What’s mom got to do with it? Contributions of maternal executive function and caregiving to the development of executive function across early childhood

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Abstract

Executive functions (EFs; e.g. working memory, inhibitory control) are mediated by the prefrontal cortex and associated with optimal cognitive and socio-emotional development. This study provides the first concurrent analysis of the relative contributions of maternal EF and caregiving to child EF. A group of children and their mothers (n = 62) completed age-appropriate interaction (10, 24, 36 months) and EF tasks (child: 24, 36, and 48 months). Regression analyses revealed that by 36 months of age, maternal EF and negative caregiving behaviors accounted for unique variance in child EF, above and beyond maternal education and child verbal ability. These findings were confirmed when using an early child EF composite-our most reliable measure of EF—and a similar pattern was found when controlling for stability in child EF. Furthermore, there was evidence that maternal EF had significant indirect effects on changes in child EF through maternal caregiving. At 24 months, EF was associated with maternal EF, but not negative caregiving behaviors. Taken together, these findings suggest that links between negative caregiving and child EF are increasingly manifested during early childhood. Although maternal EF and negative caregiving are related, they provide unique information about the development of child EF.

A video abstract of this article can be viewed at http://www.youtube.com/watch?v=NPKXFbbrkpe

Research highlights

• This study provides the first concurrent analysis of the relative contributions of maternal EF and caregiving to child EF.
• By 36 months of age, maternal EF and negative caregiving behaviors account for unique variance in child EF, above and beyond maternal education and child verbal ability.
• At 24 months, EF was associated with maternal EF, but not negative caregiving behaviors.
• Links between negative caregiving and child EF are increasingly manifested during early childhood.
• Maternal EF had significant indirect effects on changes in child EF through maternal caregiving.

Introduction

The ability to regulate memory and attention processes is essential to optimal social-emotional and cognitive development in childhood and beyond (Bell & Deater-Deckard, 2007; Blair, 2002; Nigg & Casey, 2005; Posner & Rothbart, 2007). Although we know that most children exhibit dramatic improvements in self-regulation between infancy and middle childhood, the etiology of individual differences in this developmental progression remains poorly understood. In the present study, we examine the contributions of maternal executive function (EF) and caregiving behaviors to the development of EF during early childhood.

EFs are higher-order cognitive and self-regulatory processes (e.g. working memory, inhibitory control,
Maternal caregiving and executive function

Maternal caregiving and child EF

Supportive, nurturing maternal interactions with children predict positive socio-emotional outcomes, whereas controlling, intrusive maternal interactions predict more negative outcomes (Thompson, 1998). Until recently, empirical evidence for the effects of maternal behaviors on child EF had focused on severe adverse environments (see review by Hughes, 2011) as opposed to variations in more typical environments. Research examining scaffolding (i.e. parental support during child problem-solving) with typically developing children has revealed that maternal scaffolding at 2 years of age is related to concurrent (Bibok, Carpendale & Müller, 2009) as well as future (i.e. 4-year) EF (Hughes & Ensor, 2009). Furthermore, the association between maternal scaffolding at age 2 and 4-year EF remained robust even after controlling for 2-year EF (Hughes & Ensor, 2009).

Additional EF research has examined the contribution of a variety of positive caregiving behaviors during infancy, including maternal sensitivity (i.e. providing children with successful experiences of impacting the environment), maternal mind-mindedness (i.e. using mental terms when speaking to children), and autonomy support (i.e. supporting children’s decisions and goals; Bernier, Carlson, Deschênes & Matte-Gagné, 2012; Bernier, Carlson & Whipple, 2010). These positive infant caregiving behaviors were associated with better EF performance during toddlerhood (Bernier et al., 2010) and at 3 years of age (Bernier et al., 2012), with robust effects for 3-year EF remaining even after controlling for 2-year EF. Likewise, Kraybill and Bell (in press) have recently found that maternal positive affect at 10 months of age was related to child EF at 4 and 6 years of age. Together, these findings provide strong evidence for the beneficial effects of positive caregiving behavior on child EF within the average home environment.

