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Comparison of Verbal Learning and Memory in Children with Heavy Prenatal Alcohol Exposure or Attention-Deficit/Hyperactivity Disorder

Nicole Crocker, Linnea Vaurio, Edward P. Riley, and Sarah N. Mattson

Center for Behavioral Teratology, Department of Psychology, San Diego State University, San Diego, California

Abstract

Background—Children with fetal alcohol spectrum disorders (FASD) have deficits in verbal learning and recall. However, the specificity of these deficits has not been adequately tested. In the current study, verbal learning and memory performance of children with heavy prenatal alcohol exposure was compared to children with attention-deficit/hyperactivity disorder (ADHD), a disorder commonly seen in alcohol-exposed children.

Methods—Performance on the California Verbal Learning Test – Children's Version (CVLT-C) was examined in three groups of children (N=22/group): (1) heavy prenatal alcohol exposure and ADHD (ALC), (2) nonexposed with ADHD (ADHD), and (3) nonexposed typically developing (CON). Groups were matched on age, sex, race, ethnicity, handedness, and socioeconomic status.

Results—Group differences were noted on learning trials (CON > ADHD > ALC). On the delayed recall trial, CON children performed better than both clinical groups, who did not differ from each other. Children in the ALC group demonstrated poorer recognition than children in the CON and ADHD groups, who did not differ from each other. Marginally significant group differences were noted on retention of previously learned material. Post hoc analyses indicated that ADHD children showed worse retention relative to the CON group, whereas retention in the ALC children remained intact.

Conclusions—These data suggest that children with heavy prenatal alcohol exposure and nonexposed children with ADHD show differential patterns of deficit on the CVLT-C. Performance of alcohol-exposed children reflects inefficient encoding of verbal material, whereas performance of the ADHD group may be better characterized by a deficit in retrieval of learned material. Differences noted between clinical groups add to a growing neurobehavioral profile of FASD that may aid in differential diagnosis.

Keywords

fetal alcohol syndrome; fetal alcohol spectrum disorders; verbal learning and memory; differential diagnosis; CVLT-C

INTRODUCTION

Prenatal exposure to alcohol can result in a range of neurobehavioral impairment and physical malformations including the fetal alcohol syndrome (FAS). Central nervous system (CNS) dysfunction, growth deficiency, and craniofacial anomalies, are required for a

diagnosis of FAS (Hoyme et al., 2005; Jones and Smith, 1973). However, neuropsychological and behavioral deficits are also found in alcohol-exposed children in the absence of the physical features seen in FAS (e.g., Mattson et al., 1997; Mattson et al., 1998). The adoption of the non-diagnostic term, fetal alcohol spectrum disorders (FASD), emphasizes that effects of prenatal alcohol exposure occur over a continuum (Bertrand et al., 2005). Furthermore, FASD represent a major public health concern, with prevalence estimates as high as 1 in every 100 live births (May and Gossage, 2001; Sampson et al., 1997).

Given the spectrum of effects and the lack of a definitive physical marker to identify the range of children affected by prenatal alcohol exposure, differential diagnosis is sometimes difficult, especially in the absence of maternal history confirming alcohol exposure. Clinically, children with heavy prenatal alcohol exposure display behavioral characteristics similar to children with attention-deficit/hyperactivity disorder (ADHD) and often meet diagnostic criteria for this disorder (Fryer et al., 2007a; Steinhausen et al., 1993). Some of the shared symptoms include attention deficits, hyperactivity, and impulsivity. A distinct neurobehavioral profile of children with FASD would aid in distinguishing those with prenatal alcohol exposure from non-exposed individuals with attention deficits, especially in the absence of facial dysmorphology. Determination of such a profile requires improved delineation of the cognitive deficits associated with FASD and comparison to other clinical groups, including ADHD, across a broad range of measures.

