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Performance discrepancies on the California Verbal Learning Test–Children's Version (CVLT–C) in children with traumatic brain injury

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Abstract

One hundred sixty-seven children with traumatic brain injury (TBI), selected from an 8-year series of consecutive referrals to a Midwestern rehabilitation hospital, completed the California Verbal Learning Test–Children's Version (CVLT–C) and the Wechsler Intelligence Scale for Children–Third Edition (WISC–III) within 1 year after injury. A large proactive interference (PI) effect, defined as performance on the second list that was at least 1.5 standard deviations below that on the 1st one, was statistically significantly more common in this clinical sample (21%) than in the CVLT–C standardization sample (11%). Other performance discrepancies, including retroactive interference, rapid forgetting, and retrieval problems, occurred at approximately the same rate in the clinical and standardization samples. Children with anterior cerebral lesions were about 3 times less likely to have a large PI effect than children without such lesions, but the former group performed worse on the first CVLT–C list. The impact of pediatric TBI on a wide range of CVLT–C quantitative variables was mediated by speed of information processing, as assessed by the WISC–III Processing Speed factor index. It is concluded that failure to release from PI is somewhat common, although certainly not universal, in children with TBI. Unlike with adults, anterior cerebral lesions are not associated selectively with an increased risk for PI after pediatric TBI but rather with a reduced efficiency of allocation of cognitive resources. Deficits in speed of information processing appear to be primarily responsible for the learning deficits on the CVLT–C after pediatric TBI. (*JINS*, 2004, *10*, 482–488.)

Keywords: Traumatic brain injury, Learning, Memory, Proactive interference, Processing speed

INTRODUCTION

The California Verbal Learning Test–Children's Version (CVLT–C; Delis et al., 1994) is a widely used measure of learning and remembering new information. Several studies have demonstrated the sensitivity of this instrument to various forms of cerebral compromise, ranging from acute lymphoblastic leukemia (Precourt et al., 2002) to epilepsy (Williams et al., 2001) to phenylketonuria (White et al., 2001). The CVLT–C has had particularly widespread application in the evaluation of children with traumatic brain injury (TBI; Hoffman et al., 2000; Levin et al., 2000; Roman et al., 1998). Impaired performance on the CVLT–C after TBI is strongly predictive of special education placement 2 years later (Miller & Donders, 2003) and shows only partial recovery at even more extended follow-up (Yeates et al., 2002). The goal of the current investigation was to evaluate the degree to which children with TBI demonstrate unusual performance contrasts on the CVLT–C, and whether this is related to demographic background, cerebral injury, or other psychometric variables.

The CVLT–C offers the opportunity to consider four specific performance contrasts (Delis et al., 1994), including proactive interference (PI), retroactive interference (RI), rapid forgetting (RF), and retrieval problems (RP). Poor performance on the second list as compared to the first one is thought to reflect susceptibility to PI, with prior learning making more difficult immediate subsequent learning. Poor performance on the short-delay free recall trial (after presentation of a distractor list) as compared to the final trial of

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the first list is purported to reflect RI, or a detrimental effect of new learning on recall of previously learned information. Poor savings on the long delay free recall trial as compared to the short-delay free recall trial is considered as a reflection of RF, or an increased rate of forgetting during the 20-min delay interval. Finally, better performance on the discriminability index of the recognition trial (taking into account both correct and incorrect responses) as compared to the long delay free recall trial is interpreted to reflect RP, indicating difficulty with recalling information independently but improvement in accessing that same information when multiple choices are provided.

