Learning following prenatal alcohol exposure: performance on verbal and visual multitrial tasks

Kris L. Kaemingk a,*, Shelagh Mulvaney b, Patricia Tanner Halverson c

Abstract

Verbal Learning deficits have been reported following prenatal alcohol exposure (PAE). This study examined verbal and visual multitrial learning in children with fetal alcohol syndrome (FAS) or fetal alcohol effects (FAE) and controls matched on age and gender from the same community. In this study, the FAS/FAE group’s immediate memory on the Verbal Learning and Visual Learning tasks from the Wide Range Assessment of Memory and Learning (WRAML) was significantly weaker than that of the control group. Although the FAS/FAE group also recalled significantly less information after a delay, they did retain an equivalent proportion of the visual and verbal information as compared to the control group. Thus, the overall pattern of performance on both verbal and visual measures was consistent with that observed in previous studies of Verbal Learning: despite weaker learning, the FAS/FAE group’s relative retention of information was no different than that of controls.

Keywords: Children; Prenatal alcohol exposure; Fetal alcohol syndrome; Memory; Verbal Learning; Visual Learning

1. Introduction

The term “fetal alcohol syndrome” (FAS) was coined by Jones and Smith (1973). The syndrome is characterized by significant growth retardation, dysmorphic features, and central nervous system involvement associated with a history of alcohol exposure during gestation.
(Clarren, 1981; Jones & Smith, 1973). Individuals with a history of prenatal alcohol exposure (PAE) who only partially meet the diagnostic criteria for FAS may be diagnosed with “fetal alcohol effects” (FAE; e.g., Clarren, 1981). While there continue to be discussions about diagnostic terminology (Aase, Jones, & Clarren, 1995; Stratton, Howe, & Battaglia, 1996), studies of children who have been diagnosed with FAS and FAE document deficits in general intellectual function, verbal abilities, visual–spatial abilities, motor skills, attention, and memory (for reviews, see Kaemingk & Paquette, 1999; Mattson & Riley, 1998).

Despite significant impairments in multiple cognitive domains, there is some evidence that, within domains, aspects of function may be relatively preserved. For example, within the visual perceptual domain, facial recognition may be preserved in groups of individuals with FAS or FAE who perform poorly on other tasks dependent on visual perceptual skills (Gray & Streissguth, 1991; Kaemingk & Tanner Halverson, 2000; Uecker & Nadel, 1996). Children with a history of PAE have also been found to exhibit a deficit in reproduction of local features (elements of complex designs), but not global features, on a design copying task (Mattson, Gramling, Delis, Jones, & Riley, 1996).

Studies of learning and memory also suggest that there may be relative sparing in some aspects of performance. Group differences have been documented in controlled studies of Verbal Learning (Kerns, Don, Mateer, & Streissguth, 1997; Mattson, Riley, Delis, Stern, & Jones, 1996a; Mattson, Riley, Gramling, Delis, & Jones, 1998). In both of their studies employing the California Verbal Learning Test-Children’s Version (CVLT-C), Mattson et al. reported that the FAS group recalled fewer words across trials, had weaker free recall following the delay, and made more perseverative responses. In the 1996 study, there were also trends toward weaker recall on the first learning trial and increased intrusive errors, and in the 1998 study, there were significant differences in these areas. However, the FAS group did appear to retain an equivalent percentage of the information learned relative to controls in both studies. In each study, performance on the recognition task was also characterized by significantly poorer discrimination of list from nonlist words and significantly more false-positive responses.

Kerns et al. (1997) reported a weak learning curve in nonretarded adults with FAS. The subset of subjects who had average IQs retained what they had learned, while the group of subjects with borderline IQ had relatively preserved short-term, but weaker long-term, retention. Intrusive responses were noted in both groups. Mattson et al. (1998) found that delayed free recall and recognition discriminability, but not the other memory measures, were correlated with IQ. Taken together, results of these studies suggest that individuals with FAS have decreased overall levels of learning, but that retention, defined as number of correct words named on free recall, may be relatively preserved. However, the presence of perseverative and intrusive responses on recall measures and the poor discrimination and false-positive identifications on recognition measures raise questions about the specificity of memory and susceptibility of memory to interference. Additionally, while general intellectual abilities may be related to memory findings, IQ alone does not appear to fully account for deficits.

