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Functional Play at 2 Years of Age: Effects of Prenatal Maternal Stress

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Toddler toy play evolves in a predictable manner and provides a valid, nonverbal measure of cognitive function unbiased by social behaviors. Research on prenatal maternal stress (PNMS) indicates that exposure to stress in utero results in developmental deficits. We hypothesized that children exposed to high objective PNMS from a natural disaster early in pregnancy would exhibit higher rates of stereotypical play and lower rates of mature functional play than their low-stress counterparts would. We examined the functional play abilities of 52 2-year-olds exposed to low or high objective PNMS from a natural disaster within a nonstructured play session. Toddlers exposed to high objective PNMS, subjective PNMS, or both exhibited less functional and more stereotypical toy play, with less diversity, compared to toddlers exposed to low PNMS. PNMS appears to affect functional play development in toddlers negatively. These results replicate delays in language and intellectual functioning observed in these toddlers using the Bayley Scales.

The purpose of this study was to investigate whether in utero exposure to varying levels of prenatal maternal stress (PNMS) influences the development of play abilities in young children. Although research with animals suggests that PNMS has a negative effect on cognitive development (Schneider, 1992), research with humans is hampered by ethical constraints. Relying on a natural disaster to provide the ran-

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domly distributed, independent stressor, the Bayley Mental Scale scores at 2 years of age for the participants in this study were significantly lower in those children whose mothers experienced high levels of objectively defined stress during their pregnancy compared to children whose mothers experienced low levels of stress (King & Laplante, 2005). However, performance on cognitive tests administered by an examiner may reflect temperament as well as underlying cognitive abilities. Problems in temperament and behavior have also been shown to be influenced by prenatal stress in both nonhuman primates (Schneider & Coe, 1993; Schneider, Coe, & Lubach, 1992; Schneider, Moore, Kraemer, Roberts, & DeJesus, 2002) and human infants (Buitelaar, Huizink, Mulder, de Medina, & Visser, 2003; Huizink, Mulder, & Buitelaar, 2004). To circumvent the potential confounding effects of temperament and behavior problems in the assessment of cognitive development, we included an evaluation of the maturity of toy play, which is a nonverbal and nonsocial measure of cognitive development.

Zelazo and Kearsley (1980) reported that in normally developing children "stereotypical" play, involving immature mouthing, fingering, or waving of toys, decreased from an average of 87% of total play acts at 9.5 months to an average of 22% of total play acts at 15.5 months of age. "Functional" play, involving the appropriate adult-defined usage of toys (e.g., placing a ball in a baseball glove, dressing a doll, stirring a spoon in a tea cup), on the other hand, increased from an average of 1.5% of total play acts at 9.5 months to an average of 52% of total play acts at 15.5 months. A similar increase in the number of different functional acts (i.e., "displayed hypotheses") exhibited by the infants during the play session was also observed; rising from an average of 0.32 acts per 15 min at 9.5 months to an average of 10.38 acts per 15 min at 15.5 months. This increase in both the quality (i.e., proportion of time in functional play) and breadth (i.e., number of different displayed hypotheses) corresponds to a period of cognitive metamorphism that occurs shortly after the toddler's first birthday (Zelazo & Leonard, 1983). The shift from stereotypical to functional play is believed to reflect a shift from reflexive action to conscious manipulation of mental representations of real-world objects (Zelazo & Zelazo, 1998). Moreover, the functional usage of objects also reflects the toddler's abilities to generate appropriate means to interact with the toys, thus signaling their ability to apply their cognitive competences (Zelazo & Kearsley, 1980).

Previous research has demonstrated that play abilities can effectively discriminate between healthy and at-risk children. For example, preterm birth, undernutrition, visual impairments, and in utero exposure to cocaine all impair toy play in infancy relative to healthy matched controls (Hughes, Dote-Kwan, & Dolendo, 1998; Lewis, Norgate, Collis, & Reynolds, 2000; Rodning, Beckwith, & Howard, 1989; Sigman, Neumann, Baksh, Bwido, & McDonald, 1989). Typically, the play of these infants reflects that of healthy, yet younger, infants and is frequently, but not always, related to concurrent and later linguistic or intellectual development

(Tamis-LeMonda & Bornstein, 1993). Poorer play abilities in at-risk children, especially in children who exhibit normal or near-normal intellectual abilities, are indicative of the children's inability to learn from experiences with real-world objects, making attempts to promote cognitive, social, and emotional development through play interventions less likely to succeed (Hughes et al., 1998; Troster & Brambring, 1994). Thus, play abilities may reflect the ability to benefit from intervention.

Play abilities are not perfectly correlated with scores from assessments of language or intellectual development. These latter abilities are typically assessed using standardized protocols in which behavioral problems, such as noncompliance to examiners' requests, may mask the true cognitive potentials in some children (Zelazo, 2001). Zelazo argued that because oppositional and noncompliant behaviors in young children may interfere with standardized testing procedures, particularly for at-risk populations (Zelazo, 1982, 2001), it is not always clear whether the scores obtained on standardized tests reflect the children's cognitive abilities or their level of oppositional behavior. As such, Zelazo (1982, 2001) argued for the need to verify outcomes on assessment procedures requiring rigid standardized protocols with other procedures requiring little or no compliance from the child. The assessment of functional play abilities in early childhood is a procedure that can be used to validate research results based on examiner-administered assessments of cognitive functioning.

Although research clearly demonstrates differences in the maturity of play between at-risk and normally developing children, it remains unknown whether PNMS can influence play development in children. The effects of PNMS on offspring development have been examined extensively in nonhuman primates in well-controlled studies. In general, exposure to even mild PNMS, such as daily removal from the peer group for 20 min, is related to elevated levels of inhibited behavior and decreases in cognitive and neuromotor functioning of infant monkeys (Schneider & Coe, 1993; Schneider et al., 1992).