A small but growing literature exists on the comparison of children with prenatal alcohol exposure and non-exposed children with ADHD or attention deficit disorder (ADD) (Coles et al., 1997; Crocker et al., 2009; Greenbaum et al., 2009; Kooistra et al., 2009; Nanson and Hiscock, 1990; Vaurio et al., 2008). Results from these investigations suggest that the two clinical groups are similar on parent reports of attention, communication and socialization aspects of adaptive function, and performance on the Wisconsin Card Sorting Test. Group differences have been noted on aspects of attention, daily living skills, social cognition, emotion processing, and performance on letter fluency and trail making tests. In spite of the recent increase in research comparing these two clinical groups, no studies have compared learning or memory. Similarly, although verbal learning and memory deficits have been described in children with FASD (Kaemingk et al., 2003; Mattson et al., 1996; Mattson et al., 1998; Mattson and Roebuck, 2002; Willford et al., 2004), none of the existing studies addressed specificity of reported deficits. In the current study verbal learning and memory performance was compared in children with prenatal alcohol exposure and children with ADHD. Verbal learning and memory relies on several component processes such as attention and executive function (Delis et al., 1994), which may be differentially affected in FASD and ADHD. Thus, evaluation of learning and memory function in these two clinical populations may elucidate similarities and differences between neuropsychological profiles and refine the existing profiles for each disorder.

Our previous studies have documented a consistent pattern of impairment and spared ability in alcohol-exposed children (Mattson et al., 1996; Mattson et al., 1998; Mattson and Roebuck, 2002; Roebuck-Spencer and Mattson, 2004) using the California Verbal Learning Test – Children's Version (CVLT-C, Delis et al., 1994). Children with histories of heavy prenatal alcohol exposure recalled fewer words than controls over five learning trials and after short and long delay intervals. However, both groups retained a similar proportion of learned material on the long delay trial. Thus, the deficits seen in children with prenatal alcohol exposure are associated with difficulty learning new information rather than retention of learned material. Findings of impaired learning and intact retention were replicated in separate investigations using other measures of verbal learning, including a study of lower levels of alcohol exposure (Kaemingk et al., 2003; Willford et al., 2004).

Deficits in verbal learning and memory have been found in children (Cahn and Marcotte, 1995; Kaplan et al., 1998; Loge et al., 1990; Oie et al., 1999) and adults (Downey et al., 1997; Johnson et al., 2001a; Rashid et al., 2001; Roth et al., 2004; Seidman et al., 1998) with ADHD. While some studies of ADHD demonstrate impaired initial learning of verbal and nonverbal material and intact retention of encoded material (Cahn and Marcotte, 1995; Kaplan et al., 1998; Seidman et al., 1998), other studies that have used the CVLT-C suggest that deficits in verbal learning and memory may be associated with impaired retrieval or long term retention of verbal material rather than initial learning (Cutting et al., 2003; Loge et al., 1990).

There has been a recent impetus in research on effects of alcohol exposure to improve definition of neurobehavioral abilities in several cognitive domains in order to improve diagnosis of a population that can be difficult to identify (Riley et al., 2003). Comparison of alcohol-exposed individuals with other clinical groups who share characteristics (e.g., attention deficits) may help clarify relative strengths and weaknesses, rather than simply outlining deficits in comparison to typically developing controls. More specifically, direct comparison of children with FASD and ADHD may yield distinct patterns of performance on the CVLT-C, add to growing knowledge of the neuropsychological profile of prenatal alcohol exposure, and ultimately improve differential diagnosis. Therefore, the aim of the current study was to compare performance of these two groups on the CVLT-C, which includes measures of verbal learning, recall, retention, and recognition.

Impairments on verbal learning and memory tasks in children with FASD have been consistently shown to be related to difficulty with the initial learning process, however the mechanisms underlying verbal learning and memory deficits in ADHD are less well understood. Thus, based on previous research it was hypothesized that children in the alcohol-exposed and ADHD groups would show deficits in both immediate and delayed recall relative to controls, and given the sensitivity of this measure to alcohol exposure, that children with FASD would show these impairments to a greater extent than the ADHD group. In addition, it was expected that children with FASD would show spared retention rates for learned material. Although findings from previous studies of ADHD have been inconsistent, based on memory profiles of other populations with frontal-striatal involvement, we expect that children with ADHD will show impairments in retention of previously learned material, although the pattern will be explained by retrieval deficits.