Performance contrasts on the CVLT–C have received only limited attention, even though they may have significant clinical and theoretical implications. For example, if children with TBI frequently have large RP then they might benefit from school accommodations where multiple-choice tests as opposed to open-ended questioning are used. Increased susceptibility to PI has also been linked in the adult literature to frontal dysfunction (Gershberg & Shimamura, 1995; McDonald et al., 2001; Smith et al., 1995) but this has not been explored as systematically in children with TBI. Yeates and colleagues (1995) reported that children with severe TBI did not display differential PI or RI effects but that they did have somewhat more prominent RF and RP effects, compared to demographically matched controls. However, this has not been a consistent finding (Roman et al., 1998). Furthermore, the base rate of such differences was not taken into account. Research with the CVLT–C standardization sample ($n = 920$) has demonstrated that apparently large performance contrasts are actually fairly common in children without neurological compromise (Donders, 1999). Using a criterion for unusual patterns as those occurring in less than approximately 10% of the standardization sample, potentially clinically significant values for specific performance contrasts were defined (in z score units) as PI ≤ -1.5, RI ≤ -1.5, RF ≤ -1, and RP ≥ 1.5.

When evaluating performance on pediatric memory tests, speed of information processing is also an important consideration. Kail (2002) suggested that increased speed of information processing may reduce susceptibility to PI. In children with TBI, information processing speed is often compromised (Yeates et al., 2002) and the Processing Speed index from the Wechsler Intelligence Scale for Children–Third Edition (WISC–III; Wechsler, 1991) has demonstrated considerable sensitivity to injury severity in this regard (Donders, 2001; Tremont et al., 1999). It is not clear from this previous research whether decrements in speed of information processing cause a global decline in performance on the CVLT–C or an augmentation of specific performance contrasts.

The specific goals of this exploratory investigation were threefold. First, we wanted to determine whether children with TBI demonstrate unusual PI, RI, RF, or RP performance contrasts on the CVLT–C to any statistically significant degree more than children in the standardization sample. Second, we planned to investigate with those performance contrasts for which such potentially meaningful differences were found, the degree to which occurrence of such large contrasts was related to demographic (e.g., age, parental occupational status) and neurological (e.g., coma, neuroimaging) variables. Third and finally, we intended to evaluate the possibility that speed of information processing might have a mediating effect on CVLT–C performance, both globally and in terms of magnitude of contrasts.

METHODS

Research Participants

Following institutional review board approval, the 167 participants were selected from an 8-year consecutive series of referrals to a Midwestern rehabilitation center, on the basis of the following criteria: (1) diagnosis of TBI due to an external force to the head causing alteration of consciousness, (2) age between 6 and 16 years, (3) evaluation with the CVLT–C and the WISC–III within 1 year of injury, and (4) absence of any prior psychiatric or neurological condition, learning disability, or attention deficit hyperactivity disorder. The CVLT–C and WISC–III were administered routinely to all referred children during this time period as part of a flexible assessment battery, except when there were complicating factors that would have invalidated test results (e.g., severe dysarthria, non-English language background). Characteristics of the final sample are presented in Table 1. Diffuse lesions on CT or MRI scan involved widespread involvement such as edema or axonal shearing. Focal lesions included discrete, localized abnormalities such as contusions or hematomas. Length of coma was defined as the number of days until the child responded to verbal commands.

Injury severity was classified first on the basis of the lowest post-resuscitation Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974) score within the first 24 hr after injury (see Table 1). However, consistent with previous research (Donders & Warschausky, 1996; Williams et al., 1990), neuroimaging findings were also considered to distinguish between children with truly mild *versus* complicated mild injuries. CT scans were routinely obtained within 24 hr after injury but follow-up neuroimaging was also often performed within the first subsequent week and those data were considered in the classification of injury severity as well. For example, a slowly developing subdural hematoma might not show up on the day-of-injury scan but could be picked up several days later. Children with mild injuries ($n = 41$) had GCS scores over 12 and negative neuroimaging findings, whereas children with complicated mild injuries ($n = 19$) also had GCS scores over 12 but along with neuroimaging evidence for an acute posttraumatic intracranial lesion.

