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THE INFLUENCE OF EXTRINSIC REINFORCEMENT ON CHILDREN WITH HEAVY PRENATAL ALCOHOL EXPOSURE

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Abstract

Background—Prenatal alcohol exposure affects inhibitory control and other aspects of attention and executive function. However, the efficacy of extrinsic reinforcement on these behaviors has not been tested.

Methods—Alcohol-exposed children (AE; $n=34$), children with ADHD (ADHD; $n=23$), and controls (CON; $n=31$) completed a flanker task with four reward conditions (no reward, reward, reward+occasional response cost, equal probability of reward+response cost). Inhibitory control was tested in the no reward conditions using a 3(group) x 2(flanker type) ANCOVA. Response to reinforcement was tested using 3(group) x 4(reward condition) x 4(flanker type) ANCOVA. Response time (RT) and accuracy were tested independently.

Results—Groups did not differ on demographic variables. The flanker task was successful in taxing interference control, an aspect of executive attention (i.e., responses to incongruent stimuli were slower than to congruent stimuli) and the AE group demonstrated impaired executive control over the other groups. Overall, the AE group had significantly slower response times compared to the CON and ADHD groups, which did not differ. However, reinforcement improved RT in all groups. While occasional response cost had the greatest benefit in the CON group, the type of reinforcement did not differentially affect the AE and ADHD groups. Accuracy across reward conditions did not differ by group, but was dependent on flanker type and reward condition.

Conclusions—Alcohol-exposed children, but not children with ADHD, had impaired interference control in comparison to controls, supporting a differential neurobehavioral profile in these two groups. Both clinical groups were equally affected by introduction of reinforcement, although the type of reinforcement did not differentially affect performance as it did in the control group, suggesting that reward or response cost could be used interchangeably to result in the same benefit.

Keywords

fetal alcohol spectrum disorders (FASD); attention-deficit/hyperactivity disorder (ADHD); flanker; response cost; reward; interference control

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Introduction

Fetal alcohol spectrum disorders (FASD) are characterized by both behavioral and neuropsychological deficits (Mattson et al., 2011) that lead to secondary difficulties such as poor academic performance and psychopathology (Streissguth et al., 1996). Attention difficulties are among the most commonly noted impairments, with high rates of attention-deficit/hyperactivity disorder (ADHD) diagnosis in this population (Burd et al., 2003, Fryer et al., 2007). Research involving idiopathic ADHD (i.e., unrelated to a history of prenatal alcohol exposure) indicates that academic functioning may relate to motivation (Barkley, 1997, Volkow et al., 2011), suggesting that an increase in extrinsic motivation can improve attention, and subsequently, school performance.

The current study tested the influence of extrinsic motivation on interference control, an aspect of cognition that addresses the ability to suppress competing distracters to carry out a target response. Interference control is related to working memory and response inhibition (Aron, 2007), both of which are impaired in children with prenatal alcohol exposure or ADHD (Barkley, 1997, Connor et al., 2000). A modified flanker task (Eriksen and Eriksen, 1974) was used to incorporate reinforcement paradigms (Crone et al., 2003) in children with histories of prenatal alcohol exposure, children with idiopathic ADHD, and controls. In a traditional flanker task, target arrows are flanked by congruent or incongruent stimuli. The goal is to identify a feature of the target (i.e., the direction of the center arrow); the conflict caused by the presence of incongruent flanking arrows acts to tax executive attention (Braem et al., 2012). Further, the flanker task provides measures of both speed and accuracy, which are documented methods of measuring motivation as well as interference control (Touré-Tillery and Fishbach, 2014). Children with ADHD typically perform more poorly than controls on similar tasks (Mullane et al., 2009). The modified flanker task used herein includes both reward (positive reinforcement) and response cost (negative punishment) conditions. Positive reinforcement can improve performance of children with idiopathic ADHD, while findings regarding response cost are mixed, supporting both diminished (Crone et al., 2003) and improved (Carlson and Tamm, 2000, Oosterlaan and Sergeant, 1998) performance. Deficits in motivation and response to reinforcement in ADHD are likely linked to disruption of the interface between the anterior cingulate cortex (ACC) and the dopaminergic system (Luman et al., 2010, Umemoto et al., 2014). Interestingly, abnormalities of the ACC were recently reported in subjects with FASD (Migliorini et al., 2015) and alterations in the dopaminergic system related to prenatal alcohol exposure have long been known (e.g., Druse et al., 1990, Randall and Hannigan, 1999).

Although studies involving reinforcement exist in both the human and animal literature on FASD (e.g., Engle and Kerns, 2011, Kully-Martens et al., 2013, Samson, 1986), no studies to date have examined the influence of reward and response cost on interference control in children with heavy prenatal alcohol exposure compared to other clinical groups. Given previously documented impairments in response inhibition and working memory in both FASD (Connor et al., 2000) and ADHD (Barkley, 1997), we hypothesized that the clinical groups (alcohol-exposed children and children with idiopathic ADHD) would perform more poorly than controls on measures of interference control. Finally, given the results of Engle and Kerns (2011), we predicted that alcohol-exposed children would benefit from both

reward and response cost. We also expected that children with idiopathic ADHD would benefit from reward (e.g., Carlson et al., 2000), but had no specific predictions on the effect of response cost in this group, given previous inconsistencies in the literature.

