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There are Laterality Effects in Memory Functioning in Children/Adolescents with Focal Epilepsy

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Abstract

In a sample of individuals with childhood focal epilepsy, children/adolescents with left hemisphere foci outperformed those with right foci on both measures of nonverbal learning. Participants with left foci performed worse than controls on paired associate delayed recall and semantic memory, and they had greater laterality effects in IQ. Participants with right foci performed worse than controls on delayed facial recognition. Both groups displayed reduced focused attention and poor passage retention over time. Although participants with bilateral foci displayed poor learning and lower IQ than controls, they did not have worse impairment than those with a unilateral focus.

Children with epilepsy frequently display poor memory functioning. This is particularly true of children who have focal seizures (Cormack, Vargha-Khadem, Wood, Cross, & Baldeweg, 2012; Fedio & Mirsky, 1969; Kernan et al., 2012). Thus, the aim of our study was to examine memory functioning in children with focal epilepsy, whether simple partial or complex partial in nature. It has been suggested that children with simple partial epilepsy have deficits more specific to learning/encoding (Macleod, Dekaban, & Hunt, 1978), whereas children with complex partial seizures often experience a wide range of memory problems (Von Isser, 1977). Nonetheless, some researchers have found children with focal epilepsy to have intact memory functioning (Culhane-Shelburne, Chapieski, Hiscock, & Glaze, 2002; Hershey, Craft, Glauser, & Hale, 1998). This is particularly true for idiopathic epilepsy (Williams et al., 2001). Moreover, Borden, Burns, and O'Leary (2006) compared children with epilepsy of various types to age- and IQ-matched controls on the Children's Memory Scale (CMS; Cohen, 1997), the measure used for this study, and did not find global memory impairment in children with epilepsy, as they only differed significantly from controls on paired associates learning. Thus, the controversy over whether children with focal epilepsy typically have memory difficulties is far from settled.

Research also has been discordant in terms of laterality effects. For example, various researchers have not found significant differences in memory performance between children with left and right hemisphere foci despite both groups having memory problems; this is true for both verbal and nonverbal material (Engle & Smith, 2010; Kernan et al., 2012; see MacAllister & Schaffer, 2007 for a review). Nonetheless, memory for faces may be an exception, as several researchers have found children with

right temporal lobe epilepsy (TLE) to be impaired in this ability (e.g., Gonzalez, Anderson, Wood, Mitchell, & Harvey, 2007; Mabbott & Smith, 2003). More specifically, children with right TLE often perform worse than children with left TLE on facial recognition tasks, even when no significant differences are observed on other nonverbal memory tasks (Gonzalez et al., 2007; Mabbott & Smith, 2003). These studies, along with data from functional imaging studies (e.g., Sergent, Ohta, & MacDonald, 1992), suggest that facial recognition is a distinct component of nonverbal memory. Furthermore, it has been posited that facial recognition is more strongly lateralized than other nonverbal memory skills (Gonzalez et al., 2007). In contrast to children, measures of verbal memory may be the most sensitive to lateralization in adults with epilepsy (Hermann, Seidenberg, Schoenfeld, & Davies, 1997).

Although some researchers have not found laterality effects when studying children with focal epilepsy, other researchers have demonstrated such effects. For example, laterality effects have been demonstrated in frontal lobe epilepsy (FLE), with visual working memory and immediate memory or verbal learning and immediate memory being affected, consistent with the hemisphere of focus (Hernandez et al., 2003; Svoboda, 2004). Similarly, children with a left frontal focus often have deficits on verbal measures assessing learning over a series of trials (Riva, Saletti, Nichelli, & Bulgheroni, 2002).

Several researchers have demonstrated laterality effects in childhood TLE. For example, Fedio & Mirsky (1969) found laterality effects in intelligence and memory several decades ago. Moreover, since that time various researchers have found laterality effects in learning and/or memory that were incomplete (e.g., left focus group

was not significantly different from the right focus group, but some laterality effects were shown as compared to controls; Cormack et al., 2012; Jambaqué, Dellatolas, Dulac, Ponsot, & Signoret, 1993; Nolan, et al., 2004). In general, left TLE has been associated with deficits in encoding and consolidation of verbal material (Nolan et al., 2004). Children with left TLE tend to remember less information and to forget information faster (Svoboda, 2004); thus, they frequently have problems with verbal long-term memory (Kurokawa et al., 1980). Relatedly, these children also tend to exhibit problems with semantic memory (Cormack et al., 2012; Jambaque, et al., 1993). Some researchers have found right TLE to be associated with visual learning/short-term memory problems for spatial arrangements, patterns, and geometric designs (Fedio & Mirsky, 1969; Nolan et al., 2004), as well as with visual long-term memory problems (Giovagnoli, Casazza, & Avanzini, 1995; Svoboda, 2004). Right TLE also is associated with poor memory for faces, as noted above.

When using an experimental version of the CMS, Cohen (1992) found children with left foci performed worse than controls on verbal learning and memory tasks, but the right focus group did not. In addition, the left TLE group performed worse than the right TLE group on the learning and memory portions of a verbal selective reminding task (Word Lists). Nonetheless, both left and right TLE groups performed worse than controls on the visual learning and memory subtests. While significant differences between the TLE groups were not observed, the sample means were in the expected direction (right TLE < left TLE). This pattern of results may have been related to problems using verbal mediation strategies to help encode nonverbal material in the left TLE group (Battaglia, 1998) and/or to many in the sample having early onset seizures

(Cohen, 1992). With early onset seizures, the right hemisphere may subsume many 'left hemisphere tasks' but at a cost to functions typically subserved by the right hemisphere due to a 'shifting' of language dominance (Cohen, Hynd, & Hartlage, 1983; Satz, 1972).

Research is limited and inconclusive on whether site of focus matters when studying memory functioning in children with epilepsy. For example, memory functioning did not differ between children with TLE and FLE in a study by Lendt et al. (2002), and both groups had poor list learning and design memory in a study by Hernandez and colleagues (2003). In addition, both TLE and FLE groups had poor verbal memory in a study by Jocic-Jakubi & Jovic (2006). Memory impairment has been found in children with focal epilepsy emanating from other cortical locations as well, including the parietal lobes (Jambaque et al., 1993) and the occipital lobes (Germanò et al., 2005; Gülgönen, Demirbilek, Korkmaz, Dervent, & Townes, 2000). Furthermore, Kernan and colleagues (2012) did not find an effect for localization when studying memory and other cognitions. Consistent with this, Jambaqué and colleagues (1993) argued that memory impairment was not limited to children with TLE based upon their findings. Nonetheless, Nolan and colleagues (2004) did find type of memory impairment to differ by focus site. In addition, Culhane-Shelburne and colleagues (2002) found FLE patients to have executive dysfunction but intact memory, with TLE displaying the opposite pattern of performance.

