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Objective assessment of ADHD core symptoms in children with heavy prenatal alcohol exposure

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HIGHLIGHTS

- Inattention is a core deficit in children prenatally exposed to alcohol.
- Findings are consistent with parent reports of hyperactivity in children with FASD.
- Concurrent measurement of ADHD symptoms may offer a more complete assessment of FASD.

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ABSTRACT

Attention deficits are often observed in children with prenatal alcohol exposure and attention-deficit/hyperactivity disorder (ADHD) is commonly diagnosed in this population. This study used an objective assessment tool to examine differences between alcohol-exposed and non-exposed children on core symptoms of ADHD: inattention, impulsivity, and hyperactivity. Two groups of individuals, aged 7–14 years, participated in the study: alcohol-exposed children (AE, $n = 43$), and non-exposed children (CON, $n = 54$). Subjects were evaluated with the Quotient ADHD System, which provides objective data on ADHD core symptoms by combining an infrared motion tracking system and a computerized continuous performance task. Twelve separate ANCOVAs controlling for the effects of age and sex, were conducted on attention and motion variables. Results revealed that in comparison to the CON group, the AE group was significantly (p's $< .05$) less accurate, made an increased number of omission errors, had longer response latencies, and increased variability in response time. Moreover, the AE group spent less time staying still, and made an increased number of head movements, which traveled a larger distance, covered a greater area, and demonstrated a less complex movement pattern. No significant group differences were observed on the number of commission errors and temporal scaling. Our findings provide further support for the notion that inattention is a core deficit in children prenatally exposed to alcohol. Results from this study are also consistent with parent reports of increased hyperactivity. The Quotient ADHD System may be a useful objective measure of ADHD symptomatology in children with FASD.

1. Introduction

The most widely known outcome of heavy prenatal alcohol exposure is the fetal alcohol syndrome (FAS), which is characterized by a unique pattern of facial dysmorphia, pre- and/or post-natal growth deficiency, and central nervous system (CNS) dysfunction [1,2]. Since FAS was first identified over 40 years ago, it has become increasingly apparent that individuals with histories of prenatal alcohol exposure, with or without a diagnosis of FAS, demonstrate qualitatively similar cognitive and behavioral impairments. This suggests that CNS dysfunction may be a better indicator of alcohol exposure than facial dysmorphia and growth deficiency [3]. Fetal alcohol spectrum disorders (FASD) encompass the full range of physical, cognitive, and behavioral outcomes associated with prenatal alcohol exposure [4].

Although neuropsychological studies have demonstrated deficits associated with prenatal alcohol exposure across a wide range of cognitive and behavioral domains (for review, see [5]), attention deficits are thought to be a hallmark characteristic in children with histories of prenatal alcohol exposure [6,7]. Alcohol-exposed children are also more likely to be described as hyperactive (e.g., [8–10]). Therefore it is not surprising that many children with histories of heavy prenatal alcohol

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exposure have a co-occurring diagnosis of attention-deficit/hyperactivity disorder (ADHD) [11,12].

Several studies have reported that children with FASD have attention deficits when assessed with objective measures such as continuous performance tests (CPTs) [6,8,13–15]. However, objective measurements of hyperactivity in children prenatally exposed to alcohol are limited. To the best of our knowledge only one study has objectively measured hyperactivity in FASD [8]. This study examined the correspondence of parent report and laboratory measures of inattention (CPT) and hyperactivity (non-dominant wrist actigraphy) in children prenatally exposed to alcohol, non-exposed children with ADHD, and non-exposed controls. Non-exposed children with ADHD were found to be hyperactive based on both parent reports and laboratory-measured actigraphy. However, parent ratings and objective measures were discordant for the FASD group. While parents indicated that children with FASD were hyperactive, the laboratory test found similar activity levels in the FASD and control groups. Attention deficits and hyperactivity have also been observed in animal models of FASD (e.g., [16–18]); however, findings are dependent upon numerous factors, including the pattern and timing of alcohol exposure, the age of the animal at the time of testing, and other methodological factors [19]. Given the animal findings and the parental reports of hyperactivity, further objective measurement of activity level is warranted in children with FASD.

