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Visual attention in preschool children prenatally exposed to cocaine: Implications for behavioral regulation

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Abstract

The presence of cocaine during the prenatal period disrupts the development of neural systems involved in mediating visual attention; therefore, it is possible that prenatal cocaine exposure results in impairments in visual attention in early childhood. In the current study we hypothesized that preschool children with prenatal cocaine exposure would exhibit difficulties in the disengagement operation of visual attention and in sustaining attention, particularly for targets presented in the right visual field. Fourteen cocaine-exposed children and 20 control children between 14 and 60 months of age were assessed on measures of visual attention, cognition, and behavior. Cocaine-exposed children had slower reaction times on disengagement trials in the second half of our attention task, supporting our hypotheses that impairments in disengagement and sustained attention are associated with prenatal cocaine exposure. There was a trend for slower reaction times to targets presented in the right visual field, but not to targets presented in the left visual field. Cocaine-exposed children also exhibited greater difficulties in behavioral regulation. Overall, our findings suggest that children with prenatal cocaine exposure demonstrate specific impairments in visual attention and behavioral regulation. (*JINS*, 2002, *8*, 12–21.)

Keywords: Cocaine exposure, Visual attention, Children, Neuropsychology

INTRODUCTION

The term "visual attention" is used to broadly describe operations involved in attending to visual stimuli, such as orienting to new objects, disengaging attention from one object to attend to another object, and sustaining attention for extended periods of time. The attention systems of the developing brain may be impacted by prenatal or postnatal insult, and disruption to any of the structures or neural pathways mediating attention may produce a deficit in visual attention operations (Posner, 1988). The present study specifically investigates visual attention operations in preschool children with prenatal cocaine exposure.

Effects of Prenatal Exposure to Cocaine

Children who have been prenatally exposed to cocaine may present with physical (Chasnoff et al., 1989; Doberczak et al., 1988; Eisen et al., 1991; Nulman et al., 1994), neurological (Chasnoff et al., 1989; Doberczak et al., 1988; Frank et al., 1994; Hite & Shannon, 1992), and cognitive problems (Bender et al., 1995; Bendersky et al., 1995; Chasnoff et al., 1989, 1992; Eisen et al., 1991; Graham et al., 1992; Griffith et al., 1994; Heffelfinger et al., 1997; Hurt et al., 1995; Mayes et al., 1993) which vary in duration and severity. Some children exhibit no recognizable disturbances, whereas others are obviously affected. The inconsistencies appear due to variations in the timing and frequency of exposure, as well as the presence of confounding factors such as environmental influences and prenatal exposure to nicotine, alcohol, and other drugs (LaGasse et al., 1999; Tronick & Beeghly, 1999).

When these confounding variables are controlled, cocaine exposure does not appear to produce general intelligence deficits in infants or preschool children (Bendersky et al, 1995; Chasnoff et al., 1989, 1992; Eisen et al., 1991; Hurt et al., 1995; Graham et al., 1992; Griffith et al., 1994; Mayes et al., 1993; Wasserman et al., 1998). However, previous research suggests that prenatal cocaine exposure dis-

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rupts the development of arousal and attention (Chasnoff et al., 1989; Griffith et al., 1994; Heffelfinger et al., 1997; Jacobson et al., 1996; Mayes & Bornstein, 1995; Richardson et al., 1996). In addition, specific neuropsychological difficulties in language and visual motor abilities have been found in several studies (Bender et al., 1995; Davis et al., 1992; Griffith et al., 1994; Heffelfinger et al., 1997). Although these studies have to be interpreted cautiously because of various methodological difficulties, they suggest that the selective neurophysiological actions of prenatal cocaine exposure result in a specific pattern of neuropsychological dysfunction.

These functional deficits may reflect structural alterations in the neocortex. Cortical layers were indistinct in monkeys exposed to cocaine *in utero*, and staining techniques revealed that neurons often did not migrate to appropriate layers (Lidow, 1995). In addition, degenerated neurons and dendrites were observed in the prefrontal cortex of rats (Xavier et al., 1995) and in the anterior cingulate gyrus of rabbits (Jones et al., 1996), both having had prenatal exposure to cocaine. It is important to note that not all cortical and subcortical regions underwent these alterations in neural development; the prefrontal areas appear to be particularly susceptible to the damaging effects of cocaine.