Method

General Method

The current study was part of a larger, ongoing project at the Center for Behavioral Teratology at San Diego State University. Subjects were administered four computerized attention tasks, lasting for approximately 1 hour and 45 minutes. The flanker task was administered third and lasted approximately 25 minutes. Caregivers and children gave informed consent/assent prior to assessment and monetary incentive was provided. The Institutional Review Board at San Diego State University approved this study.

Subjects

The current study included 88 children between 8–12 years old ($M=10.55$, $SD=1.54$) including: children with histories of heavy prenatal alcohol exposure (the AE group; $n=34$), children with ADHD and without heavy prenatal alcohol exposure (the ADHD group; $n=23$), and typically developing children without ADHD or heavy prenatal alcohol exposure (the CON group; $n=31$). All children were evaluated for ADHD symptoms using multiple caregiver-report measures. To be included in the ADHD group, subjects met research criteria for ADHD on at least two of the following sources: (1) the Computerized Diagnostic Interview Schedule for Children-Fourth Edition (C-DISC-4.0) (6 ADHD symptoms, Shaffer et al., 2000), (2) the Child Behavior Checklist ADHD DSM-IV Oriented Scale (65 T-score, Achenbach and Rescorla, 2001), (3) the ADHD factor score from the Disruptive Behavior Disorders rating scale (6 ADHD symptoms, Pelham et al., 1992), (4) a positive caregiver-reported ADHD screen using DSM-IV criteria, and (5) a clinician appointed ADHD diagnosis or prescription for ADHD medication. This type of multi-source assessment, requiring two or more positive indicators has been used in previous studies (e.g., Huang-Pollock et al., 2005, Glass et al., 2013) and is likely a more valid indicator of ADHD symptomology than using one measure alone. Importantly, although parents were the source for most of the information on ADHD symptoms, the DISC interview includes questions about whether symptoms are present in more than one setting, as required for a diagnosis (American Psychiatric Association, 2013). In the AE group, 29 (85.3%) of subjects met these criteria for ADHD, consistent with previous literature (e.g., Burd et al., 2003, Graham et al., 2013, Ware et al., 2013). Children in the CON group had no indicators of ADHD, as defined above, nor did they have subclinical symptoms of ADHD on the C-DISC-4.0 (presence of 3–5 symptoms within a domain). While all children on stimulant medication were asked to abstain from medication use the day of testing, 7 (20.6%) subjects in the AE group and 2 (8.7%) in the ADHD group were taking stimulant medication on the day of testing.

Children were recruited through clinical referral, flyers, word of mouth, and advertisements. For all groups, inclusion criteria required that subjects speak English as their primary language, and be between the ages of 8–12 years old. Children were excluded if they had

other known causes of mental deficiency, were adopted from abroad after the age of five, suffered a head injury involving loss of consciousness, or had any physical or psychiatric conditions that prevented involvement. Children were excluded from the CON and ADHD groups if they had greater than minimal prenatal alcohol exposure, or if exposure was unknown. Minimal exposure was defined as average exposure of less than 1 drink per week and no more than 2 drinks per occasion during pregnancy.

Children in the AE group were retrospectively recruited and had histories of heavy intrauterine alcohol exposure as determined using medical records, birth records, social services records, and maternal report, when available. In most cases, children were no longer cared for by their biological families, making precise details about prenatal exposure unavailable. In these cases, mothers were reported to be “alcoholic” or alcohol abusing or dependent during pregnancy. If maternal report was available, the following exposure criteria were used: maternal consumption of 4 or more drinks per occasion, on average, at least once per week, or more than 13 drinks per week during pregnancy. Children who had unknown histories of prenatal alcohol exposure were only included in the AE group if they met diagnostic criteria for fetal alcohol syndrome (FAS), as determined by dysmorphology exam. FAS was defined as the presence of growth deficiency ($< 10^{\text{th}}$ percentile in height or weight) and/or microcephaly ($< 10^{\text{th}}$ percentile in head circumference), and two or more characteristic facial features (short palpebral fissures, smooth philtrum, thin vermilion border) (Jones et al., 2006, Mattson et al., 2010). Five (14.7%) subjects in the AE group had a diagnosis of FAS.

Measures and Procedure

The flanker task (Crone et al., 2003) was created and administered using E-Prime computer software on an Intel Core 2 personal computer using Windows XP, with a 17-inch monitor in a room with minimal distractions and a white noise machine to mask ambient sound. Participants responded via button press to indicate direction of the target stimulus (left or right). A row of arrows was presented to subjects in the center of the screen. The task required subjects to respond to the center arrow (target) by pressing the left response button if the target arrow was pointing left, and the right response button if the target arrow was pointing right. A practice trial was administered to all subjects initially to ensure they understood the task. If the practice trial was not completed successfully, the task was discontinued and no further data were collected. The practice trial was followed by four blocks of 96 trials. Trials varied by flanker type (4) and reinforcement condition (4), described below. A total of 384 trials were administered and the task took approximately 25 minutes. The dependent variables were mean accuracy (0 to 1) and mean response time (RT), measured in msec., for each trial response. Subjects whose mean accuracy was $< 80\%$ were not included in the analyses (AE, $n=8$; ADHD, $n=6$; CON, $n=1$). For RT, within-group outliers were tested using SPSS Boxplots. Due to the natural variability associated with RT in the clinical groups (Johnson et al., 2007, Kooistra et al., 2010), only subjects identified as extreme outliers (> 3 standard deviations from the group mean) by SPSS and across multiple conditions (RT and accuracy) were excluded, removing 3 ADHD subjects and 1 CON subject, resulting in the final sample ($N=88$).

