MEMORY PATTERNS OF ACQUISITION AND RETENTION OF VERBAL AND NONVERBAL INFORMATION IN CHILDREN WITH FETAL ALCOHOL SPECTRUM DISORDERS

Jacqueline R Pei[1], Christina M Rinaldi[1], Carmen Rasmussen[2], Valerie Massey[1], Donald Massey[1]

[1]University of Alberta, Department of Educational Psychology; [2]Department of Pediatrics, University of Alberta , Edmonton, Canada

ABSTRACT

Background

Previous research indicates that children with FASD have both memory and learning deficits. However, there is no consensus about whether the deficits identified from a pattern of impairment, and whether this pattern is consistent with the current theories regarding the organization of memory. Thus, the goal of this study was to further explore memory functions and expose possible patterns that may exist in children with FASD.

Methods

The Children's Memory Scale (CMS) was used to measure visual and verbal memory, as well as learning and encoding, among 30 children with FASD (ages 9-16 years). Functioning was conceptualized through use of a model of working memory.[1]

Results

A significant difference between types of verbal memory in the FASD sample was identified. Specifically, recall of word pairs was found to be more impaired than that for stories. In addition to this, recall of immediate word pairs was significantly more impaired than that for delayed word pairs, implying the presence of encoding deficits in this area.

Conclusions

Children and adolescents with FASD displayed specific types of verbal memory deficits and these deficits were greater for immediate rather than delayed memory. These data are consistent with previous studies that describe deficits in immediate memory, and suggest that deficits in delayed memory are better accounted for by encoding deficits. Furthermore, their greatest difficulty arose with those items in which the phonological loop was required, which would have facilitated learning though internal recitation and adequate phonological storage. Further research into these distinctions in memory is warranted, as is exploration into educational techniques that could account for delayed encoding in children with FASD.

Key Words: *Memory, fetal alcohol syndrome, fetal alcohol spectrum disorder, learning*

Fetal Alcohol Spectrum Disorder (FASD) is associated with a variety of physical, mental, behavioral, and learning disabilities as a result of maternal alcohol consumption during pregnancy.[2] FASD is a broad term that includes many indicators of Central Nervous System (CNS) dysfunction. Unlike the physical features, such as facial dysmorphology and growth retardation, a consistent pattern of CNS dysfunction has been more difficult to describe. Research into FASD has identified impairment in many areas of functioning including delayed motor development[3], cognitive impairment and learning difficulties[4,5], deficits in communication, daily living skills, social behaviour[6], memory deficits[7,8,9], and response inhibition and attention.[10,11] A review of neurobehavioural deficits present in FASD was completed in 1998 by Mattson and Riley[8] in which they concluded that, “FAS is a devastating developmental disorder that is associated with a wide variety of neurobehavioural deficits in language, motor, learning, and visuospatial functioning.”(p.291). However, despite this growing understanding of the breadth of possible impairment in children with FASD, no clear pattern of neurobehavioral deficits has yet been identified. Consequently, diagnosis is difficult, many children and adolescents are not appropriately diagnosed and thus any behaviour or learning problems are often misunderstood. Due to a failure to understand that their unpredictable behaviour stems from organic brain damage, clinicians run the risk of exacerbating problems they are attempting to ameliorate, through their intervention efforts.[12] Only once a child’s behavioral and/or cognitive deficits are fully understood is effective action possible. In addition, diagnostic information can be used in individualized program planning in schools, community treatment programs, and in creating stable home environments.

One way to improve diagnostic accuracy is to continue to develop a clear clinical picture of the neurobehavioural deficits faced by children with FASD. This can be accomplished through close examination of specific deficits described in FASD. Two such areas where deficits may exist are memory and learning. Memory and learning deficits, in children with FASD in particular, are extremely problematic because of the effect they have on many other skills and abilities. Language acquisition,[13] academic performance[14], and even competent daily functioning have memory and learning functions at their foundation.[15] To further increase our understanding of the unique memory deficits found in FASD, an existing model of memory function will be utilized. In so doing, it will then be possible to discuss the specific memory deficits present in children with FASD from within a theoretical framework of memory and learning. The model of working memory presented by Baddeley and Hitch[1] is a comprehensive model in which several components of working memory are described. By identifying different components, or systems, Baddeley and Hitch allow for investigation into the specific memory deficits described in FASD from a theoretical perspective that emphasizes function rather than simply storage capacity.[16] Specifically, Baddeley and colleagues have defined working memory in terms of a three-component system used for short-term storage and manipulation of information required for diverse cognitive tasks.[17,1] The “visuospatial sketchpad” is for holding and manipulating visual-spatial information, and the “phonological loop” is for maintaining and rehearsing verbal information.[17] The “central executive”, an attentional controlling system, is involved in planning, selective attention, set shifting, and inhibition[18] (for more information on this model[19,20,21,22]). In this way, different types of memory functioning can be considered independently, which in turn allows for evaluation of the distinct effects different systems of memory may have on behaviour and learning. For instance, the phonological component of short-term memory has been closely linked with aspects of language development, including vocabulary acquisition[23,24], speech production[13,25] and spoken language comprehension.[26]