METHOD

General Method

Three groups of children were included: children with heavy prenatal alcohol exposure and ADHD (the ALC group), children with ADHD without prenatal alcohol exposure (the ADHD group), and a control group of children with neither prenatal alcohol exposure nor ADHD (the CON group). All children were recruited as part of a larger ongoing study of the behavioral teratogenicity of alcohol. Alcohol-exposed children were recruited into this larger study via several mechanisms, including professional referral or caregiver self-referral and community outreach at various agencies and child-related venues. The subset of alcohol-exposed children selected for this investigation met *DSM-IV* criteria for ADHD and was matched to the non-exposed ADHD and CON groups on age, sex and race/ethnicity. As with our exposed subjects, non-exposed subjects are recruited via several mechanisms, including community outreach at various agencies and child-related venues and caregiver self-referral. While children with ADHD were not specifically recruited for the current investigation, all children were screened for *DSM-IV* diagnoses upon enrollment and those included met diagnostic criteria as detailed below. Mothers of children in the ALC group consumed at least 4 drinks per occasion at least once per week or 14 drinks per week during pregnancy.

Teratogenic exposure history was determined through multi-source collateral report, including review of available medical, social service, and adoption agency records or maternal report, when available. Direct maternal report generally was unavailable, as many children with heavy prenatal alcohol exposure no longer reside with their biological families. The majority of children in the control and ADHD groups reside with their biological mothers. Therefore, screening for exposure to alcohol or other teratogens in these groups was determined through direct maternal report. Mothers of these children reported little (i.e., <1oz AA/day prior to pregnancy recognition), if any, alcohol use during pregnancy. These procedures are in agreement with normative standards for retrospective confirmation of maternal alcohol use within the field of clinical behavioral teratology.

Children in the alcohol-exposed group were evaluated by a dysmorphologist with expertise in alcohol teratogenesis (Kenneth Lyons Jones, MD). FAS diagnoses are based on physical measurements (height or weight $\leq$ 10 percentile), craniofacial structure analysis (presence of at least two of the following: short palpebral fissures, smooth philtrum, thin vermillion), evidence of deficient brain growth or abnormal morphogenesis (at least one of the following: structural brain abnormalities, head circumference $\leq$ 10th percentile), and alcohol exposure history (Hoyme et al., 2005).

ADHD diagnoses were determined using the computerized NIMH Diagnostic Interview Schedule for Children (DISC) (Shaffer et al., 2000) or the Schedule for Affective Disorders and Schizophrenia for School Aged Children: Lifetime Version Interview (K-SADS) (Kaufman et al., 1997) administered to the caregiver by trained examiners. A previous study comparing clinician-administered K-SADS to lay interviewer-administered DISC assessment in an epidemiological sample demonstrated moderate agreement (kappa ranges from .24 – .38) between the two measures (Cohen et al., 1987). Both K-SADS and DISC are based on DSM-IV diagnostic criteria and are commonly used to assess for ADHD diagnoses (Nigg, 1999; Rucklidge and Tannock, 2002). In addition, both measures have shown excellent interrater and test-retest reliability (Jensen et al., 1995; Kaufman et al., 1997). Although most alcohol-exposed children who participate in our ongoing research program meet criteria for ADHD (Fryer et al., 2007a), for this study, we specifically selected children who met these criteria. None of the children in the CON group met criteria for ADHD, nor did their parents report any concerning behavioral problems upon enrollment in the study. Following informed consent and assent, children were administered a battery of neuropsychological tests, including measures of general intelligence, language, learning, memory, visual-spatial and visual-motor ability, motor performance, academic performance, and executive function (cf. Mattson et al., 2006b; Mattson and Roebuck, 2002). All test administrators were blind to group status of participants and all children sign an assent agreement prior to their participation in the study. The measure included in the current study, the California Verbal Learning Test – Children's Version (CVLT-C) (Delis et al., 1994), is described below. The San Diego State University Institutional Review Board approved all procedures.

Participants

Sixty-six children (aged 7–14 years) participated in this study, distributed as follows: ALC, $n = 22$; ADHD, $n = 22$; and CON, $n = 22$. Groups were matched on age (within 6 months), sex, and race/ethnicity. At the time of testing, 31.8% of children in the ADHD group and 36.4% of children in the ALC group were taking stimulant medications.

