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

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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 HPA 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 at age 3. Short-term memory 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 that 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 and colleagues (Slykerman, Thompson, Pryor, 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 and colleagues (Beauchamp, Thompson, Howard, et al., 2008) found that preterm children are more likely to demonstrate memory deficits at older ages. In addition, Smith and colleagues (Smith, Landry, Swank, 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, et al., 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 allostasis. McEwen and Stellar (2003) introduced the concept of "allostatic load," the process by which stress response systems may be exposed to excess 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, et al, 2001; Lupien, Fiocco, Wan, et al., 2005). Bremen 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 produces later deficits in cognitive functioning.

Research with human and animal models

Research on this topic has been conducted both with humans and non-humans. Experimental work on this topic has been historically limited to non-humans. 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 (Spinelli, Chafer, Suomi 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, King, Meaney, & McEwen, 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; Gollier & 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 non-humans. 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 short-term memory, that is, the capacity to temporarily store a limited amount of information. The prefrontal cortex (PFC) has been identified as an areas of the brain that is of particular importance for short-term memory (Baddeley, 1990; Li, Gan, Gong, Luo & Zeng., 2003). Experimental research with non-humans has demonstrated that chronic stress leads to reduced short-term memory as a result of reduced dopaminergic transmission in the PFC (Mizoguchi, Yuzurihara, Ishige, et al., 2001). The PFC has also been shown to be sensitive to stress hormones (Amsten & Li, 2005; Cerqueria, Mailliet, Almeida, et al., 2007). Relevant to our concern here, the PFC is adversely influenced by mistreatment-induced stress among children (De Bellis, Keshavin, Shifflett, et al., 2002).

Neuorimaging research (as reviewed by Jonides, Lewis, Nee 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 short-term memory have been found to be particularly common among adult survivors of childhood abuse (Bremner, Randall, Scott et al., 1995). In the present paper, 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, McFarlane, Windham et al., 1999), a program that, despite early promise, has not been found to reduce child maltreatment (Bugental, Ellerson, Lin, et al., 2002; Duggan, McFarlane, Fuddy 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) parental use of harsh tactics, and/or (2) parental use of avoidance/withdrawal tactics (see Fig. 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 prefrontal cortex.

Methods

Participants

Participants included 64 mothers who participated in the Family Thriving Program (an intervention described in Bugental et al., 2002, & 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, 28% based on birth complications and 41% due to other medical risks (such as respiratory or cardiac problems). Prior to contact, families were randomly assigned to one of the two intervention conditions.

Of the 102 families who completed the one-year program, 64 were successfully recruited at the end of the third year. Retention rates (per cent of those who completed the intervention and were also available when children reached 3 years of age) were 62 % in the HV+ condition and 63 % in the HV condition. As shown in Table 1, no significant differences in demographic characteristics were found across condition; however, scores on the Social Desirability Scale (SDS) were significantly higher in the HV than the HV+ condition.

The population involved was at high risk on several bases. First, the children involved typically spent initial time in an NICU and experienced medical problems early in life. Second, mothers often lived in remote rural areas, and were highly mobile in their place of residence (e.g., migrant farm workers). Third, mothers had relatively little formal education, and most did not speak English.

Intervention

Bugental and colleagues (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/ftp_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, McFarlane, Windham, 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, McFarlane, Fuddy, et al., 2004). Although both the HV+ and the HV intervention 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 first 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. All measures taken on mothers were administered by home visitors. This included the Conflict Tactics Scale (administered at the one-year and 3-year visits) and the Social Desirability Scale (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, Kivlighan, Fortunato, et al., 2007). At older ages, saliva was collected via dental rolls. Saliva was expressed into cryogenic vials and stored at -20 degrees 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 are well-known (e.g., Haan, Gunnar, Tout, 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, one year, and two year visits, samples were taken during an in-home visit. On the three 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 one-year and three-year visits, a second saliva sample was taken 40 minutes 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 one-year visit, and $r = .50$ at the three-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 years 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, et al., in press). 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 1500 RPM for 30 minutes 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 .007 $\mu\text{g/dl}$. The average intra- and inter-assay 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, short-term memory 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 short-term memory 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 Conflict Tactics Scale (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 toddler's cortisol levels (Bugental, Martorell & Barraza, 2003). In addition, mothers completed the Marlowe-Crowne Social Desirability Scale (Marlowe & Crowne, 1960), a measure of self-report biases that are potentially important in interpreting responses given to the CTS.