Each trial consisted of one of four types of flanker stimuli: Congruent, Incongruent, Neutral, and Single (See Figure 1). In the congruent trials, the flanker arrows pointed in the same direction as the center target. In the incongruent trials, the flanker arrows pointed in the opposite direction as the target, creating conflicting stimuli, designed to tax executive attention through interference. In the neutral trials, the flanker stimuli were rectangles rather than arrows. In the single trials, the central target arrow was presented alone.

The traditional flanker task was modified to include reinforcement as in Crone et al. (2003). Four conditions were defined by type of reinforcement and were indicated by screen color: No Reward or Response Cost (NR), Reward Only (REW), Reward with Occasional Response Cost (ROR), and Equal Probability of Reward and Response Cost (EQ) (Table 1). Each condition included an equal number of the four trial types, and conditions were administered in the same order to all subjects (NR, REW, ROR, EQ). Reinforcement was provided in two ways: points and tokens. Subjects earned or lost points based on speed and accuracy: points were gained for accurate responses; points were lost for inaccurate responses and those that were slower than the mean of the subject's own performance on the NR trials, though the latter were still considered accurate. The current point total was visible on the screen, providing both feedback and extrinsic motivation (rewards and response costs) at the moment of responding, which has been suggested to be a method of improving arousal and optimal performance (Prins et al., 2011). In addition, at the end of each condition (except the NR condition), plastic tokens, corresponding to the net number of points attained by the end of the condition (rewards – response costs), were placed in a glass jar in view of the subject. This secondary reinforcer represented the cumulative effects of rewards and response costs across all the reward conditions. At the end of the task, subjects exchanged their tokens for a prize, which served as the primary reinforcer. Although subjects were told the tokens would be exchanged for a prize at the end of the task if they earned enough tokens to fill the jar, all subjects received a prize of equal value.

Statistical Analyses

All statistical analyses were conducted using SPSS 19.0 for Mac OSX. Demographics were analyzed using chi-square statistics for categorical variables (sex, race, ethnicity, and handedness), and analysis of variance (ANOVA) statistics for continuous variables [age, socioeconomic status (SES), and full scale IQ (FSIQ)]. Significant differences were followed up using pairwise comparisons. SES was measured by the Hollingshead Four Factor Index of Social Status and FSIQ by the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2004). Demographic variables were included as covariates if they were significantly correlated with the dependent variables and did not interact with group. Age was significantly correlated with RT across multiple conditions, and therefore was included in all RT analyses. FSIQ was not independent of group and therefore its inclusion as a covariate would violate the homogeneity of regression slopes assumption for ANCOVA (Maxwell and Delaney, 2004). Although FSIQ was not included as a covariate, to address the role of IQ in test performance, Pearson correlations between FSIQ and the dependent variables (RT and accuracy) by group were calculated for incongruent trials.

Accuracy and RT data were analyzed separately using repeated measure analysis of covariance (ANCOVA). An alpha level of $p < .05$ was used to determine statistical significance. Significant omnibus tests were followed up with pairwise comparisons using Tukey's Honestly Significant Difference test.

Results

Demographics

There were no significant between-group differences on sex [$\chi^2(2) = 5.02, p = .081$], handedness [$\chi^2(8) = 9.09, p = .334$], race [$\chi^2(2) = 5.05, p = .080$], ethnicity [$\chi^2(4) = 5.84, p = .211$], SES [$F(2, 85) < 1.0$], or age [$F(2, 85) = 1.95, p = .149$]. However, as expected, groups differed on FSIQ [$F(2, 83) = 34.47, p < .001$]. Pairwise comparisons revealed that the AE ($p < .001$) and ADHD ($p = .005$) groups had significantly lower FSIQ scores than CON, and the AE group also had a lower mean FSIQ score than the ADHD group ($p < .001$). Demographic data can be found in Table 2.

Inhibitory Control Performance

Prior to examining group differences related to reward condition, we examined whether the groups differed on inhibitory control in the NR condition. Two 3(group: AE, ADHD, CON) x 2(flanker type: congruent, incongruent) repeated measure ANCOVAs (controlling for age) were conducted for RT and accuracy (see Table 3).

Response Time—There were significant main effects of group [$F(2, 84) = 8.36, p < .001, \eta_p^2 = .166$] and flanker type [$F(1, 84) = 9.71, p = .003, \eta_p^2 = .104$] on RT, but no significant interaction between these factors [$F(2, 84) = 1.24, p = .295, \eta_p^2 = .029$]. The AE group was significantly slower than the CON group ($p < .001$) and the ADHD group ($p = .038$), which did not differ ($p = .114$). Response time for incongruent flankers was significantly slower than for congruent flankers ($p < .001$).