Maternal EF and caregiving

Calkins (2011) proposes that a psychobiological framework is critical for conceptualizing the multiple biological and behavioral levels at which caregiving affects children. She suggests that caregiver behavior must be regulated within the caregiver, affecting her own behavior, and that caregiver behavior must be regulatory between the caregiver and child. If we consider the construct of EF, many of its components are useful in the caregiving context. A mother must use inhibitory control to refrain from expressing ‘knee-jerk’ negative reactions that are often elicited by undesirable child behaviors. She uses working memory to maintain and manipulate information, typically in the presence of multiple distractions, while interacting with her child. Last, but not least, in this highly stimulating environment, a mother must use cognitive flexibility to switch between different situations and their corresponding demands (Barrett & Fleming, 2011).

There is evidence that maternal EF is associated with a range of caregiving behaviors (see review by Barrett & Fleming, 2011; Deater-Deckard, Wang, Chen & Bell, 2012b). Deater-Deckard and colleagues have demonstrated that low maternal EF is linked with harsher, more reactive caregiving in the face of challenging child behaviors (i.e. noncompliance, inattention, hyperactivity; Deater-Deckard, Chen, Wang & Bell, 2012a; Deater-Deckard, Sewell, Petrill & Thompson, 2010; Deater-Deckard et al., 2012b). Many challenging behaviors emerge during the first three years as children seek

cognitive flexibility) that underlie goal-directed behaviors. The prefrontal cortex is intricately linked to EF (Kane & Engle, 2002; Osaka, Osaka, Kondo, Morishita, Fukuyama, Aso & Shibasaki, 2003), and the development of both the prefrontal cortex and EFs are protracted through childhood and early adulthood. Substantial research has revealed that EFs are critical to aspects of optimal development. During early childhood, EFs are related to school readiness (Bierman, Torres, Domitrovich, Welsh & Gest, 2009; Blair & Peters, 2003) as well as concurrent and future reading and mathematics performance (Blair & Razza, 2007; Bull, Espy & Wiebe, 2008; Bull & Scerif, 2001; Clark, Pritchard & Woodward, 2010; Espy, McDiarmid, Cwik, Stalets, Hamby & Senn, 2004; Mazzocco & Kover, 2007; St Clair-Thompson & Gathercole, 2006). EF deficits, on the other hand, have been associated with difficulties in emotion regulation (Kochanska, Murray & Harlan, 2000; Lemery, Essex & Smider, 2002) and early-onset disorders, such as attention-deficit/hyperactivity disorder, autism spectrum disorder, and phenylketonuria (Berlin, Bohlin & Rydell, 2003; Diamond, Prevor, Callender & Druin, 1997; Semrud-Clikeman, Walkowiak, Wilkinson & Butcher, 2010).

As an initial step in understanding individual differences in EF development during early childhood, we begin by examining maternal measures because mothers are more likely to be the primary caregiver and they share half of their genes with their children. In the following sections, we begin by reviewing the literature on the association between maternal caregiving behaviors and childhood EF. Next, we highlight evidence that maternal EF is associated with caregiving behaviors. We conclude by noting gaps in our understanding of how maternal measures are related to the emergence of EF during early childhood.
Maternal EF and child EF

We propose that the mechanism by which maternal EF impacts early childhood EF involves gene–environment transactions (Jester, Nigg, Putter, Long, Fitzgerald & Zucker, 2009; Polderman, Gosso, Posthuma, van Beesterveldt, Heutink, Verhulst & Boomsma, 2006) operating through the maternal EF and caregiving context that the child experiences. Our focus is on the EF/caregiving context and not on elucidating the gene–environment transactions. It is important, however, to review what is known about maternal–child EF association during early childhood.