Results

Research Strategy

Analyses of covariance 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 due to child refusals in providing saliva samples (4 instances on the Year-1 visit, 2 instances on the Year-2 visit, and 1 instance on the 3-Year 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 due to 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, et al. 2002).

Effects of Condition on Children's Cortisol Levels

An initial mixed-design ANOVA was conducted to test the effects of intervention condition on children's cortisol levels across trials (intake¹, 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 post-intake visits. Exact time of day was included as a covariate in all analyses. A significant effect was found for intervention condition at the one-year visit, $F(1, 51) = 4.38, p = .04, \eta^2 = .08$. The effect of intervention at the two-year visit did not reach significance, $F(1, 50) = 2.11, p = .15$. A significant effect was found for intervention condition at the three-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 3 short-term verbal memory scales) were measured in ANCOVAs. Two variables (maternal education and maternal ethnicity) were included as covariates due to 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 short-term memory $\{F(1, 46) = 4.62, p = .04, \eta^2 = .09\}$. No significant findings were obtained for other MSCA scales, including short-term picture memory.

Effects of Intervention Condition on Parental Conflict Tactics

MANCOVAs were conducted to test the predicted effects of intervention condition on tactics used by mothers during conflict with their children, as reported during the one-year and three-year visits. In 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 analysis of variance 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 one-year visit, intervention condition yielded a significant main effect on the combined use of both tactics $\{F(2, 45) = 4.05, p = .02\}$. Follow-up univariate analyses only revealed significant effects for the use of avoidant tactics $\{F(1, 46) = 6.16, p = .01, \eta^2 = .15\}$. 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.

¹In this one analysis, the total N was 50. Saliva samples could not be obtained on 3 infants at intake.

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 one-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-year 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 one-year and three-year visits on the relationship between condition and children's short-term memory at age 3. Time of day, maternal education, and maternal ethnicity were included as covariates.

Significant support was only found for the indirect effect of children's 1-year cortisol levels in the relationship between intervention and verbal short-term memory. 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 short-term memory ($B = -.70, p = .03$). 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 was covaried ($B = -.32, p = .17$). The predicted indirect effect of children's one-year cortisol levels on verbal short-term memory 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 influence of children's early cortisol level, a second analysis was conducted in which children's concurrent levels of cortisol level were covaried in the test of mediating effects. The effects of early cortisol levels continued to be significant, $B = .23, p = .03$.

Discussion

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 short-term memory 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 relatively 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, Seabanc & 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 and colleagues (Dozier, Peloso, Lindheim, 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 bedtimes 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, Martorell, & Barraza (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, 2000; Tu, Petrie-Thomas, Haley, 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 one-year visit. The selective effects of early cortisol are demonstrated by their continuing effects on STM, even after statistical 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 Short-Term Memory

Children in the HV+ condition performed better on short-term memory tasks than did children in the HV condition. Short-term memory has often been found to be susceptible to the effects of short-term stress (Newcomer, Selke, Melson, et al., 1999). However, our findings provide evidence for the effects of *chronic* stress on short-term memory. 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 one-year visit were found to mediate the relationship between intervention condition and children’s short-term memory 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 short-term memory. Emerging evidence with non-humans and human adults suggests that this may indeed be possible (Liston, McEwen, & Casey, 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 days (thus allowing a comparison of differences in diurnal rhythms shown across intervention conditions). However, existing research by Dozier and colleagues (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, Landry & Swank, 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 short-term memory is closely related to the development of fluid intelligence (Kail, 2007). Increases in short-term memory 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 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 allow more secure causal inferences in terms of the neurohormonal pathway by which stressful environments influence key cognitive outcomes.

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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 one-year visit (within the same sample) are reported in Bugental & Schwartz (2009).