The Quotient® ADHD System (Pearson) [20] is a tool developed to provide objective information on ADHD core symptoms of inattention, impulsivity, and hyperactivity by combining an infrared motion tracking system and a computerized CPT [21]. In one study using the Quotient ADHD System, unmedicated boys with ADHD had more attention shifts and spent less time on task than controls; these group differences were more robust than differences on a standard CPT [22]. Quotient motion variables also differ between typically developing children and those with ADHD [21]. Children with ADHD make more whole body movements in less complicated patterns, whereas movements in the control group were limited to the extremities. Using this tool, we tested children with histories of heavy prenatal alcohol exposure and age-matched non-exposed controls. Given the high rates of ADHD in children with histories of heavy prenatal alcohol exposure, we hypothesized that all three ADHD core symptoms of inattention, impulsivity, and hyperactivity will be elevated in these children in comparison to non-exposed controls.

2. Materials and methods

2.1. Subjects

Subjects were children, between the ages of 7 and 14 ($M = 11.50$, $SD = 2.20$), with confirmed histories of heavy prenatal alcohol exposure (AE, $n = 43$) and non-exposed control children (CON, $n = 54$). The data from an additional 20 subjects could not be included in the analyses due to ADHD medication during the 12-hour washout period ($n = 4$), and equipment malfunction or experimenter error ($n = 16$). Subjects were drawn from larger ongoing studies taking place at the Center for Behavioral Teratology (CBT) at San Diego State University and were recruited via several mechanisms including professional or self-referral and community outreach.

History of prenatal alcohol exposure was determined through multi-source collateral report, including review of available medical, social service, and adoption agency records or maternal report when available. Alcohol-exposed children with or without a diagnosis of FAS were included in this study. Direct maternal report was not common for children in the AE group, as many of these children no longer resided with their biological families. However, in these cases, mothers were reported by family members, adoption agencies, social workers or medical health records to be “alcoholic” or alcohol abusing or dependent during pregnancy. When maternal report was available, heavy alcohol exposure was defined as consumption of an average of at least 4 drinks per occasion or 14 drinks per week at least several times during pregnancy. Direct maternal report was available for two children (0.05%) in the AE group. A diagnosis of FAS was accepted as a de facto indication of heavy alcohol exposure. Twelve children (27.91%) in the AE group met criteria for FAS based on a dysmorphology exam (for details, see [23]). All but two of the non-exposed children resided with their biological mothers and alcohol exposure histories for these children were determined through direct maternal report. Mothers of these children reported little (less than 1 alcoholic drink per week on average and never more than 2 drinks per occasion during pregnancy), if any, alcohol use during pregnancy.

The mental health status for each child was assessed using the National Institute of Mental Health Computerized Diagnostic Interview Schedule for Children (C-DISC-IV) [24], a structured diagnostic interview administered to the child's parent or primary caregiver, and/or report of a parent or primary caregiver of a psychiatric diagnosis. Children in the CON group were excluded if they had an ADHD diagnosis by parent report or if they demonstrated clinical (6 or more) or subclinical (3–5) symptoms of ADHD on the C-DISC-IV. Thirty-five children (81%) in the AE group met criteria for ADHD, which is consistent with previous reports [11,12]. Sixteen of these children were prescribed medications often used to treat ADHD that included stimulants such as amphetamines and methylphenidates, and non-stimulant medication such as atomoxetine and guanfacine. In addition, many of these children were also being treated with other types of psychiatric medication. Exclusion criteria for all groups were: primary language other than English, head injury with loss of consciousness greater than 30 min, any known physical or psychiatric disability that would prohibit participation, or any cause of mental deficiency that would prevent successful completion of the task.