FASD and Memory

While a definite pattern of memory impairment has not yet been established for children with FASD, researchers have begun to explore some of the deficits present. Mattson et al.,[27] using the California Verbal Learning Test (CVLT-C), found that children (5-16 years) with Fetal Alcohol Syndrome (FAS) had difficulty learning and recalling words after a delay, showed increased numbers of intrusion and perseverative errors, and identified more false positives during the recognition portion of the test as compared to the control group. As well, they found these deficits persisted even when intelligence was controlled They also noted that while the children had difficulty learning the information, once in their memory they seemed able to recall it after a twenty-minute delay. As such, the researchers noted that it appeared as though the deficits were in the process of encoding verbal material during learning, rather than with information recall. This is consistent with earlier findings suggesting that deficits in learning and memory lie at the encoding and storage level on verbal tasks[28], and similar findings have been reported since this time.[29,9]

In terms of visual memory, Uecker and Nadel[30] administered the Memory for 16 Objects to ten children with FASD, a task that requires the child to recall the name of the object, as well as its placement among others, and other visuospatial measures. The children with FASD displayed immediate but not delayed object recall deficits, general spatial memory deficits, and a significantly distorted spatial array. Interestingly, no deficits were identified for facial recognition tasks. In addition to spatial deficits, these results seem to also indicate encoding or learning deficits as described in research focusing on auditory verbal memory. In later research, Uecker and Nadel[31] concluded that, as in animal models, children with FAS demonstrated a spatial but not object memory impairment. The possible impairment of immediate object recall, as well as spatial recall problems, may implicate the visuospatial sketchpad. In research using rats that had been exposed to alcohol in utero, Nagahara and Handa[32] identified delay-dependent memory deficits on spatial tasks.

Using a battery composed of measures of attention and memory, Streissguth et al.[33] found that fluctuating attentional states, problems with response inhibition, and spatial learning showed the strongest association with prenatal alcohol exposure. Each of these areas plays an important role in the functioning of working memory. Authors of recent research have stated that there are consistent deficits in working memory in children diagnosed with FAS.[34,35] This preliminary research indicates that not only are memory deficits present in these children, but that not all areas of memory are affected. However, as yet there has not been clarity as to the definitions being used to define working memory since much of the research in this area with FASD is not theory-driven. Instead the research originates in the more medical or neurological models, thus the focus is on the neurological structural evidence of damage. While important, this neglects some of the valuable empirical information that does more to explain the functional implications of memory systems.

Kodituawakku et al.[36] arrived at their conclusions about memory deficits through a study in which they were seeking a better understanding of attentional deficits in FASD, through references to established theories of memory, such as that described by Baddeley and Hitch.[1] They found that the children did not show impaired performance on all tasks that were especially sensitive to self-regulatory abilities, a key element of attention. Instead, the children made more perseverative errors on the Wisconsin Card Sort Test, suggesting a difficulty with shifting response sets, and also had difficulty with tasks that evaluated planning ability and the manipulation of information in working memory. They performed similar to a control group on the delayed-response tasks that require sustained attention and the subject-ordered test. Based on these results, Kodituawakku et al.[36] suggests that the FAS/FAE group was best distinguished from the control group by that mechanism which enables us to manage goals in working memory in a flexible manner. In short, Kodituawakku et al.[36] proposed that a dysfunction exists in the ability of children with FASD to hold and manipulate information, and to manage goals in working memory. While exciting, these conclusions remain limited in their application due a small sample size which restricts the ability to form generalisations from this research. As such, they encourage further research into these areas.

Several researchers have identified many possible areas of specific impairment within the memory systems of children who are alcohol affected.[31] Unfortunately, given the small sample sizes typically used, the variations in severity, as well as the lack of theoretical underpinnings, it is difficult to decide, based on existing research, whether the deficits identified form a pattern of impairment, and whether this pattern is consistent with the current theories regarding the organization of memory. Furthermore, are there, as Kodituawakku et al.[36] suggests, specific memory processes that can be better understood when viewed in the context of memory theory?

The Present Study

The goal of this study was to specifically examine the different types of memory deficits children with FASD display using the Children's Memory Scale (CMS).[37] First, two components of visual memory were examined. While not always consistent, researchers have suggested in preliminary studies that spatial memory is more impaired than visual memory in children with prenatal alcohol exposure.[31] This evidence of greater spatial memory impairment implicates the visuospatial sketchpad, in which Tresh, Sinnamon, and Seamon[38] determined that spatial and object memories are, at least in part, distinct systems. It then follows that in children with FASD the subsystem for spatial information may be impaired, while the subsystem for visual information may be preserved. That being said, other researchers who also studied memory in children with FASD have found the opposite in which the subsystem for visual information was impaired, while the subsystem for spatial information was preserved.[39] Thus, while the distinction between these two systems is well supported, the unique pattern of deficits in FASD remains unclear.

Second, two components of verbal memory were examined. Two subtests within the verbal memory index will be compared: stories and word pairs. Word pairs is most directly linked to the articulatory rehearsal process in the phonological loop and is one of the more structured tasks on the CMS as clients are prompted with the first word in the pair. Stories on the other hand involve a more complex recall as comprehension also plays a role, which involves the phonological working memory. This latter, less structured, subtest will likely be more difficult for alcohol affected children, and perseverative and intrusion errors are likely to be numerous as they have frequently been identified in other studies with this population.[33] These types of errors are consistent with a failure or inability to shift attention or inhibit responses, functions performed by the central executive component of working memory which is responsible for the attentional functions of memory.[40] It was expected that scores for the stories subtest would be significantly lower than those for word pairs. This difference would persist into the delayed components of these subtests.