Studies of the effects of PNMS on human offspring are less common, but the findings are similar to those from animal studies. For example, maternal anxiety or exposure to severe life events during pregnancy is associated with poorer obstetric and postnatal outcomes (Crandon, 1979; Lou et al., 1994), poorer temperamental states (Buitelaar et al., 2003), and intellectual delays (Buitelaar et al., 2003; Watson, Mednick, & Wang, 1997). Human research on PNMS is hampered, however, by methodological constraints. Human studies rarely allow for stressful events to be randomly assigned during pregnancy, and thus may lack internal validity. Moreover, naturally occurring life events, such as divorce, job loss, or family and marital discord (Lou, 1993), may not be independent of the woman's own cognitive abilities or personality, which may also be passed on to her children via genetics (Rowe, 1994) or via the postnatal rearing environment. Finally, most studies do not include timely evaluations of the objective severity of the stress exposure and of the mother's subjective reaction to the event, but rather assess exposure or nonexposure long after the event (Huttenen & Niskanen, 1978; Meijer, 1985; Watson et al., 1997).

Independent stressors that affect large numbers of pregnant women are required to determine the relative impact of the objective hardship and the subjective reaction of the mother on the developing fetus. Recently, we demonstrated, using the same participants assessed in this study, that exposure to high levels of objective PNMS from exposure to a natural disaster results in lowered general cognitive and language abilities at 2 years of age (Laplante et al., 2004).

Interestingly, the timing of the stress exposure appears to moderate the effects of PNMS on postnatal outcomes. In animals, poorer outcomes are frequently associated with midgestation exposure (Schneider & Coe, 1993; Schneider et al., 1992). Similar findings have been observed in studies of human populations (Buitelaar et al., 2003; Laplante et al., 2004). In both instances, offspring exposed to either maternal anxiety (Buitelaar et al., 2003) or a natural disaster (Laplante et al., 2004) in early or midgestation scored lower on the Bayley Mental Development Index (MDI) than nonexposed children or those exposed later in pregnancy.

Natural and man-made disasters act as "natural experiments," randomizing the distribution of stress exposure. Between January 5 and 9, 1998, the province of Québec in Canada experienced a series of ice storms resulting in the loss of electrical power to approximately 1.5 million homes for periods ranging between several hours and more than 5 weeks. The Insurance Bureau of Canada (http://www.ibc.ca/en/natural_disasters/index.asp) and Environment Canada (www.msc-smc.ec.gc.ca/media/icestorm98/icestorm98_the_worst_e.cfm) have both declared that the 1998 ice storm was Canada's most expensive natural disaster, resulting in losses between $2.7 billion and $4.2 billion. More than 25 deaths and thousands of injuries were attributed to the storm. The ice storm crisis can be measured along several objective dimensions of disasters identified by Norris (1990) and others (Bromet & Dew, 1995), including scope (i.e., duration and degree of community exposure to the event), loss (i.e., tangible loss of persons or property), threat (i.e., events that threaten the life or well-being of individuals), and change (i.e., amount of deviation from normal routines).

Project Ice Storm, our longitudinal study of the 1998 Québec ice storm, offers a rare opportunity to examine the effects that quasi-randomly assigned PNMS may have on cognitive development in human children. As mentioned earlier, previous analyses with this sample indicated that high levels of objective PNMS predicted poorer general intellectual and language abilities in children at age 2 years when assessed by an examiner using the Bayley Scales of Infant Development and MacArthur Communicative Development Inventories, particularly in children exposed during the first or second trimester of pregnancy (Laplante et al., 2004). Given that these results could have been confounded by effects of PNMS on the children's temperament and subsequent ability to perform at optimal levels when being assessed by an unfamiliar examiner, the goal of this set of analyses was to determine whether in utero exposure to differing levels of objective PNMS resulting from this natural disaster could also differentiate the maturity of toy play of these 2-year-old children in a manner similar to that already demonstrated using the Bayley Scales. We expected that the toy play of toddlers exposed in utero to high levels of objective PNMS would be characterized by more frequent use of stereotypical toy play, by fewer instances of functional toy play, and by a smaller number of different functional acts (i.e., displayed hypotheses) with the toys relative to toddlers exposed in utero to low levels of objective stress. Finally, we anticipated that these effects would be limited to toddlers exposed during the first and second trimesters of pregnancy. Replication of our previous results would support our initial conclusion that objective PNMS affects intellectual development negatively. Likewise, failure to observe similar effects in the children's play abilities would suggest that another, yet unidentified, factor may have been responsible for the observed differences in language and intellectual abilities between children whose mothers were exposed to low or high levels of objective PNMS.

METHOD

Participants

The toddlers in this study represent a subsample ($n = 52$) from a prospective longitudinal study examining the potential effects of PNMS on pre- and perinatal birth outcomes and subsequent development of children exposed to the ice storm while in utero (King et al., 2000; King & Laplante, 2005; Laplante et al., 2004). The toddlers averaged 25.6 months of age ($SD = 0.9$ months) at the time of testing. We targeted the age of 2 years in this study because there is still a mix of different play modes at this age, allowing enough variance for an effect of PNMS to be observed. Because we designed this study to provide preliminary analyses of potential cognitive outcomes, we selected 60 of the nearly 150 families in the project who met the following criteria: normal vaginal term birth, normal birthweight for gestational age, and mothers who did not report smoking or consuming alcohol during pregnancy, and who did not experience any other major life event during their pregnancy. Of the families identified for participation in the study, 52 agreed to attend the laboratory assessment. Nineteen toddlers were in their first trimester of gestation at the height of the storm on January 9, 1998, 14 toddlers were in their second trimester of gestation, and 19 toddlers were in their third trimester of gestation. Thirty-two of the toddlers were boys and 29 were girls. Eighteen toddlers had mothers who experienced high levels of objective stress and 34 toddlers had mothers who experienced low levels of objective stress.

Measures

Objective PNMS. Objective stress was estimated using the mothers' responses to questions about their ice storm experiences that were from categories of exposure used in other disaster studies: threat, loss, scope, and change (Bromet & Dew, 1995). Because each natural disaster presents unique experiences to the exposed population, questions pertaining to each of the four categories must be tailored (Table 1). Each dimension was scored on a scale of 0 (*no exposure*) to 8 (*high exposure*). A total objective stress score, referred to as STORM32, was calculated by summing scores from all four dimensions using McFarlane's (1988) approach: Because there was no theoretical basis to believe that any one of the four dimensions of exposure has a greater effect than the other dimensions, and based on McFarlane's (1988) study of Australian firefighters, each dimension was weighted equally to obtain the total score of our scale. In this study, the low objective PNMS stress group was composed of toddlers whose mothers scored in the bottom third of STORM32 and the high objective PNMS stress group was composed of toddlers whose mothers scored in the top third of STORM32 of the original sample of 150 families.