2.2. Procedure

Informed consent was obtained from the parent or legal guardian and assent from the child. Children were evaluated using the Quotient ADHD System, described below. As part of larger ongoing studies at the CBT, Full Scale IQ (FSIQ) scores were available from the Wechsler Intelligence Scale for Children, Third Edition [25] or the Wechsler Intelligence Scale for Children, Fourth Edition [26]. Parents or primary caregivers of children who met criteria for ADHD diagnosis were asked to refrain from giving prescribed medication for the treatment of ADHD to their children on the day of their testing appointment. If this washout was not possible the child was allowed to participate, but the data were excluded from the data analyses ($n = 4$). The Institutional Review Board at San Diego State University approved all procedures.

2.2.1. The Quotient ADHD System

As described above, the Quotient ADHD System captures and quantifies motor movements or activity levels in subjects while they are engaged in a computerized CPT. Duration of the test is 15 min for children under age 13 ($n = 73$), and 20 min for adolescents over age 13 ($n = 24$). For ages 14 and under, the test uses a Go/No-Go paradigm in which one of two different types of stars (8-pointed or 5-pointed) are displayed on the computer screen at random screen positions for 200 ms, with a 2-second interstimulus interval. Children are asked to respond by pressing a button on the keyboard when the target (8-pointed star) appears on the screen, while withholding responses to the non-target (5-pointed star). While subjects are engaged in the task, an infrared motion tracking system captures and records movement using the two-dimensional location of a reflective marker placed on a headband worn by the child. The system collects and records motion data at a rate of 50 times per second and with sub-millimeter accuracy. A movement (i.e., microevent) is created every time the reflector moves at least 1 mm from its current location. The trajectory as defined by the microevents is plotted and displayed in 5-minute segments. CPT attention measures and measures

of motion for each participant were automatically calculated by the Quotient ADHD System and used for data analyses. As the duration of the test is 15 or 20 min depending upon age, the test dependent variables were adjusted based on the test length. For each 5-minute segment, the test scores were calculated separately and then were averaged by the number of segments per test (3 for the 15-minute test and 4 for the 20-minute test). A description of the dependent variables relevant to the present study is provided in Table 1.

2.3. Data analyses

All data were analyzed using SPSS Statistics [27]. Demographic data were analyzed using chi-square (sex, ethnicity, handedness) or analysis of variance (ANOVA; age, FSIQ, and socioeconomic status). Socioeconomic status (SES) was measured by the Hollingshead Four Factor Index [28], which takes into account marital status, education, occupation and sex to determine a raw composite score that ranges from 8 to 66. Three children from the AE group were excluded from the motion analyses due to insufficient data captured by the reflective marker. Analysis of covariance (ANCOVA) was used to examine differences in ADHD core symptoms. Prior to statistical analyses the data for each dependent variable was checked for outliers using box plot techniques (an outlier was defined as a value that fell more than 1.5 times the interquartile range below the first quartile or above the third quartile). Cases identified as outliers were excluded from corresponding analysis of these variables as follows: Accuracy (3 CON), Omission Errors (8 CON; 1 AE), Latency (4 CON; 3 AE), Variability (2 CON), C.O.V. (3 CON; 2 AE), Immobility Duration (4 CON; 3 AE), Displacement (2 CON; 1 AE), Area (3 CON), and Spatial Complexity (3 CON; 4 AE). No outliers were identified for Commission Errors, Head Movements, and Temporal Scaling. Twelve separate ANCOVAs were conducted on attention and motion variables from the Quotient ADHD System. Age at the time of testing was included as a covariate because of significant associations with the dependent variables. In addition, we examined the potential confounding effect of sex by examining the interaction between group and sex.

3. Results

3.1. Demographic information

Demographic data are presented in Table 2. No significant group differences were found on age, SES, handedness, race and ethnicity. Significant group differences were found for sex, [χ^2 (df = 1) = 5.12, $p = .024$]. The AE group had a higher percentage of males than children in the CON group. As expected, the AE group had significantly lower FSIQ than the CON group [$F(1, 89) = 48.65$, $p < .001$].

Table 2
Demographic information.

