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Executive functioning deficits in preschool children with Fetal Alcohol Spectrum Disorders

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Abstract

Executive function (EF) deficit is a hallmark of Fetal Alcohol Spectrum Disorders (FASD), but the vast majority of available evidence comes from school-age children and adolescents. Very little is known about EF during the critical developmental period prior to 6 years of age in FASD. We evaluated EF in 39 children with FASD (3.0 – 5.5 years) and a comparison group of 50 age-matched, non-exposed controls. Measures included the EF Scale for Early Childhood and a Delay of Gratification task. Compared to age-matched controls, pre-school children with FASD had impairments on the EF Scale and showed more impulsivity on the Delay of Gratification task. To confirm the EF Scale finding, FASD group performance was compared to a separate normative dataset (N=1,400). Those with FASD performed below normal ($M = -0.57$, $SD = 0.92$). Within the FASD group, IQ was correlated with the EF Scale (partial $r = .60$, $p = .001$) and Delay of Gratification (partial $r = .58$, $p = .005$). EF Scale performance did not differ significantly across levels of FASD severity [fetal alcohol syndrome (FAS), partial FAS, or alcohol-related neurobehavioral disorder (ARND)]. However, compared to normative data, those with FAS had the largest deficits ($M = -0.91$ SD, $SE = 0.23$), followed by partial FAS ($M = -0.66$ SD, $SE = 0.26$), then ARND ($M = -0.36$ SD, $SE = 0.20$). These novel data show that EF deficits manifest well before the age of 6 years in children with FASD, that they occur across the spectrum, and that EF may be most impaired in children with more severe forms of FASD and/or lower IQs.

Keywords

Fetal alcohol spectrum disorders (FAS, FASD); Pre-natal alcohol exposure; Executive function; Delay of Gratification

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Conflict of Interest Statement

The authors have no competing interests.

Introduction

As many as 2–5% of young children in the U.S. are affected by Fetal Alcohol Spectrum Disorders (FASD) (May et al., 2009). Children with FASD exhibit life-long cognitive deficits and behavior problems (Sokol, Delaney-Black, & Nordstrom, 2003). Numerous studies have revealed global cognitive deficits and low intelligence quotient (IQ) in children who were prenatally exposed to alcohol (Larroque & Kaminski, 1998; Mattson, Riley, Gramling, Delis, & Jones, 1997; Olson et al., 1997; Testa, Quigley, & Eiden, 2003), yet this is clearly not the only outcome (Mattson, et al., 1997). Children with FASD show a range of disabilities resulting from prenatal alcohol exposure (Riley & McGee, 2005; Warren et al., 2004) and research has shown that global impairment represents the most extreme outcome and specific cognitive impairments are more common. One affected domain is executive function (EF), higher order cognitive processes involving the control, monitoring, and regulation of thought and action needed for goal-directed behavior (Carlson, 2005; Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Miyake et al., 2000). Although EF deficits are well recognized in FASD, almost nothing is known about the early manifestations of these deficits in preschool children.

The construct of EF consists of inter-related, but distinct components. In general, components are thought to include cognitive flexibility/set-shifting, updating/monitoring of working memory, and inhibitory control (Blair, Zelazo, & Greenberg, 2005; Carlson, 2005; Miyake, et al., 2000). In addition to these overlapping cognitive components, EF is also characterized by the degree of the affective-motivational demands of a task, with relatively “cool” aspects of EF being non-emotional and relatively “hot” aspects being emotionally-motivating (Hongwanishkul, et al., 2005).

EF depends on efficient processing in frontal and pre-frontal cortical regions and their sub-cortical connections. Frontal circuits may be particularly vulnerable to prenatal alcohol exposure as shown by fMRI studies examining executive functioning (Fryer et al., 2007). During typical development, the prefrontal cortex and associated cognitive functioning undergo considerable growth throughout childhood (Casey, Giedd, & Thomas, 2000; Luciana & Nelson, 1998). Under age six, EF skills in typically-developing children improve in terms of capacity to inhibit reactive responses, self-regulate, act with more organization and flexibility, and follow rules (Bell & Livesey, 1985; Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008; Dowsett & Livesey, 2000; Jones, Rothbart, & Posner, 2003).

