Effects of an Early Family Intervention on Children’s Memory: The Mediating Effects of Cortisol Levels

Daphne Blunt Bugental, Alex Schwartz, and Colleen Lynch

ABSTRACT—Developmental psychologists have long been concerned with the ways that early adversity influences children’s long-term outcomes. In the current study, activity of the hypothalamic–pituitary–adrenal axis of medically at-risk (e.g., preterm) infants was measured as a result of maternal participation in a novel cognitively based home visitation program (versus a Healthy Start home visitation program). Maternal participation in the cognitive intervention predicted lower basal cortisol levels among infants—with reduced levels of maternal avoidance/withdrawal serving as a mediator of this relation. Lower cortisol levels in infancy, in turn, predicted higher verbal short-term memory (STM) at age 3. STM represents a cognitive ability that has importance for children’s later educational outcomes. Findings provide experimental evidence concerning the pathway by which an early intervention may produce hormonal changes that can, in turn, influence children’s learning outcomes.

An emerging body of research has shown a relationship between early stress and later outcomes of the young, including structural changes in the brain and functional deficits in learning and memory. However, little experimental evidence has been provided among humans for such processes or for ways of preventing such processes. Our goal here was to assess the cortisol levels and memory abilities of at-risk children as a result of maternal participation in a cognitively based home visitation intervention. Consistent with the increased use of evidence-based evaluation and practice (e.g., Chaffin & Friedrich, 2004), we employed a randomized controlled trials experimental design. This design allowed us to test the ways by which potentially harmful pathways are amplified or attenuated by systematic alterations in very early experience. We also explored the role of parental practices and child cortisol levels as mediators of later outcomes. Although community-based interventions have allowed the assessment of differences in outcomes, they have rarely given consideration to the mechanisms by which such differences occur.

Child Risk Factors
In the current study, we assessed the long-term outcomes of children born at medical risk (and who typically began life in a neonatal intensive care unit, NICU). Such experiences provide both a direct source of stress to infants and an indirect source of stress as a result of the potential responses of their parents. Later problems in cognitive development have often been observed for high-risk infants (as reviewed by Rose & Feldman, 2000). In addition, Slykerman et al. (2005) found that, when high-risk children were subsequently exposed to maternal stress, their intelligence test scores were lower at older ages.

Considerable attention in past research has been given to the early history and later outcomes of preterm infants—the primary referral group in the present study. For example, Beauchamp et al. (2008) found that preterm children are more likely to demonstrate memory deficits at older ages. In addition, Smith et al. (1996) found that high-risk (very low birth weight) preterm infants showed lower cognitive skills and receptive language than did low-risk preterm infants or full-term infants. Although all infants benefitted by mothers’ use of strategies that maintained infants’ attention, heightened benefits were shown for preterm infants. Later research within...
this program (Smith, Landry, & Swank, 2000) revealed that high-risk (preterm) children—in comparison with full-term children—were particularly likely to benefit from maternal scaffolding at 3 years of age (i.e., verbal interaction that facilitates relations between objects, actions, and concepts) in terms of their cognitive skills. At the most general level, preterm children show exceptionally high benefits (in terms of both cognitive and social skills) when they receive consistent maternal responsiveness across the first 4 years of their lives (Landry, Smith, Swank, Assel, & Vallet, 2001). The program of research conducted by these investigators documented the extent to which positive parenting practices can reduce later deficits often shown by high-risk children.

Early Stress and Hormonal Dysregulation

Although we focused here on stress experiences of infants born at medical risk, there are many potential sources of early stress in children's lives. Growing up in an aggressive or unsupportive environment affects psychological, emotional, biological, and hormonal functioning (as reviewed by Repetti, Taylor, & Seeman, 2002). In infancy and early childhood, any of these experiences predict dysregulation of children’s stress responses, including the homeostatic mechanisms of the hypothalamic–pituitary–adrenal (HPA) system. Dysregulation of the HPA axis, in turn, is associated with social–emotional problems and cognitive impairment. Research focused on the effects of chronic stress on children's HPA regulatory processes reveals both state-like effects (cortisol reactivity to an acute stressor) and trait-like effects (average cortisol levels) (Shirtcliff, Granger, Booth, & Johnson, 2005).

Stress response systems (including the HPA axis) normatively adjust to change in states of the body in adaptive ways, a process referred to as allostaticism. McEwen and Stellar (1993) introduced the concept of “allostatic load,” the process by which stress response systems may be exposed to excessive wear and tear as a function of being activated too frequently and without an adequate shutting off of the responses involved. When this latter process occurs, stress response systems become dysregulated. Specific to our predictions here, McEwen noted that chronic stress leads to alterations in basal cortisol levels.