References

- Amsten AF, Li BM. Neurobiology of executive functions: catecholamine Influences on prefrontal cortical functions. *Biological Psychiatry*. 2005; 7:133–146.
- Ashman SB, Dawson G, Panagiotides H, Yamada E, Wilkinson CW. Stress hormone levels of children of depressed mothers. *Development and Psychopathology*. 2002; 14:333–349. [PubMed: 12030695]
- Azar, ST. A cognitive behavioral approach to understanding and treating parents who physically abuse their children. In: Wolfe, DA.; McMahon, RJ.; DeV Peters, R., editors. *Child abuse: New directions in prevention and treatment across the lifespan*. Thousand Oaks, CA: Sage; 1997.
- Baddeley, A. *Human memory: Theory and practice*. Needham Height: Allyn & Bacon; 1990.
- Beauchamp MH, Thompson DK, Howard K, Doyle LW, Egan GF, Inder TE, Anderson PJ. Preterm infant hippocampal volumes correlate with later working memory deficits. *Brain: A Journal of Neurology*. 2008; 131:2986–2994. [PubMed: 18799516]
- Boyce WT, Ellis BJ. Biological sensitivity to context. I. An evolutionary-developmental theory of the origins and functions of stress reactivity. *Development and Psychopathology*. 2005; 17:271–301. [PubMed: 16761546]
- Breakey G, Pratt B. Healthy growth for Hawaii's Healthy Start: Toward a systematic statewide approach to the prevention of child abuse and neglect. *Zero to Three*. 1991; 11:16–22.
- Bremner JD. Does stress damage the brain? *Biological Psychiatry*. 1999; 45:795–805. [PubMed: 10188012]
- Bremner JD, Narayan M. The effects of stress on memory and the hippocampus throughout the life cycle: Implications for childhood development and aging. *Development and Psychopathology*. 1998; 10:871–885. [PubMed: 9886231]
- Bremner JD, Randall P, Scott TM, Capelli S, Delaney R, McCarthy G, Charney DS. Deficits in short-term memory in adult survivors of childhood abuse. *Psychiatry Research*. 59:97–107. [PubMed: 8771224]
- Brooks LR. Spatial and verbal components of the act of recall. *Canadian Journal of Psychology*. 1968; 22:349–368.
- Bugental DB, Beaulieu DA, Schwartz A. Hormonal sensitivity of preterm versus full-term infants to the effects of maternal depression. *Infant Behavior and Development*. 2008; 31:51–61. [PubMed: 17645947]

