Children’s Cortisol and the Quality of Teacher–Child Relationships in Child Care

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Teacher–child relationships were examined as predictors of cortisol change in preschool children. Saliva for assays was collected from one hundred and ninety-one 4-year-olds (101 boys) in the mornings and afternoons on 2 days at child care, and before and after a series of challenging tasks and a teacher–child interaction session outside the classroom. Parents reported on children’s temperament, teachers and children reported on teacher–child relationship quality, and observers rated group-level teacher insensitivity. Teacher-reported relationship conflict predicted cortisol increases during teacher–child interaction and teacher-reported overdependence predicted cortisol increases from morning to afternoon, even after controlling for individual teacher, child, and classroom characteristics. The findings extend earlier work by suggesting that cortisol change across the child-care day is influenced by teacher–child relationship characteristics.

A majority of preschool-aged children in the United States experience out-of-home care (Cappizzano, Adams, & Sonenstein, 2000). Researchers, policy makers, and parents have raised concerns about the potential negative effects of child care on children’s health and development (National Institute of Child Health and Human Development [NICHD] Early Child Care Research Network, 2003). A series of studies suggests that many children in full-time out-of-home care experience atypical increases across the day in cortisol, the primary stress hormone in humans (Dettling, Gunnar, & Donzella, 1999; Tout, de Haan, Campbell, & Gunnar, 1998; Watamura, Donzella, Alwin, & Gunnar, 2003; Watamura, Sebanc, & Gunnar, 2002). Although the significance of this phenomenon is still being debated (Granger & Kivlighan, 2003), elevation of cortisol under some conditions has been linked to immune suppression (Boyce et al., 1995), problems with learning, memory (Blair, Granger, & Razza, 2005; Seeman & McEwen, 1996), negative emotionality, and problem behavior (Granger, Stansbury, & Henker, 1994; Smider et al., 2002).

An important research agenda is to identify the child and child-care characteristics that are associated with cortisol elevations. Individual differences in cortisol secretion reflect a confluence of forces including previous experience, child characteristics, contextual demands, and social relationships (Granger, Stansbury, et al., 1994; Stansbury & Gunnar, 1994). However, a consistent theme across studies is that relationships with caregivers are critical in helping young children regulate hypothalamic-pituitary-adrenal (HPA) activity (Gunnar, 1998; Gunnar & Donzella, 2002; Levine & Wiener, 1988). Secure attachment relationships appear to buffer infants' HPA reactivity to challenge (Gunnar, 1998; Nachmias, Gunnar, Mangelsdorf, Parritz, & Buss, 1996). Children in child care develop attachment-type relationships with their care providers (Howes, Galinsky, & Kontos, 1998), and these relationships may serve a similar protective function (Gunnar, 1998) for young children (Cole, Michel, & Teti, 1994). Positive teacher relationships may provide external coping resources and an environment of perceived safety, whereas problematic relationships may affect children’s physiological functioning both by failing to buffer the potential...

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stress of the classroom and by causing anxiety for the child during teacher–child interactions.

The purpose of this study was to examine the role of teacher–child relationships in influencing cortisol levels in young children in child care. Cortisol changes were measured in two settings: (a) from morning to afternoon in the classroom and (b) outside the classroom across a series of challenging tasks and a teacher–child interaction. We expected that children with poorer quality relationships with teachers would show greater cortisol increases from morning to afternoon in the classroom and over the teacher–child interaction episode outside of the classroom. To assess cortisol changes across the day, saliva samples were collected from children enrolled in full-day community child care in the mornings and afternoons of 2 separate days. Because many factors operating in a child-care classroom may influence children’s HPA axis functioning, we also collected saliva from children in an out-of-class activity consisting of two segments. The first segment involved a series of mildly challenging tasks selected to simulate events young children might face in the classroom setting. The second segment consisted of a nonchallenging interaction with the child’s teacher. The teacher–child interaction session allowed for the isolation of teacher–child relationship effects from potential classroom influences. We also assessed potential child–, measurement–, and classroom-level influences on children’s HPA activity. These included child age (Gunnar, Tout, de Haan, Pierce, & Stansbury, 1997), sex (Kirschbaum, Wust, & Hellhammer, 1992), temperament (Davis, Donzella, Krueger, & Gunnar, 1997), and teacher characteristics (Dettling, Parker, Lane, Sebanc, & Gunnar, 2000).

Method

Participants

Child participants were enrolled in a larger study examining associations between preschool experience and the transition to kindergarten. All recruitment and data collection procedures were approved by Auburn University’s institutional review board. Twelve child-care centers in two adjacent small communities in the Southeastern United States participated. The centers served children from low-income families (n = 2), served employees of a regional hospital (n = 1), served employees of a public school system (n = 1), were operated by a church (n = 1), or were private/for profit (n = 7). Children in 4-year-old classrooms (i.e., children who would attend kindergarten the following year) were eligible to participate. Parents of 507 children enrolled at the centers (81% of possible participants) provided consent over a 3-year time span. Information provided by center administrators indicated comparable age, race, and SES characteristics for participants and nonparticipants. The ethnic composition of the sample was similar to that of the county according to the 2000 census (61% Caucasian, 33% African American, and 6% other ethnicity). Single-parent households were a minority (30%), and most families (98.7%) had at least one parent who was employed or a student. Among families with at least one employed adult, SES was measured using occupational prestige scores based on parents’ reported employment (Entwisle & Astone, 1994). Scores ranged from 25 (e.g., unskilled labor, janitor) to 93 (professional), with a median of 68.