The purpose of our study was to determine whether there are laterality effects in learning and memory in children with focal epilepsy and to illuminate whether children with bilateral foci have worse impairment on verbal and visual tasks than the unilateral focus groups. Our sample is unique in that it is relatively large despite the diagnosis and

classification of epilepsy being carefully defined using seizure semiology, neuroimaging and video-EEG monitoring. In addition, the sample is wide-ranging in severity, although most have seizures of sufficient frequency to warrant treatment with at least one AED, and many have refractory epilepsy. In addition, our sample includes a bilateral foci group, something most studies in this area have not done, which is why discussion of this topic is not included in the literature review. Our sample was not further broken down by site of focus within each hemisphere (e.g., frontal, temporal), as combining across focus locations helped to increase power and provide a reasonable cell size for analysis of the bilateral group. Furthermore, many children with focal epilepsy have learning and memory problems regardless of focus location within each hemisphere, as noted above.

Based upon the literature reviewed, it was hypothesized that children with left hemisphere foci would perform worse than controls on the verbal learning/short-term memory measures, Stories and Word Pairs, and worse than the right focus group on Word Pairs. The latter prediction was based upon prior research finding impairment in the left TLE group compared to the right TLE group on list learning (Cohen, 1992). In contrast, it was hypothesized that the right hemisphere focus group would perform worse than controls on the visual learning/short-term memory measures (Dot Locations, Faces) and worse than the left hemisphere focus group on Faces. The second hypothesis addressed performance on the delayed recall measures: children with left foci would perform worse than controls on the verbal memory measures, and children with right foci would perform worse than controls on the visual memory measures. It also was hypothesized that the right focus group would perform worse than the left

focus group on Faces. The third hypothesis focused on the attention/concentration and working memory measures. Given that most children with epilepsy in our sample were on AEDs, it was believed that all epilepsy groups would perform worse than controls on Numbers, Sequences, and Picture Locations, because AEDs may negatively affect focused attention and concentration (Engle & Smith, 2010), which can impact working memory functioning. All three of these tasks may require good focused attention to perform well as stimuli are presented once and must be reported verbatim. While the previous hypotheses focused on measures of episodic memory, the fourth hypothesis focused on semantic memory; it was predicted that the left focus group would perform worse than controls on vocabulary knowledge (WISC Vocabulary). In relation to all hypotheses, analysis of the bilateral group was exploratory because of the lack of literature on this group.

Method

Participants

Participants included 143 children with focal epilepsy (63 with left foci, 62 with right foci, 18 with bilateral foci) and 63 typically developing controls. All participants were between 6 and 15 years of age; 54% were male; and 88% were right handed. In terms of race, 68% were Caucasian; 23% were African American; and 9% were of another race/ethnicity. None of the participants were from the Cohen (1992) study.

Children with epilepsy were referred for a comprehensive neuropsychological evaluation at one of two pediatric neuropsychology clinical services affiliated with a tertiary care pediatric epilepsy center (a center in the Midwest and a center in the Southeast). Epilepsy diagnosis and seizure localization were determined by a pediatric

neurologist/epileptologist based on the findings from video EEG monitoring, seizure semiology (clinical description) and neuroimaging techniques, blinded to the neuropsychological test results. None had undergone surgical treatment for their epilepsy at the time of neuropsychological evaluation. When participants obtained a FSIQ score below 70 they were excluded from the study unless there was other psychometric evidence that their FSIQ score was an underestimate. Specifically, this was determined by their functioning being 70 or greater on another measure of cognition (e.g., WISC Verbal Comprehension or Perceptual Organization/Perceptual Reasoning Index score [Wechsler, 1991; 2003], academic achievement score, Wisconsin Card Sorting Test Categories Achieved score [Heaton, 1993], or the Tower subtest from the NEPSY [Korkman, Kirk, & Kemp, 1998]). Mean seizure onset was 5.26 years (SD = 3.50 years), and mean epilepsy duration was 5.54 years (SD = 4.25 years). Etiologies included idiopathic (24%), tumor (10%), developmental lesion (e.g., cortical dysplasia; 24%), mesial temporal sclerosis (18%), and acquired lesion (e.g., traumatic brain injury, stroke; 23%). Seizure type included simple partial (3%), complex partial (55%), and complex partial, secondarily generalized (18%), as well as 24% of focal origin where it was not recorded whether they were partial or complex partial in nature (these children were evaluated at the Midwest center noted above). In terms of AEDs, 6% were not on AEDs at the time of evaluation, 42% were on one, 42% were on two, and 10% were on three. Median household income was reported by the parent(s) to be $20-30,000 annually (range = < $10,000 - > $50,000).

Controls were selected from the normative sample of the Children's Memory Scale by matching them to the epilepsy participants on age, gender, race/ethnicity, and

handedness, blind to CMS data. They also were selected based on IQ to obtain a wide range of scores with a mean in the Average range, similar to the total normative sample. We were unable to match on SES as the epilepsy and control groups had different measures of SES. The normative sample was recruited from public and private schools. The following were the exclusion criteria for the normative sample: reading below grade level, repeating a grade, referred to or already receiving Title/Chapter I remedial services or special education, and being diagnosed with a neurological disorder (e.g. epilepsy, stroke, brain tumor, Tourette's syndrome, neurofibromatosis, cerebral palsy or traumatic brain injury). All controls selected for this study were evaluated with the WISC-III and the CMS. Median parent education was 12th grade (range = < 8th grade - 16 years or more). It is believed that median parent education level of the control group and median income level of the epilepsy group are generally equivalent as the most common educational attainment level for our area was a high school degree between 2008-2012, and the average per capita income for 2008-2012 was $25,300 (2012 dollars) as reported by the US Census Bureau.

Measures

The Children's Memory Scale assesses focused attention/concentration, verbal working memory, short-term memory/learning, and long-term memory. It has good psychometric properties. As reported in the CMS manual, average split-half reliability at the subtest level ranged from .71 to .91 across ages, and decision consistency test-retest coefficients ranged from .71 to .93 for the Core subtests (mean re-test interval = 59.6 days). All of the subtests used in this study are Core subtests except Picture

Locations. In terms of criterion validity, the CMS has moderate to high correlations with the Wechsler Memory Scale-III.

