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Motor Response Programming and Movement Time in Children with Heavy Prenatal Alcohol Exposure

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Abstract

The present experiment assessed motor response programming and movement time in children with histories of heavy prenatal alcohol exposure. Alcohol-exposed children between the ages of 7 and 17 years were classified into two groups: Fetal Alcohol Syndrome (FAS: $n = 9$) and children with prenatal alcohol exposure (PEA: $n = 19$) but who did not have the defining characteristics of FAS. The FAS and PEA children were compared to non-alcohol exposed children (NC: $n = 23$) when completing two tasks: a simple reaction time task (RT alone condition) and a reaction plus movement task (RT + Move condition). The movement involved responding to an imperative stimulus signal and depressing three target buttons in a set sequence. Participants completed 24 trials each for the RT alone and RT + Move response conditions. Results indicated no significant differences in performance among FAS, PEA and NC groups during the RT alone condition. However, during the RT + Move condition, the FAS group produced significantly longer and more variable reaction times than either the PEA and NC groups, which produced comparable reaction times. The FAS group also produced significantly slower movement times when moving to all three targets, whereas movement time variability did not significantly differ as a function of group. The observed results indicate children with FAS experience deficits in response programming and movement time production.

Keywords

Motor Response Programming; Reaction Time; Movement Time; Fetal Alcohol syndrome

Introduction

Fetal Alcohol Syndrome (FAS) is a consequence of maternal ethanol consumption during pregnancy and is characterized by a triad of features that include central nervous system (CNS) dysfunction, pre- and/or postnatal growth retardation and a distinct pattern of craniofacial anomalies (Jones and Smith, 1973). Estimates place the overall incidence of FAS between 2 to 7 cases per 1,000 live births in the United States and (May et al., 2009),

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although incident rates as high as 67.2 per 1,000 children have been reported for other geographical regions (Urban, 2008). However, these estimates do not include children with histories of *in utero* ethanol exposure who do not meet the defining characteristics for a diagnosis of FAS, but still suffer from alcohol-related neurological deficits. It is estimated that as many as 1 in 100 live births exhibit this larger category of fetal alcohol spectrum disorders (Sampson, et al. 1997).

Neuroimaging studies reveal that prenatal alcohol exposure leads to significant reductions in mean absolute size of the total brain, frontal lobe, caudate, putamen, hippocampus, cerebellar vermis, and corpus callosum length (Astley et al., 2009), together with increased cortical thickness and grey matter volume and decreased volume and disorganization in white matter (Norman, Crocker, Mattson and Riley, 2009). Furthermore, there is evidence that the extent of CNS damage increases as the classification of prenatal alcohol exposure moves towards the extreme end of the FASD continuum as represented by FAS (Astley, et al., 2009).

The consequences of structural damage to the CNS resulting from prenatal alcohol exposure can be expected to produce deficits in central information processing associated with motor skill performance. For the stage of response selection, which involves deciding which motor response to make, this expectation has been confirmed in the form of significantly slower reaction time (RT) in children with heavy prenatal alcohol exposure (Simmons et al., 2002). What remains unknown is whether the temporal deficit reported for response selection extends to the information processing stage of motor response programming. This stage follows response selection and involves creating an action plan in preparation for execution. Henry and Rogers (1960) were the first to document that the time taken to initiate a movement, as indexed by simple RT, is longer for more complex movements. Given that the stimulus to initiate a response is held constant, increases in RT are viewed as reflecting the additional time required to program more complex movements. The direct relation between RT and response programming has been confirmed in non-clinical populations (Sidaway, et al., 1999) and clinical groups including schizophrenics (Carnahan, et al., 1997), Parkinson's disease patients (Sheridan, et al., 1987), and individuals with autism and Asperger disorder (Rinehart, et al., 2001).