Variable	AE $n = 43$	CON $n = 54$
Sex (% male)*	67.44	44.44
Race (% White)	67.44	75.93
Ethnicity (% non-Hispanic)	67.44	64.81
Handedness (% right)	86.05	90.74
Age in years [*M* (SD)]	11.42 (2.2)	11.57 (2.2)
SES [*M* (SD)]	46.34 (12.9)	47.05 (14.7)
FSIQ [*M* (SD)][a,*]	87.12 (14.4)	108.39 (14.6)

SD, standard deviation.
[a] FSIQ data was available from 91/97 subjects.
* $p < .05$.

3.2. Attention and inhibitory control analyses

Age-adjusted group mean scores, not including outliers, for each of the attention variables are presented in Table 3. Age was a significant covariate for all attention variables (p's < .05). For Accuracy (outliers removed), the AE group was significantly less accurate than the CON group [$F(1, 89) = 8.87$, $p = .004$] and males were significantly less accurate than females [$F(1, 89) = 4.01$, $p = .048$]. No significant interaction between group and sex was found ($p = .684$). When outliers were included in the data, the main effect of group was still significant ($p = .037$), although the main effect of sex was only marginally significant ($p = .078$). The interaction between group and sex remained unchanged. Analysis of omission errors (outliers removed) revealed a significant main effect of group [$F(1, 83) = 26.70$, $p < .001$]. The AE group made significantly more omission errors than the CON group. Neither the main effect of sex, nor the interaction between group and sex reached significance (p's > .10). Group differences for omission errors were unaffected by the inclusion of outliers ($p < .001$), and neither the main effect of sex nor the interaction between group and sex was significant (p's > .10). For commission errors, we found a marginally significant main effect of sex [$F(1, 92) = 3.24$, $p = .075$], but neither the main effect of group, nor the interaction between group and sex was significant (p's > .10). There was a trend for females to make fewer commission errors than males. In terms of latency (outliers removed), the AE group was significantly slower to respond than the CON group [$F(1, 85) = 7.07$, $p = .009$]. The main effect of sex ($p = .249$) and the group by sex interaction ($p = .849$) were not significant. The main effect of group remained significant when outliers were included ($p = .004$) and there was no significant main effect of sex, and no significant group by sex interaction (p's > .10). Analysis of variability (outliers removed) yielded a significant main effect of group [$F(1, 90) = 20.30$,

Table 1
Definition of Quotient ADHD System attention and motion variables.
Adapted from http://www.quotient-adhd.com.

Variable	Definition
Attention variables	
Accuracy (percent)	Percentage of correct responses.
Omission errors (percent)	Percentage of missed targets.
Commission errors (percent)	Percentage of incorrect responses to non-targets.
Latency (milliseconds)	Mean reaction time to respond to a target.
Variability (milliseconds)	Variation in response times to the correct target.
C.O.V. (number)	Variability that is adjusted to take into account difference in response latency.
Motion variables	
Immobility duration (milliseconds)	Average amount time spent sitting still.
Head movements (number)	Average number of position changes greater than 1 mm.
Displacement (meters)	Total distance traveled by the reflector.
Area (centimeters squared)	Total area covered by the reflector's path.
Spatial complexity (scale score)	Complexity of the movement path, with values from 1 (straight line movements) to 2 (more complex movements).
Temporal scaling (scale score)	Frequency of movement, with values from 0 (lack of movements) to 1 (incessant movements).

Table 3
Performance on Quotient ADHD System attention variables and ANCOVA F test for main effects and interaction term.

Variable	AE ($n = 43$) Mean (SE)	CON ($n = 54$) Mean (SE)	Group F	Sex F	Group × sex F
Accuracy	80.35 (1.9)	87.96 (1.7)	8.869**	4.014*	.167
Omission errors	15.69 (1.8)	2.95 (1.6)	26.702**	.004	.003
Commission errors	22.93 (2.9)	22.45 (2.4)	.016	3.237	.238
Latency	519.60 (13.0)	474.30 (11.0)	7.070**	1.348	.849
Variability	193.59 (11.8)	123.87 (10.0)	20.998**	2.236	3.058
C.O.V.	33.95 (1.9)	25.12 (1.7)	11.994**	3.140	1.391

Mean scores (standard error) are adjusted for age.
* $p < .05$.
** $p < .01$.

