NEUROPSYCHOLOGICAL IMPAIRMENTS AND AGE-RELATED DIFFERENCES IN CHILDREN AND ADOLESCENTS WITH FETAL ALCOHOL SPECTRUM DISORDERS

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ABSTRACT

Background
Children and adolescents with Fetal Alcohol Spectrum Disorders (FASD) exhibit a range of physical, cognitive, behavioral, and/or learning deficits, as wells as poor executive functioning (EF). Children and adolescents with FASD often show greater impairments on complex neuropsychological tasks. However, little is known about age-related differences among children and adolescents with FASD.

Objectives
The goals of this cross-sectional study were to explore the overall profile of neuropsychological impairments and extended previous reports on age-related differences among children and adolescents with FASD.

Method
We compared 117 children and adolescents diagnosed with an FASD (aged 5-17 years), clinically assessed on a broad range of tests covering 6 neurobehavioral domains. Data from a clinical database was used to generate profiles of neuropsychological impairments for clinically referred children and adolescents evaluated for FASD between 2001 and 2005.

Results
Children and adolescents were impaired (relative to the norm) on a number of domains that include academic achievement, language, verbal memory, EF, visual-motor integration, and motor abilities. Older participants with FASD (relative to the norm) showed greater difficulty in areas involving EF or processing of complex information than younger participants.

Conclusions
These results suggest that for children and adolescents with FASD impairments in those areas important for independent functioning may become more pronounced with increasing age. However, further longitudinal research is needed to ascertain age changes over time.

Key Words: *Fetal alcohol spectrum disorders, neuropsychological impairments, age-related differences, children and adolescents*

Fetal Alcohol Spectrum Disorders (FASD) often leads to lifelong primary and secondary disabilities as a result of maternal alcohol consumption. FASD is an umbrella term used to refer to a range of abnormalities that result from alcohol exposure during fetal development. The prevalence of FASD is estimated from 1%[1] to as high as 2-5% of children[2] making it a significant public concern. Prenatal alcohol exposure (PAE) can cause permanent structural brain damage[3,4,5]

and impairments in neuropsychological, behavioral, emotional, physical, and social impairments[1] that have lifelong implications. Some of the secondary disabilities may include dropping out of school, delinquency, trouble with the law, alcohol and drug abuse, and mental health issues.[6]

The neuropsychological impairments among children and adolescents with FASD have been well documented and include deficits in intellectual ability, memory, attention, processing speed, visual-spatial abilities, motor delays, language, academics, learning, and executive functioning (EF).[7] However, general lowering of IQ does not explain the entirety of neuropsychological deficits observed in these children and adolescents.[8,9,10,11,12] In addition, recent converging evidence has shown that children and adolescents with FASD display greater difficulty on neuropsychological tasks requiring complex processing of information and increased demands on EF,[7,8,13] which may be more important and necessary in late childhood or adolescence.

Howell et al.[14] found that adolescents with FASD (n = 126) have difficulty on academic measures of reading, writing, and arithmetic, and their challenges with arithmetic were greater than that of adolescents enrolled in a special education classroom. Children with FASD may require greater educational and social supports, as they grow older. However, there are fewer educational services available in adolescence leading to adolescents with FASD to fall behind further than their peers with age. Consequently, children and adolescents with FASD may fail to meet set expectations, which could increase their risk for secondary disabilities and adverse outcomes prevalent in this population.[15] However, most previous research has not included large enough sample sizes to examine age-related differences or have been limited by studying few neuropsychological domains in recruited samples.

Streissguth et al.[16] presented the most robust evidence for continued presence of impairment for children and adolescents with FASD through to their adult years, from their Seattle Longitudinal Study that followed a cohort of over 500 children (approximately half of the mothers were reported to be heavy drinkers and half as light drinkers or abstainers).[16] The authors tested children from preschool to adolescence on a number of neuropsychological variables and identified a pattern of attention, memory, and information processing impairments present in children with PAE at birth and 7 years of age that predicted impairments exhibited at 14 years of age.[15,17,] Difficulties with attention, arithmetic, visual-spatial memory, speed of information processing, and overall lower IQ displayed in childhood continued into adolescence and adulthood.[16] These same children also had significant problems in learning difficulties and classroom behavior as well as antisocial and delinquent behavior in adolescence, suggesting that neuropsychological impairments may increase the risk for some secondary disabilities including mental health issues, alcohol and drug abuse, inappropriate sexual behaviors, delinquency, confinement, and school discontinuation.[15]

