Project Ice Storm: Prenatal Maternal Stress Affects Cognitive and Linguistic Functioning in 5½-Year-Old Children

DAVID P. LAPLANTE, PH.D., ALAIN BRUNET, PH.D., NORBERT SCHMITZ, PH.D., ANTONIO CIAMPI, PH.D., AND SUZANNE KING, PH.D.

ABSTRACT

Objective: This was a prospective study designed to determine the extent to which the degree of exposure to prenatal maternal stress due to a natural disaster explains variance in the intellectual and language performance of offspring at age 5½ while controlling for several potential confounding variables. **Method:** Subjects were eighty-nine 5½-year-old children whose mothers were pregnant during a natural disaster: the January 1998 ice storm crisis in the Canadian province of Québec that resulted in power losses for 3 million people for as long as 40 days. In June 1998, women completed several questionnaires including those about the extent of objective stress (Storm32) and subjective distress (Impact of Events Scale-Revised) experienced due to the storm. Their children were assessed with the Wechsler Preschool and Primary Scale of Intelligence-Revised (IQ) and Peabody Picture Vocabulary Test-Revised (language) at 5½ years of age, and mothers completed assessments of recent life events and psychological functioning. **Results:** Children exposed in utero to high levels of objective stress had lower Full Scale IQs, Verbal IQs, and language abilities compared to children exposed to low or moderate levels of objective prenatal maternal stress; there were no effects of subjective stress or objective stress on Performance IQs. Trend analyses show that for all outcome variables except Block Design, there was a significant curvilinear association between objective stress and functioning. **Conclusions:** Prenatal exposure to a moderately severe natural disaster is associated with lower cognitive and language abilities at 5½ years of age. *J. Am. Acad. Child Adolesc. Psychiatry*, 2008;47:(9):1063–1072. **Key Words:** prenatal maternal stress, natural disaster, intellectual and cognitive abilities.

Research findings strongly suggest that maternal anxiety or stress affects fetal[1–4] and child[5–15] outcomes. For the most part, prenatal maternal stress (PNMS) has adverse effects, particularly if the exposure occurs early in pregnancy, even after controlling for potential pre- and postnatal confounding variables (e.g., socioeconomic status [SES], obstetric complications, in utero alcohol and nicotine exposure, pre- and postnatal maternal anxiety, postpartum depression, gestational age at birth, birth weight). However, some research suggests that the association between PNMS and development is curvilinear, such that the best performance is observed in offspring exposed to moderate levels maternal anxiety, with poorer outcomes seen with lower and higher maternal anxiety levels.[16]

With the exception of the longitudinal work by Van den Bergh and colleagues,[14] the majority of studies investigating the effects of PNMS on general cognitive functioning have been conducted on infants; little is known about the potential long-term effects of PNMS

Accepted March 17, 2008.

Drs. Laplante, Brunet, Schmitz, and King are with Douglas Hospital Research Centre; Dr. Ciampi is with the Department of Epidemiology and Biostatistics, McGill University.

Article Plus (online-only) materials for this article appear on the Journal's Web site: www.jaacap.com.

This study was supported by grants from the McGill University Stairs Memorial Fund, the Canadian Institute of Health Research, and the Douglas Hospital Research Centre, and a research fellowship from the Fonds de la Recherche en Santé du Québec awarded to Suzanne King. The authors thank the families who have participated in Project Ice Storm since 1998, and Shannon Woo, Cheryl Chanson, and Sawsan Mbirkou for data entry and Lorraine Dubois for assessing the children.

Correspondence to Dr. Suzanne King, Psychosocial Division, Douglas Hospital Research Centre, 6875 LaSalle Boulevard, Verdun, QC, Canada, H4H 1R3; e-mail: suzanne.king@douglas.mcgill.ca.

DOI: 10.1097/CHI.0b013e31817eec80

on cognitive functioning. There is a need for longitudinal work in this area similar to what has been done for the influence of prenatal anxiety on the expression of behavioral problems in older children.[10,11]

Project Ice Storm studies the effects of exposure to events surrounding a natural disaster, which offered the opportunity to assess the severity of different forms of disaster-related stress. The January 1998 ice storm in the Canadian province of Québec resulted in power outages ranging from a few hours to more than 6 weeks for more than 1.4 million households in more than 700 municipalities during the coldest month of the year. The ice storm resulted in $1 billion worth of insurance claims, $3 billion of lost income to businesses, and $1 billion in hydroelectric infrastructure repairs. The Insurance Bureau of Canada has listed the ice storm as the most costly natural disaster in Canadian history (*www.ibc.ca*). Moreover, because the ice storm was a random act of nature, we were able to obtain both objective and subjective measures of PNMS that were independent of other maternal characteristics from a relatively large number of pregnant women 5 to 6 months following the storm. Our objective PNMS scale assessed the severity of specific storm-related events experienced by the pregnant women (e.g., number of days without electricity, whether they stayed in a shelter). Our subjective PNMS measure assessed the pregnant women's distress in response to these events. In addition, because the exact parameters of the ice storm are well documented (e.g., specific days during which the power was lost and reestablished), we were able to pinpoint the exact week or weeks of pregnancy during which the pregnant women's homes were without electrical power. As such, Project Ice Storm is able to determine the precise period of pregnancy during which the women were exposed to this independent stressor.