Several studies suggest that visual memory may be more vulnerable to PAE than verbal memory (Streissguth, Bookstein, Sampson, & Barr, 1989; Uecker & Nadel, 1996). Uecker and Nadel examined spatial memory using tasks requiring the recall of object names and
locations. They found that while a group of children with FAS or FAE exhibited impaired recall of the spatial location relative to controls, there were no differences in recall of the object names. These authors suggested that deficits in spatial location recall might be attributable to hippocampal damage since animal studies have demonstrated that PAE impacts hippocampal structure and function (for discussion, see Kaemingk & Paquette, 1999; Uecker & Nadel, 1996). However, this group of children also had significantly impaired performance on other measures that are dependent on visual perceptual skills, and the impact of visual perceptual and other memory abilities on findings was not examined. Subsequently, Kaemingk and Tanner Halverson (2000) also found differences in spatial location recall between FAS/FAE and control groups. In this study, the FAS/FAE group also had significantly weaker performance on visual perceptual and verbal memory measures, and differences in spatial location recall were no longer significant once these were statistically taken into account. This suggests that spatial location recall was not solely attributable to a spatial memory deficit. Nevertheless, while the results of the Seattle longitudinal study suggest that both verbal and visual memory are impacted by PAE, the pattern of findings raises the possibility that PAE may have less of an influence on verbal than visual memory (Streissguth et al., 1989).

To date, there has not been direct comparison of verbal and Visual Learning in this population. The purpose of this study was to examine performance on verbal and visual multitrial learning tasks in children diagnosed with FAS or FAE and matched controls using parallel tasks from a standardized memory battery so that verbal and visual tasks shared a common normative base. It was hypothesized that recall of visual and verbal information would be significantly weaker in the FAS/FAE group than in the control group, that the FAS/FAE group would recall significantly less information than the controls after a delay, but that both groups would retain an equivalent proportion of the previously learned information. It was also hypothesized that the FAS/FAE group would have significantly weaker performance on Visual Learning than on Verbal Learning.

2. Method

2.1. Participants

Participants were 20 Native American children, aged 6–16, who had been diagnosed with FAS or FAE by a dysmorphologist and 20 age- and sex-matched Native American controls from the same cultural and socioeconomic background. All FAS/FAE subjects were in regular classrooms for part of each school day and received special education services. An age- and sex-matched control was obtained for each FAS/FAE child at that child’s school. Vision and hearing screenings had been conducted by the school. None of the children had hearing difficulties. Several children had corrective lenses, and these were utilized during testing if needed. Controls were not receiving special education services and had no known learning problems or history of PAE. A parent/guardian gave informed consent for the participation of each child. The mean age of the FAS/FAE group was 11.13 years (S.E. = 0.56). The mean age of the comparison group was 11.12 years (S.E. = 0.56). There were 12 males and 8 females in each group.
2.2. Measures

Intelligence was assessed with the Wechsler Intelligence Scale for Children-Third Edition (WISC-III; Wechsler, 1991). Learning was assessed with the Verbal Learning and Visual Learning tasks from the Wide Range Assessment of Memory and Learning (WRAML; Sheslow & Adams, 1990). The WISC-III and WRAML were administered as standardized, and the WISC-III was administered before the WRAML. Within the WRAML, Verbal Learning is administered before Visual Learning. On the Verbal Learning task, the subject was asked to recall words from a list after each of four presentations and following a delay. On the Visual Learning task, each subject was asked to identify the locations of designs after each of four presentations and following a delay. Designs were presented in a particular location on a board. The subject was initially shown each design in its location and asked to remember where each design was located. Then, the subject was shown pictures of the designs and asked to point to the correct locations on the board. Immediate visual feedback was given by the experimenter uncovering the correct design. Stimuli were presented four times and visual feedback was given following the first three presentations.