Subjective PNMS. The mothers' distress related to the ice storm was assessed using a French adaptation (Brunet, St-Hilaire, Jehel, & King, 2003) of the Impact of Event Scale–Revised (IES–R; Weiss & Marmar, 1997). This scale is one of the most widely used measures in the disaster literature for the assessment of distress following trauma. The 22-item instrument provides scores for symptoms in three scales relevant to posttraumatic stress disorder: Intrusive Thoughts, Hyperarousal, and Avoidance. Scale items were written to reflect the mothers' symptoms relative to the ice storm crisis; for example, "When I think about *the ice storm*, my heart beats faster," or "Images of *the ice storm* suddenly appear in my thoughts." Participants respond on a 5-point Likert scale, ranging from 0 (*not at all*) to 4 (*extremely*), reflecting the extent to which the behavior describes how they felt over the preceding 7 days. We used the Total score in all analyses.

Trimester of exposure. The trimester of pregnancy during which the women were exposed to the ice storm was determined using the difference in days between the mothers' anticipated due date and January 9, 1998, the date corresponding to the peak of the ice storm: Third-trimester exposure corresponds to due dates between 0 and 93 days following January 9, second-trimester exposure corresponds to between 94 and 186 days, and first-trimester of exposure corresponds to between 187 and 279 days between January 9 and the due date.

Maternal and pregnancy factors. To control for factors other than the ice-storm-related stress, we assessed the mothers' trait anxiety and postpartum depres-

TABLE 1
Questions Used to Assess the Four Dimensions (Threat, Loss, Scope, and Change) of Our Objective Stress Questionnaire That Mothers Completed Shortly After the Ice Storm

	Threat		*Loss*		*Scope*		*Change*
1	Were you injured? No = 0 Yes = 1	1	Did your residence suffer damage as a result of the ice storm? No = 0 Yes = 2	1	How many days were you without electricity? 0 = 0–5 days 1 = 6–13 days 2 = 14–19 days 3 = 20–21 days 4 = >22 days	1	Did your family stay together for the duration of the ice storm? Yes = 0 No = 1
2	Was anyone close to you injured? No = 0 Yes = 1	2	Did you experience a loss of personal income? No = 0 Yes = 2	2	How many days were you without the use of your telephone? 0 = 0 days 1 = .01–1 day 2 = 2–4.5 days 3 = 5–7 days 4 = >8 days	2	Did you spend any time in a temporary shelter? No = 0 Yes = 1
3	Were you ever in danger due to:	3	How much was the total financial loss including income, food, and damage to home? 0 = < $100 1 = $100–$1,000 2 = $1,000–$10,000 3 = $10,000–$100,000 4 = >$100,000			3	How often were you required to change residence during the ice storm? 0 = 0 1 = 1 time 2 = 2+ times

(continued)

TABLE 1 (*Continued*)

	Threat	*Loss*	*Scope*		*Chang*
3.1	…the cold No = 0 Yes = 1			4	Did you take in guests during the ice storm? No = 0 Yes = 1
3.2	…exposure to downed electrical power lines No = 0 Yes = 1			5	Did you experience an increase in physical work during the ice storm? 0 = less or same 1 = little or lot more
3.3	...exposure to carbon monoxide No = 0 Yes = 1			6	Number of nights away from home: 0 = none 1 = 1–7.5 nights 2 = 8+ nights
3.4	...lack of potable water No = 0 Yes = 1				
3.5	...lack of food No = 0 Yes = 1				
3.6	…falling branches and ice No = 0 Yes = 1				
	8 points	8 points	8 points		8 points

sion. The mothers' trait anxiety was assessed using the Anxiety scale of the 21-item General Health Questionnaire (GHQ; Goldberg, 1972), which was sent in the June 1, 1998 postal questionnaire. The mothers' postpartum depression was assessed using the Edinburgh Postpartum Depression Scale (EPDS; Cox, Chapman, Murray, & Jones, 1996; Cox, Holden, & Sagovsky, 1987). The EPDS was included in a questionnaire mailed 6 months after each mother's reported due date. Parental socioeconomic status was computed using Hollingshead Index criteria (Hollingshead, 1973). Because perinatal factors are frequently associated with developmental outcomes (Siegel, 1982), gestational age, birthweight, and number of reported pregnancy and birth complications were included as potential predictor factors. The mothers reported gestational age at birth and birthweight on the questionnaire they received 6 months after the birth of their children: This information was transcribed from the "Health Booklet" that all mothers in Québec receive from the hospital at discharge with their newborn. The number of obstetrical complications was determined by maternal recall using an adaptation of the checklist used by Kinney (Jacobsen & Kinney, 1980) and, when available, by examination of medical charts.

Assessment of toy play. The toys used in the free play sessions are listed in Table 2. The 28 individual objects comprising the toys were divided into three gender-specific categories (female, male, and gender-neutral) based on informal adult judgments. Thirty-six different functional acts were defined a priori and represent unambiguous adult-defined appropriate uses for each toy (Zelazo & Kearsley, 1980). The numbers of possible functional acts were comparable for the three gender-specific categories ($n = 12$, 13, and 11, for the gender-neutral, female, and male toys, respectively). For example, placing the telephone's receiver to one's ear, drinking from the cup, feeding the large doll with the spoon or bottle, and pushing the truck were each considered functionally appropriate actions. Ambiguous actions, such as placing the spoon or bottle in one's own mouth and swinging the baseball bat were intentionally excluded from the list of possible functional uses of the toys because it would be unclear whether the acts served a functional purpose (i.e., feeding oneself or warming up in the batter's box) or were simply examples of stereotypical mouthing and waving of objects. The toys were initially positioned in such a manner that the toddlers were required to manipulate them before a functional action could be observed. For example, the truck was placed on its side and the cover of the teapot was upside down on the floor next to the pot.