- Bugental DB, Ellerson PC, Lin EK, Raney B, Kokotovic A, O'Hara N. A cognitive approach to child abuse prevention. *Journal of Family Psychology*. 2002; 16:243–258. [PubMed: 12238408]
- Bugental DB, Johnston C. Parental cognitions in the context of the family. *Annual Review of Psychology*. 2000; 51:315–344.
- Bugental DB, Martorell GA, Barraza V. The hormonal costs of subtle forms of infant mistreatment. *Hormones and Behavior*. 2003; 43:237–244. [PubMed: 12614655]
- Bugental DB, Schwartz A. A Bio-cognitive approach to child mistreatment prevention among medically at-risk infants. *Developmental Psychology*. 2009; 45:284–288. [PubMed: 19210009]
- Cerqueira JJ, Mailliet F, Almeida OF, Jay TM, Sousa N. The prefrontal cortex as a key target of the maladaptive response to stress. *Journal of Neuroscience*. 2007; 27:2781–2787. [PubMed: 17360899]
- Chaffin M, Friedrich B. Evidence-based treatments in child abuse and neglect. *Children and Youth Services Review*. 2004; 26:1097–1113.
- Cicchetti, D. Intervention and policy implications of research on neurobiological functioning in maltreated children. In: Aber, JL.; Bishop-Josef, SJ.; Jones, SM.; McLearn, KT.; Phillips, DA., editors. *Child development and social policy: Knowledge for action*. APA Decade of Behavior volumes. Washington, D.C: American Psychological Association; 2007. p. 167-184.
- Cicchetti D, Rogosch FA. The impact of child mistreatment. *Development and Psychopathology*. 2001; 13:783–804. [PubMed: 11771908]
- Crowne DP, Marlowe D. A new scale of social desirability independent of psychopathology. *Journal of Counseling Psychology*. 1960; 24:349–354.
- Dawson, G.; Ashman, SB. On the origins of vulnerability to depression: The influence of the early social environment on the development of psychobiological systems related to risk of affective disorder. In: Nelson, CA., editor. *The Minnesota Symposia on child psychology*, Vol. 31: The effects of early adversity on neurobehavioral development. Minnesota symposia on child psychology. Vol. 31. Mahwah, NJ: Erlbaum; 2000. p. 245-279.
- De Bellis MD, Keshaven MS, Shifflett H, Iyengar S, Beers SR, Hail J, Moritz G. Brain structures in pediatric mistreatment-related posttraumatic stress disorder: A sociodemographically matched study. *Biological Psychiatry*. 2002; 52:1066–1078. [PubMed: 12460690]
- den Heyer K, Barrett B. Selective loss of visual and verbal information in STM as measured by means of visual and verbal interpolated tasks. *Psychonomic Science*. 1971; 25:100–102.
- Diamond A, Barnett WS, Thomas J, Munro S. Preschool program improves cognitive control. *Science*. 2007; 318:1387–1388. [PubMed: 18048670]
- Dix T. Attributing dispositions to children: An interactional analysis of attribution in socialization. *Personality and Social Psychology Bulletin*. 1993; 19:633–643.
- Dozier M, Peloso E, Lindheim O, Gordon MK, Manni M, Sepulveda S, Ackerman J. Developing evidence-based interventions for foster children: An example of a randomized clinical trial with infants and toddlers. *Journal of Social Issues*. 2006; 62:767–785.
- Duggan A, McFarlane EC, Windham AM, Rohde CA, Salkever DS, Fuddy L, Rosenberg LA, Buchbinder SB, Sia CJ. Evaluation of Hawaii's Healthy Start program. *Future of Children*. 1999; 9:66–90. [PubMed: 10414011]
- Duggan A, McFarlane EC, Fuddy L, Burrell L, Higman SM, Windham, et al. Randomized trial of a statewide home visitation program. Impact in preventing child abuse and neglect. *Child Abuse and Neglect*. 2004; 28:597–622. [PubMed: 15193851]
- Essex MJ, Klein MH, Cho E, Kalin NH. Maternal stress beginning in infancy may sensitize children to later stress exposure: effects on cortisol and behavior. *Biological Psychiatry*. 2002; 52:776–784. [PubMed: 12372649]
- Evans GW. A multimethodological analysis of cumulative risk and allostatic load among rural children. *Developmental Psychology*. 2003; 39:924–933. [PubMed: 12952404]
- Evans GW, Schamberg MA. Childhood poverty, chronic stress, and adult working memory. *PNAS Proceedings of the National Academy of Sciences of the United States of America*. 2009; 106:6545–6549.
- Fisher PA, Gunnar MR, Chamberlain P, Reid JB. Preventive intervention for maltreated preschool children: Impact on children' behavior, neuroendocrine activity, and foster parent functioning.