The only examination of maternal and early childhood EF failed to find an association between biological mothers’ performance on the color Stroop task and their 27-month-old children’s (who were adopted by other families) performance on either the shape Stroop or gift delay tasks (Leve, DeGarmo, Bridgett, Neiderhiser, Shaw, Harold, Natsuaki & Reiss, in press). Although these null findings could indicate that maternal EF is not associated with early childhood EF outside of the caregiving context, it is plausible that the null findings are related to measurement problems. Specifically, EF task performance is also affected by non-EF demands (e.g. variance due to measurement error), and when possible it is highly preferred to form a composite score of a latent construct of correlated indicators (as opposed to using single tasks) because such composite scores provide more reliable measures of EF (Carlson, Mandell & Williams, 2004; Rushton, Brainerd & Pressley, 1983).

Previously, we formed EF composite measures for mothers and children in the current study and found evidence that mother and child EF are modestly correlated by 24 months of age, with this association remaining stable through 48 months (Cuevas, Deater-Deckard, Wang, Kim-Spoon, Morasch & Bell, 2013). Importantly, we found that maternal–child EF associations remained robust after controlling for verbal ability (a potential indicator of verbal or crystallized intelligence) and maternal education (a correlate of socioeconomic status and verbal intelligence). However, it is plausible that this link is driven by underlying maternal EF–caregiving associations. Maternal caregiving has been found to mediate the link between childhood EF and other informative familial measures. For instance, recent evidence from a predominately low-income sample revealed that associations between socioeconomic status and 36-month EF were mediated by maternal caregiving behaviors (i.e. positive engagement and negative intrusiveness) at 7 months of age (Rhoades, Greenberg, Lanza & Blair, 2011). To help elucidate the mechanism of maternal–child EF associations, in the present study, we examined whether maternal caregiving might mediate the association between maternal EF and early childhood EF.

The current study

The aims of the current study were (a) to examine the relative contributions of maternal EF and caregiving to child EF throughout early childhood; and (b) to determine whether maternal caregiving mediates the association between mom and child EF. In order to capture the emergence of EF as well as stability in individual differences in EF, we assessed EF from 2 (i.e. approaching the youngest assessment age) to 4 years of age (i.e. when there is moderate stability in individual differences in EF; Kochanska & Knaack, 2003). Mothers and children completed age-appropriate EF tasks (on separate occasions) that required a variety of EF skills (e.g. working memory, inhibitory control, cognitive flexibility). Children were tested at 24, 36, and 48 months of age.

As reviewed above, previous research has focused on either positive caregiving behaviors or adverse environments when examining child EF. In the present study, we were interested in whether negative caregiving behaviors, within a typical (as opposed to adverse) environment, would be negatively associated with child EF. To this end, a group of mother–child dyads completed age-appropriate interaction tasks when children were 10, 24, and 36 months of age. This developmental time span captures transitions in the caregiving context as children become more autonomous. Caregiving behaviors of interest were intrusiveness (i.e. imposing mother-centered interactions), negative affect (24 and 36 months; i.e. using negative tone, hostility, and harsh or powerless control), physical stimulation (10 months; i.e. frequency and intensity of stimulating infant’s body to heighten arousal), and failure to facilitate attention (i.e. lack of appropriate attentive responses). To reduce measurement error, we used principal component analyses to verify that our individual EF and caregiving measures were associated, and then calculated EF and caregiving composite scores.
We hypothesized that maternal negative caregiving behaviors would negatively correlate with maternal EF as well as child EF. There is evidence that both verbal ability (a measure often used as an indicator of verbal or crystallized intelligence) and socioeconomic status (a broad indicator of family material and social resources) are associated with EF (e.g. Bernier et al., 2012; Kaler & Kopp, 1990). Thus, we controlled for maternal education (a correlate of socioeconomic status and verbal intelligence) and child verbal ability in our regression analyses. Finally, we included a second set of regression analyses in which we controlled for stability in child EF (i.e. EF from the previous assessment) to determine potential contributors to important changes in EF during early childhood.