The occurrences of two classes of play (Fenson, Kagan, Kearsley, & Zelazo, 1976) were used to assess the toddlers' cognitive development through preferred styles of play. *Stereotypical play* was defined as any instance of mouthing, fingering, waving, or banging the toys. Mouthing was recorded when any toy made contact with the infant's lips, tongue, or teeth; fingering when any toy was manipulated in a nonfunctional manner with one or two digits; waving when a toy moved

TABLE 2
Toys With the 36 Adult Classified Appropriate Uses, and Order of Their Placement (From the Infant's Left in a Semicircle) in the Testing Room

Toys	*Appropriate Uses*
Baseball bat, ball, glove, and hat	Throw ball
	Roll ball
	Glove in hand
	Place ball in glove
	Place hat on head
	Hit ball with bat
Large baby doll with dress, hair brush, and bottle	Undress
	Dress
	Brush hair
	Feed with spoon
	Feed with bottle
	Feed with cup
	Cradle in arms
	Kiss doll
Telephone	Receiver to ear
	Dial
	Converse (babble)
	Present phone to other
	Replace receiver properly
Plastic dump truck, blocks, and garage	Push truck
	Make truck noises
	Push or place truck in garage
	Place block in truck
	Dump block from truck
Small unisex doll with chair, table, and bed	Set doll in chair or bed
	Lay doll in bed
	Arrange furniture
	Stand and walk doll
	Child sit on toy chair
Teapot, two cups, two saucers, and one spoon	Cover on pot
	Stir spoon in cup or pot
	Pour from pot to cup
	Drink from cup
	Drinking sounds
	Offer drink from cup to mother or doll
	Set cup in saucer

through an estimated arc of at least 60º; and banging when a toy was struck against another toy, the floor, or a wall. *Functional play* was coded whenever the toddlers used a toy in a previously determined adult manner and was consistent with Fenson's definition of appropriate functional play. For the purpose of this study, functional play was limited to the occurrence of one or more of the 36 behaviors listed in Table 2. The classes of play behavior were deliberately defined to produce mutually exclusive categories.

The number of different appropriate uses for the toys, referred to as displayed hypotheses, reflects the breadth of functional play, and was defined as the number of different functional acts conducted from among the 36 listed in Table 2. Each act was only counted the first time it occurred, for a maximum score of 36.

To determine whether differences between the toddlers in the two objective PNMS stress groups existed in the overall amount they engaged in toy play during the 15-min observation session, two additional variables were calculated: length of session and nonplay activity. Length of session was defined as the number of 10-sec units for which a judgment concerning the child's play could be made. In other words, length of session reflects the amount of time the toddler spent in the observation room during which the child's behavior (i.e., stereotypical or functional play, or nonplay activity) could be recorded during the 15-min observation session, with a maximum of 90 units of observation possible. Nonplay activity was defined as the number of 10-sec units during which the child was not actively playing with the toys. The percentage of nonplay activity was calculated by dividing the instances of nonplay 10-sec units of observation by the total length of session available for each toddler. Percentages of each type of play were calculated by dividing the instances of each play type by the length of session available for each child.

Procedure

The research protocols for this study were approved by the Douglas Hospital Research Ethics Board and by the Research Ethics Committee of the Louis-H-Lafontaine Hospital, both in Montréal, Québec.

Data on objective exposure (STORM32) and subjective stress (IES–R), maternal anxiety (GHQ), and demographic characteristics of the family were obtained from an initial questionnaire sent to potential participants on June 1, 1998, that is, 5 to 6 months after resolution of the ice storm crisis. A second questionnaire was sent to families 6 months after the due date reported in the first questionnaire. This mailing included the assessment of postpartum depression (EPDS), other life events occurring during pregnancy, perinatal outcomes such as birthweight, and obstetric complications.

Families were then contacted for participation in cognitive testing when the children were 2 years of age. The full testing protocol lasted between 90 and 120 min, beginning with the play session, followed by administration of the Bayley Scales, a structured teaching play session, and an imitation sorting task. After the parent signed the informed consent form, the parent and the toddler entered a 3.65 × 5.48 m carpeted room that contained a chair and couch adjacent to an observation room. The toys were positioned in a preset order that formed a semicircle 1.42 m in front of the parent's chair. Each toy was placed in the same location and in the same manner for each infant. Toys were placed so that toys from the same gender-specific categories were not adjacent to each other.

The 15-min (90 10-sec units) session started with the parent placing the toddler on the floor within reach of the toys and saying, "Look at all the toys. Go play with the toys," after the research assistant discreetly tapped on the window from an adjacent observation room. The parent was instructed not to interact with the toddler and was given a parent-rated language inventory to complete to facilitate this request. The parent was permitted to respond to the toddler's overtures but was asked to redirect the toddler's attention back to the toys as quickly as possible. The play session lasted for the full 15-min (90 unit) period unless the parent indicated that it should be stopped earlier. Sixty percent of the sessions lasted the full 90 units, 26% lasted between 80 and 89 units, and the remaining 14% of sessions lasted fewer than 80 units. The shortest session lasted 56 units. All play sessions were videotaped for later coding of the toddlers' toy play by a research assistant blind to the objective PNMS stress group and trimester of exposure classifications for each toddler. A timer was started when the mother placed the child in front of the toys to time the session.

Play Behavior Coding

The play behavior of the children was coded from the videotapes of the sessions. The first author trained the two research assistants on how to code the children's play using videotapes of 9 children whose mothers became pregnant within 3 months following the ice storm and who were, thus, ineligible for this part of the project. A high level of interrater agreement was reached for all measures (r = .923). Play sessions from 6 of the children in this study were recoded by the first author and one of the research assistants. An interrater reliability of r = .917 was obtained.

For each 10-sec unit, the coders indicated whether the children were actively engaged with the toys (i.e., stereotypical, functional, or nonplay activity). Likewise, if the children were actively engaged with the toys, the specific play activity (i.e., displayed hypothesis) was also noted. This method of coding permitted us to determine the percentage of time the children were actively engaged with the toys, the percentage of play units used for each style of play, and the specific play activities in which each child engaged.

