EXPRESSIVE LANGUAGE DEVELOPMENT OF CHILDREN EXPOSED TO COCAINE PRENATALLY: LITERATURE REVIEW AND REPORT OF A PROSPECTIVE COHORT STUDY

VIRGINIA DELANEY-BLACK
Department of Pediatrics, School of Medicine, Wayne State University, Detroit, Michigan

CHANDICE COVINGTON, THOMAS TEMPLIN, and TRACE KERSHAW
College of Nursing, Wayne State University, Detroit, Michigan

BETH NORDSTROM-KLEE
Department of Pediatrics, School of Medicine, Wayne State University, Detroit, Michigan

JOEL AGER
Center for Healthcare Effectiveness Research, School of Medicine, Wayne State University, Detroit, Michigan

NIKILIA CLARK and ARVIND SURENDRAN
Department of Pediatrics, School of Medicine, Wayne State University, Detroit, Michigan

SUSAN MARTIER and ROBERT J. SOKOL
Department of Obstetrics and Gynecology, School of Medicine, Wayne State University, Detroit, Michigan

It was hypothesized that prenatal exposure to cocaine and other substances would be related to delayed expressive language development. Speech and language data were available for 458 6-year olds (204 were exposed to cocaine). No significant univariate or multivariate differences by cocaine exposure group were observed. Classification and regression tree modeling was then used to identify language variable composites predictive of cocaine exposure status. Meaningful cut points for two language measures were identified and validated. Children with a type token ratio of less than 0.42 and with fewer than 97 word types were classified into a low language group. Low language children ($n = 57$) were more likely to be cocaine exposed (63.1%), with cocaine-exposed children 2.4 times more likely to be in

Address correspondence to Virginia Delaney-Black, M.D., M.P.H., Children's Hospital of Michigan, 3901 Beaubien, Detroit, MI 48201. Tel.: 313-745-5638; Fax: 313-745-5867; E-mail: <vdelaney@med.wayne.edu>.

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the low language group compared with control children after adjustment for covariates. Prenatal cigarette, but not alcohol exposure, was also significantly related to expressive language delays. © 2000 by Elsevier Science Inc.

Educational Objectives: The reader will (1) acquire knowledge of the existing literature addressing the effects of prenatal cocaine exposure on child language development; (2) develop an understanding of the need for large, well-controlled studies in identifying a link between prenatal cocaine exposure and child language outcomes; (3) acquire knowledge of different statistical techniques available for looking at the effects of prenatal exposures on child behavior; and (4) understand how prenatal cocaine and cigarette exposure predict language development.

KEY WORDS: Cocaine exposure; Language development; Teratogens

INTRODUCTION

At the beginning of the 1990s, reports in the lay literature warned of dire and pervasive educational failure among children exposed to cocaine prenatally ("Newborns and addiction," 1992; Toufexis, 1991). Educators worried that the cocaine epidemic would flood the American school system with children requiring special services (Barth, 1991). Indeed, case reports from both the medical and educational literature did suggest that children exposed to cocaine prenatally had specific language problems (Davis et al., 1992). However, although neonatal and infancy effects of prenatal cocaine exposure have been identified, limited data were available to address the areas of childhood speech and language skills scientifically (Choteau, Namerow, & Leppert, 1988; Little, Snell, Klein, & Gilstrap, 1989; Volpe, 1992). This report reviews the limited literature addressing the effects of prenatal cocaine exposure on child language development. Additionally, the results of a large prospective cohort study are also reported.

Literature Review

One of the first authors to address the issue of prenatal cocaine exposure and children's language development with a study design (not case report) was van Baar (1990). The 35 children tested before age 3 years had experienced multiple drug exposures, predominantly to heroin. However, included in the drug-exposed group were 22 children whose mothers had used cocaine during pregnancy. A control group of 37 term children from the same neighborhoods were also identified at birth. Unfortunately, the small sample consisted both of native Dutch and immigrant families (predominantly Surinamese). Although the investigator found a cocaine effect on language (Bayley, 1969), no correction was made for many of the possible confounding variables. Separate stratified analyses were used for both country of origin and prematurity, however, this procedure would have adversely affected the already small sample size.

Furthermore, stratification was not an adequate procedure to control for prematurity, because no control children were premature. Finally drugs, alcohol, and other important covariates were not evaluated.