Although these studies represent the marked neuropsychological impairments displayed in adolescence by individuals with FASD, previous research indicates that adolescents may show greater difficulty on some EF measures than younger children. Rasmussen and Bisanz.[18] found that children and adolescents (aged 8 to 16 years, n = 29) with FASD had impairments on EF measures of flexibility, inhibition, verbal fluency, abstract thinking, deductive reasoning, hypothesis testing, problem solving, and concept formation. What's more, the adolescents performed worse (relative to the norm) than younger children on some verbal tests of EF; IQ was not related to age and therefore could not account for the differences in performance. Similarly, Rasmussen, McAuley, and Andrew[19] found that adolescents with FASD had significantly worse (relative to the norm) parent-reported difficulties on a behavioral measure of EF (measured with the Behavioral Rating Inventory of Executive Functioning) than younger children with FASD. These findings indicate that some EF impairments may become more pronounced with age (relative to norm samples) among children and adolescents with FASD, although these studies were not

longitudinal and conclusions about age *changes* cannot be made.

Whilst researchers have reported age-related differences on tests of EF, there are no existing studies examining age-related differences on the broader neuropsychological profile in FASD. Very little is known about age-related differences in neuropsychological functioning from childhood to late adolescence and the ongoing impact of PAE across the course of neurodevelopment.[20] Clarifying the nature of age-related differences in neuropsychological abilities is important for neuropsychologists that assume responsibility of diagnosing and describing the impairments present in FASD, and subsequently making predictions about future functioning. Without an understanding of how neuropsychological impairments are manifested across the course of development of FASD decision making regarding appropriate intervention and remediation strategies becomes challenging. Further research would help identify specific domains of impairment that may be most vulnerable to age-related changes, which in turn will facilitate development of tailored supports and interventions that match the maturational needs of this population.

The present study aimed to extend previous research findings and further investigate age-related differences among children and adolescents with FASD on a broad range of neuropsychological measures to inform both understanding as well as clinical practice in the hopes of identifying a potential developmental profile of neuropsychological impairments that could support future longitudinal investigations. A profile of impairments in children and adolescents with FASD was examined in the domains of EF (attention and switching), memory, academic achievement, language, visual-motor integration, and motor abilities. We further examined possible age-related difference on measures in each domain and predicted that adolescents with FASD would perform relatively poorer than younger children with FASD (compared to the norm) on many measures of neuropsychological functioning, in particular on tasks involving more EF and processing of complex information because adolescence places more demands on these skills.

METHOD

Participants

This cross-sectional study included 117 children (42 females) with FASD, clinically referred for an evaluation for suspected FASD at a Private Diagnostic Clinic between 2001 and 2005. All data obtained for this study was anonymized data approved by ethics committee.

The mean age (yr;mo) was 11;4 (SD = 2;6), and the range was 5;0 to 17;9. All children had a diagnosis of Alcohol Related Neurodevelopmental Disorder (ARND) made according to the Institute of Medicine Criteria (IOM).[21] To be diagnosed according to these guidelines all children had confirmed PAE and neuropsychological impairments that would indicate a degree of brain dysfunction. PAE was confirmed through a reliable source (e.g. birth mother report, children's services records, legal documentation). Clinical domains assessed during diagnosis included attention, memory, intelligence, EF, academic functioning, and adaptive functioning. Significant impairment in a minimum of two areas was required, as documented on objective testing (i.e. questionnaires or interview information alone was not sufficient for significant impairment in a domain). A child was not typically assessed on measures of higher level functioning (e.g. EF) unless they were old enough to engage in the evaluation (i.e. above age 8 years). In our study, full-scale IQ scores were only available for 94 of the children, with a mean full-scale IQ score of 85 (Range = 51-116). Furthermore, reportedly 8.6% lived with an adoptive parent, 17.5% lived with a biological parent, 20.7% lived with a guardian, 26.2% lived in foster care, and for 27% their living situation was unknown.