The effects of stressful experiences on the regulation of the HPA axis are more pronounced when they occur early in life (as reviewed by Gunnar & Cheatham, 2003) and differ from the effects found at older ages (Tarullo & Gunnar, 2006). For example, the long-term effects of maternal depression are more pronounced when they occur during infancy (Essex, Klein, Cho, & Kalin, 2002). It is important to note that stressful events may either predict high or low average cortisol levels—based on the age of the child and the particular nature of the stress (Gunnar & Quevedo, 2007).

Effects of Elevation in Cortisol Levels on Brain Development and Cognitive Abilities

Relationships have also been found between early stress, elevation in average cortisol levels, and later cognitive abilities. Persistent elevations in cortisol levels, whether following from early experiences or medical disorders such as Cushing’s Disease, have been well established as predictors of reduced capability for learning and memory (Jameison & Dinan, 2001; Lupien, King, Meaney, & McEwen, 2001; Lupien et al., 2005). Bremner and Narayan (1998), in their review of the relevant literature on this topic, concluded that early stress (with resultant effects on the HPA axis) influences the developing brain in ways that produce later deficits in cognitive functioning.

Research With Human and Animal Models

Research on this topic has been conducted both with humans and nonhumans. Experimental work on this topic has been historically limited to nonhumans. Studies employing animal models have provided considerable evidence that early caregiving patterns influence both the stress responses and later cognitive abilities of the young (e.g., Liu, Diorio, Day, Francis, & Meaney, 2000). In addition, young primates who were peer reared, in comparison with those who were mother reared, were found to show enlargement of stress-sensitive brain regions, for example, areas within the prefrontal cortex (PFC) (Spinelli et al., 2009).

Research on humans has relied primarily on naturalistic observations. Children exposed to maternal stress (Essex et al., 2002) or depression (Bugental, Martorell, & Barraza, 2003; Lupien, King, Meaney, & McEwen, 2000) show elevation in their basal cortisol levels. In addition, exposure to poverty predicts elevation in young children's average cortisol levels (Lupien et al., 2001), as well as deficits in neurocognitive development (Noble, McCandless, & Farah, 2007). Children who have been maltreated (in particular if they show major behavior problems) are more likely to show higher average cortisol levels and more disrupted diurnal rhythms than do other children (Cicchetti & Rogosch, 2001; Golier & Yehuda, 1998; Hart, Gunnar, & Cicchetti, 1996). As might be expected, measures of cumulative risk exposure predict elevated cortisol levels (Evans, 2003). As concluded by Bremner and Narayan (1998) in their review of the effects of early stress, there is a high level of overlap in research findings in research that involves naturalistic observations of humans and experimental work with nonhumans. In both cases, early stress predicts memory deficits at later ages.

Short-Term Memory (STM) and the Brain

Considerable attention has been given to the relationship between stress and STM, that is, the capacity to temporarily store a limited amount of information. The PFC has been
identified as an area of the brain that is of particular importance for STM (Baddeley, 1990; Li, Gan, Gong, Luo, & Zeng, 2003). Experimental research with nonhumans has demonstrated that chronic stress leads to reduced STM as a result of reduced dopaminergic transmission in the PFC (Mizoguchi et al., 2001). The PFC has also been shown to be sensitive to stress hormones (Amsten & Li, 2005; Cerqueira, Mailliet, Almeida, Jay, & Sousa, 2007). Relevant to our concern here, the PFC is adversely influenced by mistreatment-induced stress among children (De Bellis et al., 2002).

Neuromaging research (as reviewed by Jonides et al., 2008) has shown the separability of brain areas involved in verbal STM and spatial STM. Selective interference studies (e.g., Brooks, 1968; den Heyer & Barrett, 1971) have also provided evidence demonstrating the distinctiveness of verbal STM and visual STM. Deficits in verbal STM have been found to be particularly common among adult survivors of childhood abuse (Bremner et al., 1995). In the present article, we provide separate measures of verbal and visual STM.

The Present Study
Families were randomly assigned at birth to either a cognitive reframing intervention (HV+) or an intervention that relied primarily on parent education and provision of support (HV). The methods used in the HV+ intervention are designed to facilitate parents’ constructive reinterpretation of caregiving challenges, along with their perceived capacity to resolve those challenges (Bugental et al., 2002). This intervention is rooted theoretically in cognitive approaches to parenting, reflecting the increasing importance that has been assigned to parents’ attributions as predictors of their affective and behavioral responses to their children (Bugental & Johnston, 2000; Dix, 1993; Grusec & Mammone, 1995). Although our focus here is on interventions directed to mothers of infants, cognitive reframing approaches have also been found to be effective with parents of older children (Azar, 1997). The HV intervention made use of methods employed in the Healthy Start Model (Duggan et al., 1999), a program that, despite early promise, has not been found to reduce child maltreatment (Bugental et al., 2002; Duggan et al., 2004).