Other important covariates were considered in the case-control study from Angelilli et al. (1994). Twenty-nine consecutive children with language delay were identified from an urban primary care clinic during a 1-year period. Language delay was described as a dichotomous variable defined by the attending physician. No additional standardized testing was performed. The children were matched (2:1) with a child of similar age seen on the same day as the index child. Discriminate analysis was performed with control for a variety of antenatal and postnatal variables (including age, race, gender, insurance status, hearing tests, growth parameters, gestational age, caretaker, and prenatal alcohol and nicotine exposure). Both prenatal cocaine and nicotine were associated with language delay.

Bland-Stewart, Seymour, Beeghley, and Frank (1998) used a number of language outcome measures to test their hypothesis that prenatal cocaine exposure would be associated with delays in semantic development. The authors reported the results of this testing battery for 22 children (11 cocaine exposed and 11 control children) at age 2 years. Control and comparison children did not differ on significant covariates, and testing was performed without knowledge of the child's exposure status. As predicted, the cocaine-exposed group did have delayed semantic development. The authors suggested caution in the interpretation of their results because of their inability to control for prenatal exposure to either alcohol or nicotine. However, Green, Ernhart, Martier, Sokol, and Ager (1990) were unable to show a relation between prenatal alcohol exposure and child language at age 2 years.

Bender et al. (1995) attempted to control for current drug use by selecting three groups of children aged 4 to 6 years: 18 were exposed to drugs prenatally, 28 were currently being exposed (but not prenatally), and 28 were neither prenatally nor currently exposed to maternal drug use. Receptive language was measured by adding points earned by each child for following commands. These items were compiled from standardized measures, but no full measure was administered. A standardized measure of expressive language was used. Even though significant differences were identified for a variety of prenatal, neonatal, and postnatal factors, the multivariate analyses of variance evaluating language outcomes controlled only for gender and age. Receptive but not expressive language was delayed in the group prenatally exposed to cocaine.

Another technique for reducing the effects of the postnatal environment on language development was used by Johnson, Seikel, and Madison (1997). In their study, 24 children with a history of multiple prenatal drug exposures (including cocaine) were matched to a nonexposed group. Language testing was performed from 14 to 50 months of age. All but two of the cocaine-exposed children had been placed in foster care, primarily (n = 20) at birth. Most had remained in the same foster home, and none of the children were currently be-

ing exposed to drugs. The Sequenced Inventory of Communicative Development (Hendrick, Prather, & Tobin, 1984) and either the Bayley Scales of Infant Development or the Peabody Picture Vocabulary Test (Dunn & Dunn, 1981) were administered without knowledge of the child's group membership. Both expressive and receptive skills were lower for the cocaine-exposed group. Bayley Scale scores and the Peabody Picture Vocabulary Test scores were lower for the cocaine-exposed group, but only the Bayley scores reached statistical significance. However, no control was introduced for prenatal alcohol or cigarette exposure. A follow-up study by the same investigative team of 50 children (25 exposed) at 22 to 51 months of age found more phonologic delays in audiotaped language samples from the cocaine-exposed group.

One of the few studies able to control for the postnatal environment of the child prenatally exposed to cocaine was reported by Nulman et al. (1994) from an adoption study. The 21 cocaine-exposed adoptive children were matched with an unexposed child. Maternal verbal ability (adoptive mothers in the cocaine-exposed group and biologic mothers in the control group) was also measured. An analysis of covariance, controlling for the number of siblings in the home, revealed delays in expressive language related to cocaine exposure. No control was made for the significant differences in prenatal cigarette exposure and no information was provided regarding prenatal alcohol exposure.

The importance of the postnatal environment cannot be overestimated. When children remain in a drug-abusing environment, language skills suffer. In a study of 21 children (ages 29–70 months) whose mothers attended a drug treatment program, 60% had serious language delays. These delays increased with the child's age, even when prenatal exposure was denied (Malakoff, Mayes, & Schottenfeld, 1994).

In contrast to these reports of the effects of prenatal and postnatal exposure on speech and language and to reports from speech pathologists (Rivers & Hedrick, 1998), Hawley, Halle, Drasin, and Thomas (1995) and Hurt, Malmud, Betancourt, Brodsky, and Glannetta (1997) reported no alterations in language development related to prenatal cocaine exposure in their samples (n = 25 and 76 participants, respectively).

In summary, much of the available literature reports small sample size, few controls for prenatal exposure, and even fewer controls for postnatal variables. No previous studies were available that also identified child lead levels. Furthermore, prior studies do not report how mental retardation was distinguished from true language problems.