How does cocaine exert a negative influence on the developing brain? In human adults, cocaine acts as a stimulant by specifically binding with a dopamine transporter and blocking the reuptake of dopamine, serotonin, and norepinephrine at post-synaptic terminals, resulting in an increase of monoamine availability in synapses (Fang & Ronnekleiv, 1999; Pitts & Marwak, 1988). Monoamine receptors and transporters are functioning early in embryonic development and reportedly have a synergistic influence on mitosis and synaptogenesis (Fang & Ronnekleiv, 1999; Leslie et al., 1994; Mayes & Bornstein, 1995; Meyer et al., 1996; Santana et al., 1992; Seidler et al., 1995). Cocaine exposure *in utero* leads to early and long term alterations in the number of monoaminergic fibers, receptors, and metabolites in rats (Akbari & Azmitia, 1992; Henderson & McMillen, 1993; Leslie et al., 1994; Lidow et al., 1999; Minabe et al., 1992; Seidler et al., 1995; Stadlin et al., 1995). Therefore, the presence of cocaine *in utero* specifically interferes with monoaminergic systems, providing a hypothetical mechanism for the structural, neuropsychological, and behavioral abnormalities (Akbari & Azmitia, 1992; Mayes & Bornstein, 1995; Meyer et al., 1996; Mirochnick et al., 1991, 1997; Seidler et al., 1995).

Effects on Arousal, Attention, and Emotional Regulation

Monoaminergic systems appear to modulate arousal, attention, and emotional regulation (Mayes & Bornstein, 1995). Several studies provide evidence that cocaine disrupts these abilities during infancy (Eisen et al., 1991; Mayes et al., 1993, 1995). Behaviorally, observational studies of attention have produced inconsistent results. Bender et al. (1995) did not rate pre- and postnatally exposed children as more hyperactive or distractible than control children. However, Griffith et al. (1994) found that cocaine-exposed children had lower scores on the Summative Perseverance Scale, an adapted ratings scale from the Stanford Binet Intelligence Scale that specifically assesses attention. Also, a qualitative evaluation of attention revealed that cocaine-exposed children had difficulty attending to several objects simultaneously (Hawley & Disney, 1992). A goal of the current study was to further define specific aspects of attention that may be affected by prenatal cocaine exposure.

Visual Attention Systems

It is important to understand the mature visual attention systems even though they may be qualitatively different from the developing systems in young children. According to Posner and Petersen (1990), a posterior attention system mediates the reflexive, cognitive operations of disengage, shift, and engage attention, and these operations appear to be mediated by the posterior parietal cortex, the pulvinar and reticular nuclei of the thalamus, and the superior colliculi, respectively. An anterior attention system, involved in awareness, sustained attention, and emotional regulation, consists partly of the anterior cingulate gyrus and its descending/ascending pathways (Corbetta et al., 1993; Posner, 1988). The anterior cingulate gyrus is involved with sustaining attention during difficult voluntary behaviors (Posner, 1988).

In adults, many of the neuroanatomical structures mediating attention receive dopaminergic inputs. For example, the cingulate gyrus has reciprocal dopaminergic connections with the ventral tegmental nucleus via the caudate nucleus of the basal ganglia (Colby, 1991). The basal ganglia also have reciprocal connections with many cortical areas, possibly including the posterior parietal cortex. Therefore, the dopaminergic system may be involved in a regulating loop for selective and sustained attention, possibly implicating attention for the negative influence of prenatal cocaine exposure (Colby, 1991).

Posner's posterior attention network appears to develop early in life as evidenced by functional imaging and developmental studies. The maturation of the parietal lobe to adult levels of activity at approximately four months appears to underlie the ability to disengage visual attention (Chugani et al., 1987; Johnson et al., 1991). Also, 4-month-old infants, but not 3-month-olds, were able to disengage attention and orient to the new stimuli consistently (Johnson et al., 1991).