For typically developing individuals, the cognitive processing associated with response programming involves numerous distributed neural systems including the medial frontal gyrus, pre-supplemental motor area, putamen and cerebellar lobule VI (Boyd, Vidoni, Siengsukon and Wessell, 2009; Thickbroom, et al., 2000), the fronto-striatal region (Cunnington, et al., 1996), caudate and lentiform nuclei (Gordon, et al., 1998), basal ganglia (Brothie, et al., 1991), and cerebellum (Shin and Ivry, 2003). As previously noted, many of these CNS structures are susceptible to the teratogenic effects of prenatal alcohol exposure, which should compromise the speed of response programming. To date, no studies have assessed response programming in children with histories of heavy prenatal alcohol exposure and it is the purpose of the present experiment to examine this issue. Specifically, we predicted that both FAS and PEA children would produce RT values comparable to control group times during a condition requiring minimal response programming. In the present experiment, this condition was represented by a simple RT response (designated as the RT alone condition). However, when response programming demands increase, as is the case when a complex movement follows the RT response (designated as the RT + Move condition), we predicted that the additional processing required to program the response would result in the alcohol-exposed children producing significantly delayed RT.

For some forms of motor tasks, such as velocity regulation, it has also been established that prenatal alcohol exposure is associated with greater response variability, particularly under

conditions of increased task complexity (Wass et al., 2002). Consequently, a second prediction of the present experiment was that alcohol-exposed children also produce significantly greater variability in RT when response programming is required.

Movement time has been previously used to evaluate motor control in a variety of clinical syndromes, including developmental coordination disorder (Ameratunga, et al., 2004), attention deficit-hyperactivity disorder (Eliasson, et al., 2004), Parkinson's disease (Jones, et al., 1992), traumatic brain injury (Incoccia, et al., 2004), and Turner's syndrome (Nijhuis-van der Sanden, et al., 2002), all of which produced slower movement times than asymptomatic controls. Similar to RT, CNS damage resulting from specific clinical syndromes is viewed as limiting the ability of individuals to efficiently and consistently execute a movement. For example, deficits in movement time in schizophrenics were attributed to anomalies in the fronto-subcortical structures (Downing, et al., 1998), whereas for Parkinson's disease bradykinesia has been linked to dysfunction of the basal ganglia (Desmuget, et al., 2004). Therefore, we predicted significantly slower and more variable movement times for the FAS and PEA groups in comparison to control group performance.

Materials and Methods

Alcohol Exposed Sample

Demographic information for the alcohol-exposed and control groups is presented in Table 1. Twenty-eight alcohol-exposed participants were recruited from a pool of children registered with the Center for Behavioral Teratology (CBT) at San Diego State University. The children were between the ages of 7 and 17 years, inclusively, with full-scale IQ (FSIQ) scores above 70 and confirmed histories of heavy prenatal alcohol exposure. Levels of maternal alcohol consumption were retrospectively established through the use of maternal report, social service records, and medical records. Reports of alcohol consumption ranged from 3-4 glasses of wine a day, to "being drunk day and night", and drinking a fifth of vodka or a case of beer each day. Children with an incomplete family history concerning prenatal alcohol exposure were not eligible to participate.

In addition to psychometric testing and questionnaire screening, participants were examined by Dr. Kenneth Lyons Jones, a dysmorphologist, using established FAS criteria of specific facial anomalies (e.g., short palpebral fissures, long philtrum, and short epicanthal folds), pre- and/or post-natal growth deficiency (at or below the 10th percentile for either height or weight) and evidence of CNS dysfunction (Jones and Smith, 1973). Based on this screening process, nine children received a diagnosis of FAS and were assigned to an FAS group. An additional nineteen children who did not meet criteria for a diagnosis of FAS, but who had experienced heavy prenatal exposure to alcohol were assigned to a prenatal exposure to alcohol (PEA) group (Mattson, et al., 1997).

Non-alcohol Exposed Control Sample

A non-alcohol exposed control group (NC) consisting of twenty-two children was also recruited from a pool of participants registered at the Center for Behavioral Teratology (CBT). All children in the NC group were evaluated using the same comprehensive neuropsychological battery administered to the alcohol-exposed children and were screened for prenatal alcohol exposure and other teratogens through a telephone interview process and completion of a parent questionnaire that elicited information concerning alcohol consumption during pregnancy.