Prospective Cohort Study

In the current study, two hypotheses were formulated and tested. We first hypothesized that prenatal exposure to cocaine would be associated with decreased speech and language skills as measured by the Arizona Articulation

Proficiency Scales and a spontaneous language sample that assessed both vocabulary and use of complex syntax. Second, we proposed that additional prenatal exposures (alcohol and cigarettes) as well as postnatal risk factors (child whole blood lead levels) would also account for significant amounts of speech and language variance.

METHODS

Participants

The study was a historical prospective. Beginning in 1986, women attending our urban, university-based maternity clinic were routinely screened at their first prenatal visit for alcohol and drug use by trained research staff as part of an National Institute on Alcohol Abuse and Alcoholism-funded prospective study. Sampling for study entry was rectangular. In other words, all women who admitted drinking around the time of conception at a level of more than 0.5 ounces of absolute alcohol per day were admitted to this study, along with approximately 5% of those who admitted to drinking less or were abstinent. A block design was used to avoid cohort effects. Further, among the light alcohol users, a specific group of women who admitted cocaine use but denied alcohol use was admitted to the study. This was done to ensure our ability to separate potential effects of alcohol and cocaine. Using this recruitment strategy, a sample of heavy alcohol users, light alcohol users, and abstainers containing persons who did and did not use cocaine and other drugs and those who smoked and did not smoke was assured. The study screened all women receiving prenatal care at the university health center, more than 20,000 pregnancies, with 300 to 500 women enrolled each year. More than 90% of women seeking prenatal care services at this center were African American. Given inadequate representation of other racial groups, the study sample was limited to African American women.

This study sample included singleton children (born from September 1, 1989 through August 13, 1991) to consecutive mothers prospectively enrolled in the Fetal Alcohol Research Center study. These participants had been extensively screened during pregnancy by research staff for tobacco, alcohol, cocaine, and other drug use, and, as clinically indicated, maternal and infant drug testing was performed. Because of the recruitment criteria for prospective prenatal assessment of drug and alcohol exposure, women with no prenatal care were excluded from study. Additional exclusions from the current report included women who were known to be HIV positive or who delivered a child with major malformations or neurosyphilis. At the time of this assessment (6 years later), families were contacted by telephone, mail, or home-visit to the last known address. The client files of all the university-affiliated hospitals (six Detroit-based institutions), the pediatric ambulatory service, and the

major internal medicine provider for the university were searched for updated contact information. Telephone numbers and state driver's license numbers were also searched. Additionally, children were sought through the private and public school systems and through an advertisement in a community-based newspaper. The 665 families who were located represent the potential study sample for this report.

Exposure Variables and Covariates

Prenatal cocaine exposure was considered positive if any of the following were positive: maternal pregnancy history (obtained either from the prospective structured research interview during pregnancy or admission of cocaine use at delivery), maternal urine, infant urine, or infant meconium. Meconium analyses were performed only at the end of the recruitment period. Additionally, 13 families retrospectively admitted to cocaine use during the study pregnancy at the time of the 6-year follow-up interview. These children were also considered to be cocaine exposed.

Because prenatal alcohol exposure has previously been associated with language problems, alcohol exposure assessed by prospective pregnancy history was evaluated (Autti-Ramo, Gaily, & Granstrom, 1992; Mattson & Riley, 1998). Alcohol consumption was ascertained for the 2-week period preceding conception and for the 2 weeks preceding each prenatal visit. Interviews were conducted for each period using a day-by-day inquiry. Each cocktail, beer, glass of wine, or wine cooler was converted to ounces of absolute alcohol by multiplying the quantity by 0.4, 0.04, 0.2, or 0.05, respectively. Ounces of absolute alcohol consumed during each period was then calculated to obtain an estimate of the absolute alcohol consumed per day across pregnancy (*AA/Day*). Because the distribution of the alcohol intake was not normal, alcohol intake was expressed as the log of $AA/Day + .01$.

Previous investigators have also identified a significant, negative effect of prenatal exposure to cigarettes on both child IQ and language (Autti-Ramo, Gaily, & Granstrom, 1992; Makin, Fried, & Watkinson, 1991). In this study, cigarette exposure was prospectively identified during the first prenatal visit. The trained research assistant queried the mother for the number of cigarettes smoked during the pregnancy. An interval-level variable of cigarettes per day was then constructed.