The focused attention measures include Numbers Forward and Picture Locations. Numbers Forward requires verbatim repetition of a string of numbers of gradually increasing length. Picture Locations requires replication of an array of animals or modes of transportation using chips, with the array gradually increasing in number of items similar to Numbers Forward. Thus, both are forward span measures. There are two measures of verbal working memory: Numbers Backward and Sequences. Numbers Backward requires saying a string of numbers of gradually increasing length in reverse order. Sequences requires mentally sequencing various rote sequences as quickly as possible. Items start out simple and become gradually more challenging. For example, reciting strings of numbers (e.g., count from 1-20), days of the week, or months of the year in forward order, to saying them in reverse order, to counting by a set amount (e.g., 2s, 4s, 6s), to alternating between letters and numbers in order on the final item.

The core verbal subtests include Stories and Word Pairs. For Stories, children are required to listen to and immediately repeat a story read to them by the examiner. The story content does not need to be recalled in order for the child to obtain credit. There are 2 stories provided at each of three age levels. The delayed recall trial (30 minute delay) is also in a free recall format and is immediately followed by a recognition trial in which the child is asked to answer questions related to each story in a “yes/no” format. For Word Pairs, children have to learn a list of 10 or 14 word pairs depending upon their age over three learning trials. Some paired associates are semantically

related, but most are not. During each learning trial, the examiner reads the list, and then the child has to say the associate that goes with the stem provided by the examiner. Immediately after the three learning trials is a free recall trial in which the child is asked to provide as many of the word pairs as possible; the pairs can be said in any order. The delayed recall trial (30 minute delay) is in a free recall format as well. This is followed immediately by a recognition trial in which the children are asked to identify the word pairs mixed with foils (in yes/no format).

The core visual subtests include Faces and Dot Locations. During the Faces Immediate subtest children are presented with a series of 12 or 16 human faces, depending upon the child's age, one at a time for 2 seconds each. Next, they are presented with 36 or 48 faces one at a time depending upon their age, and they have to say whether or not each face was one of the original target faces presented. They have to do the same thing for the delayed recall subtest (30 minutes later). However, the foils are different so as to avoid confusion with those included in the immediate recall task. Hence, both immediate and delayed presentations use a recognition format. During the Dot Locations subtest the children are presented with an array of 6 or 8 dots, depending upon their age, for 5 seconds. After the exposure, they have to immediately recall the location of the dots by placing chips on a grid. This is repeated for a total of three learning trials. After the learning trials the children are presented with a distractor trial (new array with different colored dots), followed by a short-delay recall trial of the original array. For the delayed recall subtest (30 minutes later) the children are asked to demonstrate the location of the dots from the original array presented over the learning trials. Hence, Dot Locations uses a free recall format.

Along with the CMS, participants were administered a measure of intelligence as part of their evaluation. This included the Wechsler Intelligence Scale for Children, Third or Fourth edition (WISC-III or WISC-IV) for the clinic sample and the WISC-III for the controls. Because testing of the epilepsy sample was conducted in a clinic setting, the most recent version of the test had to be used for ethical reasons. Nonetheless, the correlation between the two versions is high (r = 0.87 for FSIQ). Handedness was determined by observing with which hand the child wrote during the WISC and was validated by parent report.

Procedures

All children were evaluated individually, including controls. For the epilepsy groups, comprehensive neuropsychological evaluations were administered on one testing day in order to minimize travel requirements for the clients and time away from school/work. The CMS was administered immediately following the lunch break. A parent interview was conducted prior to testing to ensure that the child had not experienced a seizure within 24 hours prior to the evaluation. For the control group, the WISC and the CMS were administered to all participants in the linking sample, which was used for this study, with the CMS being administered first. For all participants, IRB approval was obtained from the respective institutions to use the data for research, and participants' parents provided their consent for their child's de-identified data to be used for research purposes.

Results

Preliminary Analyses

All analyses were performed using SPSS 20. Preliminary analyses were conducted to ensure the three epilepsy groups (right, left, and bilateral foci) were

comparable on epilepsy-related variables that may affect learning and memory functioning. Analyses with chi square revealed groups were comparable in etiology (idiopathic, tumor, developmental lesion, mesial temporal sclerosis, and acquired lesion), seizure type (partial, complex partial, complex partial secondarily generalized), presence/absence of lesions identified on MRI, and number of epilepsy medications used at the time of evaluation. In addition, the epilepsy groups did not differ significantly in SES (family income) or WISC version (III or IV) used. Use of one-way ANOVA revealed that the three groups were comparable in epilepsy onset and duration. Moreover, when examining the three groups combined, children who had the WISC-III were comparable to those who had the WISC-IV in FSIQ based upon one-way ANOVA; all *p*s > .10.

When comparing the children with epilepsy from the two clinics, they were comparable in side of focus, duration, gender, race/ethnicity, and handedness (*p*s > .10). The two clinics differed somewhat in etiology, as the Midwest clinic, which provided a smaller percentage of the total epilepsy sample (24%), had a greater percentage of children with an acquired lesion (44% of its sample versus 17% of the Southeast clinic's sample). The Midwest children also had an earlier mean age of seizure onset (3.93 versus 5.76). Even with the earlier onset and greater frequency of traumatic brain injury/stroke, the Midwest clinic's participants had a slightly higher FSIQ as a group (88 versus 80), suggesting that severity of their etiology was not worse despite these differences.

When comparing all four groups (3 epilepsy groups and controls) using chi square, the groups were comparable in gender, race/ethnicity, and handedness, *p*s >

.10. Use of one-way ANOVA revealed the groups were comparable in age at time of assessment as well, $F(3, 202)=2.22$, $p = .087$. Descriptive data are provided in Table 1.

Insert Table 1 about here

To determine whether IQ should be used as a covariate, MANOVA was used with the four Index scores as dependent variables: Verbal Comprehension Index (VCI), Perceptual Reasoning/Perceptual Organization Index (PRI/POI), Working Memory/Freedom from Distractibility Index (WMI/FDI), and Processing Speed Index (PSI). The omnibus tests were significant [$\boldsymbol{\lambda} = .635$, $F(12, 505.63)=7.88$, $p < .001$]. See Table 2 for univariate results. For post-hoc analysis we used Games-Howell correction because of unequal cell sizes. When using one-way ANOVA groups differed on FSIQ, $F(3, 202)=19.96$, $p <.001$, with all epilepsy groups performing worse than controls, ps < .001. Because the epilepsy groups performed worse than controls on all Indices, FSIQ was used as a covariate unless otherwise noted in order to determine whether there are impairments in learning/memory that go beyond IQ deficits. Other studies examining memory functioning in children with epilepsy have used it as a covariate as well (e.g., Borden et al., 2006; Kernan et al., 2012; Nolan et al., 2004), so our using it helps facilitate comparisons across studies.