Finally, learning or encoding was examined. Some research has suggested that memory deficits in children with FASD lie at the encoding level.[28,9] This was examined by comparing immediate index scores to delayed index scores (measures repeated after thirty minutes) for both visual and verbal areas, and by comparing the learning index to the general memory score. As such, immediate memory was believed to be more indicative of their working memory and their ability to acquire the information using the visuospatial sketchpad and the phonological loop, while delayed memory would rely on retrieval abilities as they would have been unable to continue rehearsing the information to keep it in working memory.[37] It was expected that immediate scores would be more impaired than delayed scores, and that this difference will be more pronounced for verbal memory. We also examined gender because it has been reported as a factor in the normative data used in assessment of memory functioning,[15] and because the CMS does not differentiate between genders, this analysis will rule out the possible influence of this variable. It was expected that gender would not play a significant role in the children's performance on this measure as it is likely that individual differences, as well as the effects of prenatal exposure to alcohol, will be greater than the influence of gender.

No control group was used in this study because the comparisons are within-subjects analyses comparing different types of memory within a group of children with FASD. Even if we were to compare these relations to a matched non-FASD sample, this poses many problems. It is very difficult to find an appropriate control group for children with FASD because children with FASD tend to have other negative life factors (living in foster homes, lower SES, lower IQ, minority group status, etc.) that are very difficult to match. Even if we were to match on some of these factors, matching on some variables can result in unmatching on other variables.[41] This could result in a control group that is not representative of the general population, thus making it difficult to make meaningful generalizations.

In summary, three types of memory processes: verbal, visual, and learning that were examined in an effort to better understand the unique nature of memory deficits in children with FASD. Within the context of a theoretical model of working memory, three questions were examined in the present research, with a sample of thirty children with FASD:

1) Is there a difference between spatial and object memory?

2) Is there a difference between memory for simple verbal material and verbal material requiring comprehension? and

3) Can the memory deficits observed be attributed to problems with learning rather than long-term memory systems, or immediate memory for

delayed memory (which would also reflect learning problems)?

In addition, the children in the study were identified using the most current diagnostic system to ensure clarity and consistency within the sample. Thus, this research emphasizes the differences between memory functions within this unique population.

MATERIALS AND METHODS

Participants

Thirty children with FASD participated in the study. The participants with FASD were recruited through a private practice that specializes in FASD diagnosis in conjunction with a community-based FASD diagnostic team. The participants were diagnosed using criteria based on the 4-Digit Diagnostic Code.[42] All participants were born to mothers who abused alcohol during pregnancy. This was determined through maternal reports, medical records, or information provided through Child Welfare. In the selection of participants the following criteria were used: fluency in English, no significant hearing or vision impairments, a minimum IQ score of 70 (Borderline range or above) as measured on the Wechsler Intelligence Scale for Children (WISC-III),[43] and no current diagnoses of severe psychiatric disorders (e.g., psychosis). In order to meet these criteria, a significant amount of screening was required, and consequently it required fourteen months to compile the current sample of 30 children from 64 children who were screened. Thirty children tested were found to have IQ scores below 70 and consequently were not included in this study. In addition 4 children withdrew their assent or were not compliant with testing procedures and were therefore not included in the study. The participants had a mean age of 12 years, 10 months, and ranged in age from 9-0 to 16-11. There were 14 females and 16 males. Their scores on the WISC – III ranged from 71 to 107, with a mean standard score of 84.13.

Measures

Four Digit Diagnostic Code [42]

All children in this research were diagnosed using the standardized criteria developed and recommended by researchers at the University of Washington.[42] Briefly, this system documents the magnitude of expression of the four key components of the syndrome, specifically:
1) Growth impairment,
2) The FAS facial phenotype,
3) Evidence of brain damage, and
4) Prenatal alcohol exposure, on separate four-point Likert Scales.[42]

A rank of ‘1’ on any scale means a finding within the normal range. A ‘4’ on any scale indicates a finding that corresponds with accepted cases of FAS. A score of ‘2’ or ‘3’ specifically defines intermediate steps between typical and atypical presentation of FAS characteristics. These scales do not necessarily measure increasing severity, rather they are scales of greater confidence that FAS is present, and as such, a diagnosis of FAS requires ranks of 3 or 4 in all categories. However, there are many other possible alcohol-related diagnoses provided depending on the code obtained, in which case, there was additional room for consideration of the entire spectrum of this disorder.

All of the children in this study received a brain score of ‘3’ indicating the presence of probable brain dysfunction based on performance of greater than two standard deviations below the norm in achievement, adaptation, neuropsychological measures, and/or language. Also required were alcohol exposure scores of ‘3’ indicating that while alcohol use during pregnancy was confirmed, the exact amounts consumed are unknown. Together, these two scores are sufficient to indicate the presence of Alcohol Related Neurodevelopmental Disorder (ARND) in all children included in this study. Scores on growth and facial features were not considered as criteria for the purposes of this study, as researchers have revealed that the degree of impairment does not necessarily differ among those with FAS and FAE.[44,45] Very few children prenatally exposed to alcohol display all of the physical features of FAS.[39,40] No children had scores of ‘4’ on either the growth or the face scale indicating that no children in this study presented with ‘full’ FAS.