**Method**

**Participants**

The initial sample included 63 biological mother–child dyads. Children were part of an ongoing longitudinal investigation and mothers were recruited to have their EF assessed when children were either 3 (n = 55) or 4 (n = 8) years old. One dyad was excluded because the child was premature at birth. Of the 62 children (25 boys, 37 girls; 4 Hispanic, 58 Non-Hispanic; 57 Caucasian, 5 Multi-Racial) in our final sample, all participated at 2 years (M = 2.09 years; SD = 22 days), 61 returned at 3 years (M = 3.10 years; SD = 28 days), and 57 returned at 4 years (M = 4.11 years; SD = 29 days). All mothers (1 Hispanic, 61 Non-Hispanic; 1 African American, 1 Asian, 60 Caucasian) graduated from high school (1.6% technical degree; 40.3% bachelor’s degree; 35.5% graduate degree). Mothers were between 21 and 43 years (M = 34 years, SD = 5) during the maternal EF assessment and received an honorarium for each laboratory visit.

**Procedure**

Study procedures were approved by the institutional review board.

Maternal caregiving measures

Mothers were observed as they interacted with their children during a variety of tasks at 10, 24, and 36 months of age. For each interaction task, the experimenter instructed the mother to play with her child just as she would at home and then left the room. A camera was focused on both mother and child, and maternal behavior was videotaped for off-line coding by trained research assistants. Each aspect of maternal behavior was coded on a 4-point scale (i.e. 1 = low incidence of a behavior; 4 = high incidence). Scales were adapted from Calkins, Hungerford and Dedmon (2004) and Eyberg and Robinson (1981). Behavior was coded in 30-s epochs, which were then averaged to create a mean score for that behavior across the entire task. An independent observer coded at least 19% of the dyads across the longitudinal sample to confirm reliability of coding. Intraclass correlations exceeded .76 for each maternal behavior in each age group.

**10 months.** Mothers and infants were observed in two interaction tasks adapted from Calkins et al. (2004). For the toys task, each mother and infant played together with two simple age-appropriate infant toys. During this 2-min task, the infant sat in a high chair and the mother sat in front and slightly to the left of her infant. Afterwards, mothers and infants were observed in a 2-min game of peek-a-boo.

Maternal behaviors of interest included facilitating attention, physical stimulation, and intrusiveness. Mother’s ability to facilitate attention refers to her sensitivity to her child, namely through behavioral evidence of appropriate attentive responses to her child’s arousal, interests, and abilities. Physical stimulation refers to the extent to which, in both frequency and intensity, a mother directly stimulates her infant’s body to heighten the infant’s arousal. Maternal intrusiveness refers to the extent to which an interaction is mother centered, rather than child centered, and is characterized by behaviors such as expressing negative affect, overstimulation or an overwhelmingly increased pace of activity, or intrusive physical interactions with the infant. Analogous maternal behaviors correlated across the toys and peek-a-boo tasks (rs = .43–.57) and were, thus, standardized and averaged to create a single measure for each of these three caregiving domains.

**24 and 36 months.** Mothers and children were observed as they played with age-appropriate puzzles for approximately 6 min (Smith, Calkins, Keane, Anastopoulos & Shelton, 2004). During this interaction, mother and child sat on adjacent sides of a table. Interactions were coded for facilitating attention and intrusiveness. The physical stimulation scale was replaced with the more developmentally appropriate negative affect measure, which describes a mother’s use of negative tone, hostility, and harsh or power-assertive control.

Caregiving composite measure (10, 24, 36 months). When possible, it is greatly preferred to
form a composite score of a latent construct of correlated indicators because such composite scores are most reliable (Rushton et al., 1983). Our caregiving composite included failure to facilitate attention (reverse score facilitate attention so that higher scores indicated less attention-facilitating behaviors), physical stimulation (10 months), negative affect (24 and 36 months), and intrusiveness behaviors. At 10 months, the first principal component among the three maternal behaviors explained 68% of the variance ($\lambda = .59–.96$). At 24 months, the first principal component among the three maternal variables explained 57% of the variance ($\lambda = .74–.76$). Similarly, the first principal component at 36 months explained 45% of the variance ($\lambda = .51–.79$). At each age, individual indicator scores were standardized, averaged, and standardized again to yield caregiving composite $z$-scores. Finally, an overall caregiving composite was formed by averaging the 10-, 24-, and 36-month composite $z$-scores, and the final overall composite standardized again to yield a $z$-score. The first principal component explained 47% of the variance ($\lambda = .67–.72$). This is our most reliable measure of maternal caregiving behaviors because it includes multiple measures assessed at different time points.