To be included in the study all children had to be between the ages of 7 to 17 years and speak fluent English. Participants were excluded for the following reasons: closed head injury with significant loss of memory; a FSIQ score below 70 as determined through use of

the Weschler Primary Scale of Intelligence, Third Edition. In addition, control participants were excluded if greater than the minimal prenatal alcohol exposure (1AA/day prior to pregnancy recognition) was known or suspected or if alcohol exposure information was unavailable and children were excluded from the PEA and ALC groups if mental deficiency resulted from known causes other than prenatal exposure to alcohol.

Apparatus and Procedures

A schematic diagram of the apparatus is presented in Figure 1. A rectangular response box ($28 \times 43 \times 5$ cm) was placed on a baseboard inclined towards the participant at 25 degrees relative to the horizontal plane. The baseboard was mounted to the top surface of a standard table. A single stimulus light, a reaction time (RT) key and three target keys (T1, T2, and T3) measuring 1 cm square were positioned on the top surface of the response box. A small (4.5×2.5 cm) felt pad was attached to a rigid plastic support and positioned 30 cm vertically above the RT key. The pad was included to ensure uniformity of movement in responding to the stimulus light as described in the following section. The time taken to react to the stimulus light and move to each target was recorded in milliseconds using a multifunction timing device (model 54035A: Lafayette Instrument Co, Lafayette, IN, USA).

After obtaining subject consent and assent according to Institutional Review Board procedures, the child was seated with the RT key aligned with the dominant hand (defined as the hand used for writing). After a brief explanation and demonstration of the task, the participant was allowed up to five practice trials for the RT task and RT + move task, which were not included in the statistical analyses. Participants completed two response conditions: an RT alone task and an RT + Move task. For the RT alone task, the participant extended the fingers of the right hand, placed the middle finger on the RT key and focused their attention on the stimulus light. Following a verbal 'ready' signal, the experimenter activated the stimulus light after a randomly determined delay of 1-4 seconds. The participant was instructed to lift the forearm and hand as a single unit as quickly as possible when the stimulus light was activated. For the RT + Move task, the participant completed the same RT response followed by a continuation of the hand movement upward until the back of the fingers contacted the felt pad, followed by a movement downward and forward to 'hit' the target keys in the designated sequence of T1, T2 and T3. Following standard procedures for response programming investigations (Khan, et al., 2002; Rinehart, Bradshaw, Brereton and Tonge, 2001), participants were instructed to complete the task as fast and accurately as possible using a smooth continuous movement from one target to the next. Sets of 24 trials were completed for the RT and RT + Move response tasks for a total of 48 trials. The intertrial interval was approximately 20 seconds. The presentation order of the response tasks was counter balanced across participants and separated by an interval of approximately four minutes. Statistical analyses of potential order effects for the two movement conditions produced non-significant outcomes for reaction time and standard deviation of reaction time ($p < .05$).

Trials on which the child failed to 'hit' either the felt pad or one or more target keys, responded early, or touched the targets out of order were considered mistrials and were repeated at the end of the trial block. At the conclusion of testing, each child received a small monetary award. The participants completed two tests, one of which was the response-programming test. The second test was conducted as part of another ongoing research project conducted at CBT and did not interfere with performance of the response-programming test. The order of test completion was alternated across participants. An interval of approximately 5 minutes separated the two tests and the test of response programming required approximately 25 minutes to complete.