Because of the time and labor required to collect the physiological and relationship data, we selected a subgroup of approximately one third of the participants (five to six classrooms per year in each of 3 years) as a focus sample for the more labor-intensive portions of the study. Parent, teacher, and classroom-level data were collected from all the classrooms each year. Children in the focus classrooms also provided saliva samples, were interviewed about their relationships with their teachers, and participated in the individual challenge and teacher–child interaction sessions. This study uses only information collected from the focus sample.

In the 1st year of the study, focus classrooms were selected on the basis of informal judgments of quality to take advantage of the broadest possible range of child-care environments. In subsequent years, classrooms were selected to maximize the number of different classes and teachers involved across the 3 years of the study. Classrooms in 2 of the 12 centers never served as focus classrooms at the request of center administrators. Children attending the 2 centers not participating in the physiological and teacher–child assessment portions of the study differed from the rest of the sample only in maternal education, with mothers in the nonfocus centers reporting higher education levels than mothers in focus centers (Ms = 5.07 and 4.38, respectively, on a 6-point scale). Five classrooms were used twice across the 3 years of the study, but these classrooms had different teachers and children each year.

The resulting focus sample consisted of 191 children (90 girls) ranging in age from 43 to 67 months (M = 53, SD = 4.1 months). The focus sample was 66% Caucasian, 25% African American, and 9% mixed or...
other racial group. Focus and nonfocus samples differed by age and race, with focus sample children being older (M = 53 months vs. 52 months), F(1, 506) = 10.57, p = .001, and less likely to be African American (25% vs. 38%; χ² = 9.02, p < .05).

Procedures

Saliva collection procedures. Children provided saliva samples for cortisol analysis in two settings. First, to assess morning and afternoon cortisol levels, and morning to afternoon cortisol changes, samples were collected in children’s classrooms in winter (February) and spring (May). Additionally, children individually participated in an out-of-class assessment consisting of a series of mildly challenging tasks for 30 min (challenge task) followed by an interaction with their teacher for approximately 20 min (teacher–child interaction). The challenge task and teacher–child interaction sessions took place in the spring in a familiar quiet room in the center (e.g., a library or an unused classroom). Children provided samples immediately before (pretask) and following (posttask) the challenge task and again after the teacher–child interaction (postinteraction).

All saliva samples were collected at least 30 min after children had consumed any food. Twenty minutes prior to sample collections, children drank a cup of water (4–8 oz) to rinse the oral mucosa free of food residue and particulate matter and to increase hydration. Prior to the winter saliva collection, researchers taught children to provide unstimulated saliva by passive drool into 3-oz plastic cups. Immediately following each sample collection, researchers poured the saliva from the cups into 2-ml plastic cryogenic vials. Samples were sealed in plastic storage bags and placed on ice for transport to a storage freezer, where they remained at –20°C until shipped by overnight delivery on dry ice to Salimetrics Laboratories (State College, PA), where samples were stored at –80°C until assayed.

Morning, afternoon, and daily cortisol change. For classroom samples, children sat in small groups (four to six) at a table supervised by research assistants. Morning saliva collection occurred between 8:00 and 11:00 a.m., with 85% being collected immediately before children had morning snack between 8:30 and 9:30 a.m. (M = 9:00 a.m.). There were no significant differences in a.m. or cortisol change scores for samples collected within this time frame and those collected slightly earlier or later. Following the logic of Shirtcliff, Granger, Booth, and Johnson (2005), winter and spring values were averaged to form morning and afternoon indexes of cortisol for primary analyses (average daily cortisol change). For children with full a.m. and p.m. cortisol data from only one collection day, the single a.m. and p.m. cortisol values were used, resulting in an n of 182 children. Unless otherwise specified, the average daily cortisol change was used in analyses.

Due to schedule variations and constraints at different centers, p.m. saliva collection times ranged from 1:00 to 4:00 p.m. and time between a.m. and p.m. samples varied widely (range = 3–7.25 hr, M = 5.5 hr, SD = .75 hr). Longer times between a.m. and p.m. sample collections were associated with greater cortisol increases across the day (r = .16, p < .05). Also because of scheduling constraints, 59% of afternoon saliva samples were collected within 30 min of children waking from nap. Consistent with previous findings (Watamura et al., 2002), cortisol levels were slightly lower in samples collected shortly after naptime (within 30 min, M = .17) than in samples collected later in the afternoon (M = .20), F(1, 181) = 3.78, p < .01. Nap duration (estimated from schedules provided by the centers) was associated with afternoon cortisol levels (r = .21, p < .01) and average daily cortisol change (r = .22, p < .01). Observer ratings of rest quality during naptime were collected in Year 3 of the study, but rest quality ratings were not significantly related to p.m. cortisol values or to daily change.

Challenge task. Children participated in a series of five developmentally salient tasks intended to provoke mild stress, frustration, or disappointment (Stansbury & Gunnar, 1994). Research assistants generated a randomized list of participating children from each classroom to determine the order of child participation. All children were eager to participate in the activity and no child declined. For all but 3 children, challenge task assessments occurred in the morning (M start time = 9:30 a.m., SD = 43 min). Children were accompanied to a room in the center by a familiar research assistant, seated at a small table, and immediately asked to provide a saliva sample (prechallenge). Children then participated in the challenge tasks, which consisted of a coordination game in which they were asked to drop plastic bears through a small hole in a canister, a disappointment experience in which they expected to receive an attractive toy as a prize but were given a broken toy instead (Cole, Zahn-Waxler, & Smith, 1994), an impossible puzzle task (Smiley & Dweck, 1994), a delay of gratification task (Kochanska & Aksan, 1995), and an inhibitory motor activity task (Kochanska, Murray, & Harlen, 2000). The total time to complete all tasks was approximately 30 min (M = 31.8 min, range = 24–43 min). Following the challenge tasks, children provided a second saliva sample
Challenge change cortisol was computed as postchallenge cortisol – prechallenge cortisol.