Measure

Each child was given the CVLT-C as part of a larger battery of tests. The test comprises two lists, each with 15 items that fall into one of three semantic categories. There are five

learning trials with immediate recall of the first list (A), followed by one immediate recall trial of the second list (B). After the short delay imposed by the reading and recall of list B, free and cued recall trials for list A are administered. Free and cued recall trials are repeated after a 20-minute delay with no additional exposure to the list. Lastly, a 45-item yes/no recognition trial for list A is presented. The CVLT-C has been used in previous studies of FASD (Mattson et al., 1996; Mattson et al., 1998; Mattson and Roebuck, 2002; Roebuck-Spencer and Mattson, 2004) and ADHD (Cutting et al., 2003; Loge et al., 1990) as well as language impairment (Shear et al., 1992), and pediatric traumatic brain injury (Donders and Hoffman, 2002; Donders and Minnema, 2004; Mottram and Donders, 2006; Roman et al., 1998; Yeates et al., 1995). The CVLT-C has demonstrated good internal consistency and test-retest reliability coefficients as well as good content, criterion, and construct related evidence of validity (Delis et al., 1994). CVLT-C variables used in the current study are defined in Table 1.

Statistical Analyses

Demographic Information—Demographic data were analyzed by Chi-square (sex, race/ethnicity, handedness) or standard analysis of variance (ANOVA) techniques (age, FSIQ and Freedom of Distractibility (FD) index scores, as measured by the Wechsler Intelligence Scale for Children (WISC-III), and socioeconomic status [SES]), as measured by Hollingshead. Significant group differences were followed up with pairwise comparisons (Fisher's Least Significant Difference test). At the outset of data analysis it was verified that the assumptions of ANOVA and ANCOVA were met.

Verbal Learning and Memory—Analyses of learning and memory variables conducted in this study parallel those conducted in our previous studies (Mattson and Roebuck, 2002; Roebuck-Spencer and Mattson, 2004). Learning and memory variables were analyzed by analysis of covariance (ANCOVA). Normative data are limited for performance across the individual learning trials, so raw scores were used for analyses of learning and memory. Because raw scores were used for analysis, age at time of testing was included as a covariate for all learning and memory variables in which age was found to be a significant predictor of performance. In our sample, SES was not significantly associated with the dependent variables and thus was not included as a covariate in subsequent analyses. While the groups differed on measures of general intellectual function, FSIQ was not included as a covariate in these analyses given the inappropriateness of covarying a variable on which populations differ (Adams et al., 1985; Dennis et al., 2009) and because controlling for IQ might remove important variance explained given its relationship with verbal learning and memory. Simple main effect analyses and pairwise comparisons (Fisher's Least Significant Difference test) were used to follow up significant main or interactive effects where appropriate. Alpha levels were set at $p < .05$.

RESULTS

Demographic Information

Demographic information is listed in Table 2. The groups were similar on sex ($X^2(df = 2) = 1.47, p = .48$), handedness ($X^2(df = 2) = 3.06, p = .216$), race ($X^2(df = 2) = 1.16, p = .561$), and ethnicity ($X^2(df = 2) = 4.15, p = .126$). Marginally significant differences were noted on age ($F(2, 63) = 2.49, p = .09$) and SES ($F(2, 63) = 2.66, p = .08$). Significant group differences were noted on FSIQ ($F(2, 63) = 18.86, p < .001$) and FD index scores ($F(2, 63) = 25.22, p < .001$) from the WISC-III. Pairwise comparisons indicated that for FSIQ scores, the CON and ADHD groups had significantly higher FSIQ than the ALC group ($p < .001$), but did not differ from each other ($p = .264$). The ALC group had significantly lower FD

scores than the CON and ADHD groups ($p < .001$). Also, when compared directly, the CON had significantly higher FD scores than the ADHD group ($p = .002$).

Verbal Learning and Memory

Total Learning—The number of words produced across the five learning trials was analyzed using a 3×5 univariate repeated measures ANCOVA with Group (ALC, ADHD, CON) as the between-subjects factor, Trial (A1-A5) as the within-subject variable, and age as a covariate. The Group $\times$ Trial interaction was significant ($F(8, 248) = 2.92, p = .004$) as was the main effect of Group ($F(2, 62) = 11.216, p < .001$). Overall group differences were apparent on all trials and pairwise comparisons indicated the following specific differences ($p < .05$): controls performed significantly better than the ALC group on all trials except trial 1; the ADHD group performed significantly worse than the CON group on trials 2 and 3 and significantly better than the ALC group on trials 4 and 5.