$p < .001$], such that AE group showed a greater variation when responding to the correct target relative to the CON group. No significant effect of sex ($p = .138$) was found; the interaction between group and sex was marginally significant [$F(1, 90) = 3.06$, $p = .084$]. When outliers were included, the main effect of group remained significant ($p < .001$) and no significant main effect of sex ($p = .294$) was found; however, the interaction between group and sex reached statistical significance ($p = .039$). Follow-up simple main effects revealed significant sex differences for the AE group only ($p = .043$), such that males had greater variability in response time than females. In addition, a significant difference between alcohol-exposed and non-exposed subjects was found for males only ($p < .001$), such that males in the AE group had significantly greater variability in response time than males in the CON group. After outliers were removed, a significant main effect of group [$F(1, 87) = 11.99$, $p = .001$] was also found for C.O.V. (i.e., a normalized measure of response time variation). After accounting for response latency, children in the AE group showed greater response variability in comparison to control children. The main effect of sex was marginally significant [$F(1, 87) = 3.14$, $p = .080$]. No significant effect was found for the group by sex interaction ($p = .241$). These results were largely unchanged when outliers were included. The main effect of group remained significant ($p = .013$), but marginally significant effects were found for the main effect of sex ($p = .087$) and the interaction between group and sex ($p = .077$).

3.3. Motion analyses

Age-adjusted group mean scores for each of the motion variables are presented in Table 4 (not including outliers). Age was a significant covariate for all motion variables (p's < .05). For immobility duration (outliers removed), the CON group remained still for a significantly longer period than the AE group [$F(1, 82) = 5.82$, $p = .018$]. Neither the main effect of sex nor the interaction between group and sex was significant (p's > .10). When outliers were included no significant main effects or interaction was found (p's > .10). For head movements the AE group had a significantly greater number of head position changes than the CON group [$F(1, 89) = 5.23$, $p = .025$]. The main effect of sex and the interaction between group and sex were not significant (p's > .10). For displacement (outliers removed), a significant effect of group was found [$F(1, 86) = 5.70$, $p = .019$]; the total distance traveled by the head marker was greater for the AE group than the CON group. No significant main effect of sex ($p = .339$) and no significant interaction between group and sex were found ($p = .33$). Inclusion of outliers did not affect the findings. The main effect of group remained significant ($p = .045$), and the main effect of sex and interaction between group and sex were not significant (p's > .10). For area, the total area covered by the marker's path was greater for the AE group than the CON group [$F(1, 86) = 7.09$, $p = .009$]. No significant effects were observed for sex ($p = .27$) or for the group by sex interaction term ($p = .24$). The inclusion of outliers resulted in a marginally significant effect of group ($p = .068$). The main effect of group and the interaction between group and sex were not significant (p's > .10). For spatial complexity (outliers removed) the AE group had a less complex movement pattern than CON [$F(1, 82) = 7.01$, $p = .010$]. No main effect of sex or interaction between group and sex was observed (p's > .10). With outliers included, there were no significant main effects or interactions for spatial complexity (p's > .10). The analysis of temporal scaling did not identify any significant main effects or interaction (p's > .10).

4. Conclusions

The purpose of the current study was to objectively examine symptoms of inattention, impulsivity, and hyperactivity in alcohol-exposed children. Numerous studies have documented attention deficits in children prenatally exposed to alcohol using parent report [8–10,15] and laboratory measures [6,8,10,13–15,29–31]. Despite parental reports of hyperactivity in alcohol-exposed children [8,10], to the best of our knowledge only one study to date has objectively examined activity in children prenatally exposed to alcohol [8]. In this study, the authors used wrist-worn actigraphy to measure hyperactivity and found no group differences between alcohol-exposed and non-exposed children. We used the Quotient ADHD System, a device that can provide objective measures of inattention, impulsivity and activity levels collected simultaneously.