Our previous analyses of the intellectual and linguistic abilities of a subsample of Project Ice Storm participants at 2 years of age revealed that levels of objective but not subjective PNMS were predictive of intellectual and linguistic abilities in the children[8]; high levels of objective PNMS were associated with lower intellectual and language abilities than for the low-stress group (the moderate-stress group was not assessed at that age). For intellectual but not language abilities, the effect of objective PNMS was observed only in first or second trimester–exposed toddlers. These results clearly demonstrated at least the short-term effect of exposure to high levels of objective PNMS on intellectual and linguistic development.

The goal of the present study was to determine whether disaster-related objective and/or subjective PNMS predicts intellectual and language functioning in the full cohort of children at age 5½ years. We hypothesized that children born to mothers who experienced high levels of PNMS would exhibit poorer general intellectual and language functioning than their low-stress counterparts, after controlling for past and present maternal psychological functioning, past and present maternal life events, maternal postpartum depression, obstetric complications, SES, and the children's ponderal index and gestational age. We expected that the effects of PNMS would be greatest in children whose mothers were exposed to the ice storm early in their pregnancies.

METHOD

Participants

The Research Ethics Board of the Douglas Hospital Research Centre approved the research protocols for this study. In order to identify women who were pregnant during the ice storm, we contacted obstetricians affiliated with the four hospitals in the Montérégie, a region southeast of Montreal that was most affected by the ice storm, soon after the crisis. The physicians identified women who met our inclusion criteria: being pregnant during the ice storm or became pregnant within 3 months of the ice storm, white French Canadians, and 18 years old or older (n = 1,440). Their clinics then forwarded our first questionnaire, "Reactions to the Storm," to these patients. A total of 224 women responded to the questionnaire, of whom 178 gave consent to be contacted for further follow-up. The present study included only women (n = 89) who were in their first (n = 35), second (n = 27), or third (n = 27) trimester of pregnancy during the ice storm and whose children underwent an in-depth assessment of their physical, cognitive, and behavioral development at 5½ years of age.

Outcome Variables

Intellectual Abilities. Three subtests of a validated French version of the Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R)[17] were administered: the verbal subtests of Information and Similarities and the performance subtest of Block Design. This short form has a reliability of 0.92 with the Full Scale IQ.[18] For all subtests, we converted the raw scores to standardized scores based on the child's exact age. We estimated Full Scale IQ scores using the three subtests from tables supplied by Sattler.[18]

Language Abilities. We assessed the children's vocabulary with a validated French version of the Peabody Picture Vocabulary Test-Revised (PPVT-R). Raw scores were converted to normalized scores as outlined in the accompanying manual.[19]

Predictor Variables

Objective PNMS was estimated using the mothers' responses to questionnaire items that tapped into categories of exposure used in other disaster studies: threat, loss, scope, and change.[20] Because each natural disaster presents unique experiences to the exposed population, questions pertaining to each of the four categories must be tailor-made (see Appendix 1 in the Article Plus material available on the *Journal's* Web site *www.jaacap.com*). Each of the four dimensions was scored on a scale of 0 to 8, ranging from no exposure to high exposure. We computed a total objective PNMS score (Storm32) by summing scores from all four dimensions using McFarlane's approach.[21] For some analyses, three objective PNMS groups were formed: the low objective PNMS group consisted of children whose mothers had scores ranging from 1 to 8 on Storm32 (n = 31), moderate objective PNMS group consisted of children whose mothers had scores ranging from 9 to 12 on Storm32 (n = 27), and the high objective PNMS group consisted of children whose mothers had scores ranging from 13 to 24 on Storm32 (n = 31).

A subset of mothers (n = 59) completed the same questionnaire 6 years after the ice storm to gauge the reliability of their initial responses to the objective hardships they experienced during the disaster. Strong intraclass correlation coefficients were obtained for three of the four categories (scope: ρ_I = .80; change: ρ_I = .82; and loss: ρ_I = .69). Recall for the last category, threat, was less strong (ρ_I = .42). Overall, the relation between initial Storm32 scores and scores obtained 6 years later was good (ρ_I = .78), suggesting that our initial questionnaire has excellent test-retest reliability.

Subjective PNMS was assessed using the French version[22] of the widely used Impact of Event Scale-Revised (IES-R)[23] (see Appendix 2 in the Article Plus material available on the *Journal's* Web site *www.jaacap.com*). The 22-item scale describes symptoms from three categories relevant to posttraumatic stress disorder: intrusive thoughts, hyperarousal, and avoidance. The IES-R instructions for respondents allow investigators or clinicians to "write in" the traumatic event in question. Participants thus responded on a 5-point Likert scale, from not at all to extremely, the extent to which each item described how they felt during the preceding 7 days in response to the ice storm crisis. We used the total score in all of the analyses. We published[22] validity data on this scale, which demonstrated good internal consistency for the total score with the present sample (α = .93) and 3-month test-retest validity with a postdisaster sample from France (r = 0.76).