During development, Craft et al. (1992) and Posner et al. (1984) suggested that anterior neural regions might also be involved in disengagement by regulating the parietal lobe's "allocation" of attention. Craft et al. (1992, 1994) studied children with bilateral perinatal injury to anterior brain regions and children with early-treated phenylketonuria (ETPKU), which disrupts dopamine metabolism and compromises the development of anterior neural structures. Both of these groups experienced difficulties disengaging attention to orient towards targets presented to the right visual field. Disruption of dopaminergic systems or anterior neural structures which rely on dopamine as a neurotransmitter may produce deficits of attention such as these, because, as discussed previously, dopaminergic systems appear to participate in regulating attention in these pathways (Colby, 1991; Heffelfinger et al., 1997; Mayes & Bornstein, 1995; Rothbart et al., 1990). Although tentative, it is possible that anterior neural regions may be necessary for engage and disengage processes in children, along with the superior colliculi and the parietal lobes.

Early development of the ability to sustain visual attention has not been as extensively studied as other visual attention operations even though the disruption of sustained attention is a common symptom in disorders of childhood. Although this ability improves with age, both children and adults demonstrate increasing difficulty in sustaining attention as reaction time tasks progress over time (Weissberg et al., 1990). The ability to sustain visual attention can be compromised by numerous forms of neural injury throughout development, including perinatal injury to anterior brain regions (Craft et al., 1994), prenatal exposure to alcohol (Streissguth et al., 1984), and high lead levels (Needleman et al., 1979).

Several studies of early damage to anterior brain regions have revealed deficient attention to information in the right visual field, suggesting that left anterior structures may be particularly sensitive to early disruption (Craft et al., 1992, 1994). Although the right hemisphere is more involved than the left hemisphere in overall attention processing in adults (Cohen et al., 1988; Corbetta et al., 1993), left cortical regions are necessary for attending to right visual field information (Corbetta et al., 1993). When attention was directed to the left visual field in adults, brain activity was primarily lateralized to the right superior parietal cortex; however, both hemispheres were active when attention was shifted to the right visual field. Although the neural systems mediating attention may be somewhat different in early development, it is possible that early dysfunction of neural systems or structures in the left hemisphere affect visual attention to the right visual field. In addition, prenatal cocaine exposure may result in a lateralized attention deficit because dopamine, which mediates attentional systems, is distributed asymmetrically in the developing brain (Glick et al., 1977; Seidler et al., 1995).

Findings from a preliminary study in our laboratory also indicated that prenatal cocaine exposure disrupts the disengagement of visual attention in toddlers, and the results suggested the possibility of difficulties with sustained visual attention (Heffelfinger et al., 1997). In this study, cocaine-exposed toddlers demonstrated specific visual attention difficulties on a contingency-learning visual attention paradigm (Heffelfinger et al., 1997; Johnson et al., 1991). Cocaine-exposed infants were able to learn the visual contingencies as well as normal controls, but they had slower reaction times towards the end of the task when disengaging attention to detect targets in the right visual field. These results suggested that cocaine-exposed infants did not have difficulties with visual orienting, but with the disengagement of attention and possibly with sustained attention.

The current study attempts to better document sustained attention impairments in preschool children with prenatal cocaine exposure and to replicate findings of disengagement difficulties in preschoolers. Three hypotheses were formulated. First, preschool children who were exposed to cocaine prenatally exhibit difficulties with sustained attention compared to normal control preschool children. Second, in order to replicate findings from the preliminary study, prenatal cocaine exposure will disrupt the ability to disengage attention but not the ability to orient to visual stimuli. Third, deficits in sustained attention and the disengagement of attention will be specific to the right visual field.

METHODS

Research Participants

Fourteen children who were exposed to cocaine prenatally and 20 children who were not exposed to cocaine prenatally were assessed. Ages were between 14 and 60 months. The cocaine-exposed group was recruited through the Women and Infants Safe Escape from Drugs program (WISED) at St. Louis' Regional Hospital. This program provided prenatal care for pregnant women who were using cocaine and other illegal substances. Abstinence was encouraged but not required during enrollment. All of the mothers reported moderate to high cocaine use during the first trimester, however, the majority of these mothers were no longer using cocaine in the third trimester, as documented through urine sampling. The primary inclusion requirement for the cocaine-exposed group was exposure to cocaine during gestation as identified by positive urine analysis for cocaine pre- or perinatally. Children were excluded if exposure to illegal substances other than cocaine or alcohol was reported beyond the first trimester or if they suffered from perinatal complications other than prematurity. Normal control subjects were recruited from the birth registry at Regional Hospital and from the community. Children in the normal control group had no history of prenatal drug exposure or perinatal complications other than prematurity.