Materials and Procedures

Clinical data had been collected at the time of diagnosis and testing took place during one session lasting about three hours as part of the FASD diagnostic evaluation. A trained psychometrician administered all tests to each child or adolescent that included a broad range of

neuropsychological tests covering 6 domains that had been selected for the individual diagnostic assessment. Neuropsychological domains assessed during diagnosis included Academic Achievement, Language, Visual-Motor Integration, Verbal Memory and Learning, Motor Skills, and EF. However, not all children received the same test battery, thus limiting the number of measures we could include for each domain. Therefore, only age-appropriate measures used to test between 70-117 participants in our sample could be included in our analyses. Intelligence was assessed on the Wechsler Intelligence Scale for Children (WISC), the Wechsler Adult Intelligence Scale (WAIS), or the Wide Range Intelligence Test (WRIT). IQ Scores were only available for 94 participants because some participants had received an IQ assessment prior referral to the clinic and we did not have access to these scores for research purposes.

To examine whether there were age-related differences within either of these domains a cross-sectional design was used to compare three age groups of children with FASD, divided into the following age groups: 5-8, 9-12, 13-17 years. In some analyses, sample size differed because some children did not complete some of the tests as part of their clinical assessment. Furthermore, not all tests were suitable for all ages and hence children aged between 5-8 years old were not assessed on tests of EF or Motor. The sample sizes for each test across the three age groups (5-8, 9-12, 13-17) were: Wide Range Achievement Test (WRAT) spelling (31, 33, 43), reading (31, 29, 37), and arithmetic (31, 34, 42); the Woodcock Johnson Passage Comprehension (WJ-PC; 11, 28, 37); Peabody Picture Vocabulary Test (PPVT-R; 28, 33, 41); Children's Auditory Verbal Learning Test (CAVLT; 24, 25, 29); and the Beery Visual-Motor Integration Test (VMI; 35, 34, 29). The Halstead-Reitan tests are only appropriate for older children and therefore we made comparisons between two age groups (9-12, 13-17) and samples sizes for each age group were: Grooved Peg Board (29, 38); the Hand Dynamometer (29, 38), the Finger Tapping Test (29, 38); and the Trail Making Test (31, 40).

Neuropsychological Tests

A broad range of tests was used to assess 6 domains: Academic Achievement, Language, Visual-Motor, Memory and Learning, Motor, and EF. Test protocols were administered and scored by the trained psychometrician using standardized protocol and normative data. For each test, the raw score was converted to an age appropriate standard score with a normative mean of 100 and a standard deviation of 15. For the purpose of a neuropsychological evaluation to confirm FASD diagnosis, each child was administered neuropsychological tests across 6 neurobehavioral domains. For a list of tests used in each neurobehavioral domain, see Appendix A.

RESULTS

To determine how children with FASD performed relative to the norm separate one sample t-tests on each subtest were conducted to compare the scores of children and adolescents with FASD to the normative mean of 100. Our alpha level was adjusted using the Bonferroni correction to .003 (.05/16) to take account for the multiple t-test comparisons. In our second analysis, we examined age-related differences on standard scores for each subtest using one-way ANOVAs. Finally, we conducted a one-way ANOVA to address whether a disparity in IQ could account for differences in neuropsychological performance across age group, but there was no significant difference $F(2, 91) = 2.07$, $p > 0.05$ in IQ scores across age group [aged 5-8 (M = 86), 9-12 (M = 87), and 13-17 (M = 81)].

Profile of Neuropsychological Impairments

As evident in Table 1, children with FASD performed significantly lower than the normative mean of 100 on WRAT-3 spelling, reading, and arithmetic; WJ-PC; PPVT-R; CAVLT immediate memory, levels of learning, interference, immediate recall, delayed recall; Beery VMI; Hand Dynamometer; and Trail-Making Test B. There were no significant differences compared to the normative mean on the Finger Tapping Test; Groove Pegboard; and Trail-Making Test A.