Analysis of Data

Demographic information relating to age, FSIQ, and SES were separately assessed using a one-way analysis of variance (ANOVA) test, with pairwise comparisons of significant differences being completed using Bonferroni *t*-test procedures. Raw scores for the RT alone, and RT + Move conditions, and movement times taken to move from the RT key to target 1, from target 1 to target 2 and from target 2 to target 3 were examined for outlier scores. A score was discarded if it exceeded 2.5 standard deviations from the mean score for each series of trials. The average number of RT discarded trials for the FAS, PEA and NC groups for the RT alone condition was 0.9, 0.8, 0.8, and for the RT + Move condition the corresponding numbers were 0.8, 0.9 and 1.1, respectively. The average number of discarded movement time trials for the FAS, PEA and NC groups when moving to target 1 were 0.3, 1.3, 0.4, respectively. For movement to target 2 the average number was 0.2, 0.6, and 0.4, whereas for target 3 the average number was 0.1, 0.5, and 0.4 trials. Estimates of internal consistency reliability for trial data were separately calculated for each group. An intraclass coefficient above .80 was used as a criterion to indicate acceptable levels of internal consistency (Nunnally & Bernstein, 1994).

The remaining dependent variables of the experiment were RT, movement time, and standard deviation of RT and movement time. RT was defined as the time between the onset of the visual stimulus and initiation of the response, and movement time was defined as the cumulative time taken to traverse the distance between each target. The standard deviation of RT and movement time was used to provide a comparison of response consistency across groups for each condition. Data were initially analyzed to determine if gender should be included in the main analysis. Results indicated no significant main or interaction effects for this variable and it was not included as between-subject variable.

For the RT and standard deviation of RT analyses, ANOVA procedures were adopted to analyze the data using a 3 (group; FAS, PEA or NC) $\times$ 2 (response condition; RT alone, RT + Move) mixed design. For the movement time and standard deviation of movement time analyses, a 3 (group; FAS, PEA, NC) $\times$ 3 (target; T1, T2, T3) mixed design ANOVA was utilized. For all analyses, age was entered as a covariate. Significant interactions were further examined using one-way ANOVAs in combination with Bonferroni *t*-test post hoc comparisons. For all ANOVAs, assumptions of sphericity and homogeneity of variance were examined using Mauchly's and Levene's tests, respectively. Any violations of sphericity prompted the use of the Greenhouse-Geisser estimate of degrees of freedom and violations of homogeneity of variance invoked post hoc comparisons using Games-Howell procedures. Data were analyzed using SPSS version 14.0. Alpha was set to .05 for all tests of significance.

Results

Demographic Information

Table 1 contains the demographic information for the FAS, PEA and NC groups. Comparisons of group means revealed significantly lower FSIQ for the FAS and PEA groups relative to the FSIQ of the NC group, $F(2,47) = 11.4, p < .01$. There was no difference between the three groups for age, $F(2,47) = .33, p > .05$, or socio-economic status (SES), $F(2,47) = 1.78, p > .05$.

Number of Mistrials

For the RT alone condition the average number of mistrials for the FAS, PEA and NC groups was 0.5, 0.4 and 0.2, respectively, whereas for the RT + Move task, the average

number of mistrials was 1.4, 1.9 and 1.4, respectively. There were no more than five mistrials recorded by any one participant within each response condition.

Internal Consistency

Internal consistency reliability was calculated for RT produced during each trial series for the RT alone and RT + Move conditions as well as the movement time for each series of movements to targets 1, 2, and 3. A summary of the intraclass correlation coefficients for each condition is presented in Table 2. All coefficients exceeded the criterion value of .80, indicative of consistent responses across trials (Nunnally and Bernstein, 1994). Therefore, data were collapsed across trials for all data analysis of the main dependent variables.

Reaction Time (RT)

Mean RT values as a function of group and response condition are presented in Figure 2. Results revealed a significant main effect for group, $F(2,46) = 5.57, p < .01, \eta^2 = .20$, together with a significant group $\times$ response condition interaction, $F(2, 46) = 3.56, p < .05, \eta^2 = .13$. Follow up analyses of the interaction revealed no significant difference among the three groups in RT for the RT alone condition, $F(2,49) = 2.87, p > .05$, although there was a tendency for the FAS subjects to take longer. The mean RT values for this response condition were: FAS ($M = 437.9$ ms, $SE = 46.9$), PEA ($M = 378.2$ ms, $SE = 22.9$) and NC ($M = 378.6$ ms, $SE = 8.6$). However, for the RT + Move response condition, the FAS group ($M = 612.9$ ms, $SE = 70.4$) produced significantly slower RT than either the PEA ($M = 493.5$ ms, $SE = 19.9$) or NC ($M = 476.2$ ms, $SE = 62.4$) groups, $F(2,49) = 6.15, p < .05$. Mean RT values for the PEA and NC groups did not significantly differ.