Teacher–child interaction session. Immediately after the postchallenge saliva collection, the child’s teacher came into the room to interact with the child in two tasks intended to be nonstressful. First, teachers were asked to guide the child in duplicating a printed pattern with colored blocks, and the teacher and child were left alone for 5 min to complete the task. When the researcher returned to the room, he or she removed the blocks and pattern and gave the teacher a picture book with no printed text (Mayer & Mayer, 1975) to “read” with the child. After the teacher and child finished the book, the teacher returned to the classroom and the child provided a third saliva sample (postinteraction). On average, about 30 min elapsed between postchallenge and postinteraction saliva collections (M = 29 min, range = 19–40 min). After the final saliva collection, researchers escorted the child back to the classroom. Interaction change cortisol was computed as postinteraction cortisol – postchallenge cortisol.

Behavioral and Relationship Assessments

Teacher–child relationship quality. Teachers completed the Student–Teacher Relationship Scale (STRS; Pianta, Steinberg, & Rollins, 1995). The STRS contains 26 items assessing teachers’ perceptions of relationships with individual children. Items are rated on 5-point scales. Following Pianta et al. (1995), three relationship scales were derived: closeness (11 items; α = .79; e.g., “I share an affectionate, warm relationship with this child”), conflict (12 items; α = .90; e.g., “This child and I always seem to be struggling with each other”), and overdependence or clinging (5 items; α = .73; e.g., “This child asks for my help when he/she doesn’t really need it”). Thirteen of 16 lead teachers completed questionnaires about their relationships with 155 participating children.

Child perceptions of relationship quality. Children’s perceptions of their relationships with their lead teachers were assessed in individual interviews using the Feelings About My School and Teacher (FAMST) interview (Payne, 2003). Children participated in the FAMST interviews during the spring of the academic year. The FAMST is based on a modification of the Feelings About Myself and Peers (Meece, Colwell, & Mize, 2007) and the Berkeley Puppet interviews (Measelle, Ablow, Cowan, & Cowan, 1998). Representative items include, “Does [child’s teacher] smile at you?” and “Do you like [teacher]?” For most questions, children answered verbally and by pointing to cards on which were mounted no, a few, or many milk bottle caps, corresponding to not at all, some or a little bit, and a lot, respectively. Ten items relating to the child’s evaluation of his or her relationship with the teacher were aggregated to form a single scale with higher values (3s) reflecting more negative assessments (child-reported negativity, α = .69). Pilot testing (n = 19) indicated adequate test–retest reliability (.81) over 2 weeks (Payne, 2003).

Child-level variables. Parents reported on temperament using the Children’s Behavior Questionnaire (Rothbart, Ahadi, Hershey, & Fisher, 2001). Temperament dimensions examined in this study were shyness (α = .80), fearfulness (α = .69), and surgency (α = .70). Parent evaluations of child temperament were available from 153 parents of focus sample children. Means for parent-reported temperament variables were similar to those reported in Rothbart et al. (2001). Additional child-level variables examined as potential influences on HPA activity included sex, age, and family SES.

Classroom-level variables. Group size was computed as number of children on class rolls plus the number of teachers typically present as reported by observers (Legendre, 2003). Teachers’ insensitivity at the classroom level was assessed using observer reports on the Caregiver Interaction Scale (CIS; Arnett, 1989); the CIS consists of 26 items assessing teacher insensitivity (e.g., “threatens children to control them,” and “speaks warmly to the children” [reverse scored]) rated on 4-point scales. Interrater reliability based on 40% of the classrooms in the study was adequate (ρ = .81, p < .001) and internal consistency was good (α = .96). Most teachers were rated as moderately sensitive at the classroom level (M = 2.13). However, teachers for 15% of the sample (n = 3 teachers) received average ratings greater than 3 on the scale on which 4 represented maximum insensitivity.

Measurement-level variables. On the 2 classroom saliva collection days, parents reported children’s wake-up times as they dropped their child off at child care to control for diurnal cortisol patterns. Because some children carpooled or were bussed to the centers, wake-up times were available for only 90 of 164 children providing samples in the winter (55%) and 114 of 166 in the spring (69%). For children with missing wake-up data, we substituted an estimated wake-up time based on the average of wake-up times reported by parents on other saliva collection days and on questionnaires (α = .83). There were no significant differences in any study variables between children with actual and substituted wake-up times. Wake-up times were typically not collected on the
days when children participated in the out-of-class activities. To control for diurnal cortisol fluctuations for the out-of-class teacher–child interaction analysis, we used the average of available wake-up times reported by parents on saliva collection days and questionnaires.

Salivary Cortisol Determination

All samples were assayed for salivary cortisol using a highly sensitive enzyme immunoassay U.S. Food and Drug Administration (510k) cleared for use as an in vitro diagnostic measure of adrenal function (Salimetrics). The test used 25 μl of saliva, had a lower limit of sensitivity of 0.007 μg/dl, range of sensitivity from 0.007 to 1.8 μg/dl, and average intra- and inter-assay coefficients of variation of less than 5% and 10%. The average of duplicate assays for each sample was used in all analyses and units are reported in μg/dl (micrograms per deciliter). Cortisol values were positively skewed and subject to logarithmic transformation (log10). All analyses were performed using transformed cortisol values, but to ease interpretation, untransformed μg/dl units are reported in the text, tables, and figures.