TABLE 1 Performance of Children with FASD on Each Cognitive Domain Compared to the Normative Mean

Subtest/Domain	Mean (SD)	t	df	*p*
Academic				
WRAT				
Spelling	86.21 (15.25)	-9.35*	96	< .003
Reading	85.97 (14.72)	-9.46*	106	< .003
Arithmetic	75.11 (14.49)	-17.77*	106	< .003
Woodcock Johnson				
Passage Comprehension	84.67 (11.52)	-11.60*	75	< .003
Language				
PPVT-R	79.04 (16.32)	-13.04*	101	< .003
Memory				
CAVLT				
Immediate Memory	84.58 (17.18)	-8.08*	80	< .003
Levels of Learning	86.95 (13.99)	-8.08*	74	< .003
Interference	87.36 (19.69)	-5.85*	82	< .003
Immediate Recall	88.51 (19.92)	-5.26*	82	< .003
Delayed Recall	88.57 (19.78)	-5.20*	80	< .003
Visual-Motor Coordination				
Beery				
Visual-Motor Integration	84.92 (19.78)	-11.02*	101	< .003
Motor				
Halstead-Reitan Battery				
Grooved Peg Board Dominant	100.22 (10.90)	0.17	66	.867
Hand Dynamometer Dominant	95.87 (23.80)	-1.42*	66	< .003
Finger Tapping Dominant	113.71 (16.83)	6.62	65	.160
Executive Functioning				
Halstead-Reitan Battery				
TMT A	93.89 (23.89)	-2.07	70	.042
TMT B	79.06 (42.88)	-4.09*	69	< .003

*** = P < .003**

Age-Related Differences

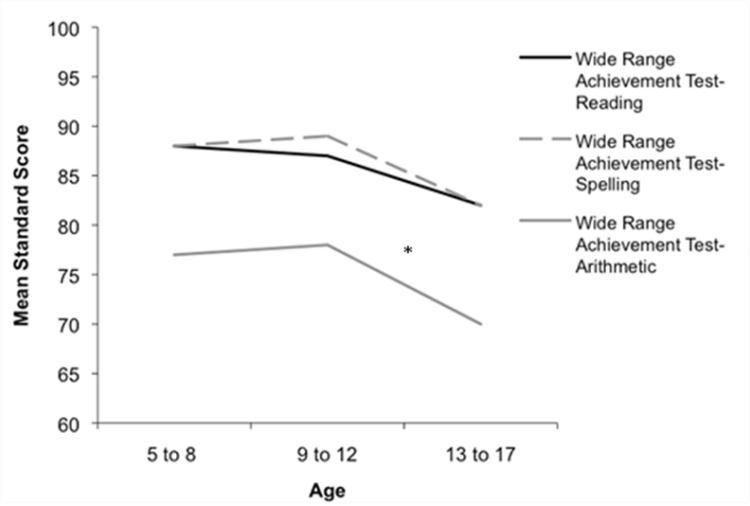
On the WRAT, there was a significant difference between the age groups on the arithmetic subtest, $F(2, 104) = 3.21$, $p = 0.04$, but not for spelling $F(2, 104) = 2.31$, $p = 0.10$ and reading $F(2, 94) = 1.95$, $p = 0.14$. However, for spelling and reading there was a trend indicating that the older participants (relative to the norm) performed worse than younger participants (see Figure 1). Mean scores between the three age groups were not significantly different on the WJ-PC, $F(2, 73) = 2.52$, $p = 0.25$, and the PPVT-R, $F(2, 99) = 1.24$, $p = 0.30$.

A significant difference was found between the three age groups on the Beery VMI, $F(2, 95) = 4.88$, $p = 0.01$ (see Figure 2), indicating that older participants (relative to the norm) performed worse than younger participants on tasks of visual-motor integration. On tests of motor skill, there was a significant difference between the two age groups on the finger tapping tasks dominant hand, $F(1, 64) = 19.66$, $p < 0.00$; the hand dynamometer dominant hand, $F(1, 65) = 6.23$, $p < 0.05$; and the groove pegboard dominant hand, $F(1, 65) = 9.37$, $p < 0.03$ (see Figure 3), suggesting that older participants performed worse (relative to the norm) than younger participants on these tests of motor skill.