Child EF measures

For all EF tasks, interrater reliability (Cronbach’s $\alpha \geq .90$) was established for at least 20% of our entire longitudinal sample.

A-not-B with invisible displacement (24 months). The toddler A-not-B looking procedure is detailed in Morasch and Bell (2011). An attractive item was hidden under a cup (central location); the cup was shifted to one side (side A, counterbalanced left/right); and a barrier was placed in front of the cup. During the 5-s delay, the experimenter distracted the toddler (kept gaze at midline) and, behind the barrier, placed a second cup (side B). The barrier was removed and toddlers were asked, ‘Where’s the ball?’ The first look toward either location was coded, and after two consecutive correct same-side searches, the hiding location was reversed (pattern AAB). Performance was the proportion of correct searches (Diamond et al., 1997).

Crayon delay (24 months). The crayon delay procedure (Calkins, 1997) is detailed in Morasch and Bell (2011). Toddlers were presented with a box of crayons and a blank piece of paper. Before the child touched the crayons, the experimenter told him/her that she needed to leave the room. She instructed the toddler not to touch the crayons, box, or paper until she returned. The experimenter left the room for 60 s. Toddlers’ behavior during the delay was scored a 0 (does not touch), 1 (touched paper), 2 (touched box), 3 (picks up box), 4 (takes crayons out of box), or 5 (colors with crayons).

Tongue task (36 months). The tongue task (Kochanska et al., 2000) required children to hold a goldfish cracker on their tongue without chewing it (three trials with delays of 10, 20, and 30 s). Performance was the proportion of successful trials.

Simon-says (36 and 48 months). The Simon-says task followed the Bear/Dragon procedure (Carlson, Moses & Breton, 2002) and is detailed in Wolfe and Bell (2007). Children were instructed to do what the nice horse (48 months: pig) ‘tells us’ and to not do what the mean cow (48 months: bull) ‘tells us’. Children passed (36 months: $n = 29$; 48 months: $n = 51$) the practice trials if they followed the horse/pig’s command but ignored the cow/bull’s command. Ten test trials followed (half for each type, alternating order), and performance was the proportion of correct responses.

Day-Night (36 months) and Yes-No (48 months). For the day-night task (Gerstadt, Hong & Diamond, 1994), children were instructed to say ‘day’ when shown a moon card and to say ‘night’ when shown a sun card. The yes-no task was created in our research lab (e.g. Wolfe & Bell, 2007) and is conceptually and procedurally similar to the day-night task. Children were instructed to say ‘yes’ when the experimenter shook her head no and to say ‘no’ when the experimenter nodded her head yes. For each task, once children passed two learning trials, they received 16 test trials (half for each type) in a pseudorandom order. Correct responses received 1 point and incorrect responses followed by self-correction received .5 point. Performance was the proportion of points earned.

Dimensional Change Card Sort (DCCS: 48 months). For this task (Zelazo, Frye & Rapus, 1996), children were instructed to sort cards based on two dimensions (i.e. color, shape). Children first sorted six cards by one dimension (pre-switch; counterbalanced across participants) and then were instructed to switch and to sort the remaining six cards by the other dimension (post-switch). Performance was the proportion of correct post-switch responses.

EF composite measures (24, 36, 48 months). Descriptive statistics for our child EF measures can be found in Table 1. The 24-month composite included crayon delay performance (reverse scored so that higher scores
Mothers were instructed to repeat the sequence aloud in reverse order, and they received two-digit practice trials. Test trials began with two different four-digit sequences, and digit span increased by a single digit until the participant failed to provide a correct response to both trials at a given span. Performance was defined as the highest digit span with a correct response.