Maternal Psychological Functioning. The level of maternal psychological functioning was assessed with a validated French version of the widely used General Health Questionnaire-28 (GHQ).[24] The GHQ is a self-report screening tool for psychiatric symptoms and includes seven items on each of the anxiety, dysfunction, somatization, and depression subscales. Items are scored on a four-point Likert scale indicating the degree to which each symptom was experienced in the preceding 2 weeks. In the present study, each item was rescored as either 0 (a rating of 0 or 1) or 1 (a rating of 2 or 3), according to the Goldberg method,[24] resulting in a minimum possible score of 0 and a maximum possible score of 28. The GHQ was included in our initial questionnaire and again when the children were 5½ years of age. The anxiety and depression subscales for both assessment periods were used in the present analyses.

Maternal Life Events. Six months after each woman's expected due date, maternal life events were assessed using the Life Experiences Survey (LES).[25] The LES is a self-report measure that lists 57 life changes, such as death of a spouse or a promotion at work. In an effort to keep the total length of the questionnaire reasonable, we reduced this list to 29 events by eliminating items not likely to have occurred in this sample (e.g., "combat experience"). Respondents indicated first whether the event occurred and the approximate date of the event and then rated the impact of the event (if it occurred) on a seven-point Likert scale ranging from extremely negative to extremely positive. In the first assessment with the LES, women were instructed to indicate events, other than the ice storm, that occurred during the 6 months before the baby's conception, during the pregnancy, and in the 6 months since the baby's birth and at the second assessment during the year preceding their child's evaluation at 5½ years. The total number of different life events from both assessment periods was used in the analyses in the present study.

Postpartum Depression. The level of postpartum depression 6 months after each woman's expected due date was assessed using the 10-item Edinburgh Postpartum Depression Scale.[26,27] The mothers responded to each question using a four-point Likert scale, from not at all to very much. The total score was calculated by summing all of the items.

Trimester of Exposure. The trimester of pregnancy during which the women were exposed to the ice storm was determined using the number of days between each mother's anticipated due date and January 9, 1998, the date corresponding to the peak of the ice storm: third trimester exposure corresponds to due dates falling between 0 and 93 days following January 9; second trimester exposure corresponds to between 94 and 186 days; and first trimester exposure corresponds to between 187 and 279 days between January 9 and the due date.

Other Maternal Factors. Information on maternal age and education, marital status, parental job classification, and household income was collected in June 1998. SES was computed using Hollingshead Index criteria.[28] The number of obstetric complications, including alcohol and cigarette use, was determined by maternal recall using an adaptation of the scale used by Jacobsen and Kinney[29] and verified using hospital records. We used the total number of obstetric complications experienced by the women that were rated as moderate to severe using the McNeil-Sjöström Scale for Obstetric Complications.[30]

Other Child Factors. The children's birth weight, birth length, and gestational age were obtained from maternal reports and hospital records. We calculated Rohrer's ponderal index (birth weight/birth height^3 $\times$ 100), as a measure of fetal growth.

Procedures

Our initial questionnaire, which included the Storm32, the IES-R, the GHQ, and demographic questions, was mailed on June 1, 1998. The second questionnaire was mailed 6 months after each woman's due date and included the Edinburgh Postpartum Depression Scale, the LES, questions about the child at birth, and the obstetric complications questionnaire. All of the families still in the cohort were invited to participate in the assessments at 5½ years (WPPSI-R and PPVT), at which time GHQ and LES were readministered to the mothers.

Statistical Analyses

Correlations among the variables were examined to determine potential covariates for each analysis. Next, we conducted an analysis of covariance (ANCOVA) for each of the outcome variables, using the appropriate covariates. We used the least squared difference post hoc tests to compare scores on the outcome for each level of objective PNMS: low, moderate, and high. Because the results of the ANCOVAs suggested the possibility of curvilinear associations between objective PNMS and outcomes, we conducted trend

analyses to confirm these associations, then included quadratic terms in hierarchical regression models to test the effects of objective PNMS in its continuous form. For these analyses, we allowed potential covariates to enter in the first blocks in stepwise fashion, then forced objective PNMS into the equation followed by the quadratic term, and then entered subjective PNMS; interaction terms between objective PNMS and other covariates were allowed to enter in the final blocks with a stepwise procedure if significant.

RESULTS

Demographic Information

The families in the present study were without electricity for an average of 15.2 days (SD 8.2 days, range 0–32). At the time of their child's birth, these mothers were on average 30.2 years of age (SD 4.9) and 70.8% were from households in the upper middle class and above (lower class, 3.4%; lower middle class, 1.1%; middle class, 24.7%; upper middle class, 51.7%; upper class, 19.1%). There were 42 boys and 47 girls in the present sample. The children were on average 5.6 years of age (SD 0.1) at the time of testing.

Mothers in our present sample differed from our original, total samples of 224 and 178 (who provided contact information) on level of education, age at time of the birth of their children, and SES (p values <.05). Mothers in the present sample were slightly better educated (15.2 versus 14.5 years of education), older (30.2 versus 28.6 years of age), and of higher SES (70.1% versus 57% from upper middle class families or higher). Finally, we compared the present sample to the catchment area from which it was initially drawn (Montérégie region of Québec) on four variables: maternal education, maternal job classification, home ownership, and family income. The mothers in the present sample were better educated (67.89% versus 47% college or university educated) and were more likely to own their own home (75.2% versus 65.2%) compared to the catchment area norms. Although not directly comparable, 69.3% of our families reported an annual income of $50,000 or greater compared to the median family income in the catchment area of $53,000/year. However, mothers in the present sample did not differ in terms of their job classification: 59.2% reported working as a professional compared to 52.0% in the catchment area.