Accuracy—There was a significant group x flanker type interaction [$F(2, 83) = 6.25, p = .003, \eta_p^2 = .131$] and main effect of group [$F(1, 83) = 3.92, p = .024, \eta_p^2 = .086$] on accuracy, but no main effect of flanker type [$F(2, 83) = 0.73, p = .397, \eta_p^2 = .009$]. Between-group pairwise comparisons by flanker type demonstrated no significant group differences for congruent trials ($p = .070$), while the AE group had poorer accuracy than the CON group during incongruent trials ($p = .001$). Within-group comparisons demonstrated that the AE group had significantly poorer accuracy between congruent and incongruent trials ($p < .001$), with no other significant within-group differences ($p > .12$). Results suggest that the flanker task was effective in evaluating interference control, taxing performance with incongruent flankers, particularly in AE subjects for whom performance significantly worsened.

Response to Reward

Response Time—Response time data by condition and trial type are presented in Table 4 and Figure 2. A 3(group: AE, ADHD, CON) x 4(reward condition: NR, REW, ROR, EQ) x 4(flanker type: congruent, incongruent, neutral, single) repeated measures ANCOVA (controlling for age) was conducted. Mauchly's test indicated that the sphericity assumption

was violated for all within-subject effects ($p < .001$) and degrees of freedom were corrected using the Greenhouse-Geisser estimate (Girden, 1992). Age significantly interacted with condition [$F(1.235, 103.725) = 7.74, p = .004, \eta_p^2 = .084$] and flanker type [$F(2.144, 180.130) = 4.24, p = .014, \eta_p^2 = .048$]. There were no other effects of age on RT.

The group x reward condition interaction (Figure 2A) was significant [$F(2.470, 103.725) = 4.51, p = .008, \eta_p^2 = .097$] indicating differential effects of reward condition by group. Follow-up pairwise comparisons were conducted first by looking at group differences within each condition and then by looking at the patterns of performance by condition within each group. For all conditions, the AE group responded significantly slower than the CON group ($p < .001$), and slower than the ADHD group ($p = .046$), except for REW ($p = .051$). The CON and ADHD groups were not significantly different ($p > .08$). These findings suggest that for the most part, the AE group is slower to respond than the CON and ADHD groups, which did not differ.

The within-group comparisons revealed a different pattern of response by reward condition. For all groups, RT in the NR condition was significantly slower than the other conditions, which contained extrinsic reinforcement (AE and ADHD, $p < .001$; CON, $p = .002$). For the AE and ADHD groups, RT was similar for all three reinforcement conditions (AE, $p > .39$; ADHD $p > .19$). For the CON group, occasional response cost (ROR) improved RT in comparison to the REW condition ($p = .03$), with no other differences ($p > .20$) for this group. These within-group results suggest that while all groups improved with reinforcement, control subjects showed the most improvement in RT when response cost was applied. For the AE and ADHD groups, the type of reinforcement was not critical.

There were no other significant interaction effects for RT. However, there were significant main effects on RT, which must be considered in light of the interaction effects just reported. There was a significant main effect of group [$F(1, 84) = 10.69, p < .001, \eta_p^2 = .203$]. Pairwise comparisons demonstrated significantly slower RT in AE compared to both CON and ADHD ($p < .017$) and the difference between ADHD and CON (ADHD < CON) were not significantly different ($p = .085$). These results support the within-condition analyses described above. The main effect of flanker type was also significant [$F(2.144, 180.130) = 11.70, p < .001, \eta_p^2 = .122$]. Pairwise comparisons revealed that RT for incongruent targets were significantly slower compared to all other target types ($p < .001$) and RT for single target trials were significantly faster than those for congruent trials ($p = .002$), with no significant differences between RT for neutral trials compared to congruent or single trials ($p > .10$). This pattern of results is expected given that incongruent stimuli induce the most conflict and generally require increased processing to respond, while single target trials have no distracting elements (Rueda et al., 2005). The main effect of condition was also significant [$F(1.235, 103.725) = 16.46, p < .001, \eta_p^2 = .164$]. Pairwise comparisons revealed that RTs were significantly slower when there was no reward compared to conditions with reinforcement trials ($p < .001$), while there were no other significant differences between conditions ($p > .11$).

Accuracy—Accuracy data by condition and trial type are presented in Table 4 and Figure 2. A 3(group: AE, ADHD, CON) x 4(reward condition: NR, REW, ROR, EQ) x

4(flanker type: congruent, incongruent, neutral, single) repeated measures ANCOVA (controlling for age) was conducted. Mauchly's test indicated that the sphericity assumption was violated ($p = .003$) and degrees of freedom were corrected using the Greenhouse-Geisser estimate.

There were no significant interaction effects involving group. The condition $\times$ flanker type interaction (Figure 2C) was significant [$F(6.667, 566.700) = 31.30, p < .001, \eta_p^2 = .269$]. Follow-up pairwise comparisons were conducted first by flanker type and then by condition. Pairwise comparisons by flanker type showed that for congruent trials, accuracy was better in the NR condition than the REW ($p = .03$) and ROR ($p = .01$) conditions. There were no other significant differences for congruent targets ($p > .058$). For incongruent trials, accuracy was greater in the NR condition than in all other conditions ($p < .001$). There were no other significant differences in accuracy for incongruent targets ($p > .08$). On neutral trials, accuracy was better in the NR condition compared to all other conditions ($p < .029$) with no other significant differences ($p > .058$). Finally, for single trials, there were no significant differences in accuracy between any conditions ($p > .28$).