Table 1. Demographic and injury characteristics of 167 children with traumatic brain injury

Child characteristic	*n*	%
Gender		
Boy	96	57.48
Girl	71	42.52
Ethnicity		
African American	13	7.78
Asian	6	3.59
White	135	80.84
Latino	13	7.78
Parental occupation		
Clerical	53	31.74
Professional	30	17.96
Skilled labor	58	34.73
Unskilled labor	26	15.57
Injury circumstances		
Cyclist or pedestrian	42	25.15
Fall or recreation	37	22.16
Motor vehicle passenger	69	41.32
Other	19	11.38
Glasgow Coma Scale		
Mild (13–15)	60	35.93
Moderate (9–12)	40	23.95
Severe (3–8)	67	40.12
Neuroimaging*		
Diffuse lesion	36	21.56
Anterior focal lesion	55	32.93
Posterior focal lesion	45	26.95
Left focal lesion	49	29.34
Right focal lesion	59	35.33
Age (years) (*M*, *SD*)	12.90	3.34
Time since injury (days) (*M*, *SD*)	85.01	63.55
Coma (days) (*M*, *SD*)	1.64	3.86

*Categories are not mutually exclusive.

Materials

The CVLT–C is an individually administered test of a child's ability to learn and remember verbally presented information. It contains two word lists with each list containing 15 shopping items, including five words from each of three semantic categories. There are five trials of full presentation and immediate reproduction of the first list (A), followed by one-time presentation and immediate reproduction of the second list (B). Measures of short delay free recall (SDFR) and semantically cued recall (SDCR) of List A are obtained immediately after the trial with List B, and again after a 20-min long delay (LDFR and LDCR). Finally, a recognition trial is presented in which the child is asked to identify the 15 items from List A from a larger list containing distractor items. The main variable of interest on the recognition trial is the discriminability index (DISC), which takes into account accurate and inaccurate responses. The task is the same for all ages in the 5 to 16 year age span. Overall performance on the CVLT–C is characterized in terms of a summary *T* score ($M = 50$, $SD = 10$), reflecting a global index of immediate free recall over five successive trials of the first list (A1–A5). All other variables described above are expressed as age-corrected *z* scores ($M = 0$, $SD = 1$), with higher scores reflecting better performance. In the complete sample, the mean composite *T* score on the CVLT–C was 47.93 ($SD = 12.19$).

There were four specific CVLT–C performance contrasts that were the focus of the present investigation; all expressed as raw differences between *z* scores. PI concerns the difference between total numbers of correct words recalled on, respectively, the second list (B) and the first trial of list A (PI = B − A1). RI represents the savings on the short delay free recall trial (SDFR) of correct words that the child recalled on the fifth trial of list A (RI = SDFR − A5). RF reflects the savings on the long delay free recall trial (LDFR) of correct words that the child recalled on SDFR (RF = LDFR − SDFR). RP indicates the degree of improvement on the multiple-choice recognition trial (DISC), compared to LDFR (RP = DISC − LDFR).

The WISC–III is a widely used comprehensive measure of psychometric intelligence that yields four-factor index scores ($M = 100$, $SD = 15$). In the complete sample, average performance on these indexes was as follows: Verbal Comprehension = 95.35 (13.96), Perceptual Organization = 94.45 (15.80), Freedom From Distractibility = 97.43 (14.94), and Processing Speed (PS) = 92.17 (17.75). For purposes of the current investigation, the primary variable of interest was the PS index.

Procedures

The CVLT–C and the WISC–III were administered and scored in a standardized manner as part of neuropsychological evaluations, requested in the context of rehabilitation. Assessments were performed only when children were medically stable and could recall meaningful information from day to day, and occurred on an outpatient basis in the vast majority (82.04%) of the sample. Parents provided informed consent, and children provided verbal assent, for all assessments. The primary variables of interest were the four performance contrasts on the CVLT–C and the WISC–III PS factor index. On the basis of research with the standardization sample (Donders, 1999), each CVLT–C contrast was considered unusual if it met the following criteria: PI ≤ -1.5, RI ≤ -1.5, RF ≤ -1, and RP ≥ 1.5.