On the verbal learning and memory task, a significant age-related difference was found between the three age groups for levels of learning trial, $F(2, 72) = 3.71$, $p = 0.02$ (see Figure 2). However, mean scores between the three age groups did not differ significantly on the immediate recall trials, $F(2, 78) = 0.99$, $p = 0.90$, interference trial, $F(2, 80) = 1.19$, $p = 0.33$, immediate free recall trial, $F(2, 80) = 2.37$, $p = 0.99$, and delayed recall trial, $F(2, 78) = 1.87$, $p = 0.16$.

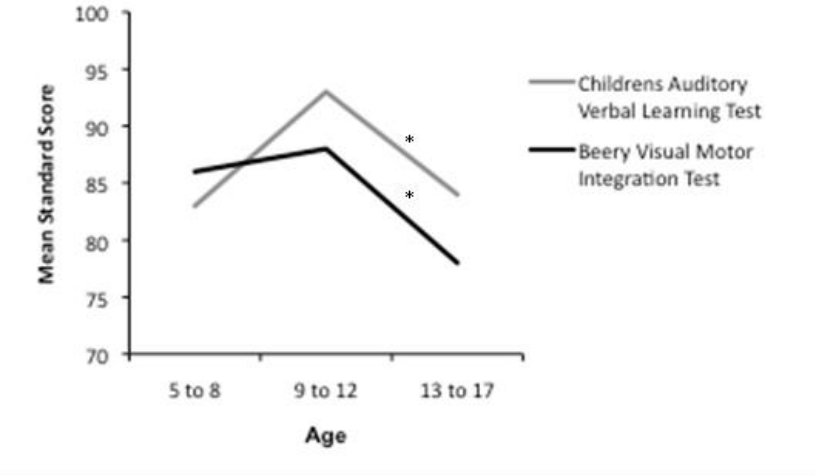
Older participants showed marked difficulty (relative to the norm) than younger participants on both Trail Making test A and B; differences between the two age groups were significantly different on both Trail A, $F(1, 69) = 12.19$, $p < 0.05$ and Trail B, $F(1, 68) = 9.71$, $p < 0.05$ (see Figure 4).

FIG. 1 Mean Differences Across Age Group on Academic Achievement



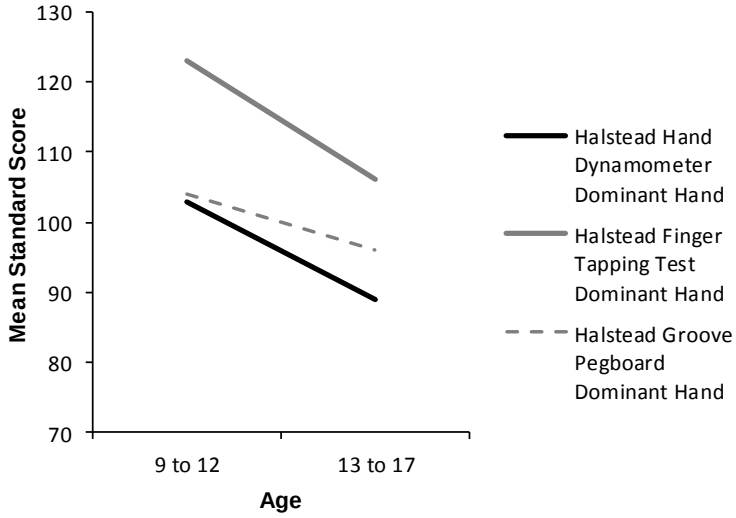
*** = P < .05**

FIG. 2 Mean Differences Across Age Group on Verbal Memory and Visual Motor Integration



*** = P < .05**

FIG. 3 Mean Differences Across Age Group on Motor Abilities Using Dominant Hand



*** = P < .05**

FIG. 4 Mean Differences Across Age Group on Executive Functioning

*** = P < .05**

DISCUSSION

The goal of this study was to examine the profile of neuropsychological impairments displayed by children and adolescents with FASD, and make age-related comparisons among a variety of neuropsychological domains (EF, memory, motor abilities, visual-motor, language, and academic achievement). Identifying the profile of neuropsychological impairments in children and adolescents with FASD is important for intervention and remediation strategies and guiding future longitudinal research. This pattern could also assist with identifying specific areas of weakness susceptible to age-related differences, which is important for calling attention to areas that should be targeted for remediation in childhood and adolescence.