2.3. Analytic approach

The WRAML learning tasks employ a different number of items for younger and older children. The Verbal Learning word list for children aged 8 and younger has 13 words, while the word list for children aged 9 and older has 16 words. The Visual Learning task has 12 items for children aged 8 and younger and 14 items for children aged 9 and older. In order to examine the pattern of performance on each trial, age-based normative scores were needed. The WRAML norms do not contain this information. Therefore, the number of items recalled by each subject on each trial and following each delay was converted to a z-score using the Age-based supplemental norms of Adams, Sheslow, and Wilkinson (1990). Z-scores have a mean of 0 and standard deviation of 1.

All analyses were carried out using SPSS software version 8.0. Since group comparisons of immediate recall, delayed recall, and retention for both verbal and visual information and comparisons of immediate recall, delayed recall, and retention of verbal and visual information within the FAS/FAE group were planned, \( P < .01 \) was designated as an indication group of statistical significance. In order to assess learning over trials, general linear models (GLM) were used to test for main effects for group and trial as well as for a Group \( \times \) Trial interactions. Relationships between immediate and delayed memory for verbal and Visual Learning and IQ were examined using correlation techniques. Partial correlations were used to see if there were changes in relationships between immediate and delayed memory after IQ was taken into account.

3. Results

Average group index and factor scores from the WISC-III and WRAML and standard errors are presented in Table 1. These scores have a mean of 100 and standard deviation of 15. The
Table 1
Group means (standard errors) for WISC-III and WRAML index and factor scores

<table>
<thead>
<tr>
<th></th>
<th>FAS/FAE (n = 20)</th>
<th>Control (n = 20)</th>
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<tbody>
<tr>
<td>WISC-III Full-scale IQ</td>
<td>66.10 (2.41)</td>
<td>97.00 (2.15)</td>
</tr>
<tr>
<td>WISC-III verbal IQ</td>
<td>64.50 (2.46)</td>
<td>92.10 (2.45)</td>
</tr>
<tr>
<td>WISC-III performance IQ</td>
<td>73.20 (2.46)</td>
<td>103.40 (2.17)</td>
</tr>
<tr>
<td>WISC-III verbal comprehension</td>
<td>64.40 (2.32)</td>
<td>93.10 (2.52)</td>
</tr>
<tr>
<td>WISC-III perceptual organization</td>
<td>77.40 (2.72)</td>
<td>105.80 (2.63)</td>
</tr>
<tr>
<td>WISC-III freedom from distractibility</td>
<td>74.55 (2.72)</td>
<td>91.16 (2.63)</td>
</tr>
<tr>
<td>WISC-III processing speed</td>
<td>74.75 (2.15)</td>
<td>98.26 (2.15)</td>
</tr>
<tr>
<td>WRAML general memory index</td>
<td>70.90 (2.92)</td>
<td>95.60 (2.49)</td>
</tr>
<tr>
<td>WRAML verbal memory index</td>
<td>66.70 (2.60)</td>
<td>88.95 (2.08)</td>
</tr>
<tr>
<td>WRAML visual memory index</td>
<td>79.47 (3.22)</td>
<td>100.55 (2.42)</td>
</tr>
<tr>
<td>WRAML learning index</td>
<td>81.25 (3.50)</td>
<td>100.75 (3.04)</td>
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</table>

FAS/FAE IQs ranged from 40 to 83, while the IQs for the control group ranged from 81 to 110. While the mean IQs and index scores in the control group were within the average range, the mean performance of the FAS/FAE group fell 1, and usually more than 1, standard deviation below the mean. Scaled scores of the control group on Verbal Learning ($M = 10.75, S.E. = 0.65$) and Visual Learning ($M = 11.00, S.E. = 0.58$) were not different from one another ($t(19) = 3.96, P = .003$). The same pattern was present in the FAS/FAE group, with no significant difference between Verbal Learning ($M = 7.95, S.E. = 0.60$) and Visual Learning ($M = 7.30, S.E. = 0.70; t(19) = 1.00, P = .330$).

The average raw number of words recalled on Verbal Learning across the four trials and after the delay is presented in Figure 1. Since there were different numbers of items on the tasks for the different age groups, the number of correct responses for children 8 years of age and younger is presented in Figure 1a, and the number of correct responses for children 9 years of age and older is in Figure 1b. There were 5 younger and 15 older subjects in both groups. Figure 2a and b present the number of locations correctly identified for younger and older subjects on Visual Learning for each of the trials and delay, respectively.