Pairwise comparisons by condition showed that within all conditions, accuracy was poorer for incongruent flanker trials compared to all other trial types ($p < .001$). For the NR and REW conditions, there were no other significant differences ($p > .16$). For the ROR condition, accuracy was significantly poorer for neutral trials compared to congruent trials ($p = .019$). There were no significant differences on accuracy between congruent and single flanker trials ($p = .739$). Lastly, for the EQ condition, responses to neutral trials were less accurate than responses for congruent ($p = .005$) and single ($p = .03$) trials, which did not significantly differ from each other ($p = .861$).

There were no other significant interaction effects on accuracy. However, there were significant main effects of flanker type [$F(1.530, 130.049) = 118.06, p < .001, \eta_p^2 = .581$] and condition [$F(2.309, 196.230) = 37.01, p < .001, \eta_p^2 = .303$], which must be considered in light of the interaction effects just reported. Pairwise comparisons within flanker type showed that accuracy was worst for incongruent trials compared to all others ($p = .001$), while accuracy was also worse for neutral trials compared to congruent ($p < .001$) and single trials ($p = .041$). Pairwise comparisons within condition demonstrated better accuracy in the NR condition compared to all conditions with reinforcement ($p = .001$), as well as in the REW condition compared to ROR ($p = .028$), with no other significant differences ($p > .18$). The main effect of group was not significant for accuracy [$F(2, 85) = 1.93, p = .152, \eta_p^2 = .043$].

Post-Hoc Analyses

Alcohol-exposed children with and without ADHD have exhibited differences on parent-reported behavioral responses (Graham et al., 2013, Ware et al., 2013). Therefore, the analyses were repeated without the five alcohol-exposed children that did not meet at least two ADHD criteria (directly comparing children with ADHD, with and without alcohol exposure). There were no changes in results and therefore, all reported analyses include all alcohol-exposed subjects (with and without ADHD), at rates of ADHD representative of this population (Burd et al., 2003, Fryer et al., 2007).

Given group differences in FSIQ, Pearson correlations were calculated between accuracy and RT and FSIQ scores. These correlations are presented in Table 5 and indicate that in general, IQ was significantly correlated with accuracy in the AE and CON groups and RT in the ADHD group.

Discussion

This study is the first to compare effects of extrinsic reinforcement on interference control between children with prenatal alcohol exposure, children with idiopathic ADHD, and typically developing controls. The flanker task successfully taxed interference control in this study; incongruent targets prompted the worst performance across groups for both response time and accuracy. The most conflict was imposed by incongruent trials and performance on these trials provides a strong indicator of executive attention, which generally develops during early school years (Jones et al., 2003). When measuring inhibitory control (without reinforcement) we found that the CON and ADHD subjects had relatively intact executive control, as neither group showed a significant decline in accuracy when incongruent targets were presented. However, alcohol-exposed children were less accurate when incongruent targets were presented and greater cognitive effort was needed. This finding suggests difficulties with executive control in the AE group that were not present in the comparison groups. The AE subjects also had slower responses compared to the CON and ADHD groups. Group differences on accuracy between the AE and CON subjects were only significant when incongruent targets were introduced (no group differences for congruent targets). This suggests a greater impact for alcohol-exposed subjects when greater cognitive effort is required.

Previous research found that an attention training intervention improved cognitive performance in alcohol-exposed children (Kerns et al., 2010). Our study extends these findings by incorporating deliberate feedback for incorrect/slow responses based on the hypothesis that such rewards and response costs are advantageous in increasing motivation (e.g., Carlson et al., 2000). Children in both clinical (AE and ADHD) groups benefited similarly from both types of extrinsic motivation (reward or response cost).

For response time, reward-based performance differed by group. We expected both clinical groups to be impaired on interference control (prior to initiation of incentive). This hypothesis was supported for the AE group but not the ADHD group: on the NR condition, the AE group had significantly slower RT than the CON and ADHD groups, which did not differ. In the presence of incentive, we expected both clinical groups to benefit from reward and that the AE group would show benefits from response cost, beyond those of reward alone. This hypothesis was also partially supported: we found that on all reinforcement conditions, the AE and ADHD groups responded faster once reward was introduced. The CON group had further advantage on the ROR condition, while the clinical (AE and ADHD) groups had similar performance on all the reinforcement conditions, indicating no benefit of response cost over reward for either clinical group.

For accuracy, performance was affected by flanker type and reward condition across groups. For all groups, performance was better with no reinforcement for all target types, with the

exception of single targets, likely due to reduced cognitive effort required with no interference from additional flankers. Overall, accuracy was equivalent across groups, which ensured that the task was conducted correctly and enabled greater focus on type of reinforcement and stimuli underlying changes in accuracy performance. The lack of significant interactions with group for accuracy prevented those direct comparisons with previous literature (Kerns et al., 2010).

