>
<td>1.67</td>
<td>15.36</td>
</tr>
</tbody>
</table>


1. Minor > severe, $p < .005$.
2. Severe > minor, $p < .005$. 

Downloaded from https://academic.oup.com/acn/article-abstract/15/1/47/1912 by guest on 24 November 2018
though they were in the hypothesized direction. Several possible explanations need to be considered in this respect.

Particularly with regard to PO, it is possible that the lack of a statistically significant difference between groups was due at least in part to the influence of the conservative Bonferroni correction. The Severe group’s performance was still about two thirds of a standard deviation below that of the Minor group on this variable, and PO also had a statistically significant correlation with length of coma in the complete sample ($r = -.35$, $p < .005$). If one administers all subtests of the WISC-III that are necessary to compute the four-factor index scores, the clinician is unlikely to miss the influence of reduced speed of performance, which may sometimes also deflate PO scores because faster performance can result in bonus points.

Potentially more concerning is the fact that the difference between the injury severity groups was far less pronounced on CCT Total (about half a standard deviation) than on CVLT-C TOTAL (more than one standard deviation). In terms of correlations with length of coma, the CCT performed even more disappointingly. These findings may suggest that the CCT is relatively less sensitive to the impact of severe THI than is the CVLT-C, and that caution may be needed when the CCT is used as the only measure of novel learning ability in the clinical evaluation of such children.

Differences in norms cannot explain the discrepancy in sensitivity between the CVLT-C and CCT because these two tests share the same standardization sample. There is also prior support for the validity of the abbreviated format of the HCT that formed the basis for the CCT, (Donders, 1996). It is possible, though, that differences in the task requirements and formats may be responsible for the somewhat disappointing CCT findings. The CCT is a very structured task with frequent feedback about performance, and minimal memory demands. The CVLT-C, in contrast, involves supra-span learning, and the Total score is based exclusively on trials where only repetition of information (and no cues or feedback of any other kind) are provided. It appears plausible that children with severe THI may have particular difficulties with new learning if a lot of information is presented to them at the same time, and if they are left to their own resources to figure out how to organize that information.

The sensitivity of CVLT-C Total to injury severity cannot be explained completely on the basis of general verbal ability level because of all the correlations with WISC-III factor index scores, this variable actually had the lowest degree of shared variance (about 21%) with VC. In contrast, the highest correlation was with PS (reflecting about 46% of common variance). This may suggest that limitations in information processing capacity (as assessed by the CVLT-C) and in information processing speed (as assessed by the WISC-III) are not independent of each other, even though they do not appear to be fully interchangeable or redundant. This may be related to the fact that words are presented on the CVLT-C at the rate of about one word per second.

Inspecting the pattern of the various CVLT-C $z$-scores, it is clear that the Minor group’s mean performance was entirely within normal limits (i.e., differing less than one half standard deviation from the normative mean) on all variables. Thus, it appears that mild to moderate pediatric THI does not generally produce significant persistent memory impairment, at least not as assessed by the CVLT-C. This is consistent with most previous studies (Jaffe et al., 1993; Levin et al., 1994) although some difficulties with independent delayed recall have been reported in such children if they are evaluated very early in their recovery (Yeates et al., 1995). The adequate performance of the Minor group in this investigation suggests that it was appropriate to use it as a contrast with the Severe group, who demonstrated significant deficits (sometimes exceeding one standard deviation from the normative mean) on several CVLT-C variables. However, in the ab-
ence of an other-injury control group, very mild verbal learning deficits in children with mild/moderate THI cannot be completely excluded, which is a limitation of this investigation. Inclusion of such a control group in future studies would be helpful in order to determine whether any postinjury cognitive deficits in children with mild head trauma are truly related to “brain” injury because some recent studies have suggested that such children do not have any more functional morbidity than children with traumatic injuries to other parts of the body (Asarnow et al., 1995; Bijur & Haslum, 1995).