In order to examine the pattern of performance across learning trials, the number of correct responses by each subject on each trial was converted to a $z$-score as described above. The mean $z$-scores (+S.E.) for Verbal Learning and Visual Learning trials and delay are illustrated in Figure 3a and b, respectively. In these figures, the bars indicate mean performance based on age appropriate norms, and zero would indicate normative performance. It should be noted that to obtain normative performance (near zero), a greater raw number of correct responses is required on each subsequent trial. A repeated-measures GLM analysis of Verbal Learning $z$-scores revealed a main effect for group [$F(1, 38) = 10.17, P = .003$]. There was no effect for learning trial [$F(3, 38) = 2.47, P = .065$] or Group × Trial interaction [$F(3, 38) = 1.25, P = .294$]. Analysis of Visual Learning $z$-scores also revealed a main effect for group [$F(1, 38) = 13.33, P = .001$], no effect for learning trial [$F(3, 38) = 0.37, P = .77$], and no Group × Trial interaction [$F(3, 38) = 0.25, P = .85$]. Thus, while the FAS/FAE group remembered less than the control group, there was no difference between groups in the pattern of responses across trials. Further evaluation revealed that while the FAS/FAE
group’s mean performance across trials was significantly below normative expectation, mean performance of the control group was not significantly different than would be expected based on the WRAML norms. In the FAS/FAE group, the average z-scores across learning trials on both tasks (Verbal Learning $M = 0.60$, S.E. = 0.17; Visual Learning $M = 0.70$, S.E. = 0.20) were both significantly below zero: Verbal Learning $t(19) = 3.47$, $P = .003$; Visual Learning $t(19) = 3.48$, $P = .002$. Control group mean z-scores (Verbal Learning $M = 0.20$, Visual Learning $M = 0.21$).
Fig. 2. (a and b) Mean number of locations correctly identified (+S.E.) on the four Visual Learning trials and after a delay for the younger FAS/FAE group and the younger controls and the older FAS/FAE group and the older controls, respectively.

S.E. = 0.18; Visual Learning $M = 0.24$, S.E. = 0.21) were not significantly different from zero: Verbal Learning $t(19) = 1.10$, $P = .284$; Visual Learning $t(19) = 1.51$, $P = .148$.

Retention was evaluated between and within groups using delay $z$-scores and savings scores. Savings scores indicate the percentage of information retained from the last learning trial after the delay and were calculated as follows: raw delay score/raw trial 4 score $\times 100$. The Verbal
Learning delay z-score for the FAS/FAE group was 0.81 (S.E. = 0.26) and that for the control group was 0.25 (S.E. = 0.18). These means were significantly different between the groups ($t(38) = 3.32, P = .002$). The Visual Learning delay z-score was 0.64 (S.E. = 0.23) for the FAS/FAE group and 0.29 (S.E. = 0.21) for the controls, and performance was significantly different between groups ($t(38) = 0.299, P = .005$). However, the average Verbal Learning savings score was 82.5 (S.E. = 6.73) for the FAS/FAE group and 94.21 (S.E. = 3.43) for the controls, and these percentages were not significantly different from each other ($t(38) = 1.54$,
Table 2

<table>
<thead>
<tr>
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<th>FAS/FAE</th>
<th>Control</th>
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<tr>
<td>Correlations between IQ, average learning trial z-scores, and delay z-scores</td>
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<tr>
<td>Verbal Learning</td>
<td>.26 ( (P = .277) )</td>
<td>.67 ( (P = .001) )</td>
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<tr>
<td>Verbal delay</td>
<td>.25 ( (P = .281) )</td>
<td>.17 ( (P = .477) )</td>
</tr>
<tr>
<td>Visual Learning</td>
<td>.42 ( (P = .064) )</td>
<td>.41 ( (P = .076) )</td>
</tr>
<tr>
<td>Visual delay</td>
<td>−.02 ( (P = .928) )</td>
<td>−.37 ( (P = .111) )</td>
</tr>
<tr>
<td>Bivariate and partial correlations between average learning trial z-scores, and delay z-scores</td>
<td></td>
<td></td>
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<tr>
<td>Verbal bivariate</td>
<td>.59 ( (P = .006) )</td>
<td>.69 ( (P = .001) )</td>
</tr>
<tr>
<td>Verbal partial</td>
<td>.61 ( (P = .005) )</td>
<td>.64 ( (P = .003) )</td>
</tr>
<tr>
<td>Visual bivariate</td>
<td>.75 ( (P = .000) )</td>
<td>.82 ( (P = .000) )</td>
</tr>
<tr>
<td>Visual partial</td>
<td>.75 ( (P = .000) )</td>
<td>.78 ( (P = .000) )</td>
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</table>