Children’s Memory Scale (CMS) [37]

To assess memory, the CMS was administered to all children. The CMS is a nationally standardized measure normed on 1,000 normally functioning children ages 5 through 16. It is composed of nine subtests that assess functioning in each of four domains: auditory/verbal learning and memory (verbal), visual/nonverbal learning and memory (visual), attention/concentration, and learning. The nine subtests include six core subtests: dot locations and faces within the visual domain, stories and word pairs within the verbal domain, and numbers and sequences within the attention domain. The learning domain is comprised of scores from dot locations and word pairs subtests. The remaining three subtests are considered supplementary: family pictures, word lists, and picture locations. Each domain is assessed through two core subtests and one supplemental subtest. For each subtest (*M* = 10, *SD* =3) normative scores are provided for evaluating specific abilities, and eight index scores (*M* = 100, *SD* = 15) are derived from the core subtest scores. The two subtests that measure visual memory (dot locations and faces) combine to yield visual immediate and visual delayed index scores. Similarly, scores from stories and word pairs yield the immediate and delayed verbal index scores. The numbers and sequences subtests combine to form an attention/concentration index score. The learning subtest from dot locations and words pairs combine to form a learning index score and the delayed recognition from stories and word pairs combine to form a delayed recognition index score. Acceptable reliability and validity are reported for this measure.[37] In all, the entire measure takes between 45 minutes to one hour to administer

Weschler Intelligence Scale for Children – Third Edition (WISC-III)[43]

The WISC-III was used to evaluate cognitive functioning. All core subtests were administered in order to obtain a Full Scale IQ score, which was used as a part of the process for screening. These subtests make up a Verbal Scale and a Performance Scale as two important dimensions of cognitive ability. The Verbal Scale includes five subtests: Information, Similarities, Arithmetic, Vocabulary, and Comprehension. The Performance Scale also includes five subtests: Picture Completion, Coding, Picture Arrangement, Block Design, and Object Assembly. Three supplementary subtests are also included; Digit Span, Symbol Search, and Mazes.

Procedure

Children and adolescents were tested as a part of a neuropsychological assessment. The measures were administered either by the leading author or another trained examiner. Both the CMS and the WISC-III were administered using the standardized instructions, and were administered in the same order for every child/adolescent. Testing lasted between two and three hours for each child/adolescent. Informed consent and assent were obtained from parents and children, respectively, before beginning their involvement in this study. All guardians and children were informed of their right to withdraw from the study at any time if they so chose.

TABLE 2

Immediate and Delayed Visual Memory by Subtest

		Immediate		*Delayed*	
Subtest	*n*	*M*	*SD*	*M*	*SD*
Dot locations	30	8.23	3.03	8.40	3.29
Faces	30	9.13	2.75	9.07	3.31

RESULTS

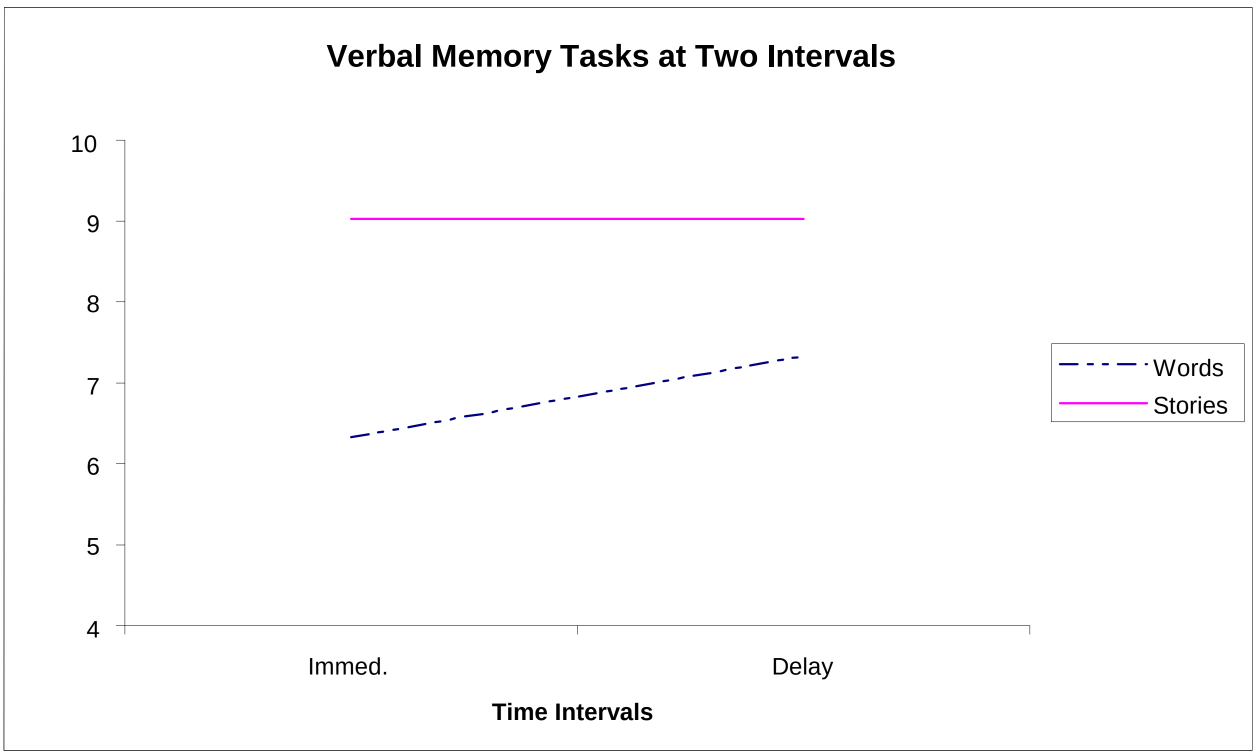
Visual Memory

Means on the two visual subtests are presented in Table 1. To test whether there was a difference between spatial and object/facial recognition memory, a 2(Gender) x 2(Task: dots, faces) x 2(Time: immediate, delayed) ANOVA was used with repeated measures on the last two factors. The means for dots were slightly lower than faces, however no main effect was found for the within subject factors of task, $F(1, 28) = 1.35$, *n.s.* and time, $F(1, 28) = .01$, *n.s.* and there were no interactions and no gender effects.