Consistent with our hypothesis, alcohol-exposed children demonstrated problems in the attention domain. Specifically, we found that

Table 4
Performance on Quotient ADHD System motion variables and ANCOVA F test for main effects and interaction term.

Variable	AE ($n = 40$) Mean (SE)	CON ($n = 54$) Mean (SE)	Group F	Sex F	Group × sex F
Immobility duration	121.00 (17.0)	175.00 (14.0)	5.824*	.861	.291
Head movements	3696.35 (321.9)	2748.43 (261.13)	5.228*	.796	.513
Displacement	6.24 (0.7)	4.17 (0.6)	5.702*	.926	.953
Area	186.87 (21.6)	111.84 (18.1)	7.088**	1.191	1.377
Spatial complexity	1.10 (0.02)	1.16 (0.01)	7.011*	.638	.007
Temporal scaling	0.77 (0.06)	0.67 (0.04)	2.198	.170	.506

Mean scores (standard error) are adjusted for age.
* $p < .05$.
** $p < .01$.

compared to non-exposed controls, alcohol-exposed children were less accurate in responding, had a greater percentage of omission errors, greater variability in response time, and longer response latencies on the CPT component of the Quotient ADHD System. However, impulsivity, measured by the number of commission errors, did not differ between our groups. Our findings of increased omission errors in the alcohol-exposed children compared to non-exposed children are supported by previous studies using similar measures (i.e., CPTs) [13–15,29], including a recent study from our group [8] and provide support that inattention is a core deficit in this population. The lack of between-group differences on the number of commission errors, is also in line with previous research suggesting inattention rather than impulsivity in alcohol-exposed children (e.g., [13,32]). However, other studies suggest deficits in both impulsivity (measured by commission errors) and inattention in children prenatally exposed to alcohol [15,33,34]. One possible explanation for this discrepancy is that the CPT task used in this study was less challenging than the CPTs used in previous studies. The Quotient ADHD CPT task stimuli are based on Greenberg's Minnesota Computer Assessment and Test of Visual Attention [35], which use two easily discriminated geometric shapes. Our finding of an average commission error rate of 22.45% seems relatively high for the CON group in comparison to the omission error rate (2.95%); however, this finding is consistent with previous studies using the same measure (e.g., [21]). Kooistra and colleagues [14] found that alcohol-exposed children were differentially affected by task difficulty compared to non-exposed controls, demonstrating increased response variability when the rate of stimulus presentation increased. Differences in response latency and variability between alcohol-exposed and non-exposed control children were also observed. Children prenatally exposed to alcohol responded more slowly and were also more inconsistent in their response time, even after the variability in response time was adjusted for differences in latency. Processing speed deficits [36,37] or impairments in peripheral processing [38] due to prenatal alcohol exposure may explain these findings.