Results from the reinforcement conditions indicate that the use of reward and response cost may be beneficial for performance for all children. While extrinsic reinforcement was helpful, there were significant group differences in attention as measured by response time between the clinical groups. These differences may be helpful in distinguishing these clinical populations and for treatment planning as groups may respond differently to intervention (Doig et al., 2008). Specifically, the slower response times and decrease in accuracy for AE during incongruent trials without reinforcement, suggest that treatment for alcohol-exposed children may need to be distinct from that for children with idiopathic ADHD, which did not have the same performance issues.

Further, the decision to use reward, response cost, or a combination of these for the greatest impact may be dependent on the type and length of training used. While the current study showed no additional benefit when response cost was introduced for the AE or ADHD groups, improvements in accuracy have been found in the literature. Kerns and colleagues (2010) showed that the combination of reward and response cost was better for academically oriented tasks that build upon preceding lessons. This was effective for working memory and math fluency in association with executive attention training in alcohol-exposed children following metacognitive training; subjects' ability to plan and organize improved and influenced the speed-accuracy trade-off (Kerns et al., 2010). Understanding the specific strengths and weaknesses in alcohol-exposed children (e.g., positive response to reinforcement versus poorer accuracy with greater cognitive effort) is important for effective remediation efforts. This is especially pertinent as studies have shown both improvement (Engle and Kerns, 2011) and no improvement (Kully-Martens et al., 2013) in short-term learning when using tangible rewards and punishments in alcohol-exposed children. Discrepancies may be related to how contingencies are presented. The use of money, which participants were well informed about prior to completing the task, was related to poor outcomes (Kully-Martens et al., 2013). However, the current study and Engle and Kerns' (2011) work utilized primary and secondary reinforcers and withheld concrete information about final prizes; this suggests that presenting a contingency too early may be unconstructive when aiming to improve performance in alcohol-exposed children.

Limitations

Although the current study provides important and clinically relevant information, results should be interpreted in light of several limitations. To ensure task comprehension, subjects were excluded if they had accuracy levels below 80%. Additionally, although all subjects were asked to refrain from taking ADHD medication on the day of testing, it was not possible for all subjects. Both of these factors may have artificially truncated the range of task performance, particularly in our AE or ADHD groups. Previous studies on the impact of

methylphenidate (e.g., Ritalin) on flanker task performance are mixed, and include findings of no effect on response times or accuracy in ADHD (Jonkman et al., 1999, Scheres et al., 2003). These two factors may also have led to the possibility of ceiling effects, especially in older children. This potential limitation was mitigated by controlling for age when appropriate and limiting the subject pool to those 12 years of age or younger, as executive attention and overall functioning improves with age (Rueda et al., 2005).

Our ADHD group comprised children with elevations on two or more standardized ADHD measures. Some, but not all, subjects had a clinical diagnosis of ADHD from a physician. It is possible that this methodology resulted in less impairment in our ADHD group, and additional studies of clinically-referred ADHD populations are warranted. In addition, previous studies have found that alcohol-exposed children and children with idiopathic ADHD have higher rates of oppositional defiant disorder and conduct disorder (Ware et al., 2013, Fryer et al., 2007, Willcutt et al., 1999), which were not addressed in the current study, but have been shown to influence poorer performance on continuous performance tasks (e.g., Newcorn et al., 2001). Future studies of reinforcement among these populations should consider this important factor.

Further, IQ was not included as a covariate, as it violated important statistical assumptions. Regardless, IQ is an important consideration and we did assess the relationship between IQ and outcome variables. There was a significant relationship between IQ and accuracy in alcohol-exposed subjects. However, as there were no group differences on accuracy, this suggests that IQ differences between groups were not reflected in their accuracy performance. On the other hand, where group differences did exist (RT), there was no relation with IQ. We also split the AE group into low (<90) and average (90) IQ groups for comparison. There were no differences on outcomes for accuracy and only one difference for RT (low IQ slower than average IQ on incongruent trials during the EQ condition, $p=.026$), additionally suggesting that the results are robust across different IQ ranges. Nonetheless, future work should investigate the relation between individual cognitive domains and accuracy and reaction time as one may expect differential correlations.

Finally, subjects were examined using standardized but experimental techniques that are likely not consistent with the child's school and home environments. Therefore, these results may not generalize to outcomes in everyday environments in which children generally perform academic tasks. Further studies examining the changes in environment or other factors are needed for generalization of findings regarding extrinsic reinforcement as a positive contributing factor for motivation and improved performance to other settings.

Future Directions

We provide evidence for poorer performance in alcohol-exposed children when more cognitive effort is required for tasks for which no reinforcement is present. However, findings suggest that use of reward and/or response cost methods may be useful to increase motivation and decrease inattentive behaviors for alcohol-exposed children, ultimately improving performance. Motivation has been reported to be positively related to executive attention (Pessoa, 2009) and can have a positive impact on academic functioning (Carlson et al., 2002). Children with ADHD-Primarily Inattentive subtype (PI) have displayed

motivational impairment, and exhibit a passive learning style and reliance on external validation (Carlson et al., 2002). Children with prenatal alcohol exposure have shown similar behavior (e.g., slow response times and sluggish cognitive behavior) to children with ADHD-PI (Kooistra et al., 2010, Graham et al., 2013) and it is possible that they have a similar motivational style that requires external reinforcement during tasks. Approximately 61% of the ADHD group and 24% of the AE group had predominantly inattentive symptoms, while the remainder had a combination of hyperactive/impulsive and inattentive symptoms (see Table 1). This suggests that inattention may be more impairing for alcohol-exposed children (as evidenced by slower response time), regardless of ADHD symptom levels.