Verbal Memory

To test whether there was a difference between words and stories verbal memory, a 2(Gender) x 2(Task: stories, word pairs) x 2(Time) ANOVA with repeated measures on the last two factors. A main effect was found for Task, $F(1, 28) = 8.47$, $p < .01$ and Time, $F(1, 28) = 9.31$, $p < .01$ indicating that the children did better at time 2 (delayed) than time 1 (immediate), and that the children did better on the stories subtest than the word pairs subtest. There were no gender effects. An interaction effect was identified for task and time, $F(1, 28)=5.61$, $p < .05$ indicating that performance between the different times (immediate and delayed) was not the same for both tasks. Specifically, no difference in time was identified for stories as the mean scores were identical (M = 9.03 for both), whereas a difference was observed for words (M = 6.33 for immediate and M = 7.33 for delayed) as can be seen in Figure 1. Means on the two verbal subtests are presented in Table 2.

FIG. 1



Note: Children with FASD performed significantly better on a task of story recall than on a task of word recall. On the task of word recall, the children performed significantly better at time 2 (delay) than time 1 (immediate), while their performance on the stories task was identical for both times.

TABLE 2

Immediate and Delayed Verbal Memory by Subtest

		Immediate		*Delayed*	
Subtest	*n*	*M*	*SD*	*M*	*SD*
Stories	30	9.03	2.95	9.03	2.74
Word Pairs	30	6.33	2.99	7.33	3.04

Learning

The third question, regarding learning, was analyzed in two ways. In the first analysis, a 2(Gender) x 2(Task: general memory, learning) ANOVA design was used, with repeated measure on the last factor. The descriptive information is presented in Table 3. It was expected that if the greatest problems for the children with FASD lay in the acquisition of information, then their scores on the learning index would be significantly lower than their scores on the general memory index. The learning index is generated through a measure of the amount of information learned during learning trials. It does not incorporate scores of immediate memory or delayed memory and is therefore independent of the general memory score that relies on these factors. No main effect was found for task, $F(1,28) = 1.58$, *n.s.*, and there were no gender or interaction effects.

In the second analysis of learning, a 2(Gender) x 2(Task: visual memory, verbal memory) x 2(Time) ANOVA design was used with repeated measures on the last two factors to determine whether there was any significant difference between working memory (visual/verbal immediate) and long term memory (visual/verbal delayed) as measured on the CMS. This was intended to further understand whether there is a difference between the ability to learn information (immediate) and the ability to recall and retrieve information after a delay (delay) on verbal and visual tasks in the children with FASD. Descriptive information is provided in Table 4. No main effects were identified for time, $F(1,28) = 2.847$, *n.s.*, and task, $F(1,28) = 1.587$, *n.s.*, and there were no gender effects.

TABLE 3

Learning by Index

Subtest	*n*	*M*	*SD*
General Memory	30	86.00	12.13
Learning	30	83.30	12.04

TABLE 4

Visual and Verbal Learning by Index

		Immediate		*Delayed*	
Subtest	*n*	*M*	*SD*	*M*	*SD*
Visual Learning	30	91.93	12.49	92.37	15.34
Verbal Learning	30	85.90	12.65	89.90	12.00

DISCUSSION

Research on memory in children with FASD has produced varying results in an effort to identify some pattern of impairment. While there has been disagreement, some consistent themes are beginning to emerge, specifically theories that memory deficits may be found primarily in the process of encoding or manipulating information in short-term memory, rather than with long-term storage of information.[9] In the present paper it was intended to further explore memory functions and expose possible patterns that may exist in children with FASD. As such, a comprehensive memory test, the Children's Memory Scale (CMS), was used to explore visual and verbal memory, as well as leaming and encoding, with an FASD population (aged 5-16 years). Functioning was conceptualized through use of a model of working memory.[1] This theoretical framework is a valuable means through which hypotheses can be tested and interpreted in a consistent manner.

Visual Memory

Examination of visual memory revealed no significant differences between the types of visual memory (spatial and object) or between different times (immediate and delayed) examined. This is in contrast to results found by Uecker and Nadel.[30,31] In their studies, Uecker and Nadel[30,31] described a general spatial memory deficit evident in difficulties reproducing a spatial array and no difficulties with facial recognition for children with FASD when compared to a control group. In addition, they reported differences between immediate and delayed visual memory in children with FASD, which could be indicative of encoding deficits. In addition, these results are not consistent with results found by Rasmussen, Horne, and Witol[39] who reported greater weakness in facial recognition rather than spatial memory. While the present research finds no support for the distinction in deficits between types of visual memory, it does not necessarily indicate the absence of encoding deficits, as evaluated through comparison between immediate and delayed memory. Even though delayed memory for visual tasks was not found to be less impaired than immediate memory, it was also not found to be more impaired. As such, there was no indication that the retrieval of information that was committed to long-term memory contributed to the deficits observed. Furthermore, observation revealed that the children tended to recall the same amount of information after the delay as before, suggesting that they did not lose a lot of information during the delay. Therefore, it is plausible that the problems are in information acquisition or the encoding process. This conclusion is consistent with other research in this area[9] which found more indication of memory deficits in the process of learning rather than recalling information in children with FASD.