**Wisconsin Card Sorting Test (WCST).** Mothers were instructed to match a card (64 total) to one of four key cards (Heaton & PAR Staff, 2003). The images on the cards varied in color, quantity, and shape, and participants must sort the cards according to an undisclosed rule (e.g. by shape) that they had to ascertain via feedback. The sorting rules changed several times. The age-standardized percentile score associated with conceptual level (i.e. executive attention measure) – the difference in reaction time between incongruent and congruent trials.

**Attention Network Test (ANT).** Mothers responded to a central target (an arrow) by hitting one of two keys to indicate whether the arrow points left or right (Fan, McCandliss, Sommer, Raz & Posner, 2002). Targets varied in the presence/absence of flankers as well as whether the flankers were congruent or incongruent. Performance was defined as the conflict score (i.e. executive attention measure) – the difference in reaction time between incongruent and congruent trials.

**Backward digit span.** An experimenter read a seemingly random series of single-digit numbers to participants. Mothers were instructed to repeat the sequence aloud in the reverse order, and they received two-digit practice trials. Test trials began with two different four-digit sequences, and digit span increased by a single digit until the participant failed to provide a correct response to both trials at a given span. Performance was defined as the highest digit span with a correct response.

**EF composite measure.** Descriptive statistics for our maternal EF measures can be found in Table 1. The first principal component among the four tasks (with ANT reverse scored so that higher scores indicated better performance) explained 44% of the variance (λ = .57–.81). Scores were standardized, averaged, and standardized again to form a composite z-score.

**Child verbal ability**

**MacArthur-Bates Communicative Development Inventory (MCDI: 24 months).** The MCDI ‘Words and Sentences’ form (Fenson, Dale, Reznick, Thal, Bates, Hartung, Pethick & Reilly, 1992) was completed by toddlers’ mothers to provide a measure of toddler verbal ability. The MCDI is an inventory of common words and...
phrases. We used the percentile score associated with vocabulary production.

**Peabody Picture Vocabulary Test (PPVT: 36 and 48 months).** The PPVT-III (Dunn & Dunn, 1997) or PPVT-IV (Dunn & Dunn, 2007) was administered to children individually to determine receptive vocabulary and verbal comprehension. The PPVT-III and -IV are nationally standardized instruments, and the measure of interest was participants’ percentile scores.

**Results**

First, we computed bivariate correlations to examine associations between early childhood EF and maternal EF as well as maternal caregiving behaviors. We hypothesized that maternal negative caregiving behaviors would be negatively correlated with child as well as maternal EF. Because of our directional hypotheses, we report one-tailed p-values for our correlations as well as the t-tests for our regression weights. Two-tailed p-values are reported for regression F-tests. The maternal caregiving composite included 10- and 24-month caregiving behaviors in all analyses, with 36-month caregiving behaviors also being included for 36- and 48-month EF analyses. Next, we used hierarchical regression analyses, controlling for child verbal ability and maternal education, to determine the unique contribution of maternal EF and caregiving behaviors in predicting early childhood EF. We also performed mediation analyses to estimate the indirect effect of maternal EF on child EF via maternal caregiving using Bias Corrected Bootstrapping (Preacher & Hayes, 2004, 2008) because it is considered to be the most accurate method for detecting indirect effect when sample sizes are small. The confidence interval (CI) was set to 95% with 1000 resamples. Finally, we examined whether maternal caregiving mediated the association between maternal and child EF.

**Regression analyses**

For each regression analysis, we began by controlling for the contribution of maternal education and child verbal ability to child EF (Step 1). Next (Step 2), we included our primary measures of interest – maternal EF and maternal education – to determine the relative contribution of each measure to child EF. Finally, we examined whether maternal caregiving mediated the association between maternal and child EF.

**Predicting 24-month EF**

The 24-month EF regression analysis was the only model that was not significant, $F(4, 56) = 1.82, p = .14$, although maternal EF and 24-month EF were correlated.