Predictions were tested regarding the effects of systematic variation in children’s early experience (as a result of type of intervention) on (1) their basal cortisol levels and (2) their later cognitive ability. For the first year of the program, we assessed the extent to which variations in mothers’ harsh or avoidant practices mediated the relationship between maternal participation in an early intervention and changes in children’s cortisol levels. Our long-term question concerned the extent to which changes in children’s cortisol levels served to mediate a relationship between maternal participation in an early intervention and children’s later cognitive abilities at age 3.

Hypothesis 1: It was predicted that children whose mothers participated in the HV+ condition, in comparison with those in the HV condition, would show lower levels of cortisol (mid-morning), as mediated by (1) reduced parental use of harsh tactics and/or (2) parental use of avoidance/withdrawal tactics (see Figure 1). Both patterns of maternal response have a pronounced impact on children’s emotional competence and/or regulation abilities (Taylor, Eisenberger, Saxbe, Lehman, & Lieberman, 2006; Volling, McElwain, Notaro, & Herrera, 2002). In the present study, we make a separate test of these two different types of parenting practices. This allows a test of the extent to which either or both parenting practices have an impact on children’s basal cortisol levels.

The expectation that the HV+ condition would influence maternal behavior is based on past findings of the effects of this intervention on mothers’ use of harsh or neglectful practices (Bugental et al., 2002). As no significant (or trend-level) effects on maternal affect or parenting practices were found for mothers in the HV condition (in comparison with a pure control condition), there was no reason to anticipate changes in child responses in the present study as a result of participation in the HV condition.

Hypothesis 2: It was predicted that children whose mothers participated in the HV+ condition, in comparison with those in the HV condition, would show enhanced short-term verbal memory at age 3, as mediated by children’s lower cortisol levels (see Figure 1). The expectation that elevated cortisol levels would influence STM is based on past findings on the influence of cortisol levels on the functioning of the PFC.

METHOD

Participants
Participants included 64 mothers who participated in the Family Thriving Program (an intervention described in Bugental et al., 2002 and Bugental & Schwartz, 2009). Families were primarily referred to this program by physicians or social workers associated with the NICU that served families in the entire county. Additional referrals were made by public health nurses or pediatricians when infants exhibited major medical problems.

Referral and selection took place soon after the infant’s birth, with a mean intake age of 9.37 weeks (SD = 5.50). Thirty-three per cent were referred based primarily on preterm birth,
mothers often lived in remote rural areas and were highly mobile in their place of residence (e.g., migrant farm workers). Third, mothers had little formal education, and most did not speak English.

**Intervention**

Bugental et al. (2002) developed a cognitively based home visitation program (HV+). Within this program, mothers are redirected away from blame attributions and receive repeated experience in problem-solving and information-seeking efforts (see http://www.psych.ucsb.edu/~bugental/frp_program_protocol-1-1.doc for information on training, supervision, and implementation of the program). The HV+ intervention also facilitates mothers’ cue-detection efforts (learning to interpret what an infant is experiencing as a result of nonverbal cues). The HV+ program was compared here with the (HV) Healthy Start home visitation program (Breakey & Pratt, 1991; Duggan et al., 1999), in which primary reliance is placed on parent education and provision of social support. Although early findings for this program were hopeful, a randomized-trials evaluation did not provide evidence for the expected reduction in child maltreatment (Duggan et al., 2004). Although both the HV+ and the HV interventions focused on increasing mothers’ knowledge about parenting and their access of social and community resources, their methods differed. In the HV condition, mothers were directly provided social support, parent education, and information about community resources. In the HV+ condition, the focus was on facilitating mothers’ problem-solving and information-seeking skills. That is, they were assisted in ways to seek information about infant development and possible ways to seek social and community support, along with repeated experience in constructive problem solving.

Prior work within our program (Bugental et al., 2002) has shown that parental practices at the end of the 1st year differed between mothers in the HV condition and mothers in a control group in which no services were provided. Thus, the HV condition may be viewed as an “attention control group.” Mothers in the HV+ condition were seen with equal frequency as were those in the HV+ condition. A bilingual–bicultural home visitor was assigned to all Spanish-speaking families. Both programs continued for a year (17 visits). However, contact was maintained (when possible) over a 3-year time period. Home visitors were blind to predictions regarding the effects of intervention condition.

**Procedure**

The complete study was conducted over an 8-year time period. Measures were taken of children’s cortisol levels at the intake visit, 1-year visit, 2-year visit, and 3-year visit by the home visitor. The 3-year visit was conducted in a laboratory setting but the other visits were conducted in the home environment.