Demographic characteristics of each group of children are listed in Table 1. The groups did not differ in mean age at time of testing, gestation age, birth weight, gender, or race. As seen in Table 2, the cocaine-exposed children had slightly lower Verbal IQ scores than normal controls [$t(12) = 1.84$, $p < .09$], although the group means were not significantly different. The groups did not statistically differ in overall cognitive ability, but it is possible that with increased sample size there would be significant group differences in overall cognitive ability.

The mothers of children in our cocaine-exposed and control groups did not differ in maternal age, number of preg-

Table 1. Means and standard deviations of demographic variables for normal control and cocaine-exposed groups

Variable	Normal control *M* (*SD*)	Cocaine exposed *M* (*SD*)
Age in months	38.8 (13.9)	37.0 (15.9)
Birth weight in ounces	115.7 (26.5)	101.7 (26.6)
Gestation age in weeks	39.4 (2.0)	38.6 (3.3)
Mother's age in years	28.8 (5.1)	30.3 (4.3)
Mother's education in years***	13.6 (2.7)	11.7 (.8)

$^*p < .10$, $^{**}p < .05$, $^{***}p < .01$.

nancies, number of children, or level of stress (based on ratings from the Parenting Stress Index). Mothers of cocaine-exposed children had significantly fewer years of education [$t(33) = 2.95$, $p < .01$] and were significantly more likely to smoke cigarettes [$\chi^2(1, N = 34) = 10.26$, $p < .01$]. Twelve of 14 mothers who used cocaine during pregnancy smoked, whereas 6 of 18 mothers of control children smoked. Seven of 14 mothers of cocaine-exposed children and 4 of 20 mothers of control children consumed minimal amounts of alcohol during the first trimester of pregnancy and reportedly refrained from alcohol use thereafter. Three of the cocaine-using mothers but none of the control mothers used marijuana during the first month of the pregnancy. The differences in alcohol and marijuana use were not statistically significant.

Procedures

Subjects participated in a 75-min testing session at Washington University. Mothers received $20.00 for their participation and written feedback about their child's performance on the Bayley Scales of Infant Development, 2nd Edition or the Differential Abilities Scale. Children received juice, cheerios, and stickers during the evaluation. At the end of the session they selected a $2.00 toy. Prior to the testing session, a semi-structured phone interview was conducted to obtain pertinent demographic and medical history information. Standard procedures for obtaining consent were conducted. Mothers were given a certificate of confidentiality, provided by the state of Missouri, stating that drug use would not be reported except under certain circumstances that were explained.

Attention measures

The sustained visual orienting task (SVOT) was designed to specifically assess sustain visual attention as well as the abilities to orient and disengage visual attention. It was administered on a three-monitor computer system as previously described (Clohessy et al., 1991; Heffelfinger et al., 1997; Johnson et al., 1991). Briefly, three 12-inch color monitors were arranged side-by-side on a table at a distance of 1 m in front of the children. The central display had a visual angle of approximately 10°, and each peripheral display was 30° from the middle of the central monitor. A video camera situated above the monitors recorded the children's eye movements. The examiner administered the tasks by watching the video output on a television monitor and controlling stimulus presentation from the computer keyboard.

Two central-fixation designs were presented in a pseudo-randomized order on the central monitor. One design consisted of a green background with colorful spiraling circles and was accompanied by a regular low frequency beat; the other consisted of a blue background with colorful spiraling squares and was accompanied by a tone of increasing frequency. Each spiraling pattern increased in size with time. The target stimuli were presented on the peripheral monitors and consisted of various geometric figures (e.g., diamond with a circle inside).

This task consisted of two types of trials: visual orienting trials and disengagement trials. For the visual orienting trials, a central-fixation design was shown until children oriented to that design. Upon fixation, the central design was removed and a target appeared on one of the peripheral monitors. Children were required to orient toward the peripheral design within 90 video frames (2970 ms). Disengagement trials were identical with the exception that the central design remained present during target presentation and more time was allowed to disengage (150 frames or 4500 ms) because of the increased complexity of the attention operation. If the children did not disengage within the allotted time, the trial was coded as incorrect. The task

Table 2. Means and standard deviations of cognitive test scores for normal control and cocaine-exposed groups