Standard deviation of RT was used to index variability of response programming and mean group values are presented in Figure 3. The results of the analysis indicated a significant main effect for group, $F(2,46) = 5.54, p < .01, \eta^2 = .19$. Neither the main effect for response condition, $F(1,46) = 0.45, p > .05, \eta^2 = .01$ nor the group $\times$ condition interaction was significant, $F(2,46) = 1.62, p > .05, \eta^2 = .07$. Post hoc analysis indicated that the FAS group ($M = 69.5$ ms, $SE = 7.9$) produced significantly ($p < .05$) greater RT variability than the NC group ($M = 39.8$ ms, $SE = 5.1$), and PEA group ($M = 41.3$ ms, $SE = 5.5$). The NC and PEA groups produced comparable levels of RT variability ($p > .05$).

Movement Time

Movement time data for each group as a function of target number are presented in Figure 4. Data analysis indicated a significant main effect for target, $F(1.16,53.5) = 24.6, p < .0001, \eta^2 = .35$, and group, $F(2,46) = 4.69, p < .05, \eta^2 = .17$, together with a significant group $\times$ target interaction, $F(2.33,53.5) = 3.06, p < .05, \eta^2 = .12$. Examination of the interaction revealed that the FAS group produced significantly slower movement time ($M = 505.74$ ms, $SE = 43.10$) than either the NC group ($M = 364.4$ ms, $SE = 27.7$) or PEA group ($M = 375.8$ ms, $SE = 29.8$), $F(2,49) = 4.13, p < .05, \eta^2 = .15$ on target 1. There was no significant difference between the NC and PEA groups. This pattern of results was repeated for target 2, $F(2,49) = 4.99, p < .01, \eta^2 = .18$, (FAS: $M = 857.4$ ms, $SE = 68.6$, NC: $M = 661.3$ ms, $SE = 44.1$, PEA: $M = 595.5$ ms, $SE = 47.4$), and target 3, $F(2, 49) = 4.22, p < .05, \eta^2 = .16$, (FAS: $M = 1171.2$ ms, $SE = 89.5$, NC: $M = 913.9$ ms, $SE = 57.5$, PEA: $M = 862.8$ ms, $SE = 61.8$). Although the cumulative movement time for the three groups increased with succeeding targets, the interaction effect was due to the FAS group producing disproportionately slower movement time with each target in comparison to the movement times of the NC and PEA groups.

Mean values for variability of movement time as a function of group and target are presented in Figure 5. Main effects for target, $F(1.38,63.5) = 4.95, p < .01, \eta^2 = .10$, and

group $F(2,46) = 3.5$, $p < .05$, $\eta^2 = .13$, were significant, but the group $\times$ target interaction failed to reach significance, $F(2.76,63.5) = 1.02$, $p > .05$, $\eta^2 = .03$. Post hoc examination of the group data indicated that in comparison to variability values for the NC ($M = 46.6$ ms, $SE = 9.2$) and PEA ($M = 49.2$ ms, $SE = 9.9$) groups, the FAS group produced significantly greater movement time variability ($M = 89.6$ ms, $SE = 14.5$). With data collapsed across groups, post hoc testing also revealed that movement time variability significantly increased for each succeeding target. The mean values for targets 1 through 3 were 43.1 ms ($SE = 4.2$), 60.9 ms ($SE = 6.7$), and 81.4 ms ($SE = 9.4$), respectively.

Discussion

The present experiment examined reaction time as a means of isolating the central response processing stage of response programming in children with and without histories of heavy prenatal alcohol exposure. In this regard, our approach substantially differs from previous work focusing on prenatal alcohol exposure, in which traditional RT protocols have been used to investigate dysfunction in response selection (Jacobson et al., 1994). Additionally, our experiment is novel in that we assessed the relation between *in utero* alcohol exposure and movement time, about which little is known in this clinical population.