Additionally, researchers have realized for decades that children exposed to lead at high doses are at risk for mental retardation and behavioral problems (Needleman et al., 1979). The related questions of whether low-level lead exposures place children at risk for learning and language disorders and other biomedical problems, and if so, what levels of lead are considered unsafe, are matters of continuing concern (U.S Department of Health and Human Services, 1991). Before 1970, significant blood lead levels were defined as levels

more than 60 ug/dl. In 1971, the threshold for blood lead levels considered unsafe was reduced to 40 ug/dl. This threshold was subsequently reduced to 25 ug/dl, and the Centers for Disease Control now states that levels as low as 10 ug/dl may be associated with adverse biomedical outcomes, and that perhaps no blood lead levels can be considered harmless (Centers for Disease Control, 1991). Recent studies have suggested that blood lead levels once considered safe, and that may be asymptomatic, are associated with decreased intelligence and impaired behavioral development, as well as reading disabilities, deficits in vocabulary, problems with attention, and lower class ranking (Needleman & Gastonis, 1990).

Previous investigators also have identified a relationship between a variety of postnatal and family characteristics, and alterations of speech and language (Greene, Ernhart, Martier, Sokol, & Ager, 1990). Significant predictors from previous studies were examined in this study to select a list of potential covariates (listed in Table 1). Parent (biologic mother or, when unavailable, primary caretaker) verbal ability was measured with the Peabody Picture Vocabulary Test—Revised (Dunn & Dunn, 1981). Family socioeconomic status was determined with a four-factor Hollingshead (1975). Child IQ was measured with the Wechsler Preschool and Primary Scale of Intelligence—Revised (1989).

Outcomes

Two methods of evaluating language, a proficiency scale and the coding of a language sample, were used in an attempt to enhance the likelihood of assessing the child's true language abilities. The first involved presentation of a

Table 1. Variables Predicting Speech and Language

Variables
Specified in hypothesis
Prenatal cocaine
Prenatal alcohol
Prenatal cigarettes
Whole blood lead level (age 6 yrs)
Additional covariates
Age of the child
Socioeconomic status (Hollingshead)
Child gender
Current drug use around the child
Intervention services/protective services
Violence exposure (Things I Have Seen and Heard)
Caretaker's marital status
Custody status
Language tester
Mother's verbal ability (Peabody Picture Vocabulary Test–Revised; Dunn & Dunn, 1981)

standardized test of speech sound development. The other involved collection and analysis of a spontaneous sample of spoken discourse during naturalistic play interactions. The latter is the most widely used context by researchers and clinicians for assessing oral language production skills and is particularly recommended for culture-fair assessments of minority language users. A number of well-established metrics of language growth can be derived from spontaneous language samples and are well suited to computer-generated computations that facilitate scoring accuracy. Both components were audiotaped in a random order for later transcription. The second edition of the Arizona Articulation Proficiency Scale (AAPS; Fudula & Reynolds, 1986) was administered to each participant. This scale is appropriate for children age 1 year and 6 months through 13 years and 11 months. Washington and Craig (1992) demonstrated its usefulness with a comparable low-income sample of African American children. The AAPS consists of 48 simple line drawings depicting common objects and assesses articulation as well as consonant and vowel production. A trained female assistant administered both the AAPS and the language sample during a 30-minute session. An independent study of interrater reliability of the AAPS conducted at the University of Oregon for children tested in grade 1 had an interrater reliability coefficient of 0.95 with a range of 0.90 to 0.99. Internal consistency reliability coefficients were very high, ranging from 0.77 to 0.94, with a median reliability coefficient of 0.89 (Fudula & Reynolds, 1986).

Language samples were collected using a dyadic interaction in a clinical setting. The examiners prompted the child with questions or comments that would require more than single word answers. The examiner encouraged the child to make more comments by avoiding attempts to fill empty space using “um” or “ah.” Duration of the language samples was restricted to 20 minutes by using a digital stopwatch. In an attempt to control for interest levels, each child was presented three toy sets: a Barbie and the Pizza Hut station, Batman and Robin action figures, and Lego blocks. Children were allowed to select only one for play. During the spontaneous play sample, both the children as well as the examiner wore individual microphones.

The language samples were transcribed verbatim by a single trained language transcriber using the CHAT transcription system, the standard transcription system for the Child Language Data Exchange System (MacWhinney, 1994). The transcriber was also familiar with African-American English. Although each free-play language sample was 20 minutes in length, only the last 15 minutes of each sample was transcribed to allow for tester–subject adjustment during the initial 5 minutes of recording. Transcription reliabilities were established for all children. Ten percent of each transcript was retranscribed by an independent reviewer. A point-to-point comparison at the level of morpheme was made between the original transcript and the verification transcript. The reliability rate was defined as the number of agreements be-

tween the transcription and the verification divided by the number of agreements plus disagreements. Initial interrater reliability averaged well over 80%. However, when the 80% interrater reliability was not reached for any given transcript, the transcription process was repeated.