Correlations

Objective and subjective PNMS were correlated (0.28; $p < .005$). Objective PNMS was significantly correlated to the children's Similarities and Information subtests, IQ, and PPVT-R scores, with higher objective PNMS associated with lower scores (Table 1). Higher SES was associated with better scores on the children's Information subtest and IQ scores, but was uncorrelated with either objective PNMS (−0.01) or subjective PNMS (−0.16). Maternal education had a significant, positive correlation with the children's Information subtest, IQ, and PPVT-R scores.

TABLE 1
Pearson Product–Moment Correlations Between the Outcome Measures and Predictors (n = 89)

Predictors	Block Design	Information	Similarities	Full IQ	PPVT-R
Objective PNMS	−0.19	−0.24*	−0.31**	−0.33**	−0.34**
Subjective PNMS	−0.14	−0.07	0.01	−0.07	−0.04
GHQ anxiety (June 1998)	0.01	−0.07	−0.19	0.05	0.01
GHQ depression (June 1998)	−0.14	0.00	−0.05	0.06	−0.19
Life events (pregnancy)	0.02	−0.10	−0.05	−0.07	0.01
Postpartum depression	0.02	−0.05	0.11	0.01	0.12
Obstetric complications	−0.07	−0.02	0.12	0.00	0.03
SES	0.05	0.32**	0.14	0.23*	0.18
Maternal education	−0.01	0.24*	0.14	0.22*	0.25*
GHQ anxiety (5½ y)	−0.15	−0.06	−0.10	−0.14	−0.15
GHQ depression (5½ y)	−0.11	−0.02	−0.08	−0.09	−0.16
Life events (5½ y)	0.04	−0.08	−0.05	−0.06	−0.02
Gestational age	0.09	0.01	−0.02	0.02	−0.18
Ponderal index	−0.02	−0.13	−0.05	−0.06	−0.14

Note: PNMS = prenatal maternal stress; GHQ = General Health Questionnaire-28; SES = socioeconomic status.
*$p < .05$; **$p < .005$.

ANCOVAs

Figures 1 and 2 present the results of the five ANCOVAs graphically. Given the lack of correlation between Block Design and Similarities scores and the potential covariates, one-way analyses of variance were conducted for these outcomes. There were no significant objective PNMS group differences on Block Design scores ($F_{1,79}$ = 0.23; p = .634). A significant main effect for objective PNMS on the children's Similarities subtest was observed ($F_{1,78}$ = 4.68; p < .05): children whose mothers had experienced moderate objective PNMS performed better than those from the high PNMS group (p < .01). Controlling for SES (p = .10) and maternal education (p = .68), there was a significant main effect for objective PNMS on the Information subtest ($F_{1,78}$ = 4.51; p < .05): children exposed in utero to low (p < .05) and moderate (p < 05) levels of objective PNMS obtained higher scores than children from the high PNMS group. For the Full Scale IQ, a significant group main effect was also obtained ($F_{1,78}$ = 5.74; p < .01) controlling for SES (p = .48) and maternal education (p = .42), and again both low (p < .05) and moderate (p < .005) objective PNMS groups obtained higher IQs than the high PNMS group. Finally, results for the PPVT-R indicated higher scores ($F_{1,78}$ = 3.06; p = .053) for low (p < .05) and moderate (p < .05) objective PNMS groups compared to children exposed to high levels of objective PNMS when maternal education (p = .04) was controlled for.

Regression Analyses

Given that the absolute values of scores on four of the five outcome variables were higher in the moderate objective PNMS group than in the low PNMS group, we tested the significance of any curvilinear associations between objective PNMS and these outcomes. Table 2 presents results of the trend analyses, which indicate that for all of the outcomes except Block Design, the quadratic function was significant. As such, in all regressions, except that for Block Design, we entered

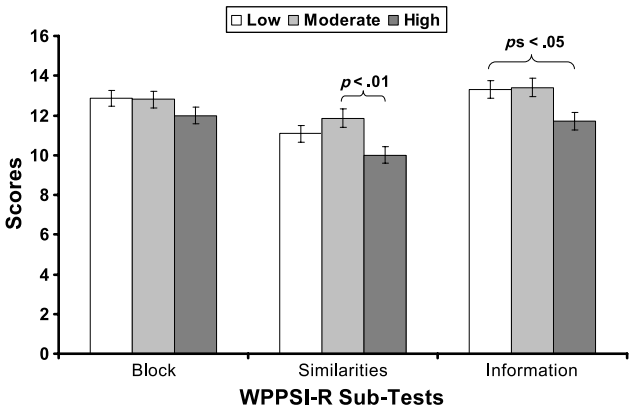

Fig. 1 Mean (Block Design, Similarities) and adjusted mean (Information) and SEs for the children's standardized scores on the three subtests of the Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R), as a function of level of objective prenatal maternal stress exposure.