Statistical Analyses

Pearson product–moment correlations were conducted between the five outcome variables (i.e., stereotypical play, functional play, displayed hypotheses, length of session, and nonplay activity) and the potential covariates (i.e., gestational age, birthweight, obstetric complications, maternal anxiety, maternal postpartum depression, and parental socioeconomic status) to determine which covariates would be retained for the subsequent between-group analyses. Analyses of covariance (ANCOVAs) were conducted separately for each outcome variable. Prenatal maternal objective stress (low, high) and trimester of exposure (first, second, or third) served as the independent variables. In all instances, prenatal maternal subjective stress (IES–R) was included as a covariate in the analyses, as this measure was of prime interest. Other potential covariates were entered into the analyses only if they were significantly correlated to the outcome variable. All significant interactions between objective PNMS and trimester of exposure were assessed by dividing the sample by trimester of exposure and conducting a one-way ANCOVA using prenatal maternal objective stress as the independent variable and maintaining the appropriate covariates.

RESULTS

Intercorrelations Between Outcome Variables and Potential Covariates

We first examined correlations between the five outcome variables and potential covariates (Table 3). Maternal subjective PNMS to the ice storm (IES–R score) was significantly related the toddlers' stereotypical play ($r = .456$, $p < .001$), functional play ($r = -.354$, $p < .01$), and displayed hypotheses ($r = -.384$, $p < .01$): Higher levels of maternal subjective stress reactions were related to lower levels of functional play and a lower number of different displayed hypotheses exhibited by the toddlers, and to higher levels of stereotypical play. Higher birthweights were associated with a longer length of session exhibited by the toddlers ($r = .273$, $p < .05$). Higher levels of postpartum depression were related to shorter length of session exhibited by the toddlers ($r = -.306$, $p < .05$). None of the remaining potential covariates were significantly related to any of the five dependent variables.

High Versus Low Objective Stress

The main purpose of this study was to determine whether exposure to high levels of objective PNMS affected the quality (i.e., level of functional play) and breadth (i.e., number of displayed hypotheses) exhibited by the toddlers. However, to eliminate the possibility that potential differences in the play of toddlers exposed to

TABLE 3
Intercorrelations Between Dependent Variables, Objective PNMS (STORM32), Subjective PNMS (IES–R), hand Other Potential Covariates

		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
1	Length of session	—	$-.364^{***}$	.007	.182	.098								
2	Nonplay activity (%)		—	$-.522^{****}$	.016	$-.278^{**}$								
3	Functional play (%)			—	$-.725^{****}$	$.675^{****}$								
4	Stereotypical play (%)				—	$-.601^{****}$								
5	Displayed hypotheses					—								
6	Objective PNMS	.044	.109	$-.367^{***}$	$.350^{**}$	$-.366^{***}$	—	–.008	.031	.164	–.149	–.301	.156	.105
7	Subjective PNMS	–.040	–.110	$-.354^{***}$	$.456^{****}$	$-.384^{***}$		—	$-.328^{**}$	–.006	–.012	.184	$.246^{*}$	.162
8	Gestational age (weeks)	.076	.108	.075	–.137	.169			—	$.287^{**}$	.118	.034	–.180	.123
9	Birthweight (g)	$-.273^{**}$	–.216	–.045	.128	.031				—	$-.337^{**}$	.017	–.083	.151
10	Number of obstetric complications	–.228	.059	.120	–.075	–.016					—	.057	–.024	–.209
11	Maternal anxiety	.037	–.010	–.073	.070	–.093						—	.030	–.052
12	Maternal postpartum depression	$-.316^{**}$	–.040	–.142	.119	–.217							—	.098
13	Parental SES	.079	–.124	–.031	.220	.086								—

Note. PNMS = prenatal maternal stress; IES–R = Impact of Event Scale–Revised; SES = socioeconomic status.
$^{*}p < .10$. $^{**}p < .05$. $^{***}p < .01$. $^{****}p < .001$.

high or low levels of PNMS might be a function of their level of attention or endurance, analyses were conducted on the amount of time the children from each stress group remained in the observation room (i.e., length of session).

Length of session. Toddlers in the high objective PNMS group spent, on average, 87.4 (SD = 6.4) units of time in the observation room compared to 85.6 (SD = 8.2) units, on average, for toddlers in the high objective PNMS group. Although the toddlers' birthweights and maternal postpartum depression scores were significantly correlated with the length of session exhibited by the toddlers, neither covariate was significantly associated with length of session after being adjusted for by the main effects and interaction terms, which all failed to reach statistical significance. Furthermore, the level of maternal subjective PNMS was not related to the amount of time the toddlers spent in the observation room. As such, any potential differences in play observed between the toddlers exposed to high or low levels of objective PNMS cannot be attributed to overall differences in the time spent in the observation room.

Nonplay activity. Maternal subjective PNMS was not significantly related to the level of nonplay activity exhibited by the toddlers. Toddlers in the high objective PNMS group exhibited a higher percentage of nonplay activity (M = 27.9%, SD = 14.6%) compared to toddlers in the low objective PNMS group (M = 21.0%, SD = 9.9%), $F(1, 45) = 4.57$, $p < .05$, even when controlling for maternal subjective PNMS. Objective PNMS accounted for 9.2% of the variance in nonplay activity. There were no significant effects of trimester of exposure, nor was there a significant interaction between trimester and objective PNMS. As such, toddlers exposed to high levels of objective PNMS spent less time interacting with the toys during the observation period than did their low-stress counterparts.

Stereotypical Play. Maternal subjective PNMS was significantly related to the percentage of stereotypical play exhibited by the toddlers, $F(1, 45) = 8.59$, $p < .01$: Higher levels of subjective PNMS were related to a greater percentage of stereotypical play, and accounted for 16.0% of the variance in the toddlers' stereotypical play. After controlling for subjective PNMS, toddlers exposed in utero to high objective PNMS exhibited a greater percentage of stereotypical play (M = 14.3%, SD = 11.5%) compared to toddlers in the low objective PNMS group (M = 5.8%, SD = 3.7%), $F(1, 45) = 9.69$, $p < .005$, and explained an additional 17.7% of the variance in the toddlers' stereotypical play after controlling for subjective PNMS. Neither the trimester of exposure, nor the trimester by objective stress interaction, was significant. As hypothesized, toddlers exposed to high levels of objective PNMS exhibited higher proportions of more immature play during the observation period. However, the anticipated trimester effect was not seen.