Data Analyses

Performance contrasts on the CVLT–C were expressed in numeric differences between *z* scores. Analyses involving all other CVLT–C variables were based on *z* scores and analyses involving WISC–III data used standard scores. Group differences on continuous variables were investigated with analysis of variance, whereas group differences on discrete variables were analyzed with chi-square. Differences in the prevalence of performance contrasts between the current sample and the standardization sample were

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analyzed with a z test for proportions. Hierarchical regression analyses were used to determine the relative contributions of neurological and demographic variables to performance on selected CVLT–C variables.

RESULTS

In the complete sample, there were 35 children (20.96%) who had PI effects -1.5 or lower, 16 children (9.58%) who had RI effects -1.5 or less, 14 children (8.38%) who had RF effects -1 or less, and 21 children (12.58%) who had RP effects 1.5 or more. Only for PI was the difference with the respective prevalence in the CVLT–C standardization sample (10.98%) statistically significant ($z = 3.33$, $p < .01$; $p > .10$ for all other comparisons). Thus, only proactive interference appeared to be more common in this sample of children with TBI than in the normative sample. For this reason, we focused the subsequent analyses on comparisons of the groups of children with ($n = 35$) *versus* without ($n = 132$) unusually large PI effects.

The performance of the children with or without PI effects -1.5 or less on the CVLT–C variables that were of primary interest for this investigation are presented in Figure 1. Inspection of Figure 1 suggests that the children without large PI effects did somewhat worse on all of the delayed recall trials than the other group, but this difference was not statistically significant ($p > .10$) when initial performance on List A was used as a covariate. In general, the presence of a large PI effect was characterized by a combination of high-average performance on the first trial of List A and below average performance on List B.

There were no statistically significant differences between the two groups in terms of gender, ethnicity, parental occupational status, injury circumstances, age, time since injury, or performance on any of the four WISC–III factor indexes ($p > .10$ for all variables). With regard to the neurological injury variables (coma and neuroimaging), a statistically significant difference was found only for the presence or absence of anterior focal lesions (regardless of the laterality). Specifically, children without anterior lesions were almost three times more likely to have a PI effect -1.5 or less than children with such lesions [$\chi^2(df = 1, N = 167) = 5.00$, $p < .05$, Odds Ratio = 2.85; 90% C.I. = 1.11–7.36]. This was associated with a small effect size ($\varphi^2 = .03$). Of the 55 children with anterior lesions, 6 (10.91%) had PI -1.5 or less whereas 29 (25.89%) of the 112 children without anterior lesions had such a large performance contrast.

Figure 2 presents the CVLT–C findings for children with ($n = 55$) *versus* without ($n = 112$) anterior lesions on neuroimaging. The children with anterior lesions did worse on A1 than the other group [$F(1,165) = 6.09$, $p < .01$] and this was associated with a small effect size ($\eta^2 = .04$). Group comparisons on the remaining variables were not statistically significant ($p > .10$) after taking into account original level of performance on A1. These findings may explain what initially appeared to be a paradoxical effect; that is, that children with anterior lesions were actually less likely to have large PI effects. As can be seen in Figure 2, children with anterior lesions already did relatively poorly on the first trial of List A, making it less likely that they subsequently had a large relative decrement on List B.

We also compared the children with and without anterior lesions on the WISC–III PS index. Children with anterior lesions had lower WISC–III PS scores ($M = 88.26$, $SD = 18.15$) than those without such lesions [$M = 94.09$, $SD = 17.32$; $F(1,165) = 4.60$, $p < .05$] and this was associated with a small effect size ($\eta^2 = .03$). This raised the possibility that reductions in speed of information processing might be at least partially to blame for the relatively poor performance of children with anterior lesions on the first trial of List A on the CVLT–C. For this reason, the groups were