Transcripts were segmented into communication units (C-units) produced by each child. A C-unit was defined as a complete thought minimally containing one subject and one verb. Segmentation between C-units was determined both by inflection and pause duration. Communication units containing words or phrases that were unintelligible were not scored, nor were C-units that did not express a thought or an idea (i.e., “um” or “uh”). A 50 C-unit sample was then isolated from the remaining intelligible C-units and scored. The variables recorded, described below, are listed in Table 2.

The type token ratio (number of word types per number of words) is a measure of vocabulary in the form of lexical diversity. The number of turns indicates the number of times throughout the sample that the child spoke noncontinuously (a child’s comment or turn is terminated when the tester speaks). The ratio of utterances over turns measures the number of complete ideas expressed by the child during each turn taken. To evaluate tester effects on the language sample, each transcript was also coded with the tester identity.

After transcription completion, transcripts that did not reach 50 C-units for scoring were retranscribed to include the initial 5 minutes of the language sample. Transcripts that were still below 50 C-units were transcribed and the number of C-unit counts was recorded.

Training of the testers, transcribers, and data entry personnel were all supervised by a speech and language consultant. Periodically, randomly selected language tapes were reviewed. The consultant’s comments were continuously incorporated into the testing procedure.

RESULTS

Six hundred sixty-five families were contacted, with 94% agreeing to participate. However, 58 families who initially agreed to participate did not keep multiple appointments and were later eliminated from the sample. A comparison of maternal and neonatal characteristics of children not able to be tested

Table 2. Variables Collected from Language Sample

Variables
Total number of words (tokens)
Total number of word types
Number of different word types:number of words (type token ratio)
Number of turns
Number of words per number of turns (mean words per turn)
Number of utterances per number of turns (mean number of complete ideas per turn)
Number of words and number of utterances (mean length of utterance)

Table 3. Comparison of Tested and Nontested Children on Relevant Background Variables

	Not Tested (n = 103)	Tested (n = 560)	Significance
Pregnancy data			
Maternal age (yrs)	24.0 ± 6.3	25.8 ± 6.4	0.018
Cigarettes per day	6.5 ± 9.0	8.4 ± 9.7	0.067
Ounces of absolute alcohol per day	0.19 ± 0.52	0.16 ± 0.39	0.070
Abruptio placenta	2.3%	0.4%	NS
Syphilis	14.0%	4.2%	0.005
Neonatal data			
Birth weight (grams)	3024 ± 552	2992 ± 636	NS
Birth length (centimeters)	48.6 ± 2.6	48.4 ± 3.7	NS
Birth head circumference (centimeters)	33.5 ± 1.7	33.4 ± 2.1	NS
Gestational age (wks)	38.6 ± 2.5	38.6 ± 2.7	NS
Apgar 1 minute (median)	8 ± 1	8 ± 2	NS
Apgar 5 minutes (median)	8 ± 1	9 ± 1	NS

Numbers represent means and standard deviations except where indicated. Significance values are for *t* tests or for chi-square tests in the case of nominal data.

with those tested appears in Table 3. Significant differences were present for maternal age and history of syphilis. There was also a nonsignificant trend toward lower alcohol intake and higher cigarette exposure for those tested.

As in previous studies, women who used cocaine during pregnancy had multiple risk factors (Table 4). These women were older and used more alcohol, cigarettes, and marijuana during the index pregnancy than control mothers. A trend was evident for mothers in the control group to have more hypertension and diabetes, and more mothers in the exposed group had syphilis. Additionally, at birth the cocaine-exposed children were smaller and had shorter gestational periods. Exposed infants did not differ from children on 1- or 5-minute Apgar scores. At the 6-year follow-up, exposed children were less likely to be in the care of their mother; however, the marital status of the primary caretaker at follow-up did not differ between groups, and few mothers in either group were married. No difference between exposed and control mothers on education status or income was evident. For both groups, the mean years of education was less than a high school diploma and the mean income was less than $20,000.