School-age children and adolescents with FASD (ages 7.5 – 16 years) demonstrate broad EF impairments across measures of cognitive flexibility, working memory, selective inhibition, planning ability, concept formation, and reasoning (Coles et al., 1997; Green et al., 2009; Mattson, Goodman, Caine, Delis, & Riley, 1999; Rasmussen & Bisanz, 2009). Scant evidence is available for children with FASD under the age of seven. One of the very few published studies found that alcohol-exposed 4 year-olds performed significantly lower on a tapping inhibition task compared to unexposed children (Noland et al., 2003).

The lack of appropriate EF measures for young children has been a barrier to characterizing EF development in preschoolers with FASD (Blair, et al., 2005). The recently developed EF

Scale for Early Childhood™ (Carlson, 2013) is a robust measure that allows for assessment of cognitive flexibility in children as young as 2 years of age using an age-appropriate card-sorting task. The EF Scale integrates widely used developmentally appropriate EF assessments [e.g., categorization/reverse categorization (Carlson, Mandell, & Williams, 2004), separated dimensional change card sort (DCCS) (Diamond, Carlson, & Beck, 2005), and integrated and advanced DCCS (Zelazo, 2006; Zelazo et al., 2003)] into a single graded scale that is sensitive to maturational changes in EF during the preschool years and is reliable in typically developing 2.5 to 5-year-olds (Beck, Schaefer, Pang, & Carlson, 2011). This measure has been used to assess EF in clinical populations (Doom et al., 2014; Hostinar, Stellern, Schaefer, Carlson, & Gunnar, 2012) and at-risk preschoolers (Chu, VanMarle, & Geary, 2013; VanMarle, Chu, Li, & Geary, in press), and it predicts kindergarten readiness and first-grade math achievement over and above IQ (Carlson & Harrod, 2013; Hassinger-Das, Jordan, Glutting, Irwin, & Dyson, 2014).

In FASD, identifying EF deficits years earlier may help in understanding the developmental course of other problems including disruptive behavior and learning deficits. Characterizing early EF deficits may also directly inform the development of interventions, of which there are very few in FASD. In a practical sense, EF skills are those processes by which an individual plans for the future, executes steps in a sequence, self-monitors performance, adjusts as necessary, inhibits inappropriate responses, and perseveres in pursuit of a goal. EF during the preschool years plays a role in the development of theory of mind, emotional regulation, social competence, conscience and moral development, and school readiness (Blair & Razza, 2007; Carlson & Wang, 2007; Kochanska, Murray, & Coy, 1997; Mischel, Shoda, & Peake, 1988). It has been suggested that EF deficits may partly be responsible for difficulties in daily functioning in children with FASD, limiting independence (e.g., routine activities like getting dressed require sequencing skills) and disrupting social interactions (Mattson, et al., 1999).

The primary goal of the current study was to formally characterize EF deficits in 3–5 year-olds with FASD. In addition to the EF Scale, a Delay of Gratification task (Mischel, Shoda, & Rodriguez, 1989) was used to examine inhibition. These EF tasks were chosen as they are developmentally-appropriate for this age range and they vary across both cognitive (flexibility and inhibitory control) and affective-motivational (cool and hot) dimensions of EF. In addition, older children and adults with FASD demonstrate clear deficits on cognitive flexibility (such as card sorting tasks); inhibition deficits have been considered a key problem in this population (Mattson, et al., 1999; Rasmussen, 2005); and these EF abilities are measureable in young children (Beck, et al., 2011; Carlson, 2005; Hongwanishkul, et al., 2005). We hypothesized that preschoolers with FASD would demonstrate EF deficits in both cognitive flexibility and inhibition.