Further complicating this issue of encoding deficits in visual memory processes is research by Mattson and Roebuck.[9] In this research they identified deficits for delayed recall, beyond what could be explained by acquisition deficits, suggesting some decay of visual information. This difference, however, may reflect the dissimilarity in the measures administered. A significant difference is the drawing requirement in the Mattson study,[9] which was not a component of the current study. In addition, the Mattson study[9] involved memory for geometric figures, while the current study involved a spatial localization task and facial recognition.

Two issues emerge from the variation in results observed in the research into the visual memory system. First, there is a wide range of visual memory tasks available, all of which are described as visual memory. Consequently, with the possibility of such diversity within this domain, specific description of the types of deficits will be necessary to obtain an accurate picture for both clinical and research purposes. Second, from the perspective of the working memory model by Baddeley and Hitch, it is difficult to know how best to separate these components within the visuospatial sketchpad. For instance, the dot locations task appears consistent with the spatial component of the sketchpad. However, it has been noted that storage of a spatial pattern and finding a path through a pattern may be different functions[46], suggesting this test alone does not provide a full picture of spatial memory. Facial recognition is even more of an enigma. The organization of facial features could encompass elements of spatial memory skills, whole object memory, or both. Likely, both spatial and object aspects of memory are implicated, in which case this task illustrates the interaction that occurs between the components of visual memory. A plausible explanation may be that deficits in one specific system are, to some degree, compensated for by another. In turn, this may result in the appearance of inconsistent behaviour in children with FASD, which may be the result of subtle situational or contextual differences that affect the ability of different systems to compensate for one another. This may also explain why other research with children with FASD has found differences between spatial recall and facial recognition that were not apparent in the current study.[30] Nonetheless, difficulty in defining the specific components of visual memory and their interconnections has also been described within the working memory literature,[16] confirming the functional complexity of our visual memory system on a theoretical level, in addition to the clinical level observed here.

At this point it should be noted that while differences between the different components in visual memory were not identified, this does not suggest the lack of deficits in visual memory in children with FASD. In fact, looking at standard scores for this population, the average was lower that the standardized mean in all areas.

Verbal Memory

In contrast to the visual memory components studied, there was a significant difference between types of verbal memory in the FASD sample. Specifically, recall of word pairs was found to be significantly more impaired than that for stories. In addition to this, recall of immediate word pairs was significantly more impaired than that for delayed word pairs. This lends itself to two levels of interpretation. The first is the difference between performances on the two tasks, which was in the opposite direction than predicted. In administering the measures, perseverative errors were noted to be numerous, as expected, however the effects of these errors were different for the two tasks. For the stories, the children tended to ‘add in’ information that seemed to make sense to them, even when they seemed to be struggling to remember the actual story. In other words, they tended to provide more information than was a part of the story. Consequently, as long as they were able to pick up the general theme behind the story, they were able to generate a similar story line, regardless of whether they truly understood the content. In doing so, it seems as though they were relying less on the phonological loop in their working memory, and more on the newest of Baddeley’s proposed functions of the Central Executive, the episodic buffer[22], which could have allowed them to either combine the new information with previous experience or use chunking strategies. While this may have compromised accuracy it did allow them to recall more information about the story, in addition to a lot of inaccurate, superfluous information for which they were not penalized. This is particularly interesting when we consider that often children with FASD present, in conversation, as more competent than they really are which tends to contribute to unrealistic expectations from those around them.[12]

Unlike stories, perseverative errors were detrimental in the word pairs task in which accuracy was required. These errors tended to involve using the same word over and over again until they found its match. The children seemed to do better on those items in which the words were related, while they had great difficulty with those pairs in which there was no relationship. Similar to Mattson and Roebuck’s[9] conclusions, it seemed as though in their work the children did continue to acquire information in successive learning trials, rather than reaching a plateau and not acquiring further information after that. Thus, it appears that their greatest difficulty arose with those items in which the phonological loop was required, which would have facilitated learning though internal recitation and adequate phonological storage.

Learning

The second level of interpretation for the verbal subtests is that of immediate and delayed recall. In this case, word pairs were found to have significantly less impairment for the delayed component. Close examination of the scores indicated that this variation was often created when the same amount of information was recalled after the delay as before the delay. Because the immediate memory scores also included an element of learning this is not a pure comparison. Slower learning or acquisition of information would also affect the immediate memory score thus this score tends to reflect the speed with which information is acquired through consecutive trials, rather than just the amount acquired in the end. Consequently, this indicates that it is likely the point of encoding or acquiring verbal information that is the greater problem for children with FASD rather than the process of accurately retaining and retrieving verbal information, a finding consistent with recent research in this area.[29,9] Thus, the evidence continues to suggest that the working memory, and in this case the phonological loop, is primarily responsible for deficits observed in children with FASD. Moreover, considering the key role of the phonological loop in language acquisition[47], a deficit in this area could be the catalyst for the many language-based problems observed in children with FASD. Further investigation is required to explore this possible relationship.

It is also possible that deficits observed in verbal learning may also be related to deficits in the central executive system. It is the central executive system that is posited to regulate our ability to sustain attention, selectively focus, and shift attention. Memory for word pairs requires both sustained and focused attention in addition to the ability to make a subtle shift between word pairs. Difficulty in any of these areas may have contributed to the difficulty observed here, particularly in terms of the tendency of children with FASD to perseverate. Use of this model of memory in future research to more closely study the types of attention deficits in individuals with FASD, from the perspective of a memory model, may help lend some clarity to this disparate area of study.