Insert Table 2 about here

In order to assess potential laterality differences in IQ, VCI_PRI/POI splits were determined by the following method: if VCI was at least 12 points less than PRI/POI participants were placed in the Low VCI group; if VCI was within 11 points of PRI/POI they were placed in the Equivalent group; and if PRI/POI was at least 12 points less than VCI they were placed in the Low PRI/POI group. A 12 point split was selected as

the criterion because this amount represents a significant split in abilities across test versions (0.05 significance level for the standardization sample as reported in the WISC-III manual = 11.8 and WISC-IV manual = 11.00). For the WISC-IV, the base rate of this split in the normative sample varies by level of FSIQ and whether one is examining VCI>PRI or PRI> VCI, but it ranges from15.4-23.8. The WISC-III manual does not break it down by IQ level, but the base rate is 18.5 on average across FSIQ (VCI > POI and POI > VCI). Because of this variability in base rates, a set level of 12 points was selected over a particular base rate as it is significant across ages and versions of the test. See Table 3 for cell counts. Although all the groups had the greatest percentage of children in the Equivalent cell, 30% of the left focus group had a Low VCI, whereas only 11% of the left focus group had a Low PRI/POI. In contrast, the other groups were more equivalent in their laterality effects. To verify whether the chi square findings were driven by the left focus group, PRI/POI was subtracted from VCI to yield a continuous variable, and site of focus was dummy coded for the left and right hemisphere groups. When using Stepwise regression, it was found that having a left focus was predictive of VCI-PRI/POI differences, Adjusted R^2 = .022, F(1, 186)= 5.17, Beta = -.17, p = .024. Presence of a right focus was not predictive of VCI-PRI/POI differences (Beta = -.04, p = .65) and was excluded from the equation.

Insert Table 3 about here

Main Results

To test the first hypothesis, a MANCOVA was used with group membership as the factor and immediate/learning memory measures as the dependent variables. At the omnibus level, FSIQ was significant [λ = .570, F(4,196)=37.02, partial η^2 = .43, p <

.001], as was group membership [λ = .799, F(12, 518.86)=3.84, partial η^2 = .07, p < .001]. At the univariate level FSIQ was a significant covariate for all dependent variables, ps $\leq$ .001. See Table 4 for univariate CMS results and for descriptive data on the CMS. All post-hoc testing used pairwise comparisons with Sidak adjustment for multiple comparisons.

Insert Table 4 about here

To test the second hypothesis, a MANCOVA was used with group membership as the factor and delayed recall measures as the dependent variables. At the omnibus level group membership was significant [λ = .842, F(12, 518.86)=2.90, partial η^2 = .06, p = .001], and FSIQ was a significant covariate [λ = .608, F(4, 196)=31.56, partial η^2 = .39, p < .001]. At the univariate level FSIQ was a significant covariate for all dependent variables, ps $\leq$ .002. A separate MANCOVA was run with the delayed recognition measures as dependent variables. The MANCOVA was not significant at the omnibus level for group membership [λ = .958, F(6, 396.00)=1.43, partial η^2 = .02, p = .202], although FSIQ was a significant covariate [λ = .641, F(2, 198)=55.39, partial η^2 = .36, p < .001]. Lack of significance for the delayed recognition measures appears to be related to the large standard deviations and use of FSIQ as a covariate given multiple means for the epilepsy groups were below average.

In order to assess loss of material over time, the immediate/learning score was regressed onto the delayed score, and the residuals were used as dependent measures in a MANOVA. It was significant at the omnibus level [λ = .803, F(12, 521.51)=3.76, partial η^2 = .07, p < .001]. At the univariate level, groups differed on Stories [F(3, 200)=10.15, partial η^2 = .13, p < .001] and Faces [F(3, 200)=2.90, partial η^2 = .04, p =

.036], but not on Word Pairs [$F(3, 200)=1.48$, partial $\eta^2 = .02$, $p = .218$] nor on Dot Locations [$F(3, 200) < 1.0$, partial $\eta^2 = .01$, $p = .542$]. Post-hoc analyses revealed none of the groups differed significantly on the Faces residual. In contrast, the left and right focus groups performed worse than controls on the Stories residual (ps < .01) but comparably to each other.

To test the third hypothesis, A MANCOVA was used with the verbal working memory measures as dependent variables and PRI/POI as the covariate. PRI/POI was used instead of FSIQ as the Digit Span subtest contributes to FSIQ and is quite similar to Numbers in format. The omnibus test was significant for PRI/POI [$\lambda = .663$, $F(3, 199)=33.70$, partial $\eta^2 = .34$, $p < .001$] and group membership [$\lambda = .843$, $F(9, 484.46)=3.90$, partial $\eta^2 = .06$, $p < .001$]. ANCOVA was used to assess group performance on Picture Locations with VCI as the covariate. VCI was a significant covariate [$F(1, 158)=19.18$, partial $\eta^2 = .11$, $p < .001$], and group membership was significant [$F(3, 158)=3.89$, partial $\eta^2 = .07$, $p = .010$] .

In order to determine whether our results were due to TLE specifically or focal epilepsy more generally, children with foci involving the temporal lobes were compared to those with exclusively extratemporal foci on the learning and memory measures using independent samples t-tests to minimize Type II error. This was performed within hemisphere. For the left hemisphere focus groups, children with temporal foci were comparable to those with extratemporal foci on all CMS measures except for Dot Locations Delayed, where children with extratemporal foci outperformed those with temporal foci, $t = -2.38$, $p = .021$. For the right hemisphere groups, children with temporal foci were comparable to those with extratemporal foci on all CMS measures except for

Stories Delayed Recognition, where children with extratemporal foci outperformed those with temporal foci, t = -2.13, p= .037. Thus, those with and without TLE were comparable on most measures.

To assess semantic memory and the fourth hypothesis, ANCOVA was used with PRI/POI as the covariate and WISC Vocabulary as the dependent measure. FSIQ could not be used as the covariate because Vocabulary is one of the subtests contributing to it. PRI/POI was a significant covariate [F(1, 201)=92.81, partial η^2 = .32, p < .001], and group membership was significant [F(3,201)=2.90, partial η^2 = .04, p = .036]. Post-hoc analyses revealed the left focus group (adjusted X = 7.36, SE = 0.34) performed worse than controls (adjusted X = 8.74, SE = 0.36), p < .05 but comparably to the other epilepsy groups.

Discussion

Research examining memory functioning in children with epilepsy has been more limited than that on adults. Moreover, the findings have been disparate, both in terms of whether there is a deficit as well as whether there are laterality effects. Thus, this study examined potential laterality effects in learning and memory in children with focal epilepsy.