Test score	Normal control	Cocaine exposed
Combined MDI and DAS	90.7 (14.6) ($n = 20$)	84.2 (8.4) ($n = 14$)
Mental Development Index (BSID–2)	95.6 (11.3) ($n = 5$)	85.2 (12.2) ($n = 5$)
General Cognitive Ability (DAS)	89.1 (15.7) ($n = 15$)	83.4 (5.4) ($n = 7$)
DAS: Verbal IQ*	92.7 (14.4) ($n = 9$)	80.0 (6.4) ($n = 5$)
DAS: Nonverbal IQ	95.8 (11.9) ($n = 9$)	88.2 (6.3) ($n = 5$)

Note. Scores are standard scores with a mean of 100 and a standard deviation of 15.
$^*p < .10$, $^{**}p < .05$, $^{***}p < .01$.

consisted of two blocks of 20 trials each. Performance between blocks was compared in order to assess sustained attention. Each block contained 10 orienting trials (5 left targets, 5 right targets) and 10 disengagement trials (5 left targets, 5 right targets) presented in a pseudo-random order. Children were instructed to look at the designs on the computers at the beginning of each block of trials. Parents were asked not to direct children's attention to the designs.

Number of incomplete orienting trials, trials in which children either did not fixate on the central design or did not orient to the peripheral design, were recorded. Disengagement trials were incomplete if children did not orient to the central design or if they looked away from the computers when the peripheral design appeared. Disengagement trials were recorded as correct if children disengaged from central fixation and oriented to the peripheral design; they were incorrect if children were unable to disengage and remained fixated on the central design. Raters who were unaware of group status coded reaction times of eye movements by counting the number of videotape frames (1 frame = 33 ms) from the onset of the peripheral target until the beginning of an eye movement. Values for orienting and disengage trials in each visual field were averaged separately for Blocks 1 and 2 to assess sustained attention and any laterality differences.

General cognitive measures

General cognitive abilities were assessed using age-appropriate measures. The Mental Development Index (MDI) of the Bayley Scales of Infant Development, 2nd Edition (BSID–2; Psychological Corporation, 1993), was administered to children under 30 months of age to assess general cognitive development. The lower preschool level of the Differential Abilities Scales (DAS; Elliot, 1990) was administered to children between the ages of 30 and 42 months; the upper preschool level was administered to children over 42 months old. Both levels of the DAS provided an overall General Conceptual Ability (GCA) score, a Verbal Abilities Score, and a Nonverbal Abilities Score. Because the MDI and the GCA scores are proposed to measure similar skills, standard scores were averaged within each group to compare overall group performances.

Behavioral and psychological measures

Examiners who were blind to group status rated behavior during the assessment with the Behavior Rating Scale of the BSID–2. Each item was rated on a 5-point scale with 5 representing optimal behavior. A total score for each factor was obtained. The Orientation/Engagement Factor represented level of initiative, involvement in tasks, and level of social interaction. The Emotional Regulation Factor incorporated activity level, adaptability, affect, cooperation, persistence, and frustration tolerance. Overall, this factor represented ability to cope with heightened levels of positive and negative emotions.

Mothers completed the Parenting Stress Index/Short Form (Abidin, 1990). Each item referred to potential stressors in the parent/child relationship and was rated on a 5-point scale. Higher scores reflected higher levels of stress. The total score reflected overall level of maternal stress that was related to parenting. Items on the Parental Distress Factor reflected the level of stress that the personality, psychological difficulties, and lifestyle of the parent contributed to the parent-child relationship. The Parental–Child Dysfunctional Interaction factor reflected the quality of the parent/child relationship (i.e., level of attachment). The Difficult Child Factor measured children's temperament and self-regulatory capacity.

RESULTS

Reaction times from correctly completed trials, number of incomplete trials, and number of incorrect trials from SVOT were analyzed using repeated measures analysis of variance (ANOVA). Group (normal control, cocaine-exposed) was the between-subjects variable, whereas visual field and task half were the within-subjects variables. One-way ANOVAs were used for *post hoc* comparisons to facilitate interpretations of significant interactions. *T* tests also were conducted on neuropsychological and behavioral variables to compare group performance. An alpha level of .05 was used for all statistical tests.