Because mental retardation can be a primary cause of language delay, 31 children (15 cocaine exposed) who were mentally retarded (performance IQ $<$ 65) were excluded from further analysis. Of the remaining 525 children, language samples were not recorded for 48 children. The absence of a language sample was related both to tester and children problems including limited testing time available for the child, equipment failure, and the absence of a female, African-American play-sample trained research assistant on some study

Table 4. Comparison of Cocaine-Exposed and Control Children on Maternal, Neonatal, and Follow-up Characteristics

	Control Children (n = 272)	Cocaine-Exposed Children (n = 186)	Significance
Pregnancy data			
Maternal age (yrs)	23.5 ± 6.6	28.3 ± 4.9	< 0.001
Cigarettes per day	5.2 ± 8.2	12.3 ± 9.6	< 0.001
Ounces of absolute alcohol per day	0.07 ± 1.4	0.25 ± 0.56	< 0.001
Marijuana use	20%	57%	< 0.001
Hypertension	9.3%	5.0%	0.085
Abruptio placenta	0%	1%	0.100
Diabetes	4%	1%	0.045
Syphilis	1%	7%	0.001
Neonatal data			
Birth weight	3129 ± 592	2822 ± 638	0.001
Birth length	49.2 ± 3.2	47.5 ± 3.5	< 0.001
Birth head circumference	33.7 ± 1.9	32.9 ± 2.3	< 0.001
Gestational age (wks)	39 ± 2	38 ± 3	0.001
Apgar 1 minute (median)	8	8	NS
Apgar 5 minutes (median)	9	9	NS
Data age 6			
Income (dollars/yr)	15,000–19,900	15,000–19,900	NS
Marital status (married)	27%	25%	NS
Parent education (yrs)	11.5 ± 1.7	11.7 ± 1.7	NS
Biologic mother is caretaker	91%	71%	< 0.001
Parent reports current drug exposure	12%	20%	0.016
Child/parent reports current drug exposure	26%	35%	0.046
Socioeconomic status (Hollingshead)	29.9 ± 10.1	28.9 ± 9.8	NS

Numbers represent means and standard deviations except where indicated. Significance values are for *t* tests or for chi-square statistics in the case of nominal data.

days. Additionally, 14 tapes were unintelligible, and five children did not complete the Arizona Articulation Proficiency Scale. There was, however, no significant relationship between prenatal cocaine exposure and failure to obtain a language sample. Among cocaine-exposed children, 86% of children had a language assessment that could be transcribed ($n = 204$), whereas 90% of the control children ($n = 289$) had usable data.

Although transcripts that did not reach 50 C-units for scoring were retranscribed to include the initial 5 minutes of the language sample, some transcripts still remained below the 50 c-units. These 35 recordings were transcribed and the number of C-unit counts was recorded. There was no relationship between tapes with inadequate C-units and child IQ or cocaine exposure status.

Relationships between the speech sample variables and maternal ability (Peabody Picture Vocabulary Test—Revised) and child IQ (verbal and performance) were evaluated. The mother's verbal ability was significantly related to the total number of word types and the length of the utterance ($r = .10$ and .09, respectively). The child's performance IQ was unrelated to any of the language sample variables. However, the child's verbal IQ and the AAPS were related to the same three language sample variables: the total number of word types, the length of the utterance, and the total number of words. The rank order of the correlations was the same for both the verbal IQ and the AAPS. The AAPS was also significantly related to the number of C-units.

Analyses were also carried out to examine the relationships between the speech and language variables and the remaining potential covariates listed in Table 1. Child age, current drug use in the home, and caretaker marital status were not significantly related to any of the language variables. Child gender, socioeconomic status, and custody change were all significantly related to most of the language variables, with receipt of early services and violence exposure related to only two language variables each. Both *t* tests without covariates, as well as regressions including covariates, were then carried out to examine the relationship between cocaine exposure status and the speech and language variables. In all cases, differences did not reach statistical significance (see Table 5 for *t* test results).

An attempt was then made to determine if any composite of the speech and language variables would discriminate exposure status. Linear Discriminant Function analysis produced no significant discriminate functions. Classification and regression tree analysis (CART; SPSS Answer Tree module), using both tree growing and pruning was then used to identify potentially meaningful cutoff points in the language variables for use in predicting cocaine exposure status. This technique, which involves recursive partitioning and resampling, produced a meaningful classification based on the combination of number of different types of words and the type token ratio. The sample ($n = 458$) was randomly divided into two subsamples: a derivation or training sample ($n = 214$) and a validation or testing sample ($n = 244$). For both samples, cocaine exposure was considered the outcome variable in developing the prediction rule. A prediction rule was developed in the training sample and then evaluated in the validation sample. The cutoffs for the split samples were very similar to those predicted when the total sample ($n = 458$) was evaluated. In each of the crossvalidation samples, children with a type token ratio of less than 0.424 and with fewer than 96.6 word types were classified into one low language group. A second group included a type token ratio less than 0.424 but more than 96.6 word types, and the third group had a type token ratio of more than 0.424. However, when the full sample was used, the cutoff points identified were a type token ratio of less than 0.42 and fewer than 97 different word types. Those children falling below both cutoff points were classified as