The first hypothesis, which predicted laterality effects in learning/short-term memory, was partially supported. Children with a right hemisphere focus performed worse than children with a left hemisphere focus on short-term recognition of faces and learning of dot locations when IQ was controlled. Those with a right focus performed worse than controls on short-term facial recognition as well. Of interest, the bilateral group also performed worse than the left focus group on the learning of spatial

locations, and they performed worse than controls on all aspects of IQ. Statistically, they performed comparably to controls on the verbal learning and memory measures when IQ was controlled; however, their mean was more than a standard deviation lower than the controls' on learning and memory for paired associates, and it was below average. In general, they did not perform worse than the unilateral focus groups on any of the IQ or memory measures, although their performance on information processing speed (PSI) was the worst of all the groups. Thus, having bilateral foci appears to affect aspects of verbal and visual learning, memory and IQ but not substantially beyond having a unilateral focus alone. However, further research is needed to verify this finding given the relatively small size and variable performance (large standard deviations) of this group, particularly in the area of processing speed. Slight laterality effects were found on a measure of verbal learning when using a paired associates task, in that the left hemisphere group tended to perform worse than controls but comparably to the right focus group. No laterality effects were found on the immediate recall of stories. In contrast, the left hemisphere focus group did show the strongest laterality effects in IQ, which is worthy of further research given the limited research assessing laterality effects in IQ in children with focal epilepsy.

Overall, our results are consistent with previous research that found laterality effects in learning/short-term memory in childhood focal epilepsy. More specifically, prior research on children typically has demonstrated laterality effects on facial recognition tasks (Gonzalez et al., 2007; Mabbott & Smith, 2003), with more variable findings on other nonverbal tasks and on verbal tasks. We also found laterality effects on short-term facial recognition, along with weak laterality effects with paired associate

learning when comparing the epilepsy groups to controls. In addition, our left focus group outperformed the right focus group on the learning of spatial positions, which is consistent with the work of Nolan and colleagues (2004) and Fedio and Mirsky (1969). Nonetheless, our right hemisphere group performed slightly below average on all learning/short-term memory measures, regardless of modality (standard scores in the 80s). Thus, they had a tight range of performance, with their worst performance being on short-term facial recognition. In contrast, our left focus group tended to perform worse on the verbal learning/short-term memory measures than the nonverbal ones, displaying a more prototypical laterality effect (paired t-tests were significant for Stories Immediate versus Dot Locations Learning and Word Pairs Learning versus Dot Locations Learning, *p*s < .01, with a trend for Word Pairs Learning versus Faces Immediate *p* = .067; Stories Immediate versus Faces Immediate was not significant; none of these contrasts were significant for the right hemisphere group). Because our mean age of onset was 5 years, it was likely too late for complete shifting of lateralization of verbal functions to the right hemisphere in many of the children in our left focus group as language is fairly well developed by age 5-6 (Ahmad, Balsamo, Sachs, Xu, & Gaillard, 2003). In contrast, mean performance of our right hemisphere group is consistent with the notion that right hemisphere lesions are not likely to result in shifting of visual-spatial functions and visual memory to the left hemisphere, even with early lesions (Kolb & Wishaw, 2009). As many visual-spatial functions are still developing through at least 10 years of age (Kovács, Kozma, Fehér, & Benedek, 1999), our mean seizure onset was early in comparison.

The poor performance on the verbal measures in the right focus group may be a result of the right hemisphere's contribution to language functioning, as the right hemisphere contributes to some aspects of linguistic functioning, especially those that are semantically related as opposed to syntax-related (Kolb & Wishaw, 2009). As an alternative or complementary possibility, the reduced performance on verbal measures in the right focus group may be due to chronic spreading of abnormal seizure activity to the non-affected hemisphere. This may account for the mildly reduced performance on nonverbal measures relative to a mean of 100 in the left focus group as well. More specifically, it has been suggested that abnormal inter-hemispheric spreading of activation from chronic seizures via white matter tracts may result in otherwise non-damaged tissue being affected (Cohen, 1992, Holmes, 1987). As many children in our sample had poorly controlled chronic epilepsy with relatively early onset, this would appear to be a feasible explanation for our findings as well. Finally, it may be that reduced verbal skills in the left focus group affected verbal mediation during the encoding of nonverbal material, resulting in the slightly lower performance as compared to a mean of 100 (Cohen, 1992).

The second hypothesis which focused on laterality effects in long-term memory was partially supported as well, in that children with a right focus performed worse than controls on delayed recognition of faces, and children with a left focus performed worse than controls on delayed recall of paired associates. However, the epilepsy groups performed comparably to each other. Our findings do not appear to be due to TLE specifically, as those with and without a temporal focus performed comparably on these tasks. For both learning and memory, it would be of interest to determine whether

laterality effects would be stronger on a measure of selective reminding (Word Lists), as prior research using an experimental version of the CMS has found lateralizing effects with this verbal learning and memory task (Cohen, 1992).

Of interest, our findings of long-term memory deficits for paired associates and faces appear to be due to encoding problems rather than storage problems, as epilepsy groups and controls were comparable on faces and paired associate delayed recall when encoding was controlled via the use of residuals. This is consistent with prior research that suggests simple partial epilepsy (Macleod et al., 1978) and complex partial epilepsy (Von Isser, 1977) are associated with encoding problems. Because our sample was comprised of both epilepsy types, it is not surprising that our sample would have encoding problems. Moreover, FLE is associated with short-term memory/working memory problems (Hernandez et al., 2003; Svoboda, 2004), as is TLE when the onset is early (Hershey et al., 1998) which was the case in our sample. In contrast, TLE has been associated with long-term storage problems more than FLE (Hershey et al., 1988). Thus, given our sample composition includes both TLE and FLE, the deficits found in encoding for faces and paired associates make sense.

In contrast to what was found for faces and paired associates, long-term storage problems were found on stories presented once for both right and left hemisphere focus groups. Both left and right focus groups tended to perform below average on delayed recall of the passages, and loss as measured by the use of residuals was significant for both groups. As opposed to the paired associates task, which includes multiple presentations of the same material, the stories are only presented once each, making the task a sensitive measure of hippocampal functioning in episodic memory (Cormack

et al., 2012; Jambaqué et al., 2007). As about a third of our sample had TLE, the role of medial temporal foci in the loss of novel verbal material presented once (Stories) is worthy of further study.