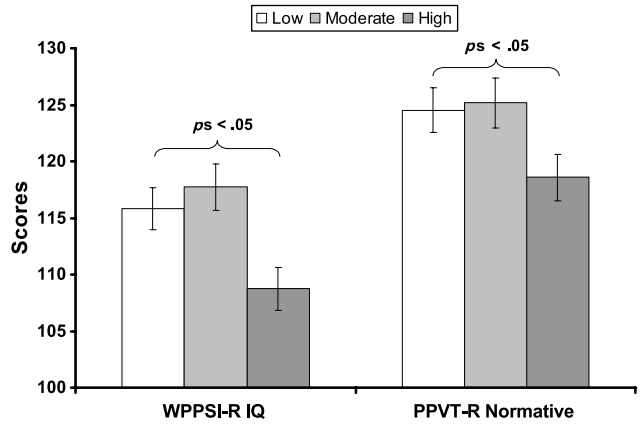

Fig. 2 Adjusted mean and SEs for the children's IQ scores on the Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R) and the children's normative scores on the Peabody Picture Vocabulary Test-Revised (PPVT-R), as a function of level of objective prenatal maternal stress exposure.

TABLE 2

Linear and Quadratic Curve Estimations for Each Outcome Measure as a Function of Objective PNMS

Predictor Variables	R^2	F	p
Block Design			
Objective PNMS			
Linear	0.026	2.30	.133
Quadratic	0.041	1.86	.163
Similarities			
Objective PNMS			
Linear	0.054	4.95	.029
Quadratic	0.122	5.90	.004
Information			
Objective PNMS			
Linear	0.032	2.85	.095
Quadratic	0.079	3.71	.029
IQ			
Objective PNMS			
Linear	0.057	5.18	.025
Quadratic	0.133	6.53	.002
PPVT-R (normalized scores)			
Objective PNMS			
Linear	0.064	5.87	.018
Quadratic	0.167	8.49	.001

Note: PNMS = prenatal maternal stress; PPVT-R = Peabody Picture Vocabulary Test-Revised.

TABLE 3
Regression Analyses for Predictor Variables and Outcome Measures

	Unstandardized Coefficients		Standardized Coefficients					
Predictor Variables	*B*	SE *B*	β	*R*	R^2	ΔR^2	*F*	ΔF
			Block Design					
Step 1[a]				0.160	0.026		2.30	
Constant	13.585	0.681						
Objective PNMS	−0.087	0.057	−0.160					
			Similarities					
Step 1[b]				0.233	0.054		4.95*	
Constant	12.415	0.689						
Objective PNMS	−0.129	0.058	−0.233*					
Step 2[c]				0.343	0.118	0.063	5.68**	6.11*
Constant	8.527	1.709						
Objective PNMS	0.631	0.312	1.15*					
Objective PNMS (quadratic)	−0.033	0.013	−1.40*					
			Information					
Step 1[b]				0.322	0.104		10.05***	
Constant	14.606	0.607						
SES	0.064	0.020	0.322***					
Step 2[c]				0.379	0.144	0.040	7.22***	4.04*
Constant	16.031	0.927						
SES	0.067	0.020	0.336***					
Objective PNMS	−0.121	0.060	−0.201*					
Step 3[d]				0.419	0.176	0.032	6.04***	3.28
Constant	12.737	2.035						
SES	0.059	0.020	0.297***					
Objective PNMS	0.478	0.336	0.796					
Objective PNMS (quadratic)	−0.026	0.014	−1.01					
			IQ					
Step 1[b]				0.225	0.050		4.57*	
Constant	119.690	2.788						
SES	0.198	0.093	0.225*					
Step 2[c]				0.339	0.115	0.065	5.53[e]	6.22*
Constant	127.683	4.195						
SES	0.214	0.090	0.242*					
Objective PNMS	−0.677	0.271	−0.255*					
Step 3[d]				0.451	0.203	0.088	7.13***	9.28**
Constant	103.467	8.903						
SES	0.158	0.088	0.179					
Objective PNMS	3.739	1.473	1.41*					
Objective PNMS (quadratic)	−0.189	0.062	1.69***					
			PPVT-R					
Step 1[b]				0.245	0.060		5.48[f]	
Constant	106.479	7.224						
Maternal education	1.099	0.469	0.231*					
Step 2[c]				0.337	0.113	0.054	5.44*	5.13**
Constant	113.516	7.709						
Maternal education	1.100	0.458	0.245*					
Objective PNMS	−0.631	0.278	−0.231*					
Step 3[d]				0.487	0.237	0.123	8.69[g]	13.57***
Constant	90.999	9.441						
Maternal education	0.780	0.437	0.174					

(continued on next page)

TABLE 3
(Continued)

Predictor Variables	Unstandardized Coefficients		Standardized Coefficients					
	B	SE *B*	β	*R*	R^2	ΔR^2	*F*	ΔF
Objective PNMS	4.714	1.474	1.73***					
Objective PNMS (quadratic)	−0.229	0.062	−1.99***					

Note: PNMS = prenatal maternal stress; SES = socioeconomic status; PPVT-R = Peabody Picture Vocabulary Test-Revised.
[a] $df = 1,87$.
[b] $df = 1,86$.
[c] $df = 2,85$.
[d] $df = 3,84$.
*$p < .01$.
**$p < .05$.
***$p < .005$.

both objective PNMS and its squared polynomial (Table 3).