Functional play. Maternal subjective PNMS was marginally related to the percentage of time spent in functional play exhibited by the toddlers, $F(1, 45) = 3.90$, $p = .054$: There was a strong tendency for higher levels of subjective PNMS to be related to fewer instances of functional play, accounting for 8.0% of the variance in the toddlers' functional play. After controlling for subjective PNMS, toddlers exposed in utero to high objective PNMS exhibited significantly lower levels of functional play ($M = 41.9\%$, $SD = 18.3\%$) compared to toddlers in the low objective PNMS group ($M = 60.7\%$, $SD = 11.1\%$), $F(1, 45) = 15.92$, $p < .001$, and explained an additional 26.1% of the variance in the toddlers' functional play after controlling for subjective PNMS. Again, neither the trimester of exposure, nor the trimester by objective stress interaction, was significant. Once again, these results support our hypothesis that high levels of objective PNMS would be associated with lower levels of more mature, functional play. The anticipated trimester effect was not observed.

Figure 1 presents a graphical representation of the differences between high and low objective stress groups for the three dependent variables of percentages of nonplay activity, stereotypical play, and functional play, by trimester of exposure.

Displayed hypotheses. Maternal subjective PNMS was significantly related to the number of displayed hypotheses exhibited by the toddlers, $F(1, 45) =$

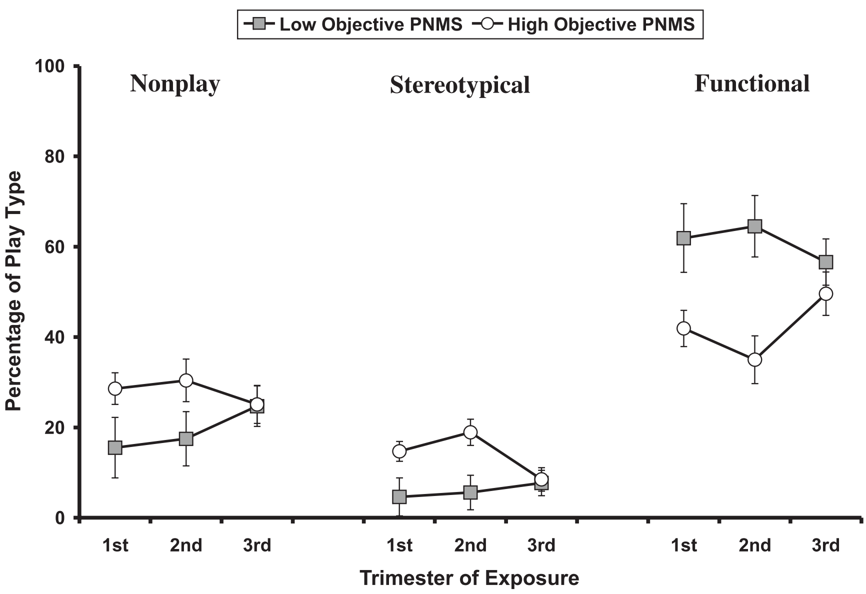

FIGURE 1 Mean percentage of nonplay, stereotypical play, and functional played (and standard errors) exhibited by the toddlers, as a function of level of objective PNMS and trimester of exposure. Means are adjusted for level of subjective PNMS.

5.57, $p < .05$: Higher levels of subjective PNMS were related to lower numbers of displayed hypotheses exhibited by the toddlers, and accounted for 11.0% of the variance in the number of displayed hypotheses exhibited by the toddlers. After controlling for subjective PNMS, toddlers exposed in utero to high objective PNMS exhibited significantly fewer different displayed hypotheses ($M = 10.1$, $SD = 4.5$) compared to toddlers in the low objective PNMS group ($M = 15.2$, $SD = 2.9$), $F(1, 45) = 23.01$, $p < .001$, explaining an additional 33.9% of the variance in the number of displayed hypotheses exhibited by the toddlers. However, the main effect of objective PNMS group was qualified by an objective PNMS Group × Trimester of Exposure interaction, $F(2, 45) = 3.75$, $p < .05$, explaining 14.3% of the variance in the number of displayed hypotheses exhibited by the toddlers.

Significant differences in the number of exhibited displayed hypotheses between toddlers in the low and high objective PNMS groups were only observed for toddlers exposed during the first trimester, $F(1, 16) = 10.05$, $p < .01$, or second trimester, $F(1, 11) = 13.73$, $p < .01$, after controlling for the nonsignificant effects of subjective PNMS (Figure 2). The level of objective PNMS accounted for 38.6% and 55.5% of the variance in the number of displayed hypotheses exhibited by the toddlers exposed during the first and second trimesters, respectively. The mean number of displayed hypotheses for toddlers in the high and low objective PNMS

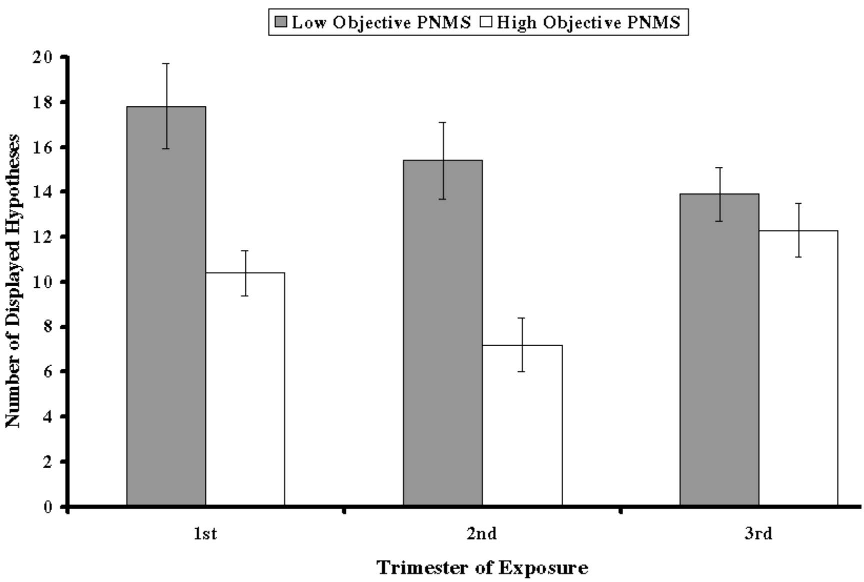

FIGURE 2 Mean number of displayed hypotheses (and standard errors) exhibited by the toddlers as a function of level of objective PNMS and trimester of exposure. Means are adjusted for level of subjective PNMS.

groups who were exposed during the third trimester were comparable, $F(1, 16) = 1.33$, $p = .365$. Subjective PNMS was not related to the number of displayed hypotheses exhibited by the toddlers when the analyses were conducted by trimester of exposure. Once again, the results confirm our hypothesis: Higher levels of objective PNMS were related to lower levels of play diversity (i.e., low number of displayed hypotheses). Unlike the results for stereotypical and functional play levels, a trimester effect was observed: Stress group differences were observed only for toddlers exposed to high levels of objective PNMS in the first or second trimester.