Analytical Strategy

The data analyzed in this study represent multiple layers of information (i.e., repeated cortisol measurements from children sharing teacher and classroom influences). Given the nested nature of the data, we selected hierarchical multivariate linear modeling (HMLM; Raudenbush & Bryk, 2002; Raudenbush, Bryk, Cheong, & Congdon, 2004) to examine our primary research questions. HMLM uses multiple covariance matrices derived from different levels of data to accommodate repeated measurements within individuals who share group membership.

Results

Descriptive Analyses

Average daily cortisol change. Some children were absent or only attended half-day on days saliva was collected, so complete cortisol data were not available for all children (8%–10% missing at each collection). Data from three additional children were excluded because extreme values suggested interference or contamination. In winter and spring there were, respectively, 164 and 166 children with both morning and afternoon cortisol data. On average, children’s cortisol levels did not change across the child-care days for either the winter or the spring assessments (see Table 1). As expected, however, there was considerable variation among children, with 51.2% and 45.8% showing cortisol increases greater than 1 SD of the mean across the day in winter and spring, respectively. Some children (29%) exhibited cortisol increases at both assessments. Winter and spring morning cortisol values were significantly associated (r = .30, p < .001), but afternoon values were only marginally related (r = .13, p = .10).

Challenge and interaction task cortisol. One hundred ninety-one children participated in the challenge task procedure. Five children were either unwilling (2) or unable (3) to give sufficient saliva volume for analysis. Four children had at least one extreme cortisol value (> 3 SD above the mean) excluded from the data. Descriptive information about challenge task cortisol values is given in Table 1. A repeated measures analysis of variance confirmed that cortisol levels declined, with postchallenge cortisol significantly lower than prechallenge, F(1, 180) = 69.14, p < .001, and postinteraction cortisol significantly lower than both pre- and postchallenge levels, Fs(1, 180) = 69.65 and 12.39, respectively, both ps < .01.

Relationship measures. In general, teachers described relationships with children as very close and relatively free of conflict, and children were seen as being moderately clingy in the relationships (see Table 1). Children’s responses to the FAMST suggested that they saw their relationships with teachers as being of moderate quality. Teacher-rated closeness was negatively skewed and a quadratic transformation was used to normalize data. Child reports of negative relationships with teachers had a positive skew, and a log10 transformation was applied. Children and teachers agreed modestly about the quality of their relationships (see Table 2).

Hierarchical Analyses: Relationship Quality and Cortisol

Repeated measures hierarchical linear modeling (HLM 6; Raudenbush et al., 2004) was used to examine whether cortisol changes across the day and across the teacher–child interaction were associated with teacher–child relationship quality. Bivariate correlations revealed associations between cortisol and time since waking for the a.m., p.m., and prechallenge samples (rs = .35, .49, and .14, ps < .001, .001, and .10, respectively). Additionally, an association at the trend level was found for parent-reported fearful temperament and cortisol change across the challenge and teacher–child interaction tasks (see Table 3). Consequently, time since
waking and fearfulness were controlled in the HLM models.

The HMLM analysis used multiple data covariance matrices to examine associations across measurement (Level 1), child (Level 2), and classroom (Level 3) influences. Level 1 data (measurement level) consisted of the cortisol levels at each assessment point as the outcome variable (each assessment occupied one row in the data set), along with the time since waking for each sample collected, and to assess the change (slope) across the interval of interest (e.g., a.m. to p.m.; postchallenge to postinteraction), a dummy-coded indicator variable for the measurement of interest (e.g., the afternoon cortisol level for the average daily change analysis; see Raudenbush et al., 2004). The second level (child level) consisted of data describing the teacher–child relationship, sex, and parent-rated fearful temperament. Level 2 (child level) variables were modeled to predict both Level 1 intercept values and the slope (cortisol change) for the time period of interest (morning to afternoon or across the teacher–child interaction). Because different numbers of teachers and children reported on relationship quality, separate HMLM analyses were performed for the teacher and child relationship reports (n = 155 and 176, respectively). Level 3 (classroom level) variables included classroom group size and teacher sensitivity.

Relationships and daily cortisol. Teacher reports of child clingingness were related to higher afternoon cortisol levels and average daily cortisol change. Results of the HMLM analyses confirmed that these associations (see Table 4) were independent of classroom, individual child, and other relationship measures. No other teacher- or child-rated relationship

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**Table 1**  
Descriptive Statistics for Study Variables Prior to Transformation