Profile of Neuropsychological Impairments

Children and adolescents with FASD showed significant impairments (relative to the norm) in all domains assessed. On the academic testing, our sample performed significantly below the normative mean on spelling, reading, arithmetic, and on reading comprehension, which confirms findings from previous reports on academic achievement.[22,23] Not surprisingly, they showed the greatest impairment on arithmetic, a weakness that is well documented in FASD.[24] Consistent with previous studies reporting impaired receptive language abilities as measured on the PPVT-R,[25,26] our sample performed significantly worse than the norm indicating deficits in receptive language as one of the weaker areas assessed in our sample.

On the CAVLT test, children and adolescents with FASD had significant difficulty on both learning and recall of verbal information. These results confirm the findings of previous studies reporting significant difficulties with verbal memory and learning in children and adolescents with FASD.[8] Their performance on the immediate free recall trials was significantly below the normative mean and confirms deficits in recalling verbal information.[27,36] They also showed significant difficulties with short delayed recall of information which is consistent with Roebuck and Mattson,[30] whose study also used a

verbal memory and learning measure that did not involve an implicit learning strategy. Children and adolescents with FASD have been known to display intact retention abilities relative to significantly poor initial verbal learning[25,30] but our results confer that perhaps for children and adolescents with FASD learning verbal information without an implicit strategy affects their retention abilities.[30]

Our sample of children and adolescents with FASD performed significantly below the norm on the Beery VMI test and confirms marked deficits in visual-motor integration abilities as documented in other studies.[28,31,32,33] They also showed significant difficulties on the hand dynamometer test (relative to the norm), which indicates relatively weaker grip strength abilities in these children and adolescents, and confirms previous research in which children and adolescents with FASD perform worse as compared to typically developing controls on this task.[34] Our sample performed well on the groove pegboard and finger tapping tests (relative to the norm) and this was surprising because previous studies have reported significant difficulties in children and adolescents with FASD on the groove pegboard[25,28,31,35] and finger-tapping tasks.[17,36]

Children and adolescents with FASD had significant difficulty on the Trail Making task, suggesting deficits in EF abilities. They performed within normative expectations on Trail A (number sequencing), but significantly below the normative mean on Trail B (number-letter sequencing) requiring cognitive flexibility and EF, which is consistent with previous studies.[11,18,28,29]

Age-Related Neuropsychological Differences

We examined age-related differences across a broad array of neuropsychological measures to further extend previous reports but comparing performance across three age groups: young children (5-8 yrs), middle-aged children (9-12 yrs), and adolescents (13-17 yrs). Older participants with FASD performed worse (relative to the norm) than their younger counterparts on a number of neuropsychological domains involving EF, arithmetic, learning and memory, visual-motor integration, and motor abilities. Notably, our analyses revealed no significant differences in mean IQ between our three age groups thus the age-related differences we report cannot be attributed to IQ.

Academic Achievement and Language

Older participants with FASD performed significantly worse (relative to the norm) than younger participants on arithmetic, but no significant age-related differences were found on tests of reading, spelling, and receptive language abilities. The discrepancy observed for arithmetic ability provides some evidence that children and adolescents with FASD are having greater problems with arithmetic as they age, relative to their peers. Rasmussen and Bisanz[37] reported impairments on tests of arithmetic in young children with FASD as highly correlated with phonological and central executive working memory impairments. Therefore, difficulties with working memory (and EF) may contribute to the age differences in arithmetic reported in the current study. Difficulties in arithmetic are most frequently reported in children with FASD[25] and are known to persist into adolescence.[14,17]

Visual-Motor Integration and Motor Function

Performance on the Beery VMI task were worse in older participants (relative to the norm) than younger participants indicating that visual-spatial skills may represent a greater challenge for older children with FASD. Deficits in this area have been described for young children with FASD[8] and our work indicates that these deficits may not only persist into adolescence, but that they may become worse relative to peer performance. Moreover, similar to Vaurio et al.[28] we found that these deficits were independent of intellectual functioning.