Attention

A significant interaction between group and task half was present for reaction time of disengagement trials [$F(1,27) = 7.26$, $p < .05$] (see Figure 1). *Post hoc* analyses revealed significant group differences in the second half of the task [$F(1,32) = 5.24$, $p < .05$]. The cocaine-exposed group exhibited significantly slower reaction times than the control group in the second half of the test, but the groups did not

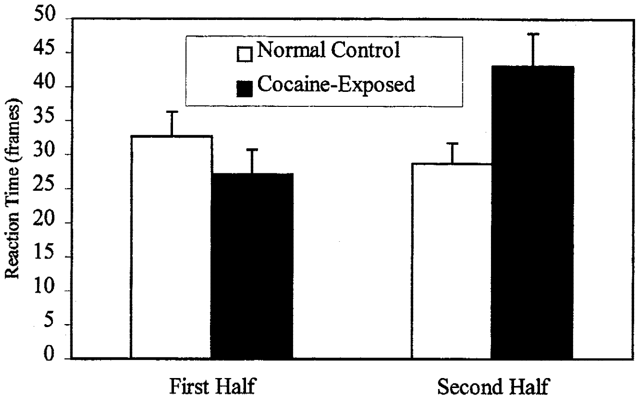

Fig. 1. Mean reaction times for disengagement trials during the first and second half of SVOT. *Note*. Means and standard errors in frames (1 frame = 33 ms). Cocaine-exposed preschoolers were slower to disengage attention in the second half of SVOT, reflecting sustained attention difficulties ($p < .05$).

differ in the first half of the test. In addition, a trend toward a significant interaction between Group × Visual Field was found [$F(1,27) = 4.05$, $p = .054$] (Figure 2), with cocaine-exposed children having slower reaction times to targets in the right visual field.

Both groups completed significantly fewer visual orienting trials [$F(1,32) = 7.66$, $p < .01$] and fewer disengagement trials [$F(1,32) = 9.82$, $p < .01$] in the second than first half of the task. Also, the total sample of children had fewer correct disengagement trials in the second than first half of the task [$F(1,32) = 27.00$, $p < .01$]. No significant interactions or main effects of group were obtained for number of completed visual orienting or disengagement trials, reaction time for visual orienting trials, or number of correctly completed disengagement trials.

Behavior Regulation

Cocaine-exposed children received significantly lower scores on the Emotional Regulation factor of the Behavior Rating Scale (BRS) [$t(28) = 2.93$, $p < .01$]. Ratings for the Orientation/Engagement factor were not different between groups. On the Parenting Stress Index, the total score between groups was statistically different [$t(29) = 2.27$, $p < .05$]. Parents of cocaine-exposed children rated their children's behavior as more stress inducing than did parents of control children [$t(29) = 2.21$, $p < .05$]. Cocaine-exposed mothers also rated the parent-child relationship as being more stressful than did control parents [$t(29) = 2.56$, $p < .05$] (see Table 3).

Table 3. Means and standard deviations for ratings on the behavior rating scale and the parenting stress index

	Normal control	Cocaine exposed
Measure	*M* (*SD*)	*M* (*SD*)
Behavior Rating Scale[a]		
Orientation/Engagement	39.28 (5.7)	34.00 (10.1)
Emotional Regulation***	44.78 (5.1)	37.92 (7.7)
Parenting Stress Index[b]		
Parental Distress	22.4 (7.5)	26.6 (7.8)
Parent/Child Distress**	17.8 (4.7)	23.0 (6.6)
Child Distress**	23.8 (7.4)	30.1 (8.0)
Total Score**	64.2 (17.1)	79.8 (21.0)

Note. Scores are raw scores.
[a]Higher scores indicate better, more appropriate behavior.
[b]Higher scores indicate higher levels of reported stress.
*$p < .10$, **$p < .05$, ***$p < .01$.

DISCUSSION

In this study, cocaine exposure was hypothesized to have a specific influence on visual attention. Specifically, it was proposed that young cocaine-exposed children would have fewer completed trials and slower reaction times during the second half of the SVOT on disengagement trials, reflecting a deficit in sustained attention. Children who were exposed to cocaine prenatally had difficulty maintaining their attention during the second half of the task for disengagement trials, but not for visual orienting trials.