The third hypothesis predicted that there would be deficits in focused attention and working memory in all the epilepsy groups relative to controls. This hypothesis was partially supported. All the epilepsy groups performed worse than controls in focused auditory attention (Numbers Forward). The right focus and bilateral groups also performed worse than controls on a measure of focused visual attention (Picture Locations). Although the left focus group did not differ from controls on this measure, they did score in the Low Average range. Thus, children with epilepsy appear to have deficits in focused attention/concentration in general. This is consistent with the work of Engle and Smith (2010) who found AEDs negatively impact focused attention/concentration. As ninety-four percent of our epilepsy sample was on AED's at the time of evaluation, use of AEDs may have played a role in their concentration difficulties. Surprisingly, working memory was comparable between children with epilepsy and controls after controlling IQ. Given we had a mixed sample in terms of focus location, it is unknown whether those with strictly frontal foci would have working memory deficits.

The fourth hypothesis predicted that there would be differences in semantic memory functioning between children with left foci and controls. This hypothesis was supported when using a measure of vocabulary knowledge and verbal reasoning (WISC Vocabulary). Hence, our study supports prior research suggesting that semantic

memory is affected in children with left hemisphere foci (Cormack et al., 2012; Jambaqué et al., 1993).

Limitations of our study include not having all participants evaluated with the same WISC edition. Nonetheless, we do not believe that this affected our results to a significant degree as the correlation between the two WISC versions is high, the proportion of WISC-III to WISC-IV administrations was comparable between the epilepsy groups, and FSIQ was comparable between children who took the WISC-III and those who took the WISC-IV in the epilepsy sample. A related strength of our study was that it utilized a pediatric epilepsy clinic sample, thereby including children with wide ranging severities of epilepsy; however, for ethical reasons this mandated the need to use the most recent WISC version available when a child was assessed. Our sample also included data from two clinics in different geographic locations, enhancing generalizability, but this led to some in the sample not having data on all the variables. Thus, future research should use the same measures on all children, and it should use a local control group. In our study, both the epilepsy group and the control group were administered the CMS when they were ‘fresh’ (either first thing for the controls or first thing after lunch for the epilepsy groups), but future research should use the identical procedure for all participants.

Another limitation of our sample was not having a sufficient number of children who took Word Lists. Word Lists is a supplemental CMS subtest, and, thus, it was not routinely administered to the epilepsy sample for time reasons as the test battery was already lengthy. Therefore, future research should incorporate this subtest given the earlier findings of Cohen (1992).

An additional limitation of our study was the heightened variability on the CMS measures in our epilepsy sample. Although our control sample had close to the expected standard deviations based on the test's normative sample, the epilepsy groups' standard deviations were often higher. This is not unexpected given that the epilepsy sample included a wide range of severities, from not requiring an AED to their seizures being poorly controlled despite being on multiple AEDs. Nonetheless, it does require more power to address this limitation. Furthermore, our bilateral foci sample was relatively small. While our including it does make a contribution to the literature given the limited literature available on memory functioning in children with bilateral focal epilepsy, further research on this group is warranted. To obtain a sufficient sample size, researchers likely will need to recruit from multiple epilepsy centers as one or two may not be sufficient.

In summary, our study was supportive of laterality effects in learning and memory in childhood focal epilepsy. This was true for paired associate and facial recognition performance. It also was supportive of laterality effects in IQ for children with left foci. While deficits found in facial recognition and paired associate delayed recall appeared to be due to poor encoding, both right and left foci groups demonstrated loss of passages over time. This finding is worthy of further research to determine the relative contribution of the hippocampus to it, as well as TLE specifically. Finally, our findings suggest that although having bilateral foci results in worse learning and lower IQ as compared to controls, it does not appear to result in worse impairment than having a unilateral focus.

References

Ahmad, Z., Balsamo, L., Sachs, B., Xu, B., & Gaillard, W. (2003). Auditory comprehension of language in young children: neural networks identified with fMRI. *Neurology*, *60*(10), 1598-1605. doi:10.1212/01.WNL.0000059865.32155.86

Battaglia, F. M. (1998). Neuropsychological aspects of TLE in children. 3rd European Congress of Epileptology, *Epilepsia*, *39* (suppl 2), 70. doi: 10.1111/j.1528-1157.1998.tb01895.x

Borden, K., Burns, T., & O'Leary, S. D. (2006). A comparison of children with epilepsy to an age- and IQ-matched control group on the children's memory scale. *Child Neuropsychology*, *12*(3), 165-172. doi:10.1080/09297040500276836

Cohen, M. J. (1992). Auditory/verbal and visual/spatial memory in children with complex partial epilepsy of temporal lobe origin. *Brain and Cognition*, *20*(2), 315-326. doi:10.1016/0278-2626(92)90024-G

Cohen, M. J. (1997). *Children's Memory Scale Manual.* San Antonio, TX: Psychological Corporation.

Cohen, M. J., Hynd, G. W., & Hartlage, L. C. (1983). A shift in language lateralization: One case for and one case against. *Clinical Neuropsychologist*, *5*, 187-202.

Cormack, F., Vargha-Khadem, F., Wood, S., Cross, J., & Baldeweg, T. (2012). Memory in paediatric temporal lobe epilepsy: effects of lesion type and side. *Epilepsy Research*, *98*(2-3), 255-259. doi:10.1016/j.eplepsyres.2011.09.004

Culhane-Shelburne, K., Chapieski, L., Hiscock, M., & Glaze, D. (2002). Executive

functions in children with frontal and temporal lobe epilepsy. *Journal of the International Neuropsychological Society*, *8*(5), 623-632. doi:10.1017.S1355617702801308

Engle, J. A. & Smith, M. L. (2010). Attention and material-specific memory in children with lateralized epilepsy. *Neuropsychologia*, *48*(1), 38-42. doi: 10.1016/j.neuropsychologia.2009.08.005

Fedio, P., & Mirsky, A. F. (1969). Selective intellectual deficits in children with temporal lobe or centrencephalic epilepsy. *Neuropsychologia*, *7*(4), 287-300. doi:10.1016/0028-3932(69)90054-2

Germanò, E., Gagliano, A., Magazù, A., Sferro, C., Calarese, T., Mannarino, E., & Calamoneri, F. (2005). Benign childhood epilepsy with occipital paroxysms: Neuropsychological findings. *Epilepsy Research*, *64*(3), 137-150. doi:10.1016/j.eplepsyres.2005.03.004

Giovagnoli, A., Casazza, M., & Avanzini, G. (1995). Visual learning on a selective reminding procedure and delayed recall in patients with temporal lobe epilepsy. *Epilepsia* ,*36*(7), 704-711. doi: 10.1111/j.1528-1157.1995.tb01050.x

Gonzalez, L. M., Anderson, V. A., Wood, S. J., Mitchell, L. A., & Harvey, A. S. (2007). The localization and lateralization of memory deficits in children with temporal lobe epilepsy. *Epilepsia*, *48*(1), 124-132. doi: 10.1111/j.1528-1167.2006.00907.x

Gülgönen, S., Demirbilek, V., Korkmaz, B., Dervent, A., & Townes, B. D. (2000). Neuropsychological functions in idiopathic occipital lobe epilepsy. *Epilepsia*, *41*(4), 405-411. doi: 10.1111/j.1528-1157.2000.tb00181.x

Heaton, R.K. 1993. *Wisconsin Card Sorting Test Manual*. Odessa, FL: Psychological Assessment Resources, Inc.