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Table 1: Characteristics of Participants in the Two Intervention Conditions

<table>
<thead>
<tr>
<th></th>
<th>HV+ condition M (SD)</th>
<th>HV condition M (SD)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestational age (weeks)</td>
<td>35.9 (3.5)</td>
<td>36.5 (4.1)</td>
<td>−0.6</td>
</tr>
<tr>
<td>Intake age (weeks)</td>
<td>11.4 (13.3)</td>
<td>9.9 (6.3)</td>
<td>1.5</td>
</tr>
<tr>
<td>Birth weight (grams)</td>
<td>2447 (848)</td>
<td>2694 (931)</td>
<td>−257</td>
</tr>
<tr>
<td>Maternal age</td>
<td>28.1 (6.4)</td>
<td>27.2 (6.2)</td>
<td>0.9</td>
</tr>
<tr>
<td>Maternal education (years)</td>
<td>9.8 (4.4)</td>
<td>9.1 (3.5)</td>
<td>0.7</td>
</tr>
<tr>
<td>Number of siblings</td>
<td>1.0 (1.3)</td>
<td>0.6 (0.8)</td>
<td>0.4</td>
</tr>
<tr>
<td>Social Desirability Score</td>
<td>46.7 (2.6)</td>
<td>49.6 (5.1)</td>
<td>−2.9*</td>
</tr>
<tr>
<td>Child gender (per cent boys)</td>
<td>43%</td>
<td>34%</td>
<td>11</td>
</tr>
<tr>
<td>Father present in family</td>
<td>79%</td>
<td>89%</td>
<td>−10</td>
</tr>
<tr>
<td>Latino (versus Anglo)</td>
<td>89%</td>
<td>87%</td>
<td>2</td>
</tr>
<tr>
<td>Twins</td>
<td>00%</td>
<td>14%</td>
<td>14</td>
</tr>
</tbody>
</table>

*p = .01.
All measures taken on mothers were administered by home visitors. This included the Conflict Tactics Scale (CTS; administered at the 1-year and 3-year visits) and the SDS (administered at the 3-year visit). Children’s cognitive abilities were measured at the 3-year visit by one of the investigators (an individual who was blind to the intervention condition of the children being tested).

Measures

Hormonal Measures

At intake, saliva was measured using passive drool (reflecting methods suggested by Granger et al., 2007). At older ages, saliva was collected via dental rolls. Saliva was expressed into cryogenic vials and stored at −20°C.

Visits were scheduled for mid-morning (as close as possible to 10:00). Measuring at a fixed time had the advantage of avoiding the effects of diurnal variation. The fluctuation of cortisol levels across time, familiarity, and setting is well known (e.g., Haan, Gunnar, Touset, Hart, & Stansbury, 1998); thus, every effort was made to maintain consistency. As shown in Table 2, the times of measurement did not differ significantly across intervention condition. Despite the narrow window in which cortisol samples were taken, time of day (by hour and minute) was included as a covariate in all analyses. The time selected was optimal in that children were normatively awake and had not eaten during the last hour (or more).

For the intake, 1- and 2-year visits, samples were taken during an in-home visit. On the 3-year visit, samples were taken in our lab. Samples were taken immediately upon entry and thus should be interpreted as reflecting the child's hormonal state while they were still riding in their parent’s car, a familiar setting that may lead to reductions in cortisol levels.

During the 1- and 3-year visits, a second saliva sample was taken 40 min after the home visitor's arrival as well as the point of arrival. Children's cortisol levels were relatively stable during this time period \((r = .54\) at the 1-year visit and \(r = .50\) at the 3-year visit). However, levels shown across longer time periods did not become stable until age 2. Partial correlations (controlling for time of day) revealed a relatively stable relationship between cortisol levels taken at 2 and 3 years of age \((r = .39, p = .008)\).

Visits were postponed if mothers or children were currently ill. Families were excluded from cortisol analyses when children used any kind of medication on a recent or regular basis (following procedures recommended by Granger, Hibel, Fortunato, & Kapelewski, 2009). Analyses were conducted to determine whether infants’ cortisol levels were influenced by mothers' smoking or use of hormonal contraceptives. No significant effects or trends were found and these cases were retained.

Prior to assay, samples were thawed and centrifuged at 1,500 rpm for 30 min to separate mucins. Levels of cortisol were measured by utilizing a commercially available enzyme immunoassay (EIA) kit (Salimetrics, LLC, State College, PA). Samples were assayed in duplicate and averaged for use in analyses. The lower limit of assay sensitivity was \(0.007 \mu\)g/dl. The average intra-assay and interassay coefficients of variation were 4.85 and 4.09%.

McCarthy Scales of Children’s Abilities (MSCA, McCarthy, 1972)

The MSCA was conducted (at a 3-year visit conducted in the lab) in either English or Spanish, depending on the participant’s first language. Although the MSCA was not designed to measure specific types of memory, three scales can be interpreted as involving short-term verbal memory. These scales include: Scale 7, part 1, immediate memory of a story; Scale 7, part 2, repetition of a series of words; Scale 14, repetition of a digit series. Scores on the three scales were combined as z-scores to create a combined short-term verbal memory measure.