Block Design Subtest. None of the potential predictor variables, including objective and subjective PNMS, were significantly related to the children's Block Design scores.

Similarities Subtest. Objective PNMS accounted for 5.4% of the variance of the children's Similarities scores: higher objective PNMS was associated with lower scores. The inclusion of the quadratic component of objective PNMS increased the amount of variance explained significantly and accounted for an additional 6.3%. Subjective PNMS did not enter the equation because it would not have significantly accounted for any further unique variance in the scores. As such, the linear and quadratic components of objective PNMS accounted for 11.8% of the variance in the Similarities scores.

Information Subtest. SES accounted for 10.4% of the variance of the Information scores: higher SES was related to higher scores. Objective PNMS accounted for an additional 4% of the variance: higher objective PNMS was associated with lower scores. Finally, the quadratic component of objective PNMS increased the amount of variance accounted for by an additional 3.2%, which was not a significant increase ($p < .10$). Subjective PNMS was not significantly related to the children's scores and so failed to enter the equation. As such, SES and the linear and quadratic components of objective PNMS accounted for 17.6% of the variance in the children's Information scores.

IQ. SES accounted for 5.0% of the variance in the children's IQ scores: higher SES was related to higher scores. Objective PNMS accounted for an additional 6.5% of the variance: higher objective PNMS was related to lower scores. Finally, the quadratic component of objective PNMS increased the amount of variance accounted for by an additional 8.8%. Subjective PNMS did not significantly account for any further variance of the children's scores and failed to enter the equation. As such, SES and the linear and quadratic components of objective PNMS accounted for 20.3% of the variance in the children's Information scores, with objective PNMS accounting for 15.3% of the total variance explained.

PPVT-R. Maternal education accounted for 6.0% of the variance of the children's PPVT-R scores: higher maternal education was related to higher scores. Objective PNMS accounted for an additional 5.4% of the variance: higher objective PNMS was associated with lower scores. Finally, the quadratic component of objective PNMS increased the amount of variance accounted for by an additional 12.3%. Subjective PNMS was not related to the children's scores. As such, SES and the linear and quadratic components of objective PNMS accounted for 23.7% of the variance in the children's Information scores, with objective PNMS accounting for 17.7% of the total variance explained.

DISCUSSION

Previous research with a subset of children in the present study indicated that high levels of objective PNMS were related to poorer cognitive and language abilities at 2 years of age.[8] The main goal of the present study was to determine whether in utero exposure to varying levels of objective PNMS resulting from a

natural disaster, the 1998 Québec ice storm, continued to influence the expression of children's intellectual and linguistic abilities at 5½ years of age. Furthermore, although women's subsequent subjective distress arising from the event was not related to outcomes at 2 years of age,[8] we wished to determine whether an effect would be observable in later stages of childhood.

The ANCOVA, trend, and regression analyses suggest that in utero exposure to high levels of objective but not subjective PNMS is associated with poorer verbal intelligence and language skills, even after controlling for the positive effects of SES and maternal education. It is important to note, however, that in this sample of children from well-educated families, the scores on all of the outcome measures were well within the normal range for children from all three of the stress groups. Objective PNMS, however, was not related to the children's performance intelligence at this age as reflected in Block Design scores. These results are similar to those reported on the effect of antenatal maternal anxiety on WISC-R scores in adolescents.[14] Together these results suggest that PNMS may have greater effects on brain structures involved in language functioning compared to areas responsible for spatial abilities. Further research assessing the development of language abilities in children exposed to PNMS is required to determine which specific aspects of language are most affected by PNMS. Once identified, it may be possible to uncover the underlying cortical structures affected by PNMS, thus allowing us to take another step in determining the mechanism by which PNMS influences language-related cognitive functioning. Further research, involving structural and/or functional magnetic resonance imagery, is required to test this hypothesis.

Interestingly, these analyses also suggest that a curvilinear and not a linear relation best describes the link between objective PNMS and language-based functioning at 5½ years of age; we could not have seen this pattern with our data from age 2 years because we had not included the moderate stress group in the assessments due to funding constraints at the time. This finding, although differing from the majority of human and animal studies,[5–15] is similar to some animal studies that suggest that mild PNMS may enhance memory abilities.[31,32] Moreover, mild to moderate levels of midgestation anxiety are related to enhanced performance on the Bayley mental scale in toddlers.[1] Although the data from the present study strongly suggest that exposure to high levels of objective PNMS results in less than optimal language-related development, exposure to moderate levels may actually enhance performance, perhaps by stimulating myelination of cortical structures.[33] However, almost nothing is known about the type, amount, or timing of in utero exposure required for optimal development, nor whether enhanced performance in one area of development (i.e., language-related abilities in the present sample) is associated with concurrent or subsequent inferior performance in other areas of development.