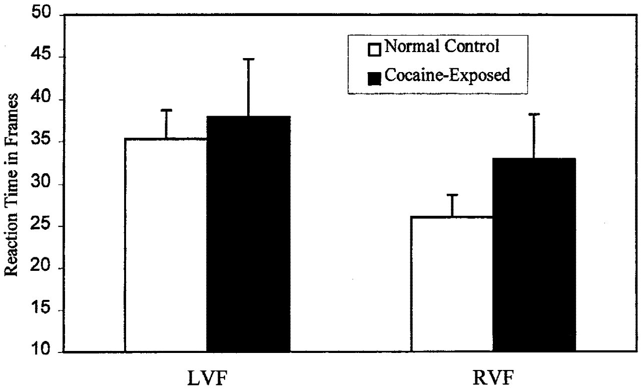

Fig. 2. Mean reaction times towards left and right visual field targets for disengagement trials of SVOT. *Note*. Means and standard errors in frames (1 frame = 33 ms). Both groups were faster to disengage attention towards targets in the right visual field; however, cocaine-exposed preschoolers were slower than normal controls to disengage to the right visual field ($p < .10$).

It is important to note that the SVOT did measure sustained attention in this study, because both groups completed fewer trials in the second than first half of the task, reflecting the natural tendency for sustained attention to diminish over time (Weissberg et al., 1990). It is also important to note that the visual attention abilities of cocaine-exposed group were not generally impaired. This group had (1) as many completed and correct visual orienting and disengagement trials as the control group, and (2) no greater difficulty sustaining attention for visual orienting trials. The groups also had similar reaction times during visual orienting trials in the first and second halves of the task, indicating that the cocaine-exposed children were as fast to orient as controls, even over time. The performance on visual orienting trials suggests that cocaine-exposed children can sustain attention when there are no distractors present and when the demands on attention are limited.

Performance on disengagement trials supported the hypothesis that cocaine-exposed children have difficulties sustaining attention when they must also disengage attention. The cocaine-exposed group was significantly slower to disengage attention during the second than first half of the task, whereas the control group exhibited fairly consistent reaction times in both halves of the test. These results are an extension of our earlier findings suggesting that young children exposed to cocaine are able to disengage attention but take longer to disengage from fixation over time (Heffelfinger et al., 1997).

The findings from the present study provide support for the concept of unique attentional operations, because cocaine-exposed children exhibited deficits specific to the disengagement of attention and sustained attention, whereas visual orienting was relatively intact. In adults, the ability to disengage attention is a specific attentional mechanism that is mediated by the posterior parietal cortex (Clark et al., 1989; Posner & Petersen, 1990). However, prenatal cocaine exposure acts on developing attention systems that may include the neural structures of the mature brain, including the posterior parietal lobe, but also on systems involving anterior brain regions which only may be part of this attentional system during development (Craft et al., 1994; Lidow, 1995). Sustained attention may also be mediated by the anterior attention system that involves the anterior cingulate gyrus and its reciprocal pathways (Corbetta et al., 1993; Posner, 1988). Prenatal cocaine exposure specifically impacts the development of prefrontal structures and neural systems (Akbari & Azmitia, 1992; Mirochnick et al., 1991; Seidler et al., 1995). Hypothetically, it is possible that prenatal cocaine exposure exerts its influence on these structures and systems by altering the catecholaminergic systems and particularly dopaminergic systems, resulting in impaired disengagement of attention and sustained attention.

Lateralized Attention Deficits

Cocaine exposure during prenatal development possibly produces a lateralized deficit in attention because dopamine is distributed asymmetrically in the brain (Castellano et al., 1989; Glick et al., 1977; Seidler et al., 1995). It was hypothesized that, over time, cocaine-exposed children would exhibit impaired attention to targets in the right visual field (Heffelfinger et al., 1997). The results of the present study provided partial support for this hypothesis. On disengagement trials, both groups disengaged faster towards right visual field targets than left visual field targets; but cocaine-exposed children were slower to disengage attention towards targets in the right visual field than were control children. There were no lateralized differences on visual orienting trials or in sustained attention. The patterns of performance on disengagement trials again suggests that prenatal cocaine exposure specifically affects the neural structures and systems that mediate disengagement. It is possible, therefore, that the lateralization of disengaging behaviors in cocaine-exposed children, independent of visual orienting behaviors and sustained attention, is due to the lateralization of attentional networks.