As noted earlier, STM buffers have been found to differ for verbal and visual tasks. Therefore, findings for Scale 3 (pictorial memory) were analyzed separately. Other measures not relevant to STM included: Scale 1, block building; Scale 2, puzzle solving; Scale 4, word knowledge; and Scale 5, number questions. Measures for which most children were unable to pass initial items were excluded as subject to floor effects.

Self-Report Measures

The CTS (Straus, 1979) was taken at the 1-year visit (as described in Bugental & Schwartz, 2009 and Bugental, Beaulieu, & Schwartz, 2008). An assessment was made of the frequency of use of different parental tactics in response to conflict: (1) harsh parenting tactics (e.g., spanking) and (2) parental avoidance/withdrawal (e.g., “stomping out of the room” in response to conflict). Both measures have been found to predict toddlers’ cortisol levels (Bugental et al., 2003). In addition, mothers completed the Marlowe–Crowne Social Desirability Scale (Crowne & Marlowe, 1960), a measure of self-report biases that are potentially important in interpreting responses given to the CTS.

Table 2

<table>
<thead>
<tr>
<th>Time of Measurement of Cortisol Levels</th>
<th>HV+ condition M (SD)</th>
<th>HV condition M (SD)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intake visit</td>
<td>10.46 (68)</td>
<td>11.05 (68)</td>
<td>−.59</td>
</tr>
<tr>
<td>1-year visit</td>
<td>10.17 (73)</td>
<td>10.47 (57)</td>
<td>−.40</td>
</tr>
<tr>
<td>2-year visit</td>
<td>11.07 (40)</td>
<td>10.40 (62)</td>
<td>.27</td>
</tr>
<tr>
<td>3-year visit</td>
<td>10.12 (54)</td>
<td>10.01 (64)</td>
<td>.11</td>
</tr>
</tbody>
</table>

Note. Mean times are A.M. SDs are shown in minutes. None of the time differences shown between the two intervention conditions reached significance at the .05 level of confidence.
RESULTS

Research Strategy
Analyses of covariance (ANCOVAs) were conducted to test the predicted main effects of intervention condition. In order to allow equivalent findings, central analyses were limited to cases in which all relevant dependent measures were available (reducing the sample from 64 to 53). Seven missing cases were because of child refusals in providing saliva samples (four instances on the year-1 visit, two instances on the year-2 visit, and one instance on the year-3 visit). Four missing cases were due to missing values on the MSCA. Missing values were not replaced.

Predicted indirect effects were measured by Preacher and Hayes' (2008) bootstrapping procedure, a method that is well suited to our data. As one advantage, it allows a test of more than one mediating variable (an advantage utilized here to assess the mediating effects of cortisol levels at different ages, as well as the mediating effects of harsh and avoidant parenting practices). As a second advantage, it provides tests that are appropriate for the non-normal distribution found for cortisol measures. Third, it is sensitive to effects found in small samples. Finally, significant mediation can be measured in the absence of a significant direct relationship between independent and dependent variables. This is because of the fact that, under some circumstances, the test of the mediated effect has greater statistical power than the test of the direct effect (MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002).

Effects of Condition on Children’s Cortisol Levels
An initial mixed-design analysis of variance (ANOVA) was conducted to test the effects of intervention condition on children's cortisol levels across trials (intake, year 1, year 2, and year 3). This analysis was limited to children’s cortisol levels at the start of each of the home visits. The cortisol data revealed positively skewed distributions. Thus, log-transformed scores were used in all analyses. The only significant effect obtained was for the interaction between intervention condition and time, $F(3, 46) = 2.78, p = .05$. Means are shown in Figure 2.

Follow-up ANCOVAs were conducted separately for measures taken at the three postintake visits. Exact time of day was included as a covariate in all analyses. A significant effect was found for intervention condition at the 1-year visit, $F(1, 51) = 4.38, p = .04, \eta^2 = .08$. The effect of intervention at the 2-year visit did not reach significance, $F(1, 50) = 2.11, p = .15$. A significant effect was found for intervention condition at the 3-year visit, $F(1, 52) = 4.75, p = .03, \eta^2 = .08$.

Effects of Intervention Condition on Children’s MSCA Scores
The effects of intervention on children’s short-term verbal memory (combined z-scores on the three short-term verbal memory scales) were measured in ANCOVAs. Two variables (maternal education and maternal ethnicity) were included as covariates because of their significant relation to child memory. As shown in Table 3, the correlation between variables was .51, $p < .01$. In addition, higher scores were found for children in Anglo families ($M = -.04, SD = .78$) than among children in Latino families ($M = -.98, SD = 1.04$), $t(55) = 4.38, p < .01$. As shown in Table 4, intervention condition yielded a significant effect on STM ($F[1, 46] = 4.62$, $p = .04, \eta^2 = .09$). No significant findings were obtained for other MSCA scales, including short-term picture memory.