- Journal of the American Academy of Child and Adolescent Psychiatry. 2000; 39:1356–1364. [PubMed: 11068890]
- Flinn MV. Evolution and ontogeny of stress response to social challenges in the human child. *Developmental Review*. 2006; 26:138–174.
- Gollier J, Yehuda R. Neuroendocrine activity and memory-related impairments in posttraumatic stress disorder. *Development and Psychopathology*. 1999; 10:857–869.
- Granger DA, Hibel LC, Fortunato CK, Kapelewski CH. Medication effects on salivary cortisol: Tactics and strategy to minimize impact on behavioral and developmental sciences. *Psychoneuroendocrinology*. (in press).
- Granger DA, Kivlighan KT, Fortunato C, Harmon AG, Hibel LG, Schwartz EB, Whembolua G-L. Integration of salivary biomarkers in developmental and behaviorally-oriented research: Problems and solutions for collecting specimens. *Physiology and Behavior*. 2002; 92:583–590. [PubMed: 17572453]
- Grusec, JE.; Mammon, N. Features and sources of parents' attributions about themselves and their children. In: Eisenberg, N., editor. *Social development: Review of personality and social psychology*. Vol. 15. Thousand Oaks, CA: Sage; 1995. p. 49-73.
- Gunnar MR, Cheatham CL. Brain and behavioral interface: Stress and the developing brain. *Infant Mental Health Journal*. 2003; 24:195–211.
- Gunnar MR, Quevedo KM. Early care experiences and HPA axis regulation in children: A mechanism for later trauma vulnerability. *Progress in Brain Research*. 2008; 167:137–147. [PubMed: 18037012]
- Haan M, Gunnar MR, Toust K, Hart J, Stansbury K. Familiar and novel contexts yield different associations between cortisol and behavior among 2-year-old children. *Developmental Psychobiology*. 1998; 33:93–101. [PubMed: 9664174]
- Hart J, Gunnar M, Cicchetti D. Altered neuroendocrine activity in maltreated children. related to symptoms of depression. *Development and Psychopathology*. 1996; 8:201–214.
- Heckman JJ. Skill formation and the economics of investing in disadvantaged children. *Science*. 2006; 312:1900–1902. [PubMed: 16809525]
- Jameison K, Dinan TG. Glucocorticoids and cognitive function: from physiology to pathophysiology. *Human Psychopharmacology*. 2001; 16:293–302. [PubMed: 12404564]
- Jonides J, Lewis RI, Nee DE, Lustig CA, Berman MG, Moore KS. The mind and brain of short-term memory. *Annual Review of Psychology*. 2008; 59:193–224.
- Kail RV. Longitudinal evidence that increases in processing speed and working memory enhance children's reasoning. *Psychological Science*. 2007; 18:312–313. [PubMed: 17470254]
- Landry SH, Smith KE, Swank PR, Assel MA, Vallet S. Does early responsive parenting have a special importance for children's development or is consistency across early childhood necessary? *Developmental Psychology*. 2001; 37:387–403. [PubMed: 11370914]
- Landry SH, Smith KE, Swank PR, Guttentag C. A responsive parenting intervention: the optimal timing across early childhood for impacting maternal behaviors and child outcomes. *Developmental Psychology*. 2008; 44:1335–1353. [PubMed: 18793067]
- Li C, Gan Z, Gong H, Luo Q, Zeng S. On short-term memory of prefrontal cortex using near-infrared spectroscopy. *Proceedings of the SPIE*. 2003; 5254:537–541.
- Liston C, McEwen BS, Casey BJ. Psychological stress reversibility disrupts prefrontal processing and attentional control. *PNAS Proceedings of the National Academy of Sciences of the United States of America*. 2009; 106:912–917.
- Liu D, Diorio J, Day JC, Francis DD, Meaney MJ. Maternal care, hippocampal neurogenesis, and cognitive development in rats. *Nature Neuroscience*. 2000; 3:799–806.
- Lupien SJ, Fiocco A, Wan N, Maheu F, Lord C, Schramek T, Tu MT. Stress hormones and human memory function across the lifespan. *Psychoneuroendocrinology*. 2005; 30:225–242.
- Lupien SJ, King S, Meaney MJ, McEwen BS. Can poverty get under your skin? Basal cortisol levels and cognitive function in children from low and high socioeconomic status. *Development and Psychopathology*. 2001; 13:653–676. [PubMed: 11523853]