Further examination of the data, looking at delayed and immediate index scores, verbal and nonverbal memory, as well as learning and general memory, failed to find any additional differences. However, as noted with visual memory, the absence of a difference in these cases does not argue against a difference in these memory systems, but simply that the data from the present study fails to provide any clear evidence in support of these conclusions. Moreover, no significance was found, in any area, for the effects of gender on the results. While not unexpected given the nature of the brain injury present in children with FASD, the consistently low power observed whenever gender was considered indicates that the ability to detect any effects was very low in this study. As such, further research into this area, possibly with a larger sample size, may provide greater insight into this area.

A comment must be made about this data in general. Overall, the scores obtained by these children showed a tremendous variability, both between children as well as within individual children, as statistically depicted by the high error scores. This variability clearly makes the quest for a pattern more difficult and possibly deceptive insofar as it may be inappropriate to apply any pattern to a group that demonstrates such variability. This is not to say that exploration of the specific nature of deficits present is not warranted - it is. It can contribute to our knowledge base and provide insight as we develop effective intervention techniques, though future researchers will need to be aware of the unique features of this population. At the same time, however, caution must be observed, as we must clearly communicate the limits of such a pattern in its application to individual children with FASD. Blind application of any pattern to FASD will only increase the possibility of misdiagnosis and rather than clarifying our conception of FASD will preclude true understanding of this complex disorder.

Memory is fundamental to our daily functioning. It shapes the way we view and interact with the world around us. It is a necessary skill within the educational system. It defines the way in which we acquire and apply information and skills on a daily basis. In addition, it is complex and interdependent on many different systems in order to be effective. As such, it is an area that warrants continued study and exploration with FASD children. Further research is necessary to continue exploring the deficits that appear to exist at the encoding level of memory, particularly with the phonological loop.[48] In addition, research into language acquisition with FASD children, as it pertains to the phonological loop may provide additional information into the foundation of many learning problems observed as these children negotiate the educational system. Further study using the CMS, or an equally comprehensive memory measure, is encouraged to permit a better understanding of the clinical presentation of this population. Use of a control group could also provide valuable information about the ability of this measure to distinguish between FASD and other groups.

SUMMARY

In summary, in the data presented in this study it is clear that children and adolescents with FASD displayed specific types of verbal memory deficits. In addition, these deficits were greater for immediate rather than delayed memory. These data are consistent with previous studies that describe deficits in immediate memory, and suggest that deficits in delayed memory are better accounted for by encoding deficits. Furthermore, contrary to previous research, retention of visual information was not found to be more impaired than verbal. Moreover, spatial acquisition was not found to be more impaired than facial recognition. Further research into these distinctions in memory is warranted, as is exploration into educational techniques that could account for delayed encoding in children with FASD. In this way educational strategies for children with FASD may be developed and implemented to help these children make the best use of the many abilities they have.

Acknowledgements
The authors extend special thanks to the children and parents who made this project possible. A special thanks to Carly Loomes for her assistance in editing this paper.

Corresponding Author:
Jacqueline.Pei@capitalhealth.ca

REFERENCES

1. Baddeley A, Hitch G. Working Memory, In: The psychology of learning and motivation (G. Bower, ed), Academic Press, San Diego, CA, pp 47-90, 1974.
2. Chudley A, Conry J, Cook J, Loock C, Rosales T, LeBlanc N. Fetal alcohol spectrum disorder: Canadian guidelines for diagnosis. Can Med Assoc J 2005;171:1-21.
3. Barr H, Streissguth A, Darby B, Sampson P. Prenatal exposure to alcohol, caffeine, tobacco, and aspirin: Effects on fine and gross motor performance in 4-year-old children. Dev Psychol 1990;26:339-348.
4. Conry J. Neuropsychological deficits in fetal alcohol syndrome and fetal alcohol effects. Alcohol Clin Exp Res 1990;14:650-655.
5. Streissguth A, Barr H, Sampson P. Moderate prenatal alcohol exposure: Effects on children's IQ and learning problems at age 71/2 years. Alcohol Clin Exp Res 1990;14: 662-669.
6. Whaley S, O'Connor M, Gunderson B. Comparison of the adaptive functioning of children prenatally exposed to alcohol to a nonexposed clinical sample. Alcohol Clin Exp Res 2001;25:1018-1024.
7. Institute of Medicine: Fetal Alcohol Syndrome - diagnosis, epidemiology, prevention, and treatment. (Stratton K, Howe C, Ballaglia F, eds). National Academy Press, Washington, 1996.
8. Mattson S, Riley E. A review of the neurobehavioral deficits in children with fetal alcohol syndrome or prenatal exposure to alcohol. Alcohol Clin Exp Res 1998;22:279-294.
9. Mattson S, Roebuck T. Acquisition and retention of verbal and nonverbal information in children with heavy prenatal alcohol exposure. Alcohol Clin Exp Res 2002;26: 875-882.
10. Nanson J, Hiscock M. Attention deficits in children exposed to alcohol prenatally. Alcohol Clin Exp Res 1990;14:656-661.
11. Streissguth A, Sampson P, Carmichael Olson H, Bookstein F, Barr H, Scott M, Feldman J, Mirsky A. Maternal drinking during pregnancy: Attention and short-term memory in 14-year-old offspring – a longitudinal prospective study. Alcohol Clin Exp Res 1994;18:202-218.
12. Streissguth A. Fetal Alcohol Syndrome: A Guide for Families and Communities. Paul H. Brooks Publishing, Maryland, 1997.
13. Adams A, Gathercole S. Phonological working memory and speech production in preschool children. J Speech Hearing Res 1995;38: 403-414.
14. Schunk D. Learning Theories, Second Edition, Prentice-Hall Inc, New Jersey, 1996.
15. Lezak M. Neuropsychological Assessment, Third Edition, Oxford University Press, New York, 1995.
16. Baddeley A. Is working memory still working? Eur Psychol 2002;7:85-97.
17. Baddeley A: Working memory. Science 1992;255:556-559.
18. Baddeley A. Exploring the central executive. Q J Exp Psychol 1996;49:5-28.
19. Baddeley A. Working Memory, Oxford University Press, New York, 1986.