The secondary goal was to characterize the relationship between clinical FASD features and EF deficits. Previous studies in older children with FASD have found few or no associations between EF ability and FASD severity or facial dysmorphology (Green, et al., 2009; Kodituwakku, May, Clericuzio, & Weers, 2001; Mattson, et al., 1999), suggesting that even children who do not have full fetal alcohol syndrome (FAS) may have clinically relevant EF impairments. Previous studies also indicate that EF deficits in FASD are not solely

attributable to low IQ (Mattson, et al., 1999; Noland, et al., 2003; Rasmussen, 2005). In our sample of young children, we examined relationships between EF and (1) FASD diagnostic category and (2) IQ. Based on research findings in older children (Kodituwakku, May, et al., 2001), we hypothesized that EF deficits would occur across the spectrum of FASD severity.

Methods

Participants

FASD—Participants included 39 children with FASD, ages 3.0 to 5.5 years, recruited from University Clinics (Table 1). Families who attended the clinics and consented to be contacted for University research studies were contacted by study staff through letters, email, and/or phone calls and invited to participate in the current study. All were seen by a pediatric psychologist and a pediatrician with training in the University of Washington diagnostic system (Astley, 2004). Data on growth, facial dysmorphology, cognition, and alcohol exposure were collected and modified Institute of Medicine (IOM) criteria (Hoyme et al., 2005) were applied. For FAS, the criteria require dysmorphic facial features (at least two of the following: short palpebral fissures, thin vermilion border of the upper lip, and smooth philtrum), growth deficiency, and deficient brain growth. For partial FAS, a dysmorphic face and either of the following are required: growth deficiency or central nervous system (CNS) impairment as defined by deficient brain growth or cognitive/behavioral impairment. For alcohol-related neurodevelopmental disorder (ARND), confirmed alcohol exposure is required with CNS impairment (either deficient brain growth and/or cognitive or behavioral impairment). Five (13%) met criteria for FAS; 18 (46%) for Partial FAS; and 16 (41%) for ARND.

Of the 39 participants, 32 had confirmed prenatal alcohol exposure, including self-report by the biological mother or social service records/medical records indicating heavy maternal use during pregnancy. Heavy exposure was defined on the basis of Rank 3 or 4 in the University of Washington system (Astley, 2004). Specific examples included daily use throughout pregnancy, use to the point of intoxication every other day, or intoxication at the time of delivery. Minimal use, such as occasional consumption of less than 4 drinks, or consumption without intoxication, did not meet this criterion. Seven participants had unconfirmed alcohol exposure, but alcohol use was suspected, and they met the modified IOM criteria for FAS ($n=1$) or partial FAS ($n=6$). Using IOM criteria, confirmed alcohol exposure is not required for a partial FAS or FAS diagnosis if dysmorphic facial features specific to alcohol exposure are present. All seven had dysmorphic faces and cognitive deficits as defined above. In 28 cases, prenatal drug use was suspected. In all cases, alcohol was the predominant substance of abuse and alcohol use was extensive.

Exclusion criteria were developmental disorder (e.g., Autism, Down Syndrome), neurological disorder, traumatic brain injury (TBI), or other medical condition affecting the brain or senses. Psychiatric co-morbidity, such as attention deficit hyperactivity disorder (ADHD), was not exclusionary as co-morbidity is high in FASD (O'Connor et al., 2002). In addition, attempting to apply formal diagnostic criteria for common co-morbid conditions such as ADHD or disruptive behavior disorders would be problematic in 3–5 year olds. All but one participant (a twin born at 36 weeks weighing 1360 grams) had a birthweight >1500

grams. All analyses were completed twice, once with this participant excluded and once with the participant included, and there were no differences in the results (all reported results include the participant with a birth weight of 1360 grams). Seven had birthweights between 1500 and *italic>*2500 grams. There were no differences on the dependent measures (EF and IQ) between those with birthweights less than 2500 grams and those with birthweights 2500 grams and greater.