We found that alcohol-exposed children were more active than those in the control group. Our findings are in line with parent reports of increased hyperactivity [8–10]. In addition, many studies have found an association between prenatal alcohol exposure and hyperactivity using animal models (e.g., [17,18]). However, it is important to note that the findings from animal studies are dependent upon a number of factors, suggesting multiple risk and/or environmental factors may impact behavioral expression [19]. This is the second study to objectively measure hyperactivity in children prenatally exposed to alcohol. The first study by Glass and colleagues [8] from our laboratory used wrist-worn actigraphy to objectively measure activity levels in alcohol-exposed children in comparison to non-exposed children with ADHD and non-exposed controls. In contrast to our findings, Glass et al. reported that while non-exposed children with ADHD demonstrated increased activity levels, children with prenatal exposure to alcohol did not differ from controls. However, Glass et al. did find that on parent report measures, the alcohol-exposed children were rated as more hyperactive than controls. The study by Glass et al. had a similar rate of ADHD diagnosis in their sample of alcohol-exposed children (34/44) as in the current sample (35/43), indicating that differences between the studies were not a result of differing rates of ADHD in the samples. The different objective measures used in the assessment of hyperactivity may explain these differences. In the Glass et al. study activity was measured with an actigraph worn on the non-dominant wrist during approximately 6 h of a neuropsychological evaluation while the current study used infrared motion tracking during a 15–20 min task. Interestingly, there are differences in the type of movement between typically developing children and ADHD [21]. For example, when children with ADHD fidget, the movements occur in their whole-body including the extremities. Fidgeting in typically developing children tends to be limited to the extremities. The lack of a difference in activity between controls and FASD children in the Glass et al. [8] study may have been due, in part, to measurement with wrist actigraphy. Wrist actigraphy may have detected the extremity fidgeting in both control and FASD children, but it may not have been sensitive enough to detect body fidgeting in FASD. In contrast, the evidence of activity differences in our study may have been detected because of our measurement with head sensors, which would detect whole body movements. Head sensors may also be more sensitive to postural sway, which is elevated in children with FASD [39,40].

Children with ADHD tend to make more linear and less complex motions with their body [21]. The spatial complexity and temporal scaling measures on the Quotient ADHD System were developed to capture some of these qualitative differences in motion between ADHD and control children. Children with FASD displayed less complex movement patterns (spatial complexity), consistent with what would be expected in children with ADHD. As 81.40% of the alcohol-exposed children in our sample also met criteria for an ADHD diagnosis, it is not unexpected that an ADHD-typic movement pattern would be observed. However, we did not observe increases in the frequency of movement (temporal scaling) in children with FASD as compared to our sample of control children. Glass and colleagues [8] reported that children with ADHD displayed a greater quantity of movement than children with FASD. However, our study identified ADHD-typical movement patterns in children with FASD but no differences in the frequency of movements between groups. Given these discrepancies, more work is needed to compare motion parameters in ADHD and FASD. Perhaps more sophisticated activity indicators may be beneficial in discriminating these two groups.

One possible limitation from this study is that many children with FASD have co-occurring ADHD (e.g., [11]) and are often treated with psychoactive medication to manage psychiatric symptoms. Although, we asked that parents withhold medications (e.g., stimulants such as methylphenidate) on the day of testing, it is probable that this was not a sufficient washout period for some of these drugs to obtain a true baseline for the children who normally take medication or that they may have demonstrated a rebound effect when tested off their medication. While it would have been preferable to test children after a longer period of medication abstinence, this may have placed an undue burden on our research subjects.

Currently, much of the research on FASD focuses on the development of a neurobehavioral profile that better characterizes alcohol-exposed individuals [41]. Findings from the current study have important implications for the evaluation of ADHD in children with prenatal exposure to alcohol. Tests such as the Quotient ADHD System may provide a more complete assessment of ADHD symptomatology in children with FASD by measuring ADHD core symptoms simultaneously. Furthermore, similarities in the behavioral profiles of children with histories of prenatal alcohol exposure and non-exposed children with ADHD (i.e., idiopathic ADHD) make the accurate identification of children with prenatal alcohol exposure challenging. Previous research has shown that alcohol-exposed children with ADHD may have a different response profile to psychostimulant medication (often used for the treatment of ADHD) compared to non-exposed children with ADHD [7,42]. Future studies will use the Quotient ADHD System to examine the efficacy of stimulant medication in children with FASD, as this test is sensitive to medication effects in children with ADHD [22]. Additionally, because this is the second study to objectively measure hyperactivity in children with FASD, additional research should be undertaken to corroborate our results with both a larger sample and the inclusion of a non-exposed ADHD contrast group for comparison.

Disclosures

Dr. Fourligas was a full time and part-time employee of BioBehavioral Diagnostic Company (BioBDx) from December 2006 through July 2013. Pearson acquired BioBDx in August 2013 and he has been a Pearson full time employee from August 2013 until present.

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