20. Baddeley A. The magic number seven: Still magic after all these years? Psychol Bull, 1994;101: 353-356.
21. Baddeley A: Essentials of Human Memory, Psychology Press, East Sussex, UK, 1999.
22. Baddeley A. The episodic buffer: A new component of working memory? Trends Cog Sci 2000;4:417-423.
23. Gathercole S, Baddeley A. Development of vocabulary in children and short-term phonological memory. J Mem Lang 1989;28:200-213.
24. Gathercole S, Pickering S. Assessment of working memory in six- and seven-year-old children. J Educ Psychol 2000; 92: 377-390.
25. Spiedel G, Nelson E (eds.): The Many Faces of Imitation in Language Learning Springer-Verlag, New York, pp 151-179, 1989.
26. Crain S, Shankweiler D, Macaruso P, Bar-Shalom E. Working memory and comprehension of spoken sentences: Investigations of children with reading disorder, In: Neuropsychological Impairments of Short-term Memory (Vallar G, and Shallice T, eds), Cambridge University Press, England, pp 477-508, 1990.
27. Mattson S, Riley E, Delis D, Stern C, Jones K. Verbal learning and memory in children with fetal alcohol syndrome. Alcohol Clin Exp Res 1996;20: 810-816.
28. Mattson S, Riley E, Jernigan T, Ehlers L, Delis D, Jones K, Stern C, Johnson K, Hesselink J, Bellugi U. Fetal alcohol syndrome: A case report of neuropsychological MRI, and EEG assessment of two children. Alcohol Clin Exp Res 1992;16:1001-1003.
29. Kaemingk K, Mulvaney S, Halverson P. Learning following prenatal alcohol exposure: Performance on verbal and visual multitrial tasks. Arch Clin Neuropsych 2003;18: 33-47.
30. Uecker A, Nadel L. Spatial locations gone awry: Object and spatial memory deficits in children with fetal alcohol syndrome. Neuropsychologia 1996;34: 209-223.
31. Uecker A, Nadel L. Spatial but not object memory impairments in children with fetal alcohol syndrome. Am J Ment Retard 1998;103:12-18.
32. Nagahara A, Handa R. Fetal alcohol exposure produces delay-dependent memory deficits in juvenile and adult rats. Alcohol Clin Exp Res 1997;21: 710-715.
33. Streissguth A, Barr H, Sampson P, Bookstein P. Prenatal alcohol and offspring development: the first fourteen years. Drug Alcohol Depen 1994;36: 89-99.
34. Jacobson J, Jacobson S. Drinking moderately and pregnancy. Alcohol Health Res W 1999;23: 25-31.
35. Rasmussen C. Executive functioning and working memory in fetal alcohol spectrum disorder. Alcohol Clin Exp Res 2005;29:1359-1367.
36. Kodituwakku P, Handmaker N, Cutler S, Weathersby E, Handmaker S. Specific impairments in self-regulation in children exposed to alcohol prenatally. Alcohol Clin Exp Res 1995;19:1558-1564.
37. Cohen M. Children’s Memory Scale, The Psychological Corporation, San Antonio, 1997.
38. Tresch M, Sinnamon H, Seamon J: Double dissociation of spatial and object visual memory: Evidence from selective interference in intact human subjects. Neuropsychologia 1993;31:211-219.
39. Rasmussen C, Horne K, Witol A. Neurobehavioral functioning in children with Fetal Alcohol Spectrum Disorder. Child Neuropsychol 2006;12:1-16.
40. Baddeley A, Baddeley H, Bucks R, Wilcock G. Attentional control in Alzheimer’s disease. Brain 2001;124:1492-1508.
41. Streissguth A, O'Malley K. Neuropsychiatric implications and long-term consequences of fetal alcohol spectrum disorders. Semin Clin Neuropsych 2000;5:177-190.
42. Stigler J, Miller K. A good match is hard to find: Comment on Mayer, Tajika, and Stanley (1991). J Educ Psychol 1993;85: 554-559.
43. Astley S, Clarren S: Diagnostic Guide for Fetal Alcohol Syndrome and Related Conditions: The 4-Digit Diagnostic Code, 2nd edition, University of Washington Publication Services, Seattle, 1997.
44. Weschler D. Wechsler Intelligence Scale for Children– Third Edition, The Psychological Corporation, San Antonio, 1991.
45. Mattson S, Riley E, Gramling L, Delis D, Jones K. Neuropsychological comparison of alcohol-exposed children with or without physical features of fetal alcohol syndrome. Neuropsychology 1998;12:146-153.
46. Sampson P, Streissguth A, Bookstein F, Barr H. On categorizations in analysis of alcohol teratogenisis. Envirom Health Persp 2000;108:421-428.
47. Smyth M, Pelky P. Short-term retention of spatial information. Brit J Psychol 1992;83:359-375.
48. Baddeley A, Gathercole S, Papagno C. The phonological loop as a language learning device. Psychol Rev 1998;105:158-173.