The results from the current multivariate analyses may add to the understanding of the nature of the learning and memory deficits of children with severe THI, as assessed by the CVLT-C. The Severe and Minor Injury groups did not demonstrate statistically significant differences on CVLT-C variables of short-term span of attention (A1 and B). The absence of a big difference between the standard scores on these two variables in the Severe group would also argue against a major proactive interference effect, which is consistent with previous research (Yeates et al., 1995). These findings suggest that children with severe THI may have sufficient immediate working memory.

By the fifth trial of List A, there was a quite significant difference (about one standard deviation) between the groups, even though children with severe injuries appeared to recall information across the five trials with approximately the same degree of consistency as did children with minor injuries. Again, this is consistent with previous findings. Yeates and his colleagues (1995) also found that, across all immediate recall trials, the largest difference between mild/moderate and severe THI groups was on variable A5, and that the groups did not differ in learning characteristics during the five presentations of List A. Thus, there does not appear to be a distinct effect of injury severity on qualitative strategy of learning during immediate recall, at least not as measured by the CVLT-C. However, the results suggest that children with severe THI may have less efficient learning as the result of a limited memory capacity: Even with multiple repetitions, they have problems expanding their recollection much beyond the span of working memory.

The difference between the two groups in eventual recall of list A persisted on the delayed recall trials. In this investigation, the Severe group recalled far fewer correct words on both short and long, free and cued, delayed recall trials than the Minor group. Previous studies with the CVLT-C in children with THI have been inconsistent with regard to short delay recall, but have most often found injury severity effects on both free and cued long delay trials (Jaffe et al., 1993; Levin et al., 1994). In the current investigation the contrasts between A5 and SDFR, and between SDFR and LDFR, were not substantial in the Severe group (i.e., less than one half of a standard deviation on average). Thus, there does not appear to be a major retroactive interference effect, nor is there evidence for rapid forgetting of the information. Again, this is consistent with previous research (Yeates et al., 1995).

We found a trend for the Severe group to have relatively more intrusions across the test than did the Minor group, but this fell just short of the a priori specified level of statistical significance. Thus, it is possible that children with severe THI may make recall errors by trying to make “plausible guesses” beyond the capacity of their memory, but this requires further investigation. One source of support for that possibility is that the results from the recognition trial during this investigation revealed that children with severe THI did not differ significantly from children with minor injuries in terms of the number of hits, but they did produce far more false positives. Previous studies have yielded conflicting findings regarding the accuracy of recognition memory in children with THI (Jaffe et al., 1993; Yeates et al., 1995), so these findings will require further independent replication before they can be interpreted with certainty.
It is also important to realize that performance on the CVLT-C by the children in this sample was influenced not only by their level of injury severity and coma duration, but also by gender. Girls had statistically significant CVLT-C Total T-scores than boys. To some extent, this may be explained by the fact that there were relatively more boys than girls in the Severe group than in the Minor group. However, such a gender difference has also been demonstrated in the CVLT-C standardization sample (Kramer et al., 1997). This implies that consideration of the influence of gender on performance on verbal learning and memory is warranted when evaluating children with THI, just like it is in the general population.

Overall, the results from this investigation suggest that the CVLT-C and WISC-III are valid and sensitive measures of cognitive sequelae of severe THI in children, whereas the CCT may need to be used more cautiously with this population until further validation research is completed. The CVLT-C findings suggest primarily a limitation in memory capacity, in the context of fairly adequate short term attention span. As a result of this limitation in capacity, these children cannot engage efficiently in supraspan learning (even with repeated presentation of the same material) and they may provide more erroneous responses under a format that includes cues or multiple choices. In addition, the WISC-III findings suggest a deficit in speed of information processing. The degree to which this impacts performance on the CVLT-C independently of limitations in capacity requires further investigation, as does the evaluation of possible subtypes of CVLT-C performance in children with THI and to what degree such subtypes are related to injury parameters.

REFERENCES