Controls—Fifty age-matched community controls were recruited for a separate study (Table 2). Recruitment processes were similar between the control and FASD groups. Both groups consented to be contacted about research participation, and were contacted by study staff through emails, letters, and/or phone calls and invited to participate in the current study. Control families who gave birth to a child at any of the area hospitals were given the opportunity to consent to be contacted for future University research. Exclusionary criteria for controls were prenatal alcohol exposure, developmental disorder, neurological disorder, TBI, medical condition affecting the brain or senses, and diseases influencing physical growth. Mothers were explicitly asked about alcohol intake during pregnancy as part of the structured intake and screening. Control participants were excluded if any alcohol intake during pregnancy was reported. All control participants were living with their biological families.

There was no group difference in median household income based on zip code of family's home residence. There was a sex difference between the groups despite balanced recruitment targets; there were more males in the control group and more females in the FASD group. Sex differences were examined for all dependent measures, and sex was included as an independent variable for all group comparisons.

All procedures were approved by a University IRB and all families underwent an informed consent procedure.

Procedure/study design

Both groups completed the EF Scale for Early Childhood, Delay of Gratification, and IQ during laboratory visits. The FASD group completed the EF measures and the IQ at separate visits, six months apart. The control group completed the EF and IQ at the same visit. Administration of the EF measures was identical for the two groups.

Measures

EF Scale for Early Childhood—This test (Carlson, 2013; Carlson & Schaefer, 2012), for ages 2.5 to 7 years, reliably assesses cognitive flexibility across seven successive levels of difficulty (Beck, et al., 2011). Children were asked to sort cards into two boxes according to one rule and then switch to sorting the same cards again using an opposite or conflicting rule. Thus, during the second portion of the task, the child was asked to inhibit her/his automatic response and to provide a response that was incompatible with the salient stimuli. Children were seated at a table containing two boxes, each with openings on top. For each level, the boxes were labeled with target cards. Children sorted 10 cards into the boxes based on the rules for that level. For each level, children sorted according to the first (pre-switch)

rule for five trials and were then told to sort according to a new rule (post-switch) for five trials. For example, during level two, children were instructed to sort cards that had either a picture of a “little kitty” or a “big kitty.” For the pre-switch rule (trials 1–5), children were instructed to place the “little kitty” cards into the box labeled with a picture of a “little kitty” and to place the “big kitty” cards into the box labeled with a picture of a “big kitty.” For the post-switch rule (trials 6–10) on the same level, children were instructed to place the “little kitty” cards into the “big kitty” box, and the “big kitty” cards into the “little kitty” box. Successful completion of 80% of the trials (4 out of 5) for both the pre-switch and post-switch rules was considered passing. The test is adaptive, such that 2–3 levels are administered to determine the child’s basal and ceiling levels. Children were reminded of the rule prior to every trial to minimize working memory demands of the task. The dependent variable used in analyses was the highest level (0–7) at which the child passed both the pre-switch and post-switch rules.

Delay of Gratification—For this test (Mischel, et al., 1989), the child chose a treat (e.g., gummy snacks) from several options. Two plates were placed in front of the child, one containing 2 treats and the other containing 10 treats. A bell was placed between the plates. The experimenter told the child that she needed to leave the room to finish some work. The child was told that if s/he waited until the experimenter returned, the child would receive the plate with 10 treats. Alternatively, the child could ring the bell earlier, but would only receive the plate with 2 treats. The experimenter left the room and monitored the child by video. The trial ended when the child: (1) rang the bell, (2) ate the treats, or (3) waited 10 minutes. The dependent measure used in analyses was total time waited.

IQ Measures—The Mullen Scales of Early Learning (Mullen, 1995), for ages 0 to 68 months, was chosen as the global cognitive assessment for the FASD group because low cognitive functioning was expected. The Mullen Scales composite score correlates well with the Bayley Mental Development Index (Mullen, 1995), and the Mullen has been shown to have good convergent validity with other measures of cognitive functioning, including the Differential Ability Scales (Bishop, Guthrie, Coffing, & Lord, 2011). Controls were assessed as part of a separate study (currently under review) that was part of the psychometric development of the EF Scale. Controls were administered the Abbreviated IQ Battery of the Stanford-Binet Intelligence Scales (Fifth Edition) (Roid, 2003). Group-specific IQ measures are sometimes used for clinical and control groups when significant cognitive impairment is expected in the clinical group (Hostinar, et al., 2012).