The study produced several significant results. First, there were no differences in RT between the FAS, PEA and control groups when responding to a single stimulus (i.e., the RT alone condition). While this null effect may be attributable to reduced statistical power associated with relatively small sample sizes, the result is consistent with previous studies reporting comparable reaction time for children with and without prenatal alcohol exposure when the response is simple and requires minimal central information processing (Burden et al., 2005; Simmons et al., 2002). Second, the results revealed significantly slower and more variable reaction time for all three groups when a relatively complex movement was required (i.e., the RT + Move condition). According to response-programming theory, the elevated reaction time reflects additional processing required to program the response. However, our expectation that children with prenatal alcohol exposure would experience disproportionately increased RT relative to control group performance was confirmed only for the FAS group. The PEA group performed at the control group level, which was significantly faster than the FAS group. The findings of delayed response programming for children with FAS are consistent with similar motor programming deficits reported for children with autism and Asperger disorder (Rinehart, et al., 2001), and individuals with schizophrenia (Carnahan, et al., 1997), Parkinson's disease (Stelmach, et al., 1992), Huntington's disease (Jones, et al., 1992), developmental apraxia of speech (Nijland, et al., 2003), and severe traumatic brain injury (Russo, et al., 2005). Third, children with FAS produced significantly longer movement times than the other two groups for all three targets, with the difference between the FAS group and the PEA and NC groups increasing with successive targets. There was no difference in movement time performance between the PEA and NC groups. Previous studies have reported slower movement times for a range of clinical syndromes including Attention-Deficit/Hyperactivity Disorder (Eliasson, et al., 2004), Developmental Coordination Disorder (Ameratunga, et al., 2004), traumatic brain injury (Incoccia, et al., 2004) and Turner's syndrome (Nijland, et al., 2003), and similar to these studies our MT results suggest a link between bradykinesia and impaired functioning associated with heavy prenatal alcohol exposure.

The existing literature regarding RT and RT variability in children prenatally exposed to alcohol is equivocal. For example, RTs for PEA and FAS adolescents (Simmons et al., 2006) and standard deviation of RT produced by PEA and FAS adolescents (Olson et al., 1998) and children (Coles et al., 1997; Conry, 1990) were found to be equivalent to non-alcohol exposed controls. In contrast, RT and standard deviation of RT of infants (Jacobson

et al., 1994) and young children (Burden et al. 2005; Nanson and Hiscock, 1990; Simmons et al., 2002; Streissguth et al., 1995) with histories of prenatal ethanol exposure was significantly slower than control children. It should be noted however, that the increased RT and RT variability observed for the FAS group in the present study occurred when programming was required, whereas previous investigations report RT performance within the context of standard RT or vigilance RT paradigms.

A particularly interesting feature of the results is the dichotomy between the FAS group and PEA group in reaction time and movement time. While these group differences are not unusual (Conry, 1990; Kalberg, 2006), they do contrast with the majority of neurobehavioral studies that report comparable performance levels for the two groups (for a review of literature see Mattson and Riley, 2006). With regard to reaction time, null effects may be related to the use of relatively gross motor tasks that involve several stages of information processing. In this context, any slowed central processing at one stage, say by the FAS group, may be compensated by increased efficiency of processing at another stage, thereby masking the deficit. In contrast, motor tasks assessing a single stage of processing, such as motor programming, may isolate the processing deficit and provide better sensitivity in discriminating between the two alcohol exposed groups. Additional work is needed to evaluate if the number of stages of processing variable impacts performance outcomes.