Behavioral and Emotional Functioning

Mayes and Bornstein (1995) suggested that cocaine exposure disrupts the development of dopaminergic pathways that are involved in arousal and emotional regulation. In the present study, examiners rated cocaine-exposed children as having difficulty regulating arousal, attention, and affect. These results suggest that cocaine-exposed children had more difficulty regulating their emotional states and adapting to novel situations. The regulation of behavior, emotion, and attention are interconnected, and may involve anterior neural systems possibly including the anterior cingulate gyrus and its dopaminergic connections (Derryberry & Rothbart, 1988; Posner & Rothbart, 1998). Although speculative, the behavioral difficulties often observed clinically in cocaine-exposed preschool children may be systemically and functionally related to the difficulties in visual attention.

Impact on Temperament

Dysregulation of behavior, affect, and attention are revealed in young children through their temperament (Derryberry & Rothbart, 1988). Temperament has been defined by individual differences in attention, affective expressiveness, motor activity, soothability, and self-regulation (Alessandri et al., 1993). Cocaine-exposed infants often have undesirable temperament characteristics. Alessandri et al. (1993) showed that they are susceptible to distress, have low frustration tolerance, and are hyperirritable. However, these infants were not necessarily overly active. In fact, they often exhibited signs of hypoarousal. Results of the present study also suggest that cocaine-exposed children have impaired abilities to regulate arousal and maintain attention.

Difficult temperament in young cocaine-exposed children can lead to disorganized expression of emotion and behavior disregulation, which strongly influences the parent/child relationship (Mayes & Bornstein, 1995). In the present study, parents indicated that the temperament of cocaine-exposed children and the parent/child dyad produce high levels of stress on the parent. Parents have to work harder than most to provide their children with inspiring and comfortable environments, and parents with weaker attachments to their children may be less likely to provide this adaptive environment. Therefore, cocaine-exposed children may be involved in less intimate and less stimulating relationships with their mothers, which might lead to greater difficulties with self-regulation of attention, behavior, and affect.

Limitations and Future Studies

The conclusions from this study are limited by several factors, some of which are inherent in all research with populations having prenatal risk factors such as drug exposure. The potential confounding factors of the possible difference in groups between cognitive abilities, the fewer years of maternal education, and exposure to nicotine and alcohol were the most significant limitations to this study. Carmichael Olson et al. (1995) found that only 10 out of 7112 women who used cocaine during pregnancy reported no other nicotine, alcohol, or illicit drug use, suggesting that it is nearly impossible to find a sample of children exposed only to cocaine. In the present study, almost all of the cocaine-using mothers reported nicotine use and about half reported alcohol use. It is unknown whether nicotine, alcohol, and cocaine act on similar developmental systems or influence separate systems. It is clear, however, that the results of the present study need to be interpreted cautiously due to these confounding variables and in terms of polydrug use, not solely cocaine use.

Future studies of the impact of cocaine on the developing system need to control for confounding factors such as maternal polydrug use. One possible solution is to have one control group and three clinical groups consisting of (1) children who were prenatally exposed to nicotine, (2) children who were prenatally exposed to alcohol, and (3) children who were prenatally exposed to cocaine, nicotine, and alcohol. With this model, the individual effects of nicotine and alcohol exposure can be compared to the effects of nicotine, alcohol, and cocaine exposure to determine whether deficits and developmental delays are qualitatively similar. It is also essential to better determine the time window during pregnancy in which these visual attention difficulties occur. In the current study, mothers who used cocaine used moderate to high amounts during the first trimester. Most of these mothers were abstaining by the third trimester, suggesting that the possible insult on attention systems occurs earlier rather than later in pregnancy. Further investigation of the timing would both assist in prevention and treatment, as well as increasing our understanding of the development of visual attention operations *in utero*. Finally, an additional question for future exploration is whether cocaine exposure is selective to visual attention or also impacts the development of auditory and tactile attention.

Conclusion

The abilities to disengage and sustain visual attention are impaired in children prenatally exposed to cocaine. It is likely that cocaine exposure disrupts the development of neural systems that mediate visual attention. Cocaine exposure may also disrupt the lateralization of the brain. It is unclear whether deficits in visual attention reflect a delay in development or will continue to be apparent throughout development. It is clear, however, that preschool children who have been prenatally exposed to cocaine experience impairments in the disengagement operation of attention and in sustained attention. In turn, it is possible that these impairments are related to poorer temperament and parent–child relationships.

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