An important aspect of Project Ice Storm is the ability to distinguish between objective exposure to the storm and the woman's subjective distress related to the event. As with our results at 2 years of age, we show that the effect of the ice storm on the cognitive development of these children is a function of objective exposure to the disaster only, with no significant role played by subjective distress as reflected in the posttraumatic stress symptom score on the IES-R obtained 6 months following the event. Thus, our results from these assessments at two different ages suggest that what happens to the pregnant woman (i.e., her objective hardship) has a greater impact on the developing fetus than does her subjective reaction to those events, at least as reflected in distress 6 months later. Although possibly paradoxical, our measure of objective PNMS included many aspects of the crisis (e.g., length of power outage, number of relocations, number of guests and duration of their stay, loss of income, damage to residence, change in daily activities, threat to personal or family members' safety), and our measure of subjective PNMS focused solely on posttraumatic stress-like reactions to the crisis. As such, it is possible that some events that contributed to higher scores on objective PNMS (e.g., number and duration of stay by guests, changes in daily activities) may have been viewed as being positive by our respondents and thus did not contribute to their subjective distress levels. However, although these events may have been viewed as being positive, they may nevertheless have placed additional stresses on the women's physiologies, changes that appear to be detrimental to the subsequent development of the exposed fetuses.

Given the challenges involved in disaster research, it was not possible to obtain a measure of disaster-related distress (subjective PNMS) in the days following the event. As such, our subjective PNMS measure reflects

prolonged stress reaction rather than acute distress in the face of the ice storm. Yet, we can probably safely assume that individuals reporting persistent distress 6 months following the ice storm would have experienced high levels of distress at the time of the event. However, the reverse is not necessarily true: among women who reported no or low levels of prolonged distress in June 1998, there were most likely some, if not many, who had experienced high levels of acute distress at the time of the crisis. Although we controlled for the effects of prolonged stress in the present sample by including the IES-R, we can say nothing about the potential effects that high levels of acute distress may have had on the development of intellectual and linguistic abilities in the children we studied. Moreover, our sample is not representative of the catchment area from which it was drawn: our sample was better educated with higher SES compared to the catchment area norms. As such, the present results cannot be generalized to the general population who may, on average, have had fewer financial resources for coping with the crisis.

Regardless of these limitations, our data indicate that objective PNMS is significantly and negatively associated with the children's verbal intelligence and language-related abilities at 5½ years of age. Our findings suggest that an independent stressful event may result in sufficiently high levels of objective maternal hardship or stress to have a long-term impact on the prenatally exposed children's intellectual and linguistic abilities that persist at a time when the children are entering school age; the women's psychological response to the crisis, however, was not related to subsequent cognitive outcomes in the exposed children. The persistence of the effect of objective PNMS on the children's intellectual and linguistic abilities is suggestive of a fetal programming effect: presumably, the differences still exist at 5½ years of age because they stem from long-lasting physical or physiological alterations that occurred in utero. The persistence of the effect of prenatal exposure to the ice storm is in contrast to the rebound of delayed abilities seen in low-risk premature infants, who generally catch up in most areas of development to their corrected-age peers by age 3.[34,35] We suspect that more severe disasters, such as the 2004 Asian tsunami or Hurricane Katrina, would result in greater observed differences in children of mothers who experienced high versus low or moderate levels of objective hardship. Although the present study is unable to elucidate the mechanisms underlying the observed differences in intellectual and linguistic abilities, we suspect that exposure to high levels of objective PNMS may have altered fetal neurodevelopment, thereby influencing the expression of the children's neurobehavioral abilities in early childhood. However, more fine-tuned language assessments and structural and/or functional magnetic resonance imaging studies of the present participants are required to test and potentially confirm a fetal programming explanation for the observed outcomes.

Disclosure: The authors report no conflicts of interest.

REFERENCES

1. DiPietro JA. The role of prenatal maternal stress in child development. *Curr Dir Psychol Sci*. 2004;13:71–74.
2. DiPietro JA, Hilton SC, Hawkins M, Costigan KA, Pressman EK. Maternal stress and affect influence fetal neurobehavioral development. *Dev Psychol*. 2002;38:659–668.
3. Van den Bergh BRH. The influence of maternal emotions during pregnancy on fetal and neonatal behavior. *Prenat Perinat Psychol J*. 1990; 5:119–130.
4. Van den Bergh BRH, Mulder EJH, Visser GHA, Poelmann-Weesjes G, Bekedam DJ, Prechtl HFR. The effect of (induced) maternal emotions on fetal behaviour: a controlled study. *Early Hum Dev*. 1989;19:9–19.
5. Brouwers EPM, van Baar EL, Pop VJM. Maternal anxiety during pregnancy and subsequent infant development. *Infant Behav Dev*. 2001; 24:95–106.
6. Buitelaar JK, Huizink AC, Mulder EJ, de Medina PG, Visser GH. Prenatal stress and cognitive development and temperament in infants. *Neurobiol Aging*. 2003;24(Suppl 1):S53–S68.
7. Huizink AC, Robles de Medina PG, Mulder EJH, Visser GHA, Buitelaar JK. Psychological measures of prenatal stress as predictors of infant temperament. *J Am Acad Child Adolesc Psychiatry*. 2002;41: 1078–1085.
8. Laplante DP, Barr RG, Brunet A, et al. Stress during pregnancy affects intellectual and linguistic functioning in human toddlers. *Pediatr Res*. 2004;56:400–410.
9. Huizink AC, de Medina PG, Mulder EJ, Visser GH, Buitelaar JK. Psychological measures of prenatal stress as predictors of infant temperament. *J Am Acad Child Adolesc Psychiatry*. 2002;41:1078–1085.
10. O'Connor TG, Heron J, Golding J, Beveridge M, Glover V. Maternal antenatal anxiety and children's behavioural/emotional problems at 4 years. *Br J Psychiatry*. 2002;180:502–508.
11. O'Connor TG, Heron J, Golding J, Glover V, Team AS. Maternal antenatal anxiety and behavioural/emtional problems in children: a test of a programming hypothesis. *J Child Psychol Psychiatry*. 2003;44: 1025–1036.
12. Van den Bergh BRH, Marcoen A. High antenatal maternal anxiety is related to ADHD symptoms, externalizing problems, and anxiety in 8- and 9-year olds. *Child Dev*. 2004;75:1085–1097.
13. Van den Bergh BRH, Mennes M, Oosterlaan J, et al. High antenatal maternal anxiety is related to impulsivity during performance on cognitive tasks in 14- and 15-year-olds. *Neurosci Biobehav Rev*. 2005; 29:259–269.
14. Van den Bergh BRH, Mulder EJH, Mennes M, Glover V. Antenatal maternal anxiety and stress and the neurobehavioural development of the fetus and child: links and possible mechanisms. A review. *Neurosci Biobehav Rev*. 2005;29:237–258.
15. Vaughn BE, Bradley CF, Joffe LS, Seifer R, Barglow P. Maternal