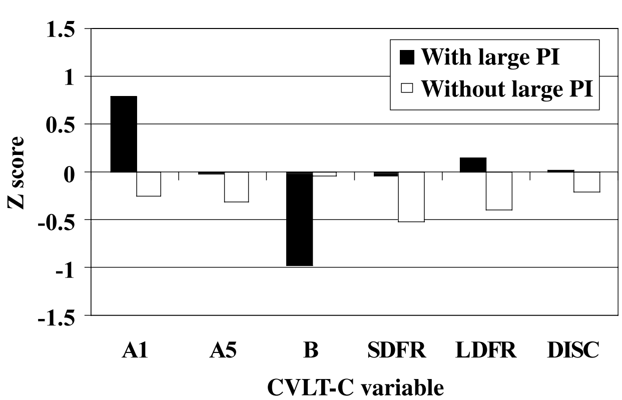

Fig. 1. Performance of children with ($n = 35$) and without ($n = 132$) proactive interference (PI) effects ≤ -1.5 on the California Verbal Learning Test–Children's Version (CVLT–C). A1 = Trial 1 of List A. A5 = Trial 5 of List A. B = List B. SDFR = short delay free recall. LDFR = long delay free recall. DISC = recognition discriminability.

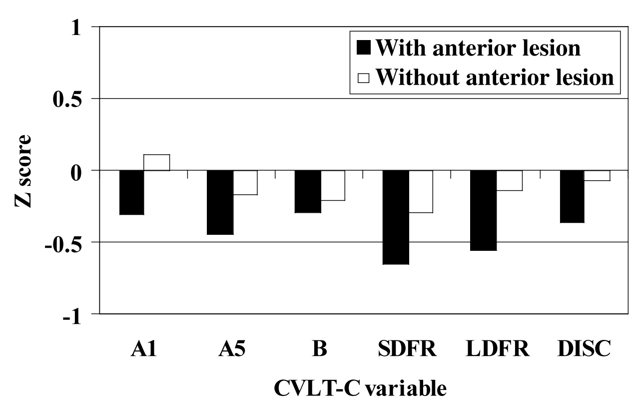

Fig. 2. Performance of children with ($n = 55$) and without ($n = 112$) anterior focal cerebral lesions on the California Verbal Learning Test–Children's Version (CVLT–C). A1 = Trial 1 of List A. A5 = Trial 5 of List A. B = List B. SDFR = short delay free recall. LDFR = long delay free recall. DISC = recognition discriminability.

compared again on A1 but with PS as a covariate. Under those conditions, the group difference in A1 was no longer statistically significant ($p > .10$).

The CVLT–C also offers the opportunity to evaluate qualitative aspects of learning style, such as the degree to which the child spontaneously reproduces items from the list by categories such as fruits or things to play with (semantic clustering) or the degree to which the child reports the same items over successive trials of the list (recall consistency). In the complete sample, average *z* scores on these variables were, respectively, 0.05 (1.28) for semantic clustering and −.02 (1.01) for recall consistency. We compared children with *versus* without large PI effects, as well as children with *versus* without anterior lesions, on these variables and did not find any statistically significant group differences ($p > .10$ for all comparisons).

Finally, to explore more specifically the relative contributions of injury severity and information processing speed on CVLT–C performance, we performed a series of hierarchical regression analyses, for each of the variables involved in any of the CVLT–C contrasts; namely, A1, A5, B, SDFR, LDFR, and DISC. Coma was entered first, followed by the neuroimaging variables, and WISC–III PS was entered last. It was decided *a priori* that variables added at each step would not be retained in the model if they did not yield statistically significant improvement. Because of the relatively large number of analyses, the criterion for such improvement in prediction was modified to .01. The resulting final regression models are presented in Table 2.

Inspection of Table 2 suggests that the same two-variable regression model resulted for all of the variables, with the exception of the distractor list (B). After accounting for the effect of length of coma, none of the diffuse or focal neuroimaging variables yielded statistically significant improvement in predictions. However, PS appeared to explain a considerable degree of variance in all CVLT–C scores, above and beyond what could be accounted for on the basis of coma alone. This was despite a fairly strong correlation between coma and PS ($r = -.48$, $p < .01$), suggesting 23% of shared variance.