Table 5. Language Variable Means (±SD) by Cocaine Exposure Status

	Control Children (n = 272)	Cocaine-Exposed Children (n = 186)	Significance
Language sample variables			
Total no. words	229.6 ± 54.8	227.5 ± 56.2	NS
No. different word types	104.1 ± 20.3	101.1 ± 20.9	NS
Type:token ratio	0.463 ± 0.004	0.456 ± 0.005	NS
No. turns	29.8 ± 8.5	29.0 ± 8.6	NS
No. words per number of turns	7.9 ± 3.4	8.9 ± 7.5	NS
No. utterances per number of turns	1.8 ± 0.73	1.9 ± 1.0	NS
Mean length of utterance (Words per utterance)	4.47 ± 0.73	4.44 ± 0.73	NS
No. communication units (max 50)	48.4 ± 6.8	48.2 ± 7.0	NS
Other language variables			
Arizona Total Proficiency Score	93.6 ± 4.9	94.2 ± 3.6	NS
Wechsler Preschool Scale of Intelligence-Revised (WPPSI) verbal IQ	80.8 ± 13.5	83.2 ± 13.7	NS
Maternal Verbal Ability (Peabody Picture Vocabulary Test–Revised)	74.2 ± 14.7	76.5 ± 15.5	NS

having low language ability, and the remaining children made up the normal language group.

As can be seen in Table 6, children falling into the low language ability group were more likely to be cocaine exposed. The low and normal language groups also differed significantly on prenatal cigarette exposure, family income, and receipt of early intervention services. However, they did not differ significantly on prenatal alcohol exposure or whole blood lead level. As evidence that the language variable cutoff points were meaningful and related to actual language ability, the two language groups differed significantly on the AAPS total proficiency score and Wechsler Preschool and Primary Scale of Intelligence—Revised verbal IQ. The low language group had significantly lower proficiency ($M = 92.7$) and verbal IQ ($M = 77.8$) than the normal language group ($M = 94.0$ and 82.4, respectively; $p < 0.05$ for both t tests).

A logistic regression, using the entire sample, was then undertaken to determine if the above identified relationship between language ability and prenatal cocaine exposure would persist after controlling for relevant covariates. In the logistic regression analysis, using dichotomous language ability as the dependent variable and prenatal cocaine exposure as the predictor, all covariates listed in Table 2 were included in the model. Cocaine exposure status re-

Table 6. Differences on Exposures, Background, and Age 6 Characteristics by Language Status Group

	Low Language Ability Group (n = 57)	Normal Language Ability Group (n = 401)	Significance
Pregnancy data			
Maternal age (yrs)	26.5 ± 5.9	25.5 ± 6.4	NS
Cocaine use	63.2%	37.4%	<0.001
Cigarettes per day	11.9 ± 11.4	8.0 ± 9.6	0.006
Ounces of absolute alcohol per day	0.19 ± 0.29	0.15 ± 0.41	NS
Marijuana use	38.6%	33.7%	NS
Hypertension	12.5%	7.0%	NS
Abruptio placenta	1.8%	0.3%	NS
Diabetes	1.8%	3.3%	NS
Syphilis	1.8%	3.3%	NS
Neonatal data			
Birth weight (grams)	2931 ± 663	3007 ± 619	NS
Birth length (centimeters)	48.1 ± 3.2	48.5 ± 3.5	NS
Birth head circumference (centimeters)	33.2 ± 1.8	33.4 ± 2.1	NS
Gestational age (wks)	38.7 ± 2.3	38.7 ± 2.6	NS
Apgar 1 minute (median)	7.8 ± 1.1	7.4 ± 1.9	NS
Apgar 5 minutes (median)	8.8 ± 0.6	8.6 ± 1.4	NS
Data age 6			
Income	10,000–14,999	15,000–19,999	0.005
Marital status (married)	28.1%	28.0%	NS
Parent education (yrs)	10.2 ± 3.9	11.0 ± 3.9	0.091
Biological mother is caretaker	80.7%	83.8%	NS
Current drug exposure (admit)	12.3%	15.7%	NS
Socioeconomic status (Hollingshead)	28.1 ± 9.3	30.0 ± 10.3	NS
Age of child (yrs)	6.9 ± 0.23	6.9 ± 0.25	NS
Sex of child (male)	56%	50%	NS
Current lead level	5.22 ± 3.3	4.86 ± 2.9	NS
Received early services	40.4%	24.7%	0.012
Arizona Total Proficiency Score	92.7 ± 5.0	94.0 ± 4.4	0.039
WPPSI-Child Verbal IQ	77.8 ± 14.0	82.4 ± 13.5	0.018
Maternal verbal ability (Peabody Picture Vocabulary Test)	71.7 ± 14.8	75.7 ± 15.1	0.060