Statistical Analysis

Covariates—Age was included as a covariate in all analyses with the EF measures. Both the EF Scale ($r=0.52$, $p<.001$) and Delay of Gratification task ($r=0.28$, $p=.015$) are positively correlated with age and neither score is age-scaled. Age was not included as a covariate in analyses examining IQ because IQ scores are scaled for age. IQ was not included as a covariate in the ANCOVA analyses comparing EF performance between the FASD and control groups. The inclusion of IQ as a covariate can create unrepresentative groups when intellectual deficits are a core feature of the neurodevelopmental disorder (e.g., FASD) (Dennis et al., 2009).

Normative data comparison for confirmatory analysis—Normative data ($N=1,400$) for the EF Scale for children ages 36 to 64 months (Carlson, 2013) were used to confirm the results. Norms were available in the form of means and standard deviations for five distinct age groupings (24–29; 30–35; 36–41; 42–48; 49–51; 52–63; 64+ months) that best represented the normal developmental progression of performance. Z-scores were created for participants with FASD based on means and standard deviations for the appropriate age-category. The difference between each participant's score and the normative mean for the appropriate age group was calculated and then divided by the normative standard deviation for the appropriate age group. On this scale, mean EF performance was 0 and the standard deviation was 1.

Results

Group differences between FASD and controls on EF

EF Scale for Early Childhood—A 2×2 (sex $\times$ group) ANCOVA with age as a covariate tested for a group difference (FASD vs. controls) on the EF Scale. There was a significant main effect for group (Table 2), and age was significant [$F(1,84)=96.05$, $p<.001$, $\eta^2=0.47$]. There was no significant effect for sex [$F(1,84)=0.00$, $p=.995$], and the interaction (group $\times$ sex) was non-significant [$F(1,84)=.86$, $p=.358$].

Delay of Gratification—A 2×2 (sex $\times$ group) ANCOVA with age as a covariate tested for a group difference (FASD vs. controls) in total time waited (minutes) during the Delay of Gratification. There was a significant main effect for group (Table 2), and age was significant [$F(1,68)=8.64$, $p=.004$, $\eta^2=0.10$]. There were no significant sex effects [$F(1,68)=0.53$, $p=.468$] and the interaction (sex by group) was non-significant [$F(1,68)=0.14$, $p=.708$]. Delay of gratification was correlated with the EF Scale for Early Childhood for the controls ($r=0.36$, $p=.010$) and for the FASD group ($r=0.60$, $p=.003$).

EF Associations with IQ

A 2×2 (sex $\times$ group) ANOVA tested for a group difference (FASD vs. control) in IQ. As expected, there was a significant main effect for group (Table 2). Neither the main effect for sex [$F(1,68)=0.53$, $p=.468$] nor the interaction (group $\times$ sex) [$F(1,68)=0.14$, $p=.708$] was significant.

Correlations between IQ and EF performance were calculated separately for each group (FASD and control). The EF Scale, controlling for age, was correlated with IQ in controls (partial $r=.37$, $p=.010$) and FASD (partial $r=.60$, $p=.001$). Delay of Gratification, controlling for age, was not correlated with IQ in the control group, but was in the FASD group (partial $r=.58$, $p=.005$).

Associations between FASD diagnosis and EF and IQ

Separate ANOVAs compared EF Scale performance and IQ across the three FASD diagnostic categories. Age was included as a covariate in the model for the EF Scale but not for IQ. The main effect for FASD diagnostic group was not significant for the EF Scale (Table 3), but age was significant [$F(1,35)=37.20$, $p<.001$, $\eta^2=0.48$]. For IQ, the main effect

for FASD diagnostic category was at a trend level [$F(2,36)=2.76, p=.077$]. Delay of Gratification performance was not compared across diagnostic categories because the sample size was too small.