characteristics measured prenatally are predictive of ratings of temperamental "difficulty" on the Carey Infant Temperament Questionnaire. *Dev Psychol*. 1987;23:152–161.
16. DiPietro JA, Novak MFSX, Costigan KA, Atella LD, Reusing SP. Maternal psychological distress during pregnancy in relation to child development at age two. *Child Dev*. 2006;77:573–587.
17. Wechsler D. *Wechsler Preschool and Primary Scale of Intelligence-Revised*. San Antonio, TX: Psychological Corporation; 1989.
18. Sattler JM. *Assessment of Children: Behavioral and Clinical Applications*. 4th ed. San Diego: Jerome M. Sattler; 2002.
19. Dunn LM. *PPVT: Peabody Picture Vocabulary Test-Revised: Manual for Forms L and M*. Circle Pines, MN: American Guidance Services; 1981.
20. Bromet E, Dew MA. Review of psychiatric epidemiologic research on disasters. *Epidemiol Rev*. 1995;17:113–119.
21. McFarlane AC. Relationship between psychiatric impairment and a natural disaster: the role of distress. *Psychol Med*. 1988;18:129–139.
22. Brunet A, St-Hilaire A, Jehel L, King S. Validation of a French version of the Impact of Event Scale-Revised. *Can J Psychiatry*. 2003;48:55–60.
23. Weiss DS, Marmar CR. *The Impact of Event Scale-Revised*. New York: Guilford Press; 1997.
24. Goldberg DP. *The Detection of Psychiatric Illness by Questionnaire: A Technique for the Identification and Assessment of Non-Psychiatric Illness*. London: Oxford University Press; 1972.
25. Sarason IG, Johnson JH, Siegel JM. Assessing the impact of life changes: development of the Life Experience Survey. *J Consult Clin Psychol*. 1978; 46:932–946.
26. Cox JL, Chapman G, Murray D, Jones P. Validation of the Edinburgh Postnatal Depression Scale (EPDS) in non-postnatal women. *J Affect Disord*. 1996;39:185–189.
27. Cox JL, Holden JM, Sagovsky R. Detection of postnatal depression: development of the 10-item Edinburgh Postnatal Depression Scale. *Br J Psychiatry*. 1987;150:782–786.
28. Hollingshead AB. *Four-Factor Index of Social Status*. New Haven, CT: Yale University Press; 1973.
29. Jacobsen B, Kinney DK. Perinatal complications in adopted and non-adopted samples of schizophrenics and controls. *Acta Psychiatr Scand*. 1980;62(Suppl 285):337–346.
30. McNeil TF, Sjöström K. *The McNeil-Sjöström OC Scale: A Comprehensive Scale for Measuring Obstetric Complications*. Malmö, Sweden: Department of Psychiatry, Lund University, Malmö General Hospital; 1995.
31. Fujioka T, Fujioka A, Tan N, et al. Mild prenatal stress enhances learning performance in the non-adopted rat offspring. *Neuroscience*. 2001;103: 301–307.
32. Hougaard KS, Andersen MB, Hansen AM, Hass U, Werge T, Lund SP. Effects of prenatal exposure to chronic mild stress and toluene in rats. *Neurotoxicol Teratol*. 2005;27:153–167.
33. Wiggins RC, Gottesfeld Z. Restraint stress during late pregnancy in rats elicits hypermyelination in the offspring. *Metab Brain Dis*. 1986;1:197–203.
34. Ungerer JA, Sigman M. Developmental lags in preterm infants from one to three years of age. *Child Dev*. 1983;54:1217–1228.
35. Barratt MS, Rioach MA, Leavitt LA. The impact of low-risk prematurity on maternal behaviour and toddler outcomes. *Int J Behav Dev*. 1996; 19:581–602.