Effects of Intervention Condition on Parental Conflict Tactics
Multivariate analyses of covariance were conducted to test the predicted effects of intervention condition on tactics used by mothers during conflict with their children, as reported during the 1- and 3-year visits. In the past work in this program (e.g., Bugental & Schwartz, 2009), stronger effects were found for prevalence (presence or absence) of harsh parenting practices than for reported frequency of use of such tactics. Correspondingly, we made use of dichotomous measure of maternal use of harsh and avoidant tactics. Rosenthal and Rosnow (1984) have argued for the legitimacy of using ANOVA methods with dichotomous variables.

Prevalence of use of harsh tactics and avoidant tactics were the dependent variables. Social desirability scores differed significantly across condition and were introduced as covariates. At the 1-year visit, intervention condition yielded a significant main effect on the combined use of both tactics.
Table 3
Correlation between Key Variables

<table>
<thead>
<tr>
<th></th>
<th>M (SD)</th>
<th>M (SD)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal memory</td>
<td>-.20</td>
<td>.04</td>
<td>-.37**</td>
</tr>
<tr>
<td>Maternal avoidance</td>
<td>-.04</td>
<td>.35**</td>
<td>-.07</td>
</tr>
<tr>
<td>Maternal harshness</td>
<td>-.17</td>
<td>-.02</td>
<td>-.05</td>
</tr>
<tr>
<td>Cortisol-year 1</td>
<td>.04</td>
<td>-.10</td>
<td>.05</td>
</tr>
<tr>
<td>Cortisol-year 2</td>
<td>-.14</td>
<td>.09</td>
<td>.08</td>
</tr>
<tr>
<td>Cortisol-year 3</td>
<td>-.11</td>
<td>-.10</td>
<td>-.25</td>
</tr>
<tr>
<td>SDS</td>
<td>.18</td>
<td>-.05</td>
<td>-.03</td>
</tr>
<tr>
<td>Maternal age</td>
<td>-.10</td>
<td>-.11</td>
<td></td>
</tr>
<tr>
<td>Maternal education</td>
<td>-.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Child gestational age</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Correlations shown for cortisol levels reflect logarithmic values. Maternal avoidance and harshness scores represent the reported frequency of these practices during the last 3 months. SDS = Social Desirability Scale.

* p < .05; ** p < .01.

Table 4
Parenting Practices at Age 1 and Child Short-Term Memory (STM) at Age 3

<table>
<thead>
<tr>
<th></th>
<th>M (SD)</th>
<th>M (SD)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV+</td>
<td>.22 (.44)</td>
<td>.43 (.50)</td>
<td>-.21</td>
</tr>
<tr>
<td>HV</td>
<td>.01 (.22)</td>
<td>.32 (.46)</td>
<td>-.31*</td>
</tr>
<tr>
<td>Child verbal STM</td>
<td>.48 (1.12)</td>
<td>-.10 (.65)</td>
<td>.58*</td>
</tr>
<tr>
<td>Child visual STM</td>
<td>1.36 (1.36)</td>
<td>.96 (1.17)</td>
<td>.40</td>
</tr>
</tbody>
</table>

Note. Parental practices reflected reported presence of use during the last three months. Children's STM is shown in z-scores. All means are adjusted for covariates.

* p < .05.

(F[2, 45] = 4.05, p = .02). Follow-up univariate analyses only revealed significant effects for the use of avoidant tactics (F[1, 46] = 6.16, p = .01, η² = .15). Adjusted means are shown in Figure 4.

Indirect Effects of Intervention Condition on Cortisol Levels
Regression analyses were employed to test the indirect effects of intervention condition on children's cortisol levels (with harsh parenting and avoidant parenting at the 1-year visit as potential mediators). Covariates included time of day and social desirability.

Intervention condition predicted maternal use of harsh tactics as a trend (B = .26, p = .08) and avoidant parenting tactics as a significant effect (B = .35, p = .01). That is, greater use was made of harsh and avoidant tactics in the HV condition than the HV+ condition. However, only avoidant parenting tactics were found to be significantly related to children's cortisol levels at the 1-year visit (B = .38, p = .01); higher average levels of cortisol were shown by infants in the HV condition than the HV+ condition. No equivalent effect was found for harsh parenting on children's cortisol levels (B = -.04, p = .68). The main effect of intervention condition on children's cortisol levels was significant (B = .24, p = .03). Consistent with the expected mediation, the effect of intervention condition was no longer significant when parenting tactics were controlled (B = .13, p = .28). The predicted indirect effect of avoidant tactics on children's cortisol levels was significant at the .05 level of confidence. This finding (as shown in Figure 3) supports and specifies one of the pathways shown in Figure 1. The indirect effects of mediators on children's cortisol levels at the 2- and 3-year visit did not approach significance.