Given the significant Group $\times$ Trial interaction, we examined group performance across the five learning trials using pairwise comparisons between trials. Children in the CON group reached learning asymptote between trials 2 and 3, as supported by significant differences ($p < .001$) between trials 1 and 2 and marginally significant differences between trials 2 and 3 ($p = .071$). Children in the ADHD group continued to acquire new information through at least trial 4; significant differences were noted between trials 1 and 2 ($p < .001$), 3 and 4 ($p = .001$), and marginal differences were noted between trials 4 and 5 ($p = .065$). Finally, children in the ALC group continued to acquire information through trial 5; significant differences were noted between trials 1 and 2 ($p < .001$) and 4 and 5 ($p = .024$). See Figure 1.

Free Recall After a 20-Minute Delay—The amount of information recalled after the 20-minute delay was examined using ANCOVA with Group as the between-subjects factor and age as a covariate. The main effect of Group was significant ($F(2, 62) = 6.01, p = .004$) and pairwise comparisons indicated that the CON group performed better than both clinical groups ($p < .05$), which did not differ significantly from one another ($p = .216$). See Table 3.

Retention—To measure retention of information over time, group differences in the number of words recalled after the 20-minute delay were compared after covarying the amount of information learned on the final learning trial (trial A5). As explained in a previous study (Mattson and Roebuck, 2002), in comparison to simple savings scores, this analysis allows for a purer examination of memory by equating groups for amount of information successfully recalled on earlier learning trials. In addition, we determined the appropriateness of A5 as a covariate by confirming the correlation with delayed recall and the absence of an interaction with Group. Thus, delayed recall was examined using ANCOVA with Group as a between-subjects factor and A5 as a covariate. Age was not a significant covariate in this analysis. Using A5 as a covariate allows for each subject to serve as his/her own control and therefore accounts for effects of age. The main effect of Group was marginally significant ($F(2, 62) = 2.851, p = .065$). Given the lack of clear differences, the marginal effect was followed up and showed that the ADHD group had worse retention relative to the CON group ($p = .023$). The ALC group did not differ from either the ADHD or CON group ($p > .05$). See Table 3.

Recognition—In order to examine the nature of deficits noted on the CVLT-C, recognition discriminability performance was analyzed using ANCOVA with Group as the between-subjects factor and age as a covariate. The discriminability index was chosen as the best measure of overall recognition performance because it takes into account a subject's hit rate relative to the false positive rate. The main effect of Group was significant ($F(2, 62) =$

4.51, $p = .015$) and pairwise comparisons indicated that the ALC group performed more poorly than both the ADHD and CON groups ($p < .01$), who did not differ from each other ($p = .868$). See Table 3.

DISCUSSION

This study is the first to compare verbal learning and memory performance in children with prenatal alcohol exposure, nonexposed children with ADHD, and typically developing controls. This comparison allowed for examination of specific deficits related to both prenatal alcohol exposure and ADHD, and whether deficits observed in children with heavy prenatal alcohol exposure are related to the high rates of ADHD in this sample. Both alcohol-exposed children and children with ADHD showed deficits in learning on the CVLT-C relative to controls. Alcohol exposure was associated with significantly impaired learning on four of five acquisition trials, while ADHD was associated with impairments in learning on two of five acquisition trials. In addition, both clinical groups recalled fewer words than controls on the delayed recall trials. Despite impaired recall in both groups, only the ALC group showed impaired recognition of presented verbal material relative to controls. Alternatively, retention of previously learned material over the delay period was only impaired in the ADHD group. These results are consistent with previous studies on the effects of alcohol exposure (Mattson and Roebuck, 2002; Roebuck-Spencer and Mattson, 2004) and ADHD (Loge et al., 1990) on verbal learning and memory and suggest that children with prenatal alcohol exposure exhibit impaired learning of verbal material but normal forgetting rates for the information they are able to acquire. Children with ADHD, however, show both impaired learning and retention but intact recognition of presented material. Because rapid forgetting of information was not observed, memory, per se, does not appear to be deficient in either group. Rather, deficient CVLT-C performance was characterized by difficulty encoding verbal material in alcohol-exposed children but a relatively greater difficulty in retrieval of learned material in children with ADHD.

By conducting pairwise comparisons between learning trials we determined the trial at which each clinical group ceased to learn new information. These data suggest that children in both clinical groups benefited from repeated exposure to verbal material as they continued to learn new information in later trials, while the performance of the control group did not improve after trial 3. However, while both clinical populations showed impaired learning, deficits observed in the alcohol-exposed groups were more severe than those in the ADHD group. This pattern of deficits may inform intervention and educational remediation strategies for the two groups. Repeated exposure to verbal material may be useful for children with ADHD and FASD as both groups showed a more protracted yet positive learning slope across trials when compared to controls. Also, because children in the ALC group showed spared retention rates for the material they were able to learn, children with FASD may benefit from intervention strategies that focus on improving encoding of relevant information, whereas retrieval strategies may be more appropriate for children with ADHD.