- Lupien SJ, King S, Meaney MJ, McEwen BS. Child's stress hormone levels correlate with mother's socioeconomic status and depressive state. *Biological Psychiatry*. 2000; 48:976–980. [PubMed: 11082471]
- MacKinnon DP, Lockwood CM, Hoffman JM, West SG, Sheets V. A comparison of methods to test mediation and other intervening variable effects. *Psychological Methods*. 2002; 7:83–104. [PubMed: 11928892]
- McCarthy, D. Manual for the McCarthy Scales of Children's Abilities. United States of America: The Psychological Corporation, Harcourt Brace Jovanovich, Inc; 1972.
- McEwen BS, Stellar E. Stress and the individual: mechanism leading to disease. *Archives of Internal Medicine*. 1993; 153:2093–2101. [PubMed: 8379800]
- Mizoguchi K, Yuzurihara M, Ishige A, Sasaki H, Chui DH, Tabira T. Chronic stress differentially regulates glucocorticoid negative feedback response in rats. *Psychoneuroendocrinology*. 2001; 26:443–459. [PubMed: 11337130]
- Newcomer JW, Selke G, Melson AK, Hershey T, Crfat S, Richards K, Alderson AL. Decreased memory performance in healthy humans induced by stress-level cortisol treatment. *Archives of General Psychiatry*. 56:527–533. [PubMed: 10359467]
- Noble KG, McCandless BD, Farah MJ. Socioeconomic gradients predict individual differences in neurocognitive development. *Developmental Science*. 2007; 10:464–480. [PubMed: 17552936]
- Parker KJ, Buckmaster CL, Sundlass K, Schatzberg AF, Lyons DM. Maternal mediation, stress inoculation, and the development of neuroendocrine stress resistance in primates. *Proceedings of the National Academy of Sciences*. 2006; 103:3000–3005.
- Preacher KH, Hayes AF. Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavioral Research Methods*. 2008; 40:879–891.
- Repetti RL, Taylor SE, Seeman TE. Risky Families: Family social environments and the mental and physical health of offspring. *Psychological Bulletin*. 2002; 128:330–366. [PubMed: 11931522]
- Rose, SA.; Feldman, JF. Relation of very low birthweight to basic cognitive skill in infancy and childhood. In: Nelson, CA., editor. *The effects of early adversity on neurobehavioral development*. Minnesota symposia on child psychology. Vol. 31. Mahwah, NJ: Lawrence Erlbaum Associates Publishers; 2000. p. 31–59.
- Rosenthal, R.; Rosnow, RL. *Essentials of behavioral research: Methods and data analysis*. NY: McGraw-Hill; 1984.
- Shirtcliff EA, Granger DA, Booth A, Johnson D. Low salivary cortisol Levels and externalizing behavior problems in youth. *Development and Psychopathology*. 2005; 17:167–184. [PubMed: 15971765]
- Slykerman RF, Thompson JMD, Pryor JE, Becroft DMO, Robinson E, Clark PM, Wild CJ, Mitchell EA. Maternal stress, social support and preschool children's intelligence. *Early Human Development*. 2005; 81:815–821. [PubMed: 16019165]
- Smith KE, Landry SH, Swank PR. Does the content of mothers' stimulation explain differences in children's development of verbal and nonverbal cognitive skill? *Journal of School Psychology*. Special Issue: Developmental perspectives in intelligence. 2000; 38:27–49.
- Smith KE, Landry SH, Swank PR, Baldwin CD, et al. The relation of medical risk and maternal stimulation with preterm infants' development of cognitive, language and daily living skills. *Journal of Child Psychology and Psychiatry*. 1996; 37:855–864. [PubMed: 8923228]
- Spinelli S, Chefer S, Suomi SJ, Higley JD, Barr CS, Stein E. Early-life stress induces long-term morphological changes in primate brain. *Archives of General Psychiatry*. 2005; 66:658–665. [PubMed: 19487631]
- Straus MA. Measuring intrafamily conflict and violence: The Conflict Tactics (CT) Scales. *Journal of Marriage and the Family*. 1979; 41:75–88.
- Tarullo AR, Gunnar MR. Child mistreatment and the developing HPA axis. *Hormones and Behavior*. 2006; 50:632–639. [PubMed: 16876168]
- Taylor SE, Eisenberger NI, Saxbe D, Lehman BJ, Lieberman MD. Neural responses to emotional stimuli are associated with childhood family stress. *Biological Psychiatry*. 2006; 60:296–301. [PubMed: 16460697]