\( P = .130 \). The average Visual Learning savings score was 126.29 (S.E. = 31.03) for the FAS/FAE group, indicating that this group had more correct responses after the delay than on the final learning trial. The Visual Learning savings score for the control group was 94.87 (S.E. = 4.94). Visual Learning savings scores were not significantly different between groups \( t(38) = 1.00, P = .324 \).

The within-group comparisons revealed no differences in retention between the verbal and visual tasks. Verbal Learning and Visual Learning delay z-scores were not significantly different for the FAS/FAE group \( t(19) = 0.497, P = .625 \) or for the control group \( t(19) = 0.176, P = .862 \). Likewise, there were no significant differences between verbal and visual savings scores for the FAS/FAE group \( t(19) = 1.60, P = .125 \) or the control group \( t(19) = 0.109, P = .914 \).

Relationships between immediate and delayed memory for verbal and Visual Learning and Full-scale IQ were examined in both groups by correlating the average z-scores across learning trials and the z-scores for delayed memory. As can be seen in Table 2, some, but not all, relationships were significant. Further examination revealed that relationships between the average z-scores across learning trials and delay z-scores were significant for both groups on both verbal and visual tasks. Partial correlation techniques (controlling for IQ) were used to see if relationships changed once general intellectual performance was taken into account. These are also presented in Table 2, and relationships remained significant once IQ was taken into account.

4. Discussion

This section will address the following questions. What do the results of this study suggest regarding FAS/FAE? Can intellectual impairments account for learning and memory impairments following PAE? What are the implications for clinical assessment and future research?

What do the results of this study suggest regarding FAS/FAE? This study extended previous work by examining performance on verbal and Visual Learning measures with a common normative base. In this study, the FAS/FAE group’s immediate visual and Verbal Learning
was significantly lower than that of a matched control group. However, there was no overall difference between groups in the pattern of recall across learning trials. While the FAS/FAE group’s learning was significantly below normative expectation, learning in the control group was not significantly different than would be expected based on the WRAML norms. Thus, while the study sample differed considerably from the WRAML standardization sample, the control group exhibited age appropriate performance. Although the FAS/FAE group recalled less after a delay, they did retain an equivalent percentage of the visual and verbal information as compared to the control group. Thus, the overall pattern of performance on both verbal and Visual Learning measures in this study was consistent with that reported by Mattson et al. (Mattson, Riley, et al., 1996a; Mattson & Riley, 1998) in their studies of Verbal Learning: despite significantly weaker overall learning, the FAS group’s relative retention of the information they had learned was no different than that of controls.

Contrary to expectation, there was no evidence to support the hypothesis that visual memory is more vulnerable to PAE than verbal memory in this study. When the FAS/FAE group’s performance on Verbal Learning and Visual Learning measures was compared, there were no significant differences in recall across learning trials, delayed recall, or retention of visual and verbal information. In the Seattle longitudinal study of PAE, there was a stronger relationship between the latent variable (LV) reflecting alcohol consumption and the visual memory LV than the alcohol LV and the verbal memory LV (Streissguth et al., 1989). Uecker and Nadel (1996) found differences in recall of object spatial location but not in recall of object names in their study comparing children with FAS/FAE and matched controls. However, neither of these studies directly compared performance on verbal and visual memory tasks. In this study, use of z-scores allowed for comparisons relative to normative expectation. While current findings may be related to the measures selected since different measures were utilized across these studies, at this point in time, there is not sufficient evidence indicating a disparity between verbal and visual memory function.