Older participants performed worse (relative to the norm) than younger participants on the hand dynamometer, finger tapping, and groove pegboard motor tasks, indicating that deficits in motor abilities appear to become more pronounced with age. These results are similar to previous work reporting impairments in motor abilities that persist with age.[17,36,38] Therefore, further investigation into the motor abilities in children with FASD is warranted, particularly as it

may relate to intervention and support planning.

Memory

Older participants with FASD showed significantly greater difficulty (relative to the norm) for learning verbal information when compared to younger participants (aged 10-12 years), a result not observed for recalling verbal information. Thus, deficits in the area of verbal processing and learning appear to be more pronounced with increasing age, suggesting that older children with FASD appear to learn words at a much slower rate (compared to the norm) and may not benefit from repeated word list learning at a level expected for their age group. The age-related discrepancy in performance confirms previous research reporting difficulties in verbal learning and memory in adolescents with heavy prenatal alcohol exposure.[39] Difficulties in the areas of verbal EF have been found when comparing older children with FASD to younger children.[19] These findings suggest that verbal task involving EF skills may be particularly difficult for older children with FASD, leading children with FASD to fall behind further than their peers with age.[18] Notably, in our sample children aged 5-9 years also performed worse than children aged 10-12 years. However, this finding may be accounted for by previous reports of a linear relationship between age and learning on the CAVLT in typically developing children that appears to plateau at 10 years of age.[40]

Executive Functioning

Age-related differences were identified on the Trail-Making test; older participants performed worse (relative to the norm) than younger participants on both Trial A (number sequencing) and Trail B (number-letter sequencing) tasks. Moreover, the greatest difference was noted for the Trail B task, indicating that as children age they may have greater difficulty on the more complex component of EF involving cognitive flexibility relative to their peers.

Summary

Age differences were found on a variety of complex neuropsychological tasks, but were not found on basic tests of reading, spelling, and receptive language abilities, which are relatively less complex tasks and require less EF and processing of complex information. Notably, we observed deficits in domains that have been consistently reported as persistent areas of difficulty for these children and adolescents, and most probably relate to FASD and not concurrent deficits in intellectual functioning.[28,41] Adolescence also tends to place more demand on such complex executive skills, which may in part explain the decrement in performance on these tasks among the adolescents in our sample.

Clinical Implications

This study provides further evidence for increasing neuropsychological impairments in individuals with FASD with increasing age. As the abilities of youth with FASD continue to diverge progressively more from their peers they may struggle to keep up with age expectations and as a result it may appear as though their learning is declining or that their effort is reduced, when they are simply failing to progress at the same rate as their peers, despite the effort invested. Consequently, children and adolescents with FASD may experience frustration with increasing expectations, which may contribute to the development of secondary disabilities and adverse outcomes. Recognition of this developmental trend in children and adolescents with FASD may equip caregivers and educators to respond proactively to increasing challenges experienced by these children. Ongoing evaluation of student needs to ensure supports are best suited to current progress will permit adaptation to changing developmental needs. Notably, strengths identified for children with PAE or FASD may not remain strengths as the children age, due to their developmental trajectory. Consequently, ongoing assessment of strengths and impairments needs to be an important part of intervention and support planning. Additionally, knowledge of this trend may reframe the perceptions of the support people in the lives of children and adolescents with FASD, such that increasing difficulties may not be seen as decreasing effort, thus impacting expectations and interpretations of behavior. In addition, recognition of the increasing difficulties experienced by children and adolescents with

FASD as they age underscores the need for the investigation into the development of interventions and services that may support optimal development.