- Tu MT, Grunau RE, Petrie-Thomas J, Haley DW, Weinberg J, Whitfield MF. Maternal stress and behavior modulate relationships between neonatal stress, attention, and basal cortisol at 8 months in preterm infants. *Developmental Psychobiology*. 2007; 49:150–164. [PubMed: 17299787]
- Volling B, McElwain NL, Notaro PC, Herrera C. Parents' emotional availability and infant emotional competence: Predictors of parent-infant attachment and emerging self-regulation. *Journal of Family Psychology*. 2002; 16:447–465. [PubMed: 12561291]
- Watamura SE, Donzella B, Alwin J, Gunnar MF. Morning-to-afternoon cortisol concentrations for infants and toddlers at child care: Age differences and behavioral correlates. *Child Development*. 2003; 74:1006–1020. [PubMed: 12938695]
- Watamura SE, Sebanc AM, Gunnar MF. Rising cortisol at childcare; Relations with nap, rest, and temperament. *Developmental Psychobiology*. 2002; 40:33–42. [PubMed: 11835149]

Fig. 1.

Predicted direct and indirect effects of intervention condition. The direct effect of intervention on cortisol levels is shown as a broken line to indicate that the direct effect was not expected to be significant after controlling for mediating variables.

Fig. 2.

Basal cortisol levels (log transformed) of children in HV and HV+ conditions at intake, 1-year, 2-year, and 3-year visits. Standard errors are .05 and .03 at intake (for HV+ and HV conditions), .02 and .06 at Year 1, .03 and .04 at Year 2, and .01 and .02 at Year 3. Mean untransformed cortisol values were .31 and .18 at intake, .15 and .28 at Year 1, .18 and .23 at Year 2, and .11 and .17 at Year 3.

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.

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

Table 1

Characteristics of Participants in the Two Intervention Conditions

	HV+ Condition M (SD)	HV Condition M (SD)	Diff.
Gestational age (weeks)	35.9 (3.5)	36.5 (4.1)	-.6
Intake age (weeks)	11.4 (13.5)	9.9 (6.3)	1.5
Birth weight (grams)	2447 (848)	2694 (931)	-257
Maternal age	28.1 (6.4)	27.2 (6.2)	.9
Maternal education (years)	9.8 (4.4)	9.1 (3.5)	.7
Number of siblings	1.0 (1.3)	.6 (.8)	.4
Social Desirability Score	46.7 (2.6)	49.6 (5.1)	-2.9**
Child gender (per cent boys)	43%	34%	11
Father present in family	79%	89%	-10
Latino (versus Anglo)	89%	87%	2
Twins	00 %	14%	14

**
p =.01

Table 2

Time of measurement of cortisol levels

	HV+ Condition M (SD)	HV Condition M (SD)	Diff.
Intake visit	10.46 (68)	11.05 (68)	– .19
One-year visit	10.17 (73)	10.47 (57)	– .40
Two-year visit	11.07 (40)	10.40 (62)	.27
Three-year visit	10.12 (54)	10.01 (64)	.11

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

Table 3

Correlation between Key Variables

	Avoid	Harsh	Cort-1	Cort-2	Cort-3	SDS	M-Age	M-Educ	Gest-age
Verbal Memory	-.20	.04	-.37**	.03	-.13	-.22	-.03	.51*	.21
Maternal Avoidance		-.04	.35***	-.07	.23	.04	-.01	-.23	.15
Maternal Harshness			-.17	-.02	.07	-.05	-.18	.10	.08
Cortisol-Year 1				.04	-.10	.05	.05	-.05	.06
Cortisol-Year 2					-.14	.09	.08	-.12	.01
Cortisol-Year 3						.11	-.10	-.25	.24
SDS							.18	-.05	-.05
Maternal Age								-.10	-.11
Maternal Education									-.08
Child Gestational Age									--

* p < .05

Note. SDS = Social Desirability Scale. 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.

Table 4

Parenting practices at Age 1 and Child Short-Term Memory at Age 3

	HV+ M (SD)	HV M (SD)	Difference
Harsh practices	.22 (.44)	.43 (.50)	-.21
Avoidant practices	.01 (.22)	.32 (.46)	-.31*
Child Verbal STM	.48 (1.12)	-.10 (.65)	.58*
Child Visual STM	1.36 (1.36)	.96 (1.17)	.40

 $p < .05$

Note: Parental practices reflected reported presence of use during the last 3 months.

Children's STM is shown in z-scores. All means are adjusted for covariates.