This study adds to the converging evidence that aspects of both verbal and Visual Learning are impacted in FAS and FAE. Within the visual domain findings of this study, Kaemingk and Tanner Halverson (2000) and Uecker and Nadel (1996) suggest that learning of spatial location is adversely impacted in children with FAS/FAE. In discussion of their results, Uecker and Nadel had suggested that differences in location recall may be attributable to right hippocampal injury.

Spatial learning and memory are impaired in humans (Goldstein, Canavan, & Polkey, 1989; Piggot & Milner, 1993; Smith & Milner, 1981, 1989) and animals (Nadel, 1991) with hippocampal lesions. Animal studies have demonstrated that alcohol exposure can alter the anatomic development of the hippocampus (e.g., Abel, Jacobson, & Sherwin, 1983; Barnes & Walker, 1981; West, Hodges, & Black, 1981) and adversely impact hippocampally mediated behaviors including spatial learning and memory (e.g., Blanchard, Riley, & Hannigan, 1987; Greene, Diaz-Granados, & Amsel, 1992, 1994; Kim et al., 1993; Zimmerberg, Mattson, & Riley, 1989). On the other hand, while studies have demonstrated that the hippocampus plays an important role in spatial memory, these studies were conducted in animals and humans with documented lesions. Additionally, in a study of patients with hippocampal lesions and poor spatial memory, Smith and Milner (1981) concluded that it could not be determined whether mesial temporal lobe structures were responsible for encoding object location. In
another study, Milner (1968) found that facial recognition deficits were correlated with the extent of hippocampal damage in patients with right temporal lesions. However, there was no evidence of facial recognition deficits in FAS/FAE groups in the studies of Uecker and Nadel (1996) or Kaemingk and Tanner Halverson (2000), and Gray and Streissguth (1991) did not find group differences in facial memory in a case-controlled study of adults with FAS or FAE. Finally, Kaemingk and Tanner Halverson found that group differences in spatial location recall were no longer significant once performance on visual perceptual and other memory measures was taken into account, suggesting that differences in spatial location recall were not solely attributable to a spatial memory deficit.

Within the Verbal Learning domain, this study and those of Mattson et al. (Mattson, Riley, et al., 1996a; Mattson & Riley, 1998) and Kerns et al. (1997) provide converging evidence that word list learning is adversely impacted. Mattson, Riley, et al. (1996a) discussed findings of perseveration, false-positive errors, and poor discriminability on recognition testing in the context of poor response inhibition. Response inhibition deficits have been reported in humans and animals following PAE (for review, see Kaemingk & Paquette, 1999). It was suggested that response inhibition deficits might be attributable to hippocampal and/or frontal system involvement. Anatomical connections between the frontal lobes and basal ganglia were also discussed, as these authors have found volumetric reductions in the basal ganglia following PAE (Mattson, Riley, Jernigan, & Jones, 1992a; Mattson, Riley, et al., 1994; Mattson et al., 1996b).

There are many potential anatomical explanations for cognitive deficits in FAS/FAE. Studies have documented a wide range of neuropathology in FAS cases, including aberrant neuronal migration, incomplete development of the cerebral cortex, cerebellum, and brain stem, enlarged ventricles, and abnormalities in the corpus callosum, including agenesis (Clarren, 1986; Clarren, Alvord, Sumi, Streissguth, & Smith, 1978; Coulter, Leech, Schaefer, Scheithauer, & Brumbach, 1993; Jones & Smith, 1973, 1975; Majewski, 1993). In addition to decreased proportional basal ganglia volume, decreased cerebral and cerebellar volume, increased proportional volumes of cortical and subcortical fluids, and proportionally smaller corpus callosa have been documented on imaging studies (Mattson et al., 1992b; Mattson, Jernigan, & Riley, 1994; Mattson, Riley, et al., 1994), and both structural and functional imaging studies have implicated the cerebellum (Hannigan, Martier, Chugani, & Sokol, 1995; Sowell, Mattson, Riley, & Jernigan, 1995). Since PAE clearly impacts brain development, functional relationships between regions may be significantly altered. As a result, comparisons with populations with relatively circumscribed lesions and normal development may have limited utility.