Confirmation of EF Results with Normative Data

We confirmed the finding of impaired performance on the EF Scale in FASD by comparing performance of the FASD group to a large normative sample. The results of a one-sample t -test revealed that the mean for the FASD group ($M = -0.57, SD = 0.92$) was significantly different from the expected mean of 0 [$t(38) = -3.97, p < .001$; Figure 1]. Age was not included as a covariate because it was accounted for in the z -score calculation. One-sample t -tests were conducted separately for each FASD diagnostic group (Figure 1). The results revealed that the means for FAS and partial FAS were significantly different from the expected mean of 0 [$t(4) = -4.00, p = .016$ and $t(17) = -2.60, p = .019$, respectively]. The mean for ARND did not differ from the expected mean of 0 [$t(15) = -1.78, p = .096$], but was at a trend level.

Discussion

We examined EF in preschool children with FASD using developmentally-appropriate measures (EF Scale for Early Childhood and Delay of Gratification). Consistent with studies that reported EF deficits in older children with FASD (Coles, et al., 1997; Green, et al., 2009; Mattson, et al., 1999; Rasmussen & Bisanz, 2009), we found measurable EF impairments already present prior to the age of six. Characterizing EF during the preschool period in this population is important both for understanding the effects of prenatal alcohol exposure on brain development as well as for ultimately designing early interventions aimed at improving EF.

The EF assessments we used vary on two dimensions. First, successful EF Scale performance depends primarily on cognitive flexibility/set-shifting whereas Delay of Gratification depends primarily on inhibitory capacity and impulse control (Beck, et al., 2011). Research in typically-developing children (Carlson, 2005) suggests that EF is a more homogeneous construct in young children, and differentiation between these components increases with age, but the components still remain moderately correlated (Miyake, et al., 2000). In the current study, young children with FASD showed deficits on both tasks, and performance on the two measures was highly correlated. Second, the two EF assessments differ on the affective-motivational demands of the task, with the EF Scale being relatively “cool” (non-emotional) and the Delay of Gratification being relatively “hot” (affective). Prior studies of older children with prenatal exposure have documented deficits in both cognitive flexibility/set-shifting and inhibition (Mattson, et al., 1999; Rasmussen & Bisanz, 2009) as well as in affective measures of EF (Kodituwakku, May, et al., 2001; Kully-Martens, Treit, Pei, & Rasmussen, 2013). Together, these findings suggest that the EF deficits in FASD are broad, but a more comprehensive understanding is clearly needed.

Much growth in EF skills is thought to occur between the ages of 3 and 5 in normative samples (Bierman, et al., 2008). At these ages, children typically begin to learn how to self-regulate and think with increasing flexibility (Barkley, 2001). Higher-order EF processes,

such as planning and verbal working memory, are thought to emerge in middle childhood and continue to develop into adulthood (Zelazo & Müller, 2002). In the current study, we found that children with FASD already demonstrate disruptions in both cognitive flexibility and inhibition. Longitudinal studies are needed to determine whether these early deficits remain stagnant, improve, or decline over time and whether these early deficits translate to impairments in higher order EF processes (e.g., planning) which have a protracted development and are best measured at older ages. Cross-sectional research in children and adolescents with FASD suggest that both verbal and hot EF deficits may worsen over time (Rasmussen & Bisanz, 2009; Rasmussen, McAuley, & Andrew, 2007).

EF during early childhood is associated with later cognitive development and social competence in both typically-developing populations and clinical samples. EF predicts academic ability (Biederman et al., 2004; Bierman, et al., 2008; Neuenschwander, Röthlisberger, Cimeli, & Roebbers, 2012) and social functioning (Bierman, et al., 2008; Schonfeld, Paley, Frankel, & O'Connor, 2006) in high risk and clinical groups (e.g., children with ADHD; children enrolled in Head Start—a program that provides child development and education services to low-income or at-risk children and families), and EF predicts academic and social competence, wealth, health, and even adult criminal behavior in the general population (Mischel, et al., 1988; Moffitt et al., 2011). In individuals with FASD, EF deficits are associated with maladaptive outcomes, including behavioral problems (Kodituwakku, Kalberg, & May, 2001), hindrance of daily activities (Mattson, et al., 1999), adaptive behavior problems (Ware et al., 2012), and poor reasoning and social functioning, which may contribute to increases in inappropriate sexual behavior and legal problems (Fast & Conry, 2009).