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>M (Mdn)</th>
<th>SD</th>
<th>Minimum to Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cortisol</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter a.m.</td>
<td>171</td>
<td>0.17</td>
<td>0.12</td>
<td>0.06 to 0.93</td>
</tr>
<tr>
<td>Winter p.m.</td>
<td>168</td>
<td>0.17</td>
<td>0.11</td>
<td>0.05 to 0.83</td>
</tr>
<tr>
<td>Winter daily change</td>
<td>164</td>
<td>0.00</td>
<td>0.14</td>
<td>−0.64 to 0.44</td>
</tr>
<tr>
<td>Spring a.m.</td>
<td>170</td>
<td>0.19</td>
<td>0.13</td>
<td>0.04 to 0.78</td>
</tr>
<tr>
<td>Spring p.m.</td>
<td>171</td>
<td>0.19</td>
<td>0.11</td>
<td>0.04 to 0.65</td>
</tr>
<tr>
<td>Spring daily change</td>
<td>166</td>
<td>−0.01</td>
<td>0.16</td>
<td>−0.62 to 0.57</td>
</tr>
<tr>
<td>Prechallenge</td>
<td>181</td>
<td>0.15</td>
<td>0.09</td>
<td>0.04 to 0.59</td>
</tr>
<tr>
<td>Postchallenge</td>
<td>182</td>
<td>0.12</td>
<td>0.08</td>
<td>0.03 to 0.57</td>
</tr>
<tr>
<td>Postinteraction</td>
<td>182</td>
<td>0.11</td>
<td>0.05</td>
<td>0.03 to 0.42</td>
</tr>
<tr>
<td>Interaction change</td>
<td>182</td>
<td>−0.02</td>
<td>0.05</td>
<td>−0.25 to 0.12</td>
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<td><strong>Teacher–child relationship quality</strong></td>
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<td></td>
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<tr>
<td>Teacher-reported close</td>
<td>155</td>
<td>4.34</td>
<td>0.52</td>
<td>2.4 to 5.0</td>
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<tr>
<td>Teacher-reported clingy</td>
<td>155</td>
<td>2.46</td>
<td>0.92</td>
<td>1.0 to 4.8</td>
</tr>
<tr>
<td>Teacher-reported conflict</td>
<td>155</td>
<td>1.99</td>
<td>0.83</td>
<td>1.0 to 5.0</td>
</tr>
<tr>
<td>Child-reported negative</td>
<td>176</td>
<td>1.56</td>
<td>0.37</td>
<td>1.0 to 3.0</td>
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<tr>
<td><strong>Control variables—child level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fearful temperament</td>
<td>153</td>
<td>4.03</td>
<td>1.2</td>
<td>1.0 to 6.67</td>
</tr>
<tr>
<td>Shy temperament</td>
<td>153</td>
<td>3.69</td>
<td>1.35</td>
<td>1.0 to 6.83</td>
</tr>
<tr>
<td>Surgent temperament</td>
<td>153</td>
<td>4.61</td>
<td>0.75</td>
<td>2.74 to 6.68</td>
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<tr>
<td>Child age in months</td>
<td>191</td>
<td>53</td>
<td>4.20</td>
<td>36 to 67</td>
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<tr>
<td>Family socioeconomic status</td>
<td>148</td>
<td>(65)</td>
<td></td>
<td>25 to 93</td>
</tr>
<tr>
<td><strong>Control variables—measurement</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average wake to saliva a.m.</td>
<td>173</td>
<td>2 hr 25 min</td>
<td>40 min</td>
<td>12 min to 4 hr 14 min</td>
</tr>
<tr>
<td>Average wake to saliva p.m.</td>
<td>173</td>
<td>8 hr</td>
<td>51 min</td>
<td>5 hr 21 min to 10 hr 12 min</td>
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<tr>
<td>Duration of saliva collection</td>
<td>187</td>
<td>5 min</td>
<td>3 min</td>
<td>&lt; 1 min to 18 min</td>
</tr>
<tr>
<td><strong>Control variables—classroom level</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group size</td>
<td>16</td>
<td>(17)</td>
<td></td>
<td>11 to 24</td>
</tr>
<tr>
<td>Teacher insensitive</td>
<td>16</td>
<td>(2.04)</td>
<td></td>
<td>1.31 to 3.38</td>
</tr>
</tbody>
</table>

*aCortisol values indicate mean of duplicate assay values in μg/dl prior to logarithmic transformation to correct skew. **Mean is hours and minutes between child wake up and saliva collection averaged over winter and spring. *Does not include families reporting that there were no employed adults in their households.
Variables were associated with average daily cortisol change. Because of the potential influence of nap variables on afternoon cortisol levels, we tested a separate HMLM model with time since waking from nap in Level 2 and classroom nap duration in Level 3. Patterns of associations between relationship variables and average daily cortisol change were identical in the two models. For parsimony, we only report the results for the model without the nap variables.

**Relationships and cortisol during challenge and teacher-child interaction.** As seen in Table 3, children with more positive relationships with teachers (closer, less conflict, and less negative) began the challenge procedure with higher cortisol levels. Children with whom teachers reported more conflict and less closeness had greater cortisol increases across the teacher-child interaction (see Table 3). HMLM analyses (presented in Table 5) indicated that only teacher-child conflict predicted cortisol increases during the interaction session when classroom and child-level variables were included in the model.

**Discussion**

Within the past two decades, methodological advances in the noninvasive measurement of individual differences and intraindividual change in the psychobiology of stress have enabled developmental science to translate research with animals (Hofer, 2004; Meaney, 2005) into a basic understanding of early caregiving effects on children’s physiology and behavior. Given the nature of the basic work with animals, it is not surprising that much of the research effort with children has focused on various aspects of mother-child relationship quality such as attachment (Ahnert, Gunnar, Lamb, & Barthel, 2004), conflict (Granger, Weisz, McCracken, Ikeda, & Douglas, 1996), and maternal behavior (Jones et al., 1997). Other research has examined differences between extreme groups defined by “natural experiments,” such as child maltreatment and neglect (Cicchetti & Rogosch, 2001) and adoption and foster parenting (Dozier et al., 2006; Gunnar, Morison, Chisholm, & Schuder, 2001). This study extends this translational research by showing that relationships with care providers in out-of-home child-care settings during early childhood contribute to variability in children’s HPA activity. Specifically, teacher reports of child overdependence predicted increases in cortisol levels across the child-care day, and reports of teacher-child relationship conflict predicted cortisol increases during a teacher-child interaction session.
Importantly, these associations persisted when controlling for child-, classroom-, and measurement-level factors known to influence variation in HPA activity. Consistent with previous studies, approximately half of the children showed cortisol increases across the day at each of two assessments. However, descriptive analyses suggested considerable within-child variability in cortisol patterns, with only 29% of children experiencing cortisol increases across the day in both winter and spring. Morning cortisol had moderate intradividual stability from winter to spring; afternoon values did not. These findings highlight the contextual sensitivity of the HPA axis (Flinn, 1999; Sapolsky, 2004). Shirtcliff et al. (2005) estimated that about 70% of variance in cortisol is attributable to situational influences. This study suggests that teacher–child relationship characteristics may be a contextual contributor to cortisol variability.