DISCUSSION

In previous analyses with this sample, we observed significant differences in the level of the toddlers' cognitive and linguistic abilities as a function of objective PNMS: 2-year-olds whose mothers were exposed during the first or second trimester of pregnancy to high levels of objective PNMS, but not subjective PNMS, because of the ice storm had lower Bayley MDI scores, and understood and spoke fewer words compared to toddlers whose mothers were exposed to low levels of objective PNMS (Laplante et al., 2004). Given the potential for PNMS to influence infant temperament (Schneider & Coe, 1993; Schneider et al., 1992), which could compromise the toddlers' ability to perform at their optimal levels when being tested by an unfamiliar examiner, our goal was to determine whether similar group differences were observable when we assessed the children's play abilities in a free play session. If similar effects of PNMS were observed on the children's play abilities and on the formal Bayley Scales assessment, we would be in a better position to conclude that PNMS has a major effect on cognitive development in early childhood. As such, the goal of this study was to determine whether different aspects of toy play, which reflect general cognitive abilities, would differ for children exposed to two levels of objective PNMS, while controlling for other potential risk factors, in particular the mothers' subjective stress reaction to the ice storm. Furthermore, we wished to determine whether the timing of the exposure to a stressful event moderates the influence of PNMS on the toddlers' toy play.

A major advantage of Project Ice Storm is the use of our independent, external stressor that was distributed in a quasi-random manner, as our source of PNMS. Without a stressor of this type, any effects uncovered in this study would reflect an immeasurable mix of genetic transmission of temperament or cognitive abilities from parent to child, the prenatal environment, and postnatal rearing practices. Given the random, independent nature of the ice storm, as well as our ability to control for parental socioeconomic status, maternal trait anxiety, and other postnatal confounds, our results are able to implicate stress from the ice storm as the most likely factor.

Of the six potential covariates, only subjective PNMS was consistently related to the children's play abilities: Higher subjective PNMS was related to more immature play in the children. Of the remaining potential covariates, the children's birthweight and the level of maternal postpartum depression were negatively related to the length of session. Children who had lower birthweights and whose mothers reported higher levels of postpartum depression spent less time in the observation room. Therefore, these children had less time to engage the toys in any type of play.

No effects of objective or subjective PNMS were observed on the length of the observation session during which our measures of toy play were assessed. Thus, toddlers from the two objective PNMS stress groups had similar opportunities to engage the toys with either stereotypical or functional play. However, toddlers in the high objective PNMS stress group engaged in more nonplay activity; that is, toddlers in the high objective PNMS stress group spent less time directly interacting with the toys in either stereotypical or functional play than did toddlers in the low objective PNMS stress group. Thus, although exposure to the toys was comparable for the toddlers in the two objective PNMS stress groups, toddlers in the high objective PNMS stress group played less.

The level of objective PNMS had a clear negative impact on the quality of the toddlers' play: Toddlers in the high objective PNMS stress group engaged in more nonplay activity, exhibited fewer instances of functional toy play, greater amounts of immature stereotypical toy play, and played with the toys in more limited fashion. The magnitude of the differences between high and low objective PNMS stress groups are not only statistically significant, they are also clinically meaningful. Controlling for maternal subjective distress from the ice storm, toddlers from the high objective PNMS stress group spent 31% less time in functional play (41.9% vs. 60.8%), and 2.3 times more time in stereotypical play (14.3% vs. 5.8%) than did their low objective stress counterparts. As well, they exhibited a third fewer unique functional acts with the toys (10.1 vs. 15.2): This effect was even greater among toddlers who were exposed during the first or second trimester of pregnancy, with those in the high objective stress group exhibiting approximately half the number of displayed hypotheses as their low objective stress counterparts.

Our results suggest that high exposure is associated with significant developmental delays. Zelazo and Kearsley (1980) reported that at 15½ months of age, children engage in functional play an average of 52% of the time. The 24-month-olds in our high objective PNMS group averaged even less time in functional play (42%), suggesting a delay of greater than 9 months that is attributable to prenatal stress. Moreover, the children in our high objective PNMS group performed an average of 10 different functional acts during the 15-min play session, which is comparable to the number displayed by typical children at 15½ months of age (i.e., 10.4 acts), that is, 8½ months younger (Zelazo & Kearsley, 1980). These effects of objective PNMS remained even after controlling for the effects of the covariates, including subjective PNMS levels.

The mothers' subjective ice storm stress, assessed by the IES–R and reflecting symptoms like those of posttraumatic stress disorder, was a significant covariate for all three of the play quality variables. The magnitude of these effects, however, was consistently lower (η^2 range = .08–.16) than the effects for objective stress exposure (η^2 range = .177–.339). Although conventional wisdom would suppose that the effects of a major life event during pregnancy on the fetus would be mediated by the mother's subjective distress and accompanying physiological arousal, our results suggest that objective and subjective stress are relatively independent predictors (given a low correlation between them), and that the objective severity of the exposure to a natural disaster is of greater potency than the pregnant woman's reaction to it. To date, no other study of PNMS has been able to compare the relative effects of objective and subjective stress on the fetus.

We found that the effects of PNMS on the diversity of play were moderated by the timing of the stressor during pregnancy: Effects were greatest for children exposed during the first and second trimesters. These timing results complement those obtained with nonhuman primates (Schneider, 1992) and assessments of the influence of maternal antenatal anxiety on the cognitive functioning of toddlers (Buitelaar et al., 2003; Laplante et al., 2004). As expected, these results are also nearly identical to the results obtained with the same sample using the Bayley Scales (Laplante et al., 2004). Interestingly, this early period of prenatal development is associated with rapid development of cortical and limbic structures involved in higher order cognitive functioning (Herschkowitz, 2000).