Table 2. Hierarchical regression models for predicting CVLT–C performance in 167 children with traumatic brain injury

CVLT–C variable	Predictor variables	Final SRC	Composite model R^2	R^2 change
A1	coma	−.14	.11	—
	PS	.46	.22	.11
A5	coma	−.31	.22	—
	PS	.31	.29	.07
B	PS	.30	.09	—
SDFR	coma	−.31	.25	—
	PS	.40	.38	.13
LDFR	coma	−.30	.26	—
	PS	.43	.40	.14
DISC	coma	−.29	.22	—
	PS	.37	.33	.11

Note. All predictor variables statistically significant ($p < .01$). CVLT–C = California Verbal Learning Test–Children's Version. SRC = standardized regression coefficient. A1 = Trial 1 of List A. A5 = Trial 5 of List A. B = List B. SDFR = short delay free recall. LDFR = long delay free recall. DISC = recognition discriminability. PS = Processing Speed.

DISCUSSION

The goal of the current investigation was to evaluate the degree to which children with TBI demonstrate unusual degrees of proactive or retroactive interference, rapid forgetting, or retrieval problems on the CVLT–C, and whether this is related to demographic, neurological, or processing speed variables. The findings suggest that only in terms of proactive interference (PI) did these children show more frequent susceptibility compared to the standardization sample, with about 1 in every 5 children with TBI showing a *z*-score difference −1.5 or less between the first trials of, respectively, List A and List B. Children with anterior focal cerebral lesions tended to have such large contrasts almost three times less likely than children without such lesions. Speed of information processing, as assessed by the WISC–III PS index, was strongly positively correlated with all quantitative CVLT–C variables.

The current findings stand in contrast to those of Yeates et al. (1995) and Levin et al. (2000), who did not find evidence for specific PI effects. Previous studies have yielded inconsistent findings regarding the possible presence other than performance contrasts, such as retrieval problems, after pediatric TBI (Roman et al., 1998; Yeates et al., 1995). These differences are likely due to the fact that a much stricter definition of performance contrasts was used in the current investigation, taking into account the base rate of these discrepancies in the CVLT–C standardization sample. Previous studies have looked at averaged group differences but have not considered the relative proportions of participants with *a priori* defined unusually large performance contrasts. Since clinicians are likely to underestimate the normal frequency of occurrence of any given value of differences between test scores (Schinka et al., 1998), an actuarial approach such as taken here may yield more reliable findings.

Initially, it appeared somewhat counter-intuitive that children with anterior cerebral lesions were relatively less likely to have unusually large PI effects, given that the reverse has been described in several adult samples with different conditions (Gershberg & Shimamura, 1995; McDonald et al., 2001; Smith et al., 1995) or adults with TBI (Numan et al., 2000). However, inspection of the complete test performance of the children with known anterior lesions indicated that they already performed relatively poorly on List A. Levin et al. (2000) also reported relative deficits in verbal memory, as assessed by the CVLT–C, in children with frontal lesions. In addition, Sowell et al. (2001) reported that, in normal children, greater frontal lobe maturation was associated with improved performance on the CVLT–C. In both of those previous studies, the effects were most pro-

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nounced on the delayed recall measures. However, the current findings suggested that it was the initial learning of the information that was crucial in this regard because the differences between subgroups with and without frontal lesions on delayed memory variables were no longer statistically significant when initial performance on the first trial of List A was used as a covariate in the analyses. Thus, in children with TBI, anterior lesions tend to be associated with general difficulties in allocation or inefficient use of learning resources, and not necessarily specific PI effects. This may reflect an executive problem, as suggested in recent research (Hanten et al., 2002). In the absence of anterior lesions, such children acquire new facts or details relatively better when these are limited to only one set of information, but they are at increased risk for having difficulty with release from PI when competing units of information are to be learned in rapid succession. Whether any of these difficulties are also reflected in the daily lives of these children will need to be addressed in future research, with inclusion of ecologically valid measures of executive functioning. An example of this would be the Behavior Rating Inventory of Executive Function (Gioia et al., 2000), which has been used in several recent investigations of children with TBI (Mangeot et al., 2002; Vriezen & Pigott, 2002).