Our finding that movement time is significantly slower in the FAS children may be related to the teratogenic effects of prenatal alcohol on the CNS and peripheral nervous system (PNS). With regard to the PNS, *in utero* alcohol exposure negatively impacts muscle development (David and Subramaniam, 2005) reduces or delays peripheral nerve myelination (Bichenkov and Ellingson, 2001), and reduces nerve conduction velocity (Avaria, et al., 2004), all of which could negatively impact movement speed. Structural damage to the CNS (Astley, et al., 2009) may compromise executive function, which involves holding a mental image of the planned response in a short-term motor buffer for the purpose of comparison to the ongoing movement (Welsh and Pennington, 1988). When the comparison reveals a discrepancy between the planned and actual movement outcomes, a correction is made at the CNS level and is executed by the neuromuscular system (Smiley-Oyen and Worringham, 2001). If executive function deficits are apparent, as is the case for FAS children (Mattson, et al., 1999), the time taken to complete and execute any online processing could be expected to increase MT.

While these CNS and PNS deficits may account for the slower MT reported for the FAS group, they do not explain the control level MT values for the PEA group. It is possible that behavioral differences between the two groups are based on distinct patterns of neural activity that uniquely mark each group, a notion that has been previously confirmed using neuroimaging techniques (Astley, et al., 2009).

Based on our results, children with FAS will find activities of daily living challenging. Performance of relatively complex movements will be characterized by slower response initiation and completion time. For most tasks these deficits might constitute little more than an inconvenience but for practical tasks in which time is imperative, the slowness in responding could have critical implications. Additionally, the data have implications for clinicians and therapists working with children with FAS. The universal practice of administering rehabilitation exercises to FAS and PEA children is challenged and exercises with greater specificity are suggested. These exercises should focus on reducing reaction time by emphasizing compensatory strategies or reducing the complexity of the response, while movement speed may be improved through resistance training (Dibble, Hale, Marcus, Gerber. and Lastayo, 2009).

In summary, relative to PEA and control children, FAS children experienced significant temporal delays in two domains: response programming time and movement time. The results may be associated with structural CNS deficits and PNS damage observed in the FAS children.

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Figure 1.
Schematic diagram of the apparatus (not drawn to scale)

Figure 2. Average reaction time (RT) + SEM for groups as a function of response condition. FAS subjects took significantly longer RT during the RT + Move condition, compared to both PEA and NC groups.

Figure 3. Standard deviation of reaction time (RT) for groups as a function of response condition. Responses of subjects with FAS were significantly more variable, regardless of response condition.

Figure 4. Cumulative average movement time (+ SEM) for groups as a function of target number. Children with FAS were significantly slower in movement time compared to control groups, which did not differ significantly from one another.

Figure 5.
Standard deviation of cumulative movement time as a function of group and target number.

Table 1

Demographic information by group.

	FAS	PEA	NC
Sex (M:F) (M:F%)	5:4 (55.5:44.4)	9:10 (47.4:52.6)	10:13 (43.4:56.5)
Age (yrs) M (SD)	13.1 (3.3)	13.0 (2.2)	13.6 (2.0)
FSIQ ¹ M (SD)	87.2 (9.9)	90.0 (10.8)	102.3 (9.2)
Hollingshead Score ²	42.1 (8.8)	46.5 (9.2)	49.8 (12.3)
Hand Dominance			
L:R	2:7	4:15	1:21
L:R%	(22.2:77.8)	(21.1:78.9)	(4.5:95.5)
Race n(%)			
African American	1 (11.1)	1 (5.3)	1 (4.5)
Caucasian	7 (77.8)	8 (42.1)	13 (59.1)
Mixed	1 (11.1)	9 (47.4)	6 (27.3)
Hispanic	0 (-)	1 (5.3)	2 (9.1)

¹ Intelligence scores were derived from either the Wechsler Preschool and Primary Scale of Intelligence-Revised or the Wechsler Intelligence Scale for Children-III depending on the child's age at the study entry

² Socioeconomic status was estimated using the Hollingshead Four Factor Index of Social Status (Hollingshead 1975, unpublished data)

Table 2

Internal consistency coefficients for response and movement conditions as a function of group designation.

	FAS	PEA	NC
RT condition	.983	.984	.936
RT + Move condition	.985	.960	.954
Movement to Target 1	.837	.927	.985
Movement to Target 2	.878	.987	.978
Movement to Target 3	.895	.974	.978