As suggested by animal research, PNMS may influence the postnatal development of the fetus through its direct effects on limbic development, specifically the Hypothalamus-Pituitary-Adrenal (HPA) axis, and as mediated by placental functioning (Avishai-Eliner, Brunson, Sandman, & Baram, 2002; Coe et al., 2003; Takahashi, Turner, & Kalin, 1998; Uno et al., 1994). Acute and chronic stress depletes the placenta's ability to protect the fetus against teratogens, such as maternal cortisol, increasing the risk of permanent neurological impairments (Avishai-Eliner et al., 2002; Uno et al., 1994). This is particularly true when fetuses are exposed early in the pregnancy (Avishai-Eliner et al., 2002) when limbic structures are initially forming and before the placenta begins producing the enzyme 11 beta-hydroxysteroid dehydrogenase, which converts noxious cortisol to benign cortisone (Welberg & Seckl, 2001). A similar process is suspected to occur when pregnant women are exposed to high levels of anxiety (Buitelaar et al., 2003; Huizink et al., 2004), as may have been the case for many women in this study. However, a more thorough examination of this potential relation is required in humans before any causal links between PNMS and problems in limbic development can be elucidated.

The inclusion of maternal subjective PNMS (IES–R scores) was an important addition to our analyses. In bivariate associations, higher levels of the mothers' subjective ice-storm-related distress were correlated with a higher percentage of immature stereotypical play and with a lower number of displayed hypotheses. There was also a strong tendency for higher levels of subjective PNMS to be correlated with a lower percentage of the more advanced functional play. The negative effects of maternal subjective PNMS remained even in our analyses alongside the effects of objective PNMS exposure. Given that unpublished analyses with our full sample of mothers indicate that IES–R tends to correlate only moderately with the degree of objective PNMS exposure, $r(222) = .310$, but correlates more strongly with our measure of state anxiety problems (GHQ), $r(222) = .353$, associations between maternal IES–R levels and child outcomes could be a function of postnatal parenting influences. For example, elevated subjective PNMS, because it is related to elevated maternal anxiety in our full sample, suggests that mothers who are predisposed to react negatively to stressful situations may interact differently with their children during early childhood compared to mothers who do not react negatively to stressful situations, in a similar manner as anxious women have been shown to interact (Kaitz & Maytal, 2005). Although possible, neither maternal anxiety nor levels of postpartum depression were significantly related to the mothers' subjective PNMS levels or to the functional play abilities in the toddlers in this sample. Why subjective PNMS was not related to maternal anxiety and postpartum depression in this sample is unclear, but it may be related to the fact that we chose only healthy children for inclusion in the study. Regardless, our findings indicate that measures of maternal anxiety and postpartum depression may not be sufficient predictors of functional play abilities in toddlers. Our results suggest that mothers' subjective reaction to a specific traumatic event, however, does predict future functional play abilities. Thus, subjective PNMS may be seen as an additional factor that, whether alone or coupled with objective PNMS, contributes to the level of functional play exhibited by toddlers at 2 years of age. How subjective PNMS affects functional play development remains unclear. It may have a direct effect on the fetus, as outlined earlier, or an indirect effect via mother-child postnatal interactions.

The findings reported here demonstrate a clear relation between PNMS and the quality of the toddlers' toy play at 2 years of age. However, several limitations exist in this study. First, the findings are based on a relatively small sample size. The initial 224 participants in Project Ice Storm represent only 15.5% of the toddlers from the Montérégie (i.e., the region of Québec most affected by the ice storm) who were in utero during the ice storm and whose mothers were invited by their physicians by mail to participate in the initial phase of Project Ice Storm; the 52 participants in this study were selected from among these initial participants. Thus, our findings cannot be generalized to the population of the region. Second, although we carefully selected the toddlers in this study from among the 150 families who continue to participate in our study, and made every effort to construct a sample of toddlers whose mothers reported not having smoked or consumed alcohol during their pregnancies, our information was obtained from self-report questionnaires for which veridicality is always a concern. Likewise, the mothers may not have accurately reported other prenatal complications, such as gestational diabetes, which may have affected the toddlers' development. Third, dividing the toddlers by objective stress severity (i.e., low vs. high) and timing (first, second, or third trimester) of exposure resulted in several small cell sizes. Fourth, the findings reported here represent a single point in time of the toddlers' development. It remains unknown whether the observed relation between PNMS and the toddlers' development, as measured by toy play at 2 years of age in this study, will be maintained, strengthened, or weakened with age. We are presently analyzing data from a follow-up assessment of the intellectual, language, behavioral, and neuromotor development of the full sample of families conducted when the children were 5½ years of age. The findings of our ongoing longitudinal study will further determine whether PNMS will have long-term effects on development across a wider range of abilities. Finally, replication of these findings is required. Future research must assess both the objective and subjective aspects of PNMS and obtain samples of maternal cortisol, and should obtain these measures as soon as possible following the stressful event, as our findings suggest that both aspects of PNMS may place the unborn fetus at risk for developmental problems.

This study was successful, however, in its goal of highlighting the importance of measuring the objective aspect of PNMS and dissociating it from the subjective stress reactions of the mothers. Regardless of the limitations inherent in this study, objective and subjective PNMS were negatively related to the quality of toy play in 2-year-old toddlers. This relation is important when one considers that the stress faced by the pregnant women in this study was relatively minor (i.e., one third of the sample reported that the ice storm was altogether a positive experience) when compared to that experienced by pregnant women during the September 11, 2001 terrorist attack in the United States or the more recent natural disasters throughout the world. In the latter events, a substantial number of husbands and children of pregnant women perished, events that are much more stressful, both objectively and subjectively, than losing electricity for an extended period even during a Canadian winter. Thus, if development is placed at risk by the level of stress experienced by pregnant women in this study, how much greater would the effects of larger catastrophic events be? Moreover, the results of this study highlight the need to assist pregnant women, especially those in their first and second trimesters of pregnancy, during crises to minimize the severity of their exposure and initiate counseling to reduce their traumatic reactions to the crisis. Early invention, such as closer monitoring of fetal development to reassure the mother (Field, Sandberg, Quetel, Garcia, & Rosario, 1985), may help reduce the delays that we observed in this sample of toddlers exposed to high levels of objective PNMS in the first and second trimesters of pregnancy.

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