A major concern for alcohol-affected children is difficulty in school settings due to behavioral and cognitive impairments interfering with effective learning (Streissguth et al., 1996). Motivation is an important target for minimizing obstacles, preferably prior to school attendance; early intervention has shown to serve as a protective factor in this population (Streissguth et al., 1996). Additionally, increasing motivation through extrinsic reinforcement may improve behavioral problems (McInerney and Kerns, 2003), which could have far reaching effects throughout life. Our study and previous findings suggest that positive effects of extrinsic reinforcement on performance may not be universal (e.g., only improving response time and not accuracy of responses) (Deci et al., 1999). However, others have shown benefits of extrinsic reinforcement on accuracy following executive attention training that were associated with improvements on more difficult achievement tests (e.g., Kerns et al., 2010). It has been suggested that such gains are associated with progressively demanding performance standards, which improves intrinsic motivation through increased time spent on the task (Pierce et al., 2003). Positive effects of reinforcement on accuracy may not have been observable given the high rates of overall accuracy in all groups.

The combination of technology and reinforcement can improve executive attention in alcohol-exposed children, which may indirectly impact academic achievement (Kerns et al., 2010, Gathercole et al., 2006). In addition to reinforcement, the digitization of tasks may help maintain attention (Ross et al., 2010) even in populations with special needs who often have difficulty with task performance and classroom participation (Hasselbring and Glaser, 2000). The findings suggest that a focus on positive reinforcement and response cost may be beneficial in strengthening sustained attention or processing speed in alcohol-exposed children. Improving these skills can be helpful in academic settings where children need to engage in learning and thus, the efficacy of reinforcement techniques should be pursued in future intervention studies.

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(A).

(B).

(C)

(D).

Figure 1.
Example of (A) congruent (B) incongruent (C) neutral, and (D) single flanker trials.

Figure 2.

Response time and accuracy on the flanker task by condition and flanker type.

(A) Mean response time ($\pm$ SEM) for the reinforcement conditions by group. (B) Mean response time ($\pm$ SEM) for the flanker trials by group. (C) Mean ($\pm$ SEM) accuracy for the reinforcement conditions by flanker type. There were no main or interactive effects of group on accuracy. See text for details.

Note: NR=No Reward; REW=Reward Only; ROR=Reward and Occasional Response Cost; EQ=Equal Probability of Reward and Response Cost; AE=Children with heavy prenatal alcohol exposure; ADHD=children with attention-deficit/hyperactivity disorder (ADHD) and without heavy prenatal alcohol exposure; CON=typically developing children without ADHD or heavy prenatal alcohol exposure

Table 1

Description of Flanker Task Conditions

Condition	Description
No Reward (NR)	White stimuli on a blue background. Subjects earned a point for each correct response that was faster than their individual baseline.
Reward Only (REW)	White stimuli on a blue background. Subjects earned a point for each correct response that was faster than their individual baseline.
Reward + Occasional Response Cost (ROR)	White stimuli on either a blue or a red background. The blue background again indicated reward trials, as described above. The red background indicated response cost trials, in which a point was taken away if the subject responded incorrectly or too slowly compared to their individual baseline. Reward trials were more frequent (66.7%) than response cost trials (33.3%).
Equal Probability of Reward and Response Cost (EQ)	Presented in an identical manner to the ROR condition, except that reward and response cost trials occurred at an equal frequency.

Table 2

Demographic data for children with prenatal alcohol exposure (AE), attention-deficit/hyperactivity disorder (ADHD), and typically developing controls (CON).

Demographic Variable	AE (<i>n</i> = 34)	ADHD (<i>n</i> = 23)	CON (<i>n</i> = 31)
Sex [<i>n</i> (%) Females]]	12 (34.3)	6 (26.1)	17 (54.8)
Race [<i>n</i> (%) White]]	22 (64.7)	20 (87.0)	26 (83.9)
Ethnicity [<i>n</i> (%) Hispanic]	3 (8.8)	6 (26.1)	10 (32.3)
Handedness [<i>n</i> (%) Right]	26 (76.5)	19 (82.6)	28 (90.3)
Age [<i>M</i> (<i>SD</i>)]	10.9 (1.50)	10.1 (1.54)	10.5 (1.63)
SES [<i>M</i> (<i>SD</i>)]	48.4 (12.31)	48.4 (11.72)	48.4 (12.46)
Psychostimulant use day of testing [<i>n</i> (%)]	7 (20.6%)	2 (8.7)	0 (0)
FSIQ [<i>M</i> (<i>SD</i>)] *	83.5 (15.64)	99.8 (12.25)	112.5 (12.93)
FAS diagnosis [<i>n</i> (%)]	5 (14.7)	0 (0)	0 (0)
ADHD Symptoms [<i>n</i> (%)]	29 (85.3)	23 (100.0)	0 (0)
Inattentive	8 (23.5)	14 (60.9)	0 (0)
Hyperactive/Impulsive	0 (0)	0 (0)	0 (0)
Combined	20 (58.8)	4 (17.4)	0 (0)

Note: SES: Socioeconomic status, measured by Four factor index of social status

FSIQ: Full scale IQ score, measured by Wechsler Intelligence Scale for Children-Fourth Edition

FAS: Fetal alcohol syndrome

ADHD Symptoms: number of children with symptoms consistent with a diagnosis of attention deficit/hyperactivity disorder. ADHD subtype is only based on information given by the C-DISC-4.0, thus is not available for all subjects.