Limitations

We acknowledge that because our study is cross-sectional we cannot conclude that these impairments are *caused* by age or *change* with age. However, we recognize that longitudinal studies can be challenging because these require sustainable funding and a well-defined neurobehavioral protocol that are ideally supported by previous age-related studies. Furthermore, there is risk for drop out especially in this population where many children are involved in the foster-care system or have other life adversities that may complicate follow up. Our cross-sectional study aimed to increase our knowledge and clinical understanding of a developmental profile for children with FASD across different age groups. Our study was challenging because we were reporting on clinical data collected at the time of diagnosis and the participants in our study had only completed tests that were appropriate for their diagnostic assessment, hence we were unable to maintain equal sample sizes and conduct sophisticated statistical analyses. However, clinical data is valuable to report on and can be advantageous because we are able to report data from diagnosis hence the extent of their impairments may be well reflected. Particularly because access to targeted interventions specifically for individuals affected by FASD prior diagnosis is not likely. However, we cannot overlook the possibility that older children in our sample simply had greater neuropsychological impairments that may have also occurred when they were younger or that they had more exposure to other risk factors such as unstable environment, family violence, physical abuse, comorbidities, secondary disabilities etc. However, these questions can be asked with further longitudinal research.

We aimed to compare children with FASD on the same tests to make direct comparisons among older and younger children with FASD that could assist in identifying domains that may be more susceptible to the developmental affects of PAE. A potential problem may be that because some neuropsychological tests are only appropriate for children older than 8 years, we were unable to report on tests that had been used with all ages. Similarly, because some children had been assessed for IQ prior referral to the Clinic, we were missing IQ scores for some children, but this occurred in all age groups and not just the older group and no differences in IQ between the three age groups were found. Another potential limitation is the lack of control group in our study, however, there are many environmental variables that are difficult to control for in this population and we were more interested in the profile of performance among the FASD participants and differences between the age groups. Finally, we acknowledge that only receptive language processing was examined in this study. Future research in which other domains of language such as word retrieval, phonology, syntax, and morphology are studied will be important in defining the language profile of children and adolescents with FASD.

Future Directions

The findings reported in this study confirm that children and adolescents with FASD show impairments in many different neuropsychological domains and suggest that older participants with FASD perform relatively poorer in areas involving more EF and processing of complex information. These areas may simply be more sensitive to the direct affects of PAE and may potentially reflect the neurodevelopmental trajectory in children affected by FASD. Although we cannot conclude that the differences in abilities are due to age, we also cannot assume that the abilities for the older children would necessarily remain within normative expectations. The results from this study indicate that adolescents with FASD show a significant age-related weakness in EF, learning verbal information, visual-motor integration, fine motor skills, and arithmetic, these results must be interpreted with caution because we are not reporting on longitudinal data. Developmental trajectories have been rarely explored.[7] Therefore, further research is required to investigate these

age-related trends longitudinally and on a comprehensive set of neuropsychological tests appropriate for both younger and older children with FASD. Reporting on age-related impairments in children with FASD is important for identifying appropriate interventions and remediation strategies that target and alleviate neuropsychological abilities most vulnerable to PAE and making long-term clinical decisions and recommendations about reassessment, intervention, remediation strategies, and transitions for children and adolescents affected by FASD. Often these children are seen at an FASD clinic once to receive a diagnosis and immediate recommendations. However, there is limited knowledge about the stability of these impairments and the different types of services that may be required as these children grow older. Neuropsychological impairments may also impact other areas of weakness reported in children and adolescents with FASD such as secondary disabilities. Recognizing relative strengths and weaknesses across the course of development in children and adolescents with FASD could ultimately improve diagnosis and lead to appropriate intervention and remediation strategies.

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Appendix A

Neurobehavioral Domain	Tests Used to Assess
Academic	Wide Range Achievement Test Third Edition (WRAT-3) Woodcock Johnson - Passage Comprehension (WJ-PC)
Language	Peabody Picture Vocabulary Test Revised (PPVT-R)
Motor/Visual-Spatial	Beery Visual Motor Integration (VMI) Halstead-Reitan Groove Pegboard Halstead-Reitan Finger-Tapping Task Halstead Reitan Hand Dynamometer
Memory	Children's Auditory Verbal Learning Test (CAVLT)
Executive Function	Halstead-Reitan Trail Making Task (TMT)

Not all children received every test on the list, or each test listed in each domain. Some children were too young for some of these tests. Measures used were primarily selected based on individual needs.