Indirect Effects of Children's Cortisol Levels on Short-Term Verbal Memory
Bootstrapping analyses were also conducted to test the indirect effects of children's cortisol levels at the 1- and 3-year visits on the relationship between condition and children's STM at age 3. Time of day, maternal education, and maternal ethnicity were included as covariates.

![Diagram](image)

Fig. 3. Effects of intervention condition on children's 1-year cortisol levels, as mediated by maternal avoidance tactics. Values shown are unstandardized beta coefficients.
High and Low Cortisol Levels

Fig. 4. Effects of intervention condition on children's short-term memory, as mediated by their 1-year cortisol levels. Values shown are unstandardized beta coefficients.

Significant support was only found for the indirect effect of children's 1-year cortisol levels in the relationship between intervention and verbal STM. No comparable effect was found for children's concurrent cortisol levels at age 3 ($B = .12$, $p = .22$). Condition served as a significant predictor of 1-year cortisol levels ($B = .21$, $p = .05$). Cortisol levels, in turn, were significantly related to children's verbal STM ($B = -.70$, $p = .03$). The direct effect of condition on children's memory was significant $B = -.45$, $p = .05$; the effect of condition on child memory did not reach significance when children's cortisol levels were covaried ($B = -.32$, $p = .17$). The predicted indirect effect of children's 1-year cortisol levels on verbal STM was significant at the .05 level of confidence. This finding (shown in Figure 4) supports and specifies one of the pathways shown in Figure 1.

As additional evidence of the selective influences of children's early cortisol level, a second analysis was conducted in which children's concurrent levels of cortisol level were covaried in early cortisol level, a second analysis was conducted in which the pathways shown in Figure 1.

This study examined the long-term cognitive and neurohormonal outcomes of a cognitively enhanced home visitation intervention and the mediators of these outcomes. Support was obtained for the pathways shown in Figure 1. First, children's cortisol levels were lower in the HV+ than the HV condition—an effect that was mediated by mothers' (low) use of avoidant parenting tactics. Second, children in the HV+ condition showed better STM at 3 years of age—an effect that was mediated by children's reduced cortisol levels. These relations demonstrate the biological mediating mechanism by which early parental practices influence children's neurohormonal regulatory systems. Findings support Boyce and Ellis's (2005) theoretical arguments regarding biological sensitivity to context early in life, along with predictions regarding the impact of neurobiological functioning on children's later development (Cicchetti, 2007; Repetti et al., 2002). In addition, they support the relationship between stress hormones early in life and later cognitive abilities (e.g., Liston, McEwen, & Casey, 2009; Mizoguchi, Ishige, Takeda, Aburada, & Tabira, 2004).

Reduced Cortisol Levels

The low mid-morning cortisol levels shown here by at-risk children in the HV+ condition are comparable to those shown by an advantaged group of toddlers and preschool children measured in a home environment (Watamura, Donzella, Alwin, & Gunnar, 2003; Watamura, Sebanc, & Gunnar, 2002). The higher cortisol levels shown by at-risk children in the HV condition are consistent with the elevated levels shown by children who have experienced chronic stress in their interpersonal (Flinn, 2006) and/or community environments (Lupien et al., 2001). The reduced cortisol levels obtained as a result of an early intervention mirror those obtained by Dozier et al. (2006) with very young children who had entered foster care. These investigators found that an “Attachment and Biobehavioral Catch-up Intervention Group” for parents led to reduced children's cortisol levels for both wakeup and bedtime measures. The reduction in cortisol levels in response to an experimentally produced change in children's early environment reflects the plasticity of the developing HPA axis.

Only one of the two types of parenting practices measured predicted reduction in children's basal cortisol levels. Maternal avoidance/withdrawal in response to conflict—but not use of harsh practices—served to mediate the relationship between intervention condition and children's early cortisol levels. These findings are consistent with the observations of Bugental et al. (2003), who found that avoidant parenting but not harsh parenting predicted elevation in children's basal cortisol levels (harsh parenting, in turn, predicted cortisol reactivity to a short-term stressor within this earlier research). Maternal avoidance or withdrawal assumes particular importance early in life in that infants have less ability than older children to regulate their own emotional states. Thus, parental failure to respond appropriately to infant distress may lead to problems in the development of children's own emotion regulation ability (Dawson & Ashman, 2000). The net effect of such an environment is the creation of chronic psychosocial stress early in life. In contrast, responsive parenting has been found to buffer against infants' emotional and neuroendocrine stress responses (e.g., Fisher, Gunnar, Chamberlain, & Reid, 2000; Tu et al., 2007).