Hermann, B. P., Seidenberg, M., Schoenfeld, J., & Davies, K. (1997). Neuropsychological characteristics of the syndrome of mesial temporal lobe epilepsy. *Archives of Neurology*, *54*(4), 369-376. doi:10.1001/archneur.1997.00550160019010

Hernandez, M. T., Sauerwein, H. C., Jambaqué, I., Guise, E., Lussier, F., Lortie, A.,…Lassonde, M. (2003). Attention, memory, and behavioral adjustment in children with frontal lobe epilepsy. *Epilepsy and Behavior*, *4*(5), 522-536. doi:10.1016/j.yebeh.2003.07.014

Hershey, T., Craft, S., Glauser, T.A., Hale, S., 1998. Short-term and long-term memory in early temporal lobe dysfunction. *Neuropsychology*, *12*(1), 52-64. doi: 10.1037/0894-4105.12.1.52

Holmes, G. L., (1987). *Diagnosis and management of seizures in children.* Philadelphia: Saunders.

Jambaqué, I., Dellatolas, G., Dulac, O., Ponsot, G., & Signoret, J. L. (1993). Verbal and visual memory impairment in children with epilepsy. *Neuropsychologia*, *31*(12), 1321-1337. doi:10.1016/0028-3932(93)90101-5

Jambaqué, I., Dellatolas, G., Fohlen, M., Bulteau, C., Watier, L., Dorfmuller, G.,… Delalande, O. (2007). Memory functions following surgery for temporal lobe epilepsy in children. *Neuropsychologia*, *45*(12), 2850-2862. doi:10.1016/j.neuropsychologia.2007.05.008

Jocic-Jakubi, B. & Jovic, N. J. (2006). Verbal memory impairment in children with focal

epilepsy. *Epilepsy and Behavior*, *9*(3), 432-439. doi: 10.1016/j.yebeh.2006.07.010

Kernan, C. L., Asarnow, R., Siddarth, P., Gurbani, S., Lanphier, E. K., Sankar, R., & Caplan, R. (2012). Neurocognitive profiles in children with epilepsy. *Epilepsia*, *53*(12), 2156-2163. doi: 10.1111/j.1528-1167.2012.03706.x

Kolb, B. & Wishaw, I. Q., (2009). *Fundamentals of human neuropsychology*. NY: Worth.

Korkman, M., Kirk, U., & Kemp, S. (1998). NEPSY: A developmental neuropsychological assessment manual. San Antonio, TX: Psychological Corporation.

Kovács, I., Kozma, P., Fehér, Á., & Benedek, G. (1999). Late maturation of visual spatial integration in humans. *Proceedings of the National Academy of Sciences of the United States of America*, *96*(21), 12204-12209. doi:10.2307/48959

Kurokawa, T., Goya, N., Fukuyama, Y., Suzuki, M., Seki, T., & Ohtahara, S. (1980). West syndrome and Lennox Gastaut syndrome: survey of natural history. *Pediatrics*, *65*(1), 81-88.

Lendt, M., Gleissner, U., Helmstaedter, C., Sassen, R., Clusmann, & H., Elger, C. E. (2002). Neuropsychological outcome in children after frontal lobe epilepsy surgery. *Epilepsy and Behavior*, *3*(1), 51–59. doi:10.1006/ebeh.2001.029

Mabbott D. J. & Smith, M. L. (2003) Memory in children with temporal or extra-temporal excisions. *Neuropsychologia*, *41*(8), 995–1007. doi:10.1016/S0028-3932(02)00318-4

MacAllister, W. S., & Schaffer, S. G. (2007). Neuropsychological deficits in childhood

epilepsy syndromes. *Neuropsychology Review*, *17*(4), 427-444. doi:10.1007/s11065-007-9048-4

Macleod, C. M., Dekaban, A. S., & Hunt, E. (1978). Memory impairment in epileptic patients: selective effects of phenobarbital concentrations. *Science*, 202, 1102-1104. doi:10.1126/science.715461

Nolan, M. A., Redoblado, M. A., Lah, S. S., Sabaz, M. M., Lawson, J. A., Cunningham, A. M., & ... Bye, A. E. (2004). Memory function in childhood epilepsy syndromes. *Journal of Paediatrics & Child Health*, *40*(1/2), 20-27. doi:10.1111/j.1440-1754.2004.00284.x

Riva, D., Saletti, V., Nichelli, F., & Bulgheroni, S. (2002). Neuropsychological effects of frontal lobe epilepsy in children. *Journal of Child Neurology*, *17*(9), 661-667.

Satz, P. (1972). Pathological left-handedness: An exploratory model. *Cortex*, *8*(2), 121-135. doi:10.1016/S0010-9452(72)80013-3

Sergent, J., Ohta, S., MacDonald, B. (1992). Functional neuroanatomy of face and object processing: a positron emission tomography study. *Brain*, *115*(1), 15-36. doi: 10.1093/brain/115.1.15

Svoboda, W. B. (2004). Memory. *Childhood epilepsy: Language, learning, and behavioral complications* (289-309). United Kingdom: Cambridge University Press.

Von Isser, A. (1977). Psycholinguistic abilities in children with epilepsy. *Exceptional Children*, 43(5), 270-275.

Wechsler, D. (1991). *Wechsler Intelligence Scale for Children -- Third Edition*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (2003). *Wechsler intelligence scale for children* (4th ed.). San Antonio, TX: Psychological Corporation.