EF is known to be malleable through intervention. The most successful interventions have integrated repeated practice with increasingly difficult challenges to EF; some of the most successful interventions for younger children are programs that employ mindfulness, aerobic exercise, classroom curricula (e.g., *Tools of the Mind*, Montessori education), and add-ons to classroom curricula (e.g., PATHS (Bierman, et al., 2008), Chicago School Readiness Project) (Diamond & Lee, 2011). A review of EF interventions (Diamond & Lee, 2011) demonstrated that children with the greatest EF deficits benefit the most from intervention. EF interventions have been shown to promote social-emotional competence (Bierman, et al., 2008; Lillard & Else-Quest, 2006), aggression control (Bierman, et al., 2008), and academic skills in preschoolers (Bierman, et al., 2008; Bodrova, Leong, & Akhutina, 2011; Donnelly & Lambourne, 2011) and, thus, could potentially reduce maladaptive behavior in FASD.

Data from the current study suggest that the full spectrum of children affected by alcohol exposure may be appropriate targets for EF interventions, but also that children with more severe FASD and those with lower cognitive functioning need more intensive efforts. In this study, IQ was correlated with both the EF Scale and Delay of Gratification, a finding consistent with results in typically developing children (Hongwanishkul, et al., 2005). We observed EF deficits across the spectrum of FASD severity, as did studies of older children (Green, et al., 2009; Kodituwakku, May, et al., 2001; Mattson, et al., 1999). However, relative to a large normative dataset, we observed an association between the EF Scale and the severity of FASD diagnosis. Children with FAS had the largest EF deficits, averaging

almost one standard deviation (SD) below norms, followed by those with partial FAS ($-2/3^{\text{rd}}$ SD), then those with ARND (approximately $-1/3^{\text{rd}}$ SD). One limitation of the current study relates to the challenge of matching a control group to a sample of children with FASD on factors known to influence cognitive performance (other than alcohol). We matched for age and median household income, but acknowledge that numerous other factors—including other prenatal factors, early home environment, and abuse history—were not controlled. However, the goal of the study was not to definitively establish a causal link between prenatal alcohol exposure and EF impairment absent of any confounders. Rather, the goal was to determine whether EF deficits manifest in children with FASD during the preschool years. The control group was necessary to describe typical EF development because the EF assessments used do not have age-scaled scores. Another limitation is that parental education and IQ, which may have explained some of the variance in the children's IQ and/or EF performance, were not controlled for in analyses.

We specifically chose not to include IQ as a covariate in the analyses testing for group differences in EF. Although commonly done, there are methodological arguments against doing so when intellectual deficits are a core feature of the neurodevelopmental disorder (e.g., FASD) (Dennis, et al., 2009), because this can create unrepresentative groups. In the current study, using IQ as a covariate would have adjusted the mean EF performance for the FASD group based on an IQ of 99. However, an IQ of 99 is unrepresentative of our FASD sample, where eighty percent had IQs <99. Furthermore, even if IQ was included as a covariate in analyses and accounted for the group differences on EF performance, the role of IQ as a cause, an outcome, or a result of a latent construct could not be identified (Dennis, et al., 2009).

Conclusion

We found that EF deficits are present at a measurable level in children with FASD prior to six years, an age when many will be entering kindergarten. EF skills during childhood are important for academic success, adaptive functioning, and long term outcomes, including improved health and fewer legal/criminal problems. Studies are needed to determine whether treating children early with evidence-based EF interventions (1) lessens the gap in EF abilities observed in older samples of children with FASD and (2) improves both immediate functioning and long-term outcomes.

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Figure 1.

Performance on the EF Scale for Early Childhood by age group for the normative sample and children with Fetal Alcohol Spectrum Disorders (FASD)

Figure 2.