**Teacher–Child Relationships as Contextual Influences**

Different aspects of the teacher–child relationship were associated with HPA axis activation in different settings. Children rated by teachers as clingy or overdependent showed increases in cortisol over the day in the classroom. In contrast, children in more conflicted relationships showed elevated cortisol when interacting with the teacher outside of the classroom. In classrooms, children may be able to avoid interacting with teachers with whom they experience relationship difficulties. In the out-of-class activity, however, interaction was unavoidable. Previous research demonstrates that episodes of parent–child conflict can be accompanied or followed by cortisol increases (Flinn, 1999; Granger et al., 1998), especially for children who perceive a lack of social control (Granger, Weisz, & Kauneckis, 1994). The animal literature suggests that subordinate, rather than dominant, members of dyads are more likely to experience HPA axis activation to conflict (Haller, Kiem, & Makara, 1996; Loving, Heffner, Kiecolt-Glaser, & Malarkey, 2004; Sapolsky, 2004). Certainly, children were the less powerful partners in the dyadic interaction sessions, and some children may have experienced these interactions as stressful, though they were not intended to be so.

The hypothesis that positive teacher–child relationships would predict decreases in cortisol across the day and during teacher–child interaction received modest support. Low conflict was related to greater decreases in cortisol across the teacher–child interaction, whereas teacher-reported closeness and child reports of less negativity in the relationship

### Table 3: Correlations Among Cortisol and Relationship, Child, and Classroom Variables

<table>
<thead>
<tr>
<th>Cortisol</th>
<th>Average classroom a.m.</th>
<th>Average classroom p.m.</th>
<th>Average daily (t)</th>
<th>Average daily (p)</th>
<th>Postchallenge</th>
<th>Prechallenge</th>
<th>Postinteraction</th>
<th>Preinteraction</th>
<th>Challenge change (t)</th>
<th>Challenge change (p)</th>
<th>Interaction change (t)</th>
<th>Interaction change (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher-reported close</td>
<td>-0.05</td>
<td>-0.22**</td>
<td>-1.7</td>
<td>0.06</td>
<td>0.13</td>
<td>0.03</td>
<td>-0.07</td>
<td>-0.06</td>
<td>-0.05</td>
<td>-0.08</td>
<td>-0.06</td>
<td>-0.05</td>
</tr>
<tr>
<td>Teacher-reported clingy</td>
<td>-0.02</td>
<td>-0.06</td>
<td>-0.06</td>
<td>-0.06</td>
<td>-0.07</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.06</td>
<td>-0.01</td>
<td>-0.04</td>
<td>-0.04</td>
<td>-0.04</td>
</tr>
<tr>
<td>Teacher-reported conflict</td>
<td>-0.07</td>
<td>-0.08</td>
<td>-0.08</td>
<td>-0.06</td>
<td>-0.07</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.06</td>
<td>-0.02</td>
<td>-0.04</td>
<td>-0.04</td>
<td>-0.04</td>
</tr>
</tbody>
</table>

Positive values indicate that cortisol increases over the time period. Positive values indicate that cortisol increases over the time period. 

* $p < 0.10$, $p < 0.05$, $p < 0.01$, one-tailed.
were marginally related to declines in cortisol during teacher–child interaction in bivariate analyses. When controlling for other child and classroom variables in the HMLM models, only teacher–child conflict predicted cortisol change during the teacher–child interaction. The modest links between teacher-reported closeness and children’s cortisol levels may be explained by low variability in closeness ratings; teachers may be constrained by social desirability to describe relationships with children under their care in positive terms. Alternative methods for quantifying positive aspects of teacher–child relationships, such as observation of classroom interactions (Howes et al., 1998), should be explored.

**Alternative Hypotheses**

*Temperament.* It is possible that teacher-reported clinginess reflects assessments of behavioral temperament rather than relationship characteristics. Children described as clingy by teachers may lack confidence in their abilities to cope with challenges in the classroom. Similarly, children with whom teachers said they had more conflict may have been

### Table 4

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cortisol intercept</th>
<th>Cortisol slope</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$B$</td>
<td>$\beta$</td>
</tr>
<tr>
<td><strong>Level 1: Measurement</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time since wake up</td>
<td>$-0.02$</td>
<td>$-0.32$</td>
</tr>
<tr>
<td><strong>Level 2: Child</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex of the child</td>
<td>$0.00$</td>
<td>$0.01$</td>
</tr>
<tr>
<td>Fearful temperament</td>
<td>$0.02$</td>
<td>$0.08$</td>
</tr>
<tr>
<td>Teacher-reported conflict</td>
<td>$0.01$</td>
<td>$0.02$</td>
</tr>
<tr>
<td>Teacher-reported close</td>
<td>$-0.02$</td>
<td>$-0.06$</td>
</tr>
<tr>
<td>Teacher-reported clingy</td>
<td>$-0.02$</td>
<td>$-0.06$</td>
</tr>
<tr>
<td><strong>Level 3: Classroom</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group size</td>
<td>$0.00$</td>
<td>$0.06$</td>
</tr>
<tr>
<td>Teacher insensitive</td>
<td>$0.04$</td>
<td>$0.15$</td>
</tr>
</tbody>
</table>