Impaired learning and retrieval has been observed in patients with frontal lobe damage (Baldo et al., 2002) suggesting that deficits may be explained by impaired ability to organize information during learning or application of inefficient strategies to aid in retrieval of encoded material. Deficits in executive function have been documented in both clinical groups (e.g., Vaurio et al., 2008) and may relate to diminished ability of encoding learned information. Because learning deficits were more pronounced in children with alcohol exposure when compared to those with ADHD and no alcohol exposure, it is possible that deficits in inhibition and attention are compounded with more fundamental difficulty of processing verbal information in the alcohol-exposed population. One study using functional neuroimaging provides support for this hypothesis. While performing a verbal learning task,

children with prenatal alcohol exposure demonstrated increased activation in frontal regions, possibly associated with labored executive function processing, as well as deactivation in medial and lateral temporal regions (Sowell et al., 2007), which have been shown to be involved in aspects of language processing (Johnson et al., 2001b; Saykin et al., 1999). These differences in brain activity were observed even after controlling for relatively poorer performance in the alcohol-exposed group by covarying verbal learning performance. Thus, it may be that prenatal alcohol exposure leads to greater reliance on an inefficient frontal system when performing verbal memory tasks.

Functional neuroimaging has not been used to examine the underlying brain mechanisms of the observed learning and retrieval deficits in individuals with ADHD, however abnormalities in frontal-subcortical systems are consistently found on structural imaging (Bush et al., 2005; Seidman et al., 2005) and the pattern of performance observed in the ADHD group herein is consistent with memory difficulty associated with damage to this system (Delis et al., 1991). Although frontal-subcortical abnormalities occur in both FASD and ADHD (Barkley, 1997; Fryer et al., 2007b), additional involvement of temporal structures in alcohol-exposed children may be responsible for the more severe verbal learning impairments seen in children with FASD when compared to children with ADHD.

In summary, this study adds to the growing literature describing similarities and differences between children with FASD and children with ADHD. Based on this and previous studies, both clinical populations have shown impairments on parent report and laboratory measures of attention, set shifting, encoding, letter fluency, and adaptive ability. In addition, verbal learning appears to be affected in both groups, although in different ways. Children with FASD show unique impairments in category fluency and some aspects of social and emotion processing.

Limitations

We did not examine scores on the CVLT-C relative to IQ scores. In this study, alcohol-exposed groups had significantly lower IQ scores than the other two groups. Therefore, it is possible that the deficits found on the CVLT-C in children with prenatal alcohol exposure are a result of overall diminished cognitive ability, while in ADHD these deficits may be related to other specific impairments unique to the disorder. Examining verbal learning and memory deficits in groups matched on IQ may provide insight into how the patterns of performance in the two populations differ, if at all. However, in two separate investigations of alcohol-exposed and control children matched on mental age or IQ, deficits in CVLT-C performance were still apparent in the FASD groups, suggesting that differences in verbal learning and memory performance in alcohol-exposed individuals are not solely attributable to differences in IQ (Mattson et al., 1996; Vaurio et al., submitted 2010). In addition, because children in the ADHD group were not recruited specifically because of ADHD diagnosis, it is possible that our sample may differ from one that was clinically referred. For example, the proportion of children in our ADHD sample on medication is lower compared to the proportions reported in the literature (Rowland et al., 2002), which may be related to our ascertainment strategy, which did not specifically target children with ADHD. Sample size also did not allow for separate ADHD subgroup evaluation. It is possible that inattentive versus hyperactive-impulsive types may have different patterns of performance on the CVLT-C, although there is little evidence to support neuropsychological differences by subtype in ADHD (Nigg et al., 2002). In addition, some findings were of marginal statistical significance. Larger sample sizes may allow for greater statistical power to detect group differences.