* Indicates significant differences at $p < .05$ level

Table 3

Interference Control Performance: Data are presented as mean response time (RT) and accuracy (ACC) across groups for congruent (No Interference) and incongruent (Interference) Flanker Types. Only Trials without reinforcement are included in these results.

Flanker Type	AE		ADHD		CON	
	RT	ACC	RT	ACC	RT	ACC
Congruent [M(SD)]	809.73 ^{##} (320.98)	.975 (.047)	716.61 [*] (299.65)	.946 (.092)	591.03 [#] (110.76)	.965 (.071)
Incongruent [M(SD)]	919.97 ^{##} (432.08)	.854 [#] (.155)	815.22 [*] (384.12)	.902 (.079)	652.06 [#] (117.84)	.953 [#] (.047)

Note: Mean response times (RT) in msec and accuracy (ACC) scores (0–1) with standard deviations (SD) for children with prenatal alcohol exposure (AE), children with attention-deficit/hyperactivity disorder (ADHD) and typically developing children (CON) for each Flanker Type.

^{*} significant differences between AE and ADHD

[#] significant differences between AE and CON

Table 4

Mean response time (RT) and accuracy (ACC) of performance across groups by reward condition and flanker type

Condition	AE		ADHD		CON		All Subjects	
	RT	ACC	RT	ACC	RT	ACC	RT	ACC
NR [<i>M</i> (<i>SD</i>)]	816.91 (320.47)	.916 (.088)	731.39 (310.73)	.949 (.047)	605.74 (110.78)	.972 (.027)	720.17 (275.61)	.945 (.066)
REW [<i>M</i> (<i>SD</i>)]	555.44 (120.51)	.899 (.077)	529.83 (97.74)	.918 (.056)	481.74 (81.99)	.935 (.049)	522.78 (106.17)	.917 (.065)
ROR [<i>M</i> (<i>SD</i>)]	561.74 (130.88)	.900 (.084)	515.87 (100.78)	.904 (.081)	459.74 (72.85)	.916 (.070)	513.82 (113.30)	.906 (.078)
EQ [<i>M</i> (<i>SD</i>)]	558.41 (150.57)	.900 (.084)	519.09 (113.80)	.916 (.081)	463.10 (68.37)	.922 (.072)	514.56 (123.24)	.912 (.079)
Flanker Type								
Congruent [<i>M</i> (<i>SD</i>)]	588.26 (141.08)	.933 (.076)	542.52 (114.68)	.961 (.047)	482.77 (77.51)	.967 (.040)	539.15 (122.58)	.952 (.060)
Incongruent [<i>M</i> (<i>SD</i>)]	658.21 (175.39)	.821 (.130)	615.52 (117.73)	.833 (.102)	548.81 (96.17)	.865 (.081)	608.51 (143.56)	.840 (.108)
Neutral [<i>M</i> (<i>SD</i>)]	580.91 (138.76)	.928 (.070)	532.17 (104.68)	.942 (.057)	479.16 (73.16)	.953 (.051)	532.33 (117.69)	.940 (.061)
Single [<i>M</i> (<i>SD</i>)]	575.38 (143.68)	.932 (.073)	530.70 (108.19)	.951 (.049)	472.55 (73.06)	.961 (.039)	527.48 (120.85)	.947 (.057)
Across All Conditions and Flanker Types [<i>M</i> (<i>SD</i>)]	648.24 (128.33)	.909 (.064)	562.96 (128.18)	.927 (.062)	501.91 (128.95)	.939 (.061)		

Note: Mean response times (RT) in msec and accuracy (ACC) scores (0–1) with standard deviations (SD) for children with prenatal alcohol exposure (AE), children with attention-deficit/hyperactivity disorder (ADHD) and typically developing children (CON) for each Condition and Flanker Type.

Table 5

Pearson correlations between (A) FSIQ and response times and (B) FSIQ and accuracy for incongruent trials within each condition

(A) Response Times				
	NR	REW	ROR	EQ
<i>AE</i>	-.218	-.338	-.280	-.363 *
<i>ADHD</i>	-.044	-.162	-.083	-.174
<i>CON</i>	-.129	-.296	-.355 *	-.307
(B) Accuracy				
	NR	REW	ROR	EQ
<i>AE</i>	.415 *	.464 *	.457 *	.401 *
<i>ADHD</i>	.097	.317	.138	.122
<i>CON</i>	-.399 *	-.282	-.057	.011

Note: FSIQ = Full scale IQ score, as measured by the Wechsler Intelligence Scale for Children-Fourth Edition; NR = no reward; REW = reward only; ROR = reward and occasional response cost; EQ = equal probability of reward and response cost

* indicates significant at the $p < .05$ level