**Table 5**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cortisol intercept</th>
<th>Cortisol slope</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$B$</td>
<td>$\beta$</td>
</tr>
<tr>
<td><strong>Level 1: Measurement</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time since wake up</td>
<td>$0.02$</td>
<td>$0.06$</td>
</tr>
<tr>
<td><strong>Level 2: Child</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex of the child</td>
<td>$0.03$</td>
<td>$0.07$</td>
</tr>
<tr>
<td>Fearful temperament</td>
<td>$0.00$</td>
<td>$0.00$</td>
</tr>
<tr>
<td>Teacher-reported conflict</td>
<td>$-0.03$</td>
<td>$-0.11$</td>
</tr>
<tr>
<td>Teacher-reported close</td>
<td>$0.00$</td>
<td>$0.06$</td>
</tr>
<tr>
<td>Teacher-reported clingy</td>
<td>$-0.00$</td>
<td>$-0.01$</td>
</tr>
<tr>
<td><strong>Level 3: Classroom</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group size</td>
<td>$0.01$</td>
<td>$0.22$</td>
</tr>
<tr>
<td>Teacher insensitive</td>
<td>$0.00$</td>
<td>$0.02$</td>
</tr>
</tbody>
</table>

*p < .05.*

**p < .01.**
the more difficult or active children who felt constrained in the interaction session. This interpretation is consistent with previous research linking temperament to children’s cortisol at child care (Dettling et al., 1999; Gunnar, Sebanc, Tout, Donzella, & van Dulmen, 2003; Watamura et al., 2002).

By and large, however, the pattern of associations among study variables does not support the temperament interpretation. Had teachers based their relationship ratings on children’s temperament, some correlations between relationship quality and parent temperament ratings would be expected. However, there was no significant correlation between any teacher-reported relationship scale and any parent-reported temperament dimension. In contrast, children and teachers agreed modestly about the quality of their relationships, and children rated relationships with less sensitive teachers as being more negative. This pattern suggests that both teachers’ and children’s reports captured some specifically dyadic aspects of their relationships.

Of the three temperament qualities examined in this study, only fearfulness was associated with any cortisol measure: More fearful children showed a trend toward greater decreases in cortisol over both the challenge task and the teacher–child interaction session. The nonsignificant associations between child characteristics and HPA activity are consistent with the notion that context is a stronger influence on cortisol than are individuals’ traits (Shirtcliff et al., 2005), but contrary to some previous research reporting that children who are shy (Gunnar et al., 1997), have poorer effortful control, or have greater negative emotionality (Dettling et al., 1999; Dettling et al., 2000; Gunnar et al., 2003) are more likely to experience cortisol increases over the day at child care. This discrepancy may be attributed to measurement and sample characteristics. Some previous studies have used teacher reports of temperament (Gunnar et al., 2003; Watamura et al., 2002), or composites of teacher and parent reports (Dettling et al., 2000), and teacher reports may be more likely than parent reports (Manz, Fantuzzo, & McDermott, 1999) to correspond to children’s behavioral and emotional characteristics at school (Culp, Howell, Culp, & Blankemeyer, 2001). However, parent reports of low effortful control and impulsivity also have been linked to cortisol increases across the day in children attending a university child-care program (Dettling et al., 1999). Parents in the current sample represented a wide range of economic and educational backgrounds and may have interpreted the temperament questionnaire differently than did parents in previous studies. In particular, the moderate internal reliability for the temperament scales in this study may have limited the ability to detect associations with children’s cortisol.

**Age.** Younger preschool children are more likely to experience increases in cortisol over the day in child-care settings (Dettling et al., 1999), especially younger children in mixed-age groups (Legendre, 2003). Age was not associated with any cortisol measures in this study, perhaps because of the restricted age range of children. However, age may indirectly influence cortisol through children’s experiences with their teachers. Teachers rated relationships with older children as being closer and less conflicted and older children were marginally less clingy than younger children. Examining age differences in social behavior may inform our understanding of children’s physiological experience in classrooms.

**Methodological influences relating to the teacher–child interaction.** The fact that the challenge task always preceded the teacher–child interaction session is both a strength and a weakness of the current study. On the one hand, carryover effects of stress children may have experienced during the challenge task could influence cortisol during the teacher–child interaction. On the other hand, all children were exposed to a comparable experience prior to interacting with their teachers. This consistency allows for better isolation of the effects of the teacher–child relationship on cortisol than would be possible if children had been in their classrooms prior to the interaction.

Another methodological consideration is the timing of the out-of-class assessment. In this study, the teacher–child interaction occurred in the morning. Because of the typical decrease in cortisol levels across the day, the HPA axis may be more sensitive to stressors in the afternoon than in the morning (Dickerson & Kemeny, 2004). Higher morning cortisol may obscure stressor effects (Ramsay & Lewis, 2003) in part because of stronger genetic effects on morning cortisol as compared to afternoon cortisol levels (Bartels, de Geus, Kirschbaum, Sluyter, & Boomsma, 2003). Results may have been different had the challenge and interaction procedures occurred in the afternoon when, theoretically, the influence of context would have been more powerful. However, because of the timing of naps, snacks, variation in parent pickup time, and child-care staff shift changes, staging the teacher–child interaction in the afternoon was logistically impossible.

**Classroom influences.** Of all study variables, group size had the most consistent pattern of bivariate associations with cortisol levels and changes. Children in classrooms with more members had marginally lower morning cortisol but significantly higher afternoon cortisol and greater cortisol increases
across the day. The afternoon and morning to afternoon cortisol change data are consistent with previous research showing higher cortisol in toddlers in larger groups (Legendre, 2003) and with studies of the effects of crowding on stress and HPA axis functioning (Nelson, 2005; Thiessen & Rogers, 1961). Larger groups are louder, offer more opportunities for conflict and competition for scarce resources (including teachers’ time), and are more stressful for teachers (French, 1993). Teachers with larger classrooms were rated by observers as less sensitive to children’s needs. Thus, class size may operate directly and indirectly (through teacher behavior) to influence children’s cortisol.