Performance on the EF Scale for Early Childhood by FASD diagnosis: fetal alcohol syndrome (FAS), partial FAS, and alcohol-related neurodevelopmental disorder (ARND). Scores on the EF Scale for Early Childhood were transformed to z-scores using data from the normative sample. A z-score of 0 represents the mean for the normative sample.

Table 1

Characteristics of participants with Fetal Alcohol Spectrum Disorders

N(%) or mean (SD)	N=39
<i>Age (years)</i>	4.4 (0.76)
Range (years)	(3.0 – 5.5)
<i>Living Situation</i>	
Biological Parent(s)	1 (3%)
Adoptive Family	35 (92%)
Foster Care	3 (8%)
<i>Gender</i>	
Male	13 (33%)
Female	26 (67%)
<i>Dysmorphic Facial Features</i>	
2 Facial Features Present	23 (59%)
<i>Growth Deficiency (10th percentile)</i>	
Height	9 (23%)
Weight	8 (21%)
<i>Deficient Brain Growth (10th percentile)</i>	
Occipital-Frontal Circumference	13 (33%)
<i>Alcohol/Drug Exposure</i>	
Alcohol Confirmed	31 (80%)
Alcohol Suspected	8 (20%)
Other Drug Exposure Suspected	28 (78%)
<i>IOM Diagnostic Category</i>	
FAS	5 (13%)
Partial FAS	18 (46%)
ARND	16 (41%)

Note: IOM: Institute of Medicine; ARND: Alcohol-related neurodevelopmental disorder; FAS: Fetal alcohol syndrome

Table 2

Participant characteristics and executive function (EF) performance for the control group and the Fetal Alcohol Spectrum Disorders (FASD) group

<i>Means (SD) or %</i>	Controls (n=50)	FASD (n=39)	Statistical Test
Age (years)	4.2 (1.00)	4.4 (0.76)	$t(87) = -0.95, p = 0.346$
Range (years)	(3.0 – 6.5)	(3.0 – 5.5)	
Gender			$\chi^2(1) = 10.57, p = .001$
Male	68%	33%	
Female	32%	67%	
Median income for residential zip code (\$)	\$64,316 (17,468)	\$60,202 (18,877)	$t(93) = 1.06, p = 0.290$
<i>Estimated Means (SE)</i>			
EF Scale for Early Childhood (highest level) ^a	4.4 (0.2)	2.8 (0.2)	$F(1,84) = 29.00, p < .001, \eta^2 = 0.14$
Delay of Gratification (minutes) ^{a,b}	8.3 (0.6)	4.6 (0.8)	$F(1,68) = 14.85, p < .001, \eta^2 = 0.16$
IQ Measure ^c	114 (2)	85 (3)	$F(1,85) = 76.00, p < .001, \eta^2 = 0.46$
Range	(82 – 142)	(52 – 128)	

^a Means are estimated after controlling for sex and age^b FASD group: $n = 23$ ^c Means are estimated after controlling for sex

Table 3

Participant characteristics and executive function (EF) performance for the Fetal Alcohol Spectrum Disorders (FASD) diagnostic groups

	FAS <i>n</i> =5	Partial FAS <i>n</i> =18	ARND <i>n</i> =16	Statistical Test
<i>Means (SD) or %</i>				
Age (years)	4.1 (0.9)	4.7 (0.7)	4.1 (0.7)	$F(2,36)=2.54, p=.093$
Gender				$\chi^2(2)=0.48, p=.789$
Male	40%	28%	38%	
Female	60%	72%	62%	
<i>Estimated Means (SE)</i>				
EF Scale for Early Childhood (highest level) ^a	2.4 (0.50)	2.8 (0.27)	3.2 (0.29)	$F(2,35)=1.26, p=.295$
IQ Measure	81 (8)	79 (4)	93 (4)	$F(2,36)=2.76, p=.077$
Range	(64 – 95)	(52 – 112)	(59 – 128)	

Note: FAS: Fetal alcohol syndrome; ARND: Alcohol-related neurodevelopmental disorder

^aMeans are estimated after controlling for age