Williams, J., Phillips, T., Griebel, M. L., Sharp, G. B., Lange, B., Edgar, T., & Simpson, P. (2001). Patterns of memory performance in children with controlled epilepsy on the CVLT-C. *Child Neuropsychology*, *7*(1), 15-20. doi: 10.1076/chin.7.1.15.3148

Table 1

Participant Demographic Data

Characteristic	Controls	Left Focus	Right Focus	Bilateral Foci
Gender (% Male)	52.4	52.4	52.4	77.8
Race (% Caucasian)	71.4	60.0	65.3	88.2
Handedness (% Right-handed)	82.5	88.1	91.7	88.9
	M(SD)	*M(SD)*	*M(SD)*	*M(SD)*
Age (Years)	10.10(2.47)	11.13(2.60)	10.18(2.38)	10.57(2.81)
[95% Confidence Interval]	[9.47-10.72]	[10.48-11.79]	[9.58-10.79]	[9.17-[11.97]

Table 2

WISC III/IV Differences Between Groups

Variable	Controls *Mean(SD)*	Left Focus *Mean(SD)*	Right Focus *Mean(SD)*	Bilateral Focus *Mean(SD)*	*F*(3,194)	Partial η^2	*p*
VCI[a]	101.17(15.31)	83.52(15.84)	88.54(17.22)	89.78(15.55)	12.47	.16	<.001
	[97.04-105.30]	[79.79-87.85]	[84.41-92.67]	[82.30-97.26]			
PRI/POI[b]	99.86(15.68)	87.58(16.89)	88.58 (16.94)	85.33(13.57)	7.87	.11	<.001
	[95.68-104.05]	[82.50-91.46]	[84.40-92.76]	[77.76-92.90]			
WMI/FDI[c]	103.34(14.59)	83.52(15.59)	86.10(16.99)	82.00(11.26)	21.27	.25	<.001
	[99.38-107.30]	[79.66-87.38]	[82.15-90.06]	[74.84-89.16]			
PSI[c]	106.64(15.34)	83.95(16.67)	88.36(16.51)	75.78(18.18)	27.46	.30	<.001
	[102.44-110.85]	[79.85-88.05]	[84.15-92.56]	[66.17-83.39]			

Note. a = clinical groups differed from controls at $p < .001$ except for bilateral foci where $p = .05$; b = left focus group differed from controls at $p < .001$, and right and bilateral foci differed from controls at $p < .01$; c = clinical groups differed from controls at $p < .001$. 95% confidence intervals for the means are presented in brackets.

Table 3

Frequencies of IQ Splits by Location of Seizure Focus

Variable	Controls (n=63)	Left Focus (n=63)	Right Focus (n=62)	Bilateral Foci (n=18)
VCI < PRI	6	19	13	4
VCI = PRI	48	37	33	8
PRI < VCI	9	7	16	6

Note. Observed cell counts differed from expected cell counts, $X^2 = 16.90$, $p = .01$

Table 4

CMS Differences Between Groups

	Controls	Left Focus	Right Focus	Bilateral Focus			
Variable	*Mean(SD)*	*Mean(SD)*	*Mean(SD)*	*Mean(SD)*	*F(3,199)*	Partial η^2	*p*
Hypothesis 1 (STM/Learning)							
Stories	96.75(15.71)	86.51(18.04)	88.06(18.00)	93.06(21.77)	1.19	.02	.32
	[85.37-93.56]	[87.08-94.90]	[86.56-94.19]	[90.14-104.28]			
Word Pairs	101.59(17.22)	82.42[a](17.57)	86.05(18.36)	82.50(21.02)	2.60	.04	.05
	[90.26-98.81]	[82.19-90.36]	[84.31-92.26]	[79.14-93.93]			
Dot Locations	102.14(15.23)	94.44(15.51)	88.79[b](17.53)	82.50[a,b](18.25)	4.84	.07	.003
	[92.63-100.64]	[93.83-101.48]	[86.81-94.27]	[78.73-92.56]			
Faces	98.41(12.98)	90.00(17.20)	83.06[b,c](14.64)	90.28(15.67)	6.33	.09	<.001
	[91.71-99.71]	[87.89-95.53]	[80.20-87.65]	[84.91-98.73]			
Hypothesis 2 (Delayed Recall)							
Stories	97.86(15.57)	82.14(15.47)	85.73(18.49)	90.28(22.06)	1.18	.03	.14
	[86.75-94.59]	[82.52-90.01]	[84.36-91.66]	[87.61-101.15]			
Word Pairs	102.30(14.28)	85.73[d](18.31)	88.06(16.36)	85.83(20.67)	3.14	.05	.03
	[92.94-101.40]	[84.40-92.47]	[85.76-93.63]	[81.47-96.06]			
Dot Locations	101.11(13.90)	95.56(14.37)	93.95(14.57)	86.67(13.83)	2.24	.03	.09
	[93.68-101.03]	[94.18-101.20]	[91.73-98.57]	[82.47-95.16]			
Faces	99.13(15.77)	86.94(17.21)	82.34[c](15.57)	87.78(18.65)	5.93	.08	.001
	[91.97-100.71]	[84.47-92.82]	[79.16-87.30]	[81.82-96.92]			

	(Delayed Recognition)						
Stories	98.81(16.23)	85.87(19.73)	86.37(19.53)	94.44(22.81)	1.99	.03	.12
	[86-94-95.89]	[86.14-94.63]	[84.53-92.86]	[91.70-107.52]			
Word Pairs	100.95(14.89)	84.11(22.57)	87.98(21.07)	83.82(21.98)	0.69	.01	.56
	[88.36-97.78]	[84.09-93.03]	[86.08-94.84]	[79.45-96.12]			
Hypothesis 3 (Attention/Concentration and Working Memory)							
Numbers F.	101.43(15.15)	83.97[c](16.14)	87.66[c](17.17)	80.00[c](12.49)	10.67	.14	<.001
	[95.24-103.18]	[81.09-88.78]	[84.65-92.39]	[74.25-88.59]			
Numbers B.	102.30(13.97)	91.51(15.52)	91.13(17.16)	93.33(12.13)	2.44	.04	.07
	[95.22-102.38]	[89.57-96.50]	[89.00-95.97]	[89.11-102.03]			
Sequences	102.94(12.94)	90.24(17.59)	91.69(17.95)	87.78(12.51)	2.52	.04	.06
	[94.80-101.68]	[88.96-95.62]	[90.16-96.87]	[84.56-96.99]			
Picture Loc.	100.24(15.69)	89.88(15.95)	85.71[d](19.80)	84.06[d](13.93)	3.89	.07	.01
	[92.67-101.13]	[87.76-97.78]	[82.82-92.68]	[76.45-92.14]			

Note. Numbers F.= Numbers Forward, Numbers B. = Numbers Backward, and Picture Loc. = Picture Locations. a = differed from controls at $p = .05$; b= differed from left focus group at $p < .05$; c = differed from controls at $p \leq .001$; d = differed from controls at $p < .05$. 95% confidence intervals for the adjusted means are presented in brackets. Means and standard deviations are unadjusted.