More unexpected were associations between group size and higher cortisol in the out-of-class activity. Because each child had been out of the classroom for about half an hour prior to beginning the teacher interaction session, direct effects of classroom factors on cortisol during teacher–child interaction were expected to be minimal. Even so, children in larger groups had greater increases in cortisol over the challenge task and higher cortisol levels after the challenge and teacher interaction procedures. Stressful classroom events prior to the challenge procedure, which may have occurred more often in larger groups, may have continued to influence children’s HPA axis activity even after children had been out of the classroom for half an hour or more. This seems an unlikely explanation, however, given that pre-challenge cortisol was not associated with group size. Perhaps, children in smaller groups develop better coping skills, more confidence, or are less reactive to stressful situations, all of which would support better adaptation to unexpected challenges.

Why children in larger groups had lower morning cortisol levels is not obvious, and, given the modest magnitude, it may be spurious. In contrast, some studies have documented low morning cortisol for children in center-based child care (Dettling et al.; Dettling et al., 2000), which affords some degree of confidence in the finding. The explanation may lie in family conditions that covary with child-care arrangements (NICHD Early Child Care Research Network, 1997). Perhaps parents who reported to work earlier tended to place their children in child-care arrangements serving larger groups so that children in larger groups were awake longer prior to the morning saliva collections. As expected, children in our study who had been awake longer had lower cortisol levels at the morning assessments. However, controlling for the amount of time children had been awake at the morning collections did not affect the magnitude of the association between group size and any cortisol value. The link between group size and lower morning cortisol could be a concern if it suggests disruption of the normal diurnal pattern (Gunnar & Vasquez, 2001).

Conclusions and Implications

This study used a community-based sample to replicate findings that a substantial proportion of preschool-aged children in full-day child care experience an afternoon cortisol increase, rather than decrease, across the day. We found that aspects of the teacher–child relationship predicted cortisol increases both in the classroom and during a dyadic teacher–child interaction outside the classroom, even after controlling for measurement-, child-, and classroom-level factors previously found to influence cortisol. Previous research demonstrates the importance of teacher–child relationships for young children’s school and behavioral adjustment concurrently (Birch & Ladd, 1997) and longitudinally to early adolescence (Hamre & Pianta, 2001). This study demonstrated associations between teacher–child relationships and children’s physiological functioning.

Whether elevated cortisol functions as more than simply a marker of children’s immediate discomfort, anxiety, or exertion is not clear. Cortisol elevations in many circumstances are adaptive (Sapolsky, 2004) and a marker of social competence, particularly in new situations (Gunnar et al., 1997). Higher baseline cortisol levels among preschool-aged children predict internalizing symptoms in elementary school, even after controlling for early behavioral evidence of anxious–fearful behavior (Smider et al., 2002). Conversely, low baseline cortisol is a robust psychophysiological correlate of antisocial behavior (McBurnett, Lahey, Rathouz, & Loeber, 2000; Scarpa & Raine, 2006). Low morning cortisol appears to be a marker of current or previous adversity and is characteristic of adults with a history of childhood trauma (Weissbecker, Floyd, Dedert, Salmon, & Sephton, 2006) and children growing up in Eastern European orphanages (see Gunnar & Vasquez, 2001, for a review). Gunnar and Vasquez (2001) have argued that low morning cortisol, or hypocortisolism, in young children can reflect a downregulation of the HPA axis in response to chronic activation and appears to be a risk factor for problems in several domains, including attentional, behavioral, and health-related conditions. In contrast, animal studies suggest moderate levels of cortisol are necessary for supporting neural development (de Kloet, Oitzl, & Joëls, 1999). Identifying optimal cortisol levels in children and factors that contribute to
healthy HPA axis functioning constitutes an important agenda for developmental research.

The modest across-time stability of cortisol measures in this study and the high moment-to-moment variability in cortisol in general (Shirtcliff et al., 2005) likely reflect unmeasured and transient experiences. In the child-care setting, these experiences would include peer conflict, injuries, and discipline encounters. The apparent importance of such events suggests the need for more fine-grained, moment-to-moment analysis of children's experiences in child care in conjunction with concurrent collection of multiple saliva samples to chart experience—cortisol links (Coste, Strauch, Letrait, & Bertagna, 1994; Flinn, 1999). This approach would be consistent with the view that more global aspects of child-care environments, such as group size and teacher sensitivity, are best conceptualized in terms of how they influence children's actual experiences (Pianta, 1999). Cortisol fluctuations in child care most likely reflect interplay between individual child, teacher, peer, and classroom influences.

Some have argued that concurrent examination of multiple physiological systems is necessary to fully understand the significance of these systems and their disrupted functioning for children’s development (Bauer, Quas, & Boyce, 2002; Granger & Kivlighan, 2003). In particular, asynchrony in reactivity of the sympathetic-adrenal-medullary (SAM) and the HPA systems may mark or condition risk for adjustment problems (Bauer et al., 2002). The development of procedures to measure alpha-amylase, a marker of SAM activation (Chatterton, Vogelsong, Lu, Ellman, & Hudgens, 1996), in saliva makes it feasible to noninvasively assess both HPA and SAM activity in young children (Granger et al., 2006). Future research should incorporate other aspects of children’s physiological functioning to better understand how child care influences children.

This study sheds additional light on an as yet incompletely understood phenomenon—disruption of the typical pattern of HPA activity among many young children attending full-day child care. Additionally, the data begin to situate child care—cortisol research in the context of a broader conceptual and empirical literature on the role of relationships in shaping baseline functioning and reactivity of physiological systems in developing organisms (Sanchez, Ladd, & Plotisky, 2001).

References