Can intellectual impairments account for learning and memory impairments following PAE? While general intellectual abilities may be related to aspects of memory function, IQ did not fully account for memory deficits in other studies (Kerns et al., 1997; Mattson et al., 1998), and in the present study, relationships between immediate and delayed memory remained once IQ was statistically taken into account. However, examining patterns of cognitive deficits independent of intelligence poses serious interpretive challenges. Intelligence is a higher-order construct, as performance on IQ measures requires many specific neuropsychological abilities. Thus, it may be of questionable conceptual value to try to “extract” intelligence from cognitive profiles given its clear hierarchical relationship with other cognitive abilities.
Additionally, it has been argued that many neurological deficits manifest both globally and specifically (Pennington & Bennetto, 1998), and even in children with severe mental retardation, memory performance across domains is not completely flat (Turnure, 1991). For example, in Down Syndrome, relatively reliable patterns of short-term verbal memory deficits have been found (Pennington & Bennetto, 1998). Spatial and visual memory abilities have not been as extensively studied, but cognitive phenotypes in Turner Syndrome include difficulties in coding and transforming visual–spatial information, with relatively spared spatial memory (Bender, Linden, & Robinson, 1994). Studies of FAS/FAE have documented problems with attention, visual perceptual and motor skills, and language function (for reviews, see Kaemingk & Paquette, 1999; Mattson & Riley, 1998), and difficulties in each of these areas could impact learning. Nevertheless, there is some evidence to suggest that children with mental retardation attributed to FAS and a number of other different etiologies (e.g., Down Syndrome and Williams Syndrome) have relatively spared savings or retention of information on the CVLT-C despite other differences in cognitive presentation in these groups (Delis, Kramer, Kaplan, & Ober, 1994).

What are the implications for future research and for clinical assessment? There are many reasons to continue to examine learning and memory function in FAS/FAE. It appears that some aspects of memory function may be relatively preserved, but the nature, extent, and practical significance of these remain to be examined. In this study and those of Mattson et al. (Mattson, Riley, et al., 1996a; Mattson & Riley, 1998), the FAS/FAE and control groups retained equivalent proportions of new verbal information. There are questions about the specificity of recall and susceptibility of memory to interference. While these were not examined in the present study, Kerns et al. (1997) and Mattson et al. documented perseverative and intrusive responses on Verbal Learning recall trials, and performance on recognition testing was characterized by poor discrimination and false-positive identifications. Clearly, relatively spared retention of information may not be of much benefit if memory is very susceptible to interference. Thus, practical significance of these findings, the specificity of visual memory, and the vulnerability of Visual Learning to interference all merit attention.

On the other hand, while discrimination of list from nonlist words in the FAS group was poor with significantly more false-positive responses in the Verbal Learning studies, Mattson and Riley (1999) did not find differences in recognition on another forced choice task requiring subjects to choose which words had been presented in a study of children with heavy PAE. Thus, performance on explicit memory tasks may be related to the type of task or type of response required. From a clinical neuropsychological perspective, this is of both theoretical and practical interest. Future studies characterizing encoding or acquisition of new information, storage, and retrieval across modalities are also important since these are distinguishable aspects of memory function and because they are important for treatment planning. Implicit and procedural learning and memory also merit additional study (Mattson & Riley, 1994). Relationships between attention, perception, and language function and performance on different types of learning and memory tasks have yet to be systematically examined, and such studies may help clarify the nature of brain behavior relationships following PAE and aid in the identification of preserved abilities and strategies to maximize function in individuals exposed to alcohol before birth. However, there may also be difficulties identifying replicable patterns of performance given the nature of the etiology of FAS/FAE. There may be interactions between
the level and time of exposure and developmental outcome. Understanding these interactions remains a significant challenge for neuropsychology.

Acknowledgments

This publication was made possible by Grant Number R55AAOD10923 from the National Institute on Alcohol Abuse and Alcoholism (NIAAA). The authors wish to thank study participants and their parents/guardians and Drs. Andrea Hammond and Minoo Shah for their contributions to this work.

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