mained a significant predictor in the presence of these covariates ($p = 0.008$), with cocaine-exposed children 2.4 times more likely to be in the low language ability group than the unexposed control children. A logistic regression analysis with covariates was also performed using prenatal cigarette exposure as the predictor and dichotomous language ability as the dependent variable. Ciga-

rette exposure remained a significant predictor ($p = 0.003$). Prenatal alcohol exposure and whole blood level at age 6 years were not significantly related to the dichotomous language variable when univariate analyses were performed, and the same results were produced when logistic regression with controls was used.

DISCUSSION

In this report of more 400 6-year-old children, prenatal cocaine and cigarette exposure were important predictors of poor language development. Neither alcohol nor the child's whole blood lead level at school age were predictive of expressive language skills. Although these findings are largely consistent with those of previous researchers, this prospective cohort study is the largest such study and provides control for both other prenatal exposures, postnatal risk factors, and examiner effects. Blinded evaluation of expressive language with a culturally appropriate tool are additional strengths.

Although no mean differences by cocaine exposure status were observed in the individual language variables, CART analysis successfully identified a group of children with low language skills and increased exposure to cocaine during pregnancy. These findings are not, in fact, inconsistent and suggest the existence of a language threshold, with exposed children significantly more likely to fall below the threshold on a combination of variables, even when the mean language difference between the cocaine-exposed and control children for each variable is not significant. In this study, even when the cutoff points identified through CART were used and the cocaine and control groups were compared, there was no significant difference on each language variable. It was only when the cutoff points for the two variables were used together to create a composite variable for use in logistic regression that language differences resulting from cocaine exposure emerged. Thus CART provides a way to identify meaningful cutoff points or thresholds in variables, such as these from the language sample where no diagnostic criteria yet exist. And, as was the case in this study, CART assisted in the identification of the key feature in expressive language, number of different word types, related to cocaine exposure.

Although the findings in this study were crossvalidated with a split-sample design, verification of the parameters for identification of low language ability with an additional sample is recommended. The results obtained in this study do, however, have content validity because the identified relationships (between prenatal cigarettes, services, and maternal verbal ability) have been previously found to affect child language development. Furthermore, the use of recursive partitioning in the development of the prediction rule improves the likelihood that the relationship will hold up in a future sample. Finally, because women who did not receive prenatal care were not eligible for study entry, it is likely that this report excludes many women with the heaviest cocaine

exposure. Non-African Americans were also excluded. Thus whether the relationships found here will apply to other populations and at different levels of prenatal exposure remains to be seen. Although the results require repetition, they do confirm the work of previous investigators and suggest an additional important area of risk for the child prenatally exposed to cocaine.

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CONTINUING EDUCATION

Expressive Language Development of Children Exposed to Cocaine Prenatally: Literature Review and Report of a Prospective Cohort Study

QUESTIONS

1. The relationship between prenatal cocaine exposure and language development:

a. Has been studied extensively in many large scale studies
b. Has not been adequately researched
c. Has been evaluated in previous studies that have also measured lead levels
d. Is unaffected by prenatal exposure to other substances
e. Is believed to be small and insignificant

2. The current study did NOT:
   a. Measure prenatal exposure to cocaine, cigarettes, and alcohol
   b. Measure maternal verbal ability and socioeconomic status
   c. Include women with no prenatal care
   d. Include only African American children
   e. Use both a language sample as well as standardized paper and pencil tests to measure child language ability

3. The current study found significant cocaine group differences in expressive language ability using which statistical technique?
   a. *t* test
   b. Regression
   c. Multivariate analysis of variance
   d. Analysis of variance
   e. Classification and regression tree analysis

4. Child language ability (measured either with language sample or standardized tests) was NOT significantly related to which potential covariate?
   a. Current drug use in the home
   b. Custody status
   c. Child gender
   d. Socioeconomic status
   e. Child violence exposure

5. Which of the following was NOT a conclusion of the current study?
   a. Because of the nature of the statistical procedures used, the results are in need of repetition
   b. Prenatal cocaine exposure was a significant predictor of poor language development
   c. Prenatal cigarette exposure was a significant predictor of poor language development
   d. Prenatal alcohol exposure was a significant predictor of poor language development
   e. The results are generally consistent with those of previous studies