A recent meta-analysis suggested that susceptibility to PI declines systematically during normal childhood and that this is mediated by an age-related improvement in speed of information processing (Kail, 2002). We did not find prominent age effects on PI in the current investigation. In this context, it should be noted that we used age-corrected scores for all analyses. Furthermore, we had no children below the age of 6 years whereas about three quarters of the participants (74.85%) were between the ages of 10 and 16 years. Important changes in executive skills related to prefrontal functioning take place between the ages of 5 and 7 years (Welsh et al., 1991). Kail (2002) also reported that the majority of the studies concerning PI have concentrated on the ages between 4 and 9 years. Thus, it is possible that age effects in susceptibility to PI could be found in a sample with predominantly younger children with TBI. At the same time, we did find evidence to suggest that, in the current sample, deficits in speed of information processing were associated strongly with broad-based reduced efficiency of verbal learning. First of all, the impact of anterior focal lesions on initial learning on the CVLT–C appeared to be mediated by the effects of information processing speed, as assessed by the WICS–III PS factor. Second, PS explained a statistically significant degree of incremental variance in a wide range of CVLT–C variables, above and beyond what could be accounted for exclusively on the basis of length of coma. Qualitative CVLT–C variables such as semantic clustering did not appear to provide much incremental information in this regard, which is consistent with previously expressed reservations about the utility of those variables (Donders, 1999).

It should also be realized that, although we did find an effect of absence of anterior focal lesions on the presence of unusually large PI effects, the effect size was rather small. Furthermore, although the rate of large PI effects in this clinical sample was almost twice that reported for the CVLT–C standardization sample, the vast majority (79.04%) of our children with TBI did not have such great differences in performance between the two lists to be learned. In contrast, the association between WISC–III PS and performance on the CVLT–C was typically of a medium or moderate size, even after accounting for the effects of injury severity. Thus, reduced ability to process the rapidly presented words on the CVLT–C in an efficient manner is apparently a more pervasive consequence of pediatric TBI than difficulty with release from PI.

Potential limitations of this investigation must also be considered. This was a referred convenience sample, selected at a rehabilitation hospital, and consequently included relatively more children with intracranial lesions and prolonged coma than would be found with consecutive emergency room admissions. However, this also provided the broad range of injury severity that is necessary to detect potential influences of such variables. In this investigation, we made comparisons to the CVLT–C standardization sample, and future studies may wish to explore comparisons with a demographically matched control group with non-brain (e.g., orthopedic) injuries. Our sample was also limited to children for whom norms for both the CVLT–C and the WISC–III were applicable, and further research on PI phenomena and other performance contrasts in preschoolers with TBI is still needed. A more significant limitation is that we did not have access to many of the original CT or MRI scans and consequently could not perform volumetric lesion analyses, which have been applied previously with some success in similar investigations (e.g., Levin et al., 2000). At the same time, relative strengths of this investigation include large sample size as well as the fact that children with various confounding premorbid or comorbid complicating factors were systematically excluded.

With these reservations in mind, we conclude that children with TBI do have an increased susceptibility to PI but that this is not their main problem with regard to learning and memory, which instead appear to be affected relatively more by reductions in speed of information processing. For the majority of these children, clinical implications may be that information needs to be presented at lower rates, possibly in smaller chunks. For those children who do demonstrate unusually large PI effects, additional recommendations may include attempting to space different tasks apart rather than massing them together or jumping rapidly from one to the other. In general, however, performance contrasts alone will likely not provide sufficient information about the learning and memory skills of children with TBI. A specific goal for future research is the evaluation of different subtypes of performance, based on a wide range of CVLT–C variables, and to relate these to injury severity parameters as well as long-term educational outcome.

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