The long-term effects of children's cortisol levels on their STM at age 3 were limited to the cortisol levels shown at the 1-year visit. The selective effects of early cortisol are
demonstrated by their continuing effects on STM, even after statistically controlling for children’s concurrent levels of cortisol at age 3. This highlights the significance and long-term effects of children’s early experiences. It may be speculated that stress-induced elevation in cortisol levels affects development of key areas of the brain, which, in turn, has a long-term impact on children’s STM.

Enhanced STM
Children in the HV+ condition performed better on STM tasks than did children in the HV condition. STM has often been found to be susceptible to the effects of short-term stress (Newcomer et al., 1999). However, our findings provide evidence for the effects of chronic stress on STM. As suggested by Evans and Schamberg (2009), chronic stress early in life leads to resultant wear and tear on multiple physiological response systems (allostatic load), which in turn predicts deficits in memory at older ages. No significant changes were observed here for perceptual or performance measures or more general cognitive abilities.

Children’s cortisol levels at the 1-year visit were found to mediate the relationship between intervention condition and children’s STM at age 3. Although these findings are in need of replication, they support the key role of early experiences during infancy (consistent with the work of Essex et al., 2002 and Gunnar & Cheatham, 2003). If further evidence supports our findings, it would suggest that the benefits that follow from a remedial environment are most enduring when they occur during infancy. Although no direct inferences can be drawn about neural processes from our observations, findings are consistent with past research demonstrating the neurohormonal pathway by which stressful experiences influence memory (Taylor et al., 2006; Mizoguchi et al., 2001).

Further work is needed to determine whether reductions in psychosocial stress in children’s environments at older ages can reverse the resultant deficits in STM. Emerging evidence with nonhumans and human adults suggests that this may indeed be possible (Liston et al., 2009).

Limitations
One limitation of this study involves sampling bias. Most of the families were Latino from a low-income, low-education background. Effects of the HV+ condition may differ in European American, African American, or Asian American families or among those who are more highly educated. We intentionally selected children who experienced perinatal complications or other medical problems as a group that would be more susceptible to both the harmful and the protective features potentially present in families. However, in future research, it will be important to determine if similar benefits follow in families who are at a lower level of risk or who pose other types of caregiving challenge. Future support for the findings presented here will also compensate for the limited sample size employed in the current study.

As an additional limitation, measures were not taken of children’s waking time. Although families (including children) normatively arose early, findings might have been stronger if time of waking had been controlled within our analyses. A second limitation in assessment of cortisol levels involves the limited number of measurements taken. Although the findings observed were relatively stable, stronger evidence would have been provided by repeated measurement of cortisol across different hours of the day (thus allowing a comparison of differences in diurnal rhythms shown across intervention conditions). However, existing research by Dozier et al. (2006) suggests that an effective early intervention can be expected to lead to reduced cortisol levels at different times of day.

Our reliance on self-report in assessing parental use of harsh or avoidant practices also poses a limitation. In addition, harsh or avoidant parental practices variables only represent a subset of potential stressors early in life and are limited to variables we found to be malleable in response to an intervention. More complete longitudinal studies (e.g., Flinn, 2006) may provide additional insights to the range of events that create stress early in life, and thus may influence early cortisol levels.

Implications
Increasing evidence has emerged concerning the benefits of early experience on children’s later outcomes, including their cognitive skills (e.g., Landry, Smith, Swank, & Guttentag, 2008; Smith et al., 2000). This study provides insights into the means by which an early cognitive reframing intervention during infancy may produce later cognitive benefits for children. Findings are particularly useful in suggesting the utility of the intervention methods described here with families that include medically high-risk infants. Early intervention carries potential long-term benefits in terms of the reduced cost of high-risk children in later years (as noted by Heckman, 2006). The cognitive reframing intervention ultimately led to enhancement of children’s STM, as mediated by reductions in their basal cortisol levels. These changes have implications for children’s learning, in that the development of STM is closely related to the development of fluid intelligence (Kail, 2007). Increases in STM assume key importance as a result of their implications for more efficient learning in classroom settings (Diamond, Barnett, Thomas, & Munro, 2007). As argued by Bremner and Narayan (1998), there is increasing evidence regarding the relationship between early stress and cognitive skill, which suggests the importance of such processes on children’s academic achievement.

The use of a randomized-control trials design in testing the effects of an early intervention allows for the possibility...
of assessing changes in infants’ neuroendocrine responses as a result of systematically varied differences in their early experience. Although similar effects have been observed in naturally occurring processes, the method employed here allows more secure causal inferences in terms of the neurohormonal pathway by which stressful environments influence key cognitive outcomes.

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NOTES

1 In this analysis, the total N was 50. Saliva samples could not be obtained on three infants at intake.

2 Findings reported here for harsh parenting are restricted to families that returned for the 3-year visit. The findings obtained for all families at the 1-year visit (within the same sample) are reported in Bugental and Schwartz (2009).

REFERENCES