Future Directions

While these results add to a growing neurobehavioral profile of alcohol-exposed children, additional comparison of verbal learning and memory in populations of children with FASD or ADHD is necessary. In particular, examining patterns of performance using other measures of memory and learning is recommended. For example, measures without implicit strategies could be investigated. Some research suggests that, in alcohol-exposed children, retention of verbal information occurs on the CVLT-C, which has an implicit organizational strategy, but not on the Verbal Learning subtest of the Wide Range Assessment of Memory and Learning, which does not include an organizational strategy (Roebuck-Spencer and Mattson, 2004). In addition, comparison of these two clinical populations should be conducted across different modalities to determine if the patterns observed here are consistent across multiple domains. For example, it has been reported that both groups show deficits in learning of visuospatial information (Barnett et al., 2005; Carmichael Olson et al., 1998; Coles et al., 1991; Mattson et al., 2006a), and research also suggests that retention of nonverbal material is more impaired than retention of verbal material in alcohol-exposed children (Mattson and Roebuck, 2002). Understanding the specificity of these learning deficits may also prove beneficial in identifying characteristic patterns of neuropsychological performance in FASD and ADHD.

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Figure 1.

Table 1

Description of CVLT-C variables analyzed for this study

Variable	Description
Trials 1–5	Number of correctly recalled items on the five learning trials
Long Delay Free Recall	Number of correctly recalled items following a 20min. delay interval
Retention (Adjusted Delayed Recall)	Number of correctly recalled items following a 20min. delay interval, adjusted for amount of learned information on the final learning trial
Recognition Discriminability	Index of recognition performance that takes into account both correct hits and false positive recognition errors

Table 2

Demographic information for children with heavy prenatal alcohol exposure (ALC), children with attention-deficit/hyperactivity disorder (ADHD), and non-exposed controls (CON).

Variable	ALC	ADHD	CON	Statistic
N	22	22	22	
Sex [N, (%) Female]	12 (54.5)	8 (36.4)	10 (45.5)	$\chi^2 = 1.467$
Race [N, (%) White]	17 (77.3)	18 (81.8)	15 (68.2)	$\chi^2 = 5.131$
Ethnicity [N, (%) Hispanic]	4 (18.2)	6 (27.3)	1 (4.5)	$\chi^2 = 4.145$
Handedness [N, (%) Right]	17 (77.3)	18 (81.8)	21 (95.5)	$\chi^2 = 1.155$
Age in years [M (SD)]	10.75 (1.59)	9.69 (1.87)	10.66 (1.78)	$F = 2.491$
SES [M (SD)] ⁺	47.64 (9.02)	43.66 (10.65)	50.96 (11.66)	$F = 2.663$
FSIQ [M (SD)]	86.91 (14.50)	106.27 (14.91)	110.95 (11.67)	$F = 18.862^*$
FD [M (SD)]	82.95 (12.91)	98.82 (13.62)	111.91 (14.07)	$F = 25.215^*$
Diagnosis: FAS [N, (%) FAS]	13 (59.1)	0 (0)	0 (0)	
Diagnosis: ADHD [N, (%) ADHD]	22 (100)	22 (100)	0(0)	

⁺ Socioeconomic status (SES) was measured using the Hollingshead Four Factor Index of Social Status.

* Significant group differences were noted on FSIQ and FD ($ps < .001$).

Table 3

Mean raw scores for CVLT-C recall and retention variables for children with heavy prenatal alcohol exposure (ALC), attention-deficit/hyperactivity disorder (ADHD), and non-exposed controls (CON).

Variable	ALC M (SD)	ADHD M (SD)	CON M (SD)	Statistic	Contrast
Long Delay Free Recall	8.36 (4.12)	8.77 (3.10)	11.41 (2.20)	$F = 6.01^*$	ALC vs. CON $p = .001$ ALC vs. ADHD $p = .216$ ADHD vs. CON $p = .041$
Retention ⁺	9.27 (0.50)	8.83 (0.48)	10.45 (0.50)	$F = 2.07^{**}$	ALC vs. CON $p = .105$ ALC vs. ADHD $p = .528$ ADHD vs. CON $p = .023$
Recognition Discriminability	90.10 (9.25)	93.74 (7.02)	95.76 (6.47)	$F = 4.51^*$	ALC vs. CON $p = .009$ ALC vs. ADHD $p = .017$ ADHD vs. CON $p = .868$

* Significant group differences noted ($p < .05$).

** Marginal effect noted ($p = .065$).

⁺ Long delay free recall adjusted for information learned on the last learning trial (A5)