**Predicting 36-month EF**

The results of the 36-month EF regression analysis can be found in Table 3. Step 1 was not significant. Step 2 indicated that maternal EF and caregiving accounted for an additional 16% of the variance in 36-month EF. An examination of the regression weights revealed that maternal EF accounted for the majority of unique variance in 36-month EF (i.e. 6%). There were unique contributions of maternal caregiving and education to 36-month EF (i.e. 4% and 5% of the variance, respectively). Mediation analysis revealed a significant indirect effect of maternal EF on 36-month EF through maternal caregiving.

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**Table 2** Correlations between child EF and maternal EF and caregiving

<table>
<thead>
<tr>
<th></th>
<th>Maternal EF composite</th>
<th>Maternal negative caregiving composite$^a$</th>
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<tbody>
<tr>
<td>24-month EF composite</td>
<td>.22*</td>
<td>-.06</td>
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<tr>
<td>36-month EF composite</td>
<td>.35**</td>
<td>-.37**</td>
</tr>
<tr>
<td>48-month EF composite</td>
<td>.32**</td>
<td>-.51***</td>
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<tr>
<td>Child EF composite</td>
<td>.41***</td>
<td>-.35**</td>
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Note: One-tailed p-values: ***$p \leq .05$, *$p \leq .01$, **$p \leq .001$. $^a$The caregiving composite includes 10- and 24-month behaviors for all analyses. The 36- and 48-month analyses also include 36-month caregiving behaviors.

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caregiving, with a point estimate of 0.08, \( SE = 0.06 \), and 95% CI \([.0006, .2504]\).

Next, we controlled for 24-month EF to examine maternal contributors to 36-month EF over and above the stability in EF between 24 and 36 months. The results of the regression analysis can be found in Table 4. Step 2 indicated that 24-month EF accounted for an additional 8% of the variance in 36-month EF, above and beyond maternal education and 36-month verbal ability. Step 3 revealed that maternal EF and caregiving accounted for an additional 13% of the variance in 36-month EF. An examination of the regression weights indicated that maternal EF, maternal caregiving, and 24-month EF each accounted for 4%–5% of the unique variance in the final step. Mediation analysis revealed a significant indirect effect of maternal EF on the change in EF between 24 and 36 months via maternal caregiving, with a point estimate of 0.09, S.E. \( = 0.06 \), and 95% CI \([.0051, .2697]\). Thus, we found a similar pattern of findings as our initial analysis of 36-month EF when not controlling for 24-month EF (see Tables 3 and 4).

### Predicting 48-month EF

Table 5 shows the results of the 48-month EF regression analysis. Step 1 indicated that maternal education and 48-month verbal ability accounted for 21% of the variance in 48-month EF. Including maternal EF and caregiving in Step 2 accounted for an additional 18% of the variance in 48-month EF. An examination of the regression weights revealed that the majority of unique variance in 48-month EF was accounted for by maternal caregiving (10%) and 48-month verbal ability (6%). There was also a unique contribution of maternal EF (i.e. 3% of the variance). Mediation analysis revealed a significant indirect effect of maternal EF on 48-month EF.

### Table 3 Results of hierarchical regression analysis predicting 36-month EF from maternal education, maternal EF, maternal caregiving, and 36-month verbal ability

<table>
<thead>
<tr>
<th>R</th>
<th>( R^2 )</th>
<th>( R^2 \Delta )</th>
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<th>F</th>
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<th>t</th>
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<td>Step 1</td>
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<tr>
<td>Verbal Ability (36 months)</td>
<td>.30</td>
<td>.09</td>
<td>2.84</td>
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<td>Maternal Education</td>
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<td>Verbal Ability (36 months)</td>
<td>.50</td>
<td>.25</td>
<td>.16</td>
<td>5.64**</td>
<td>4.47**</td>
<td>-.13</td>
<td>-.90</td>
<td>-.12</td>
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<tr>
<td>Maternal Education</td>
<td>.34</td>
<td>2.38*</td>
<td>.30</td>
<td>.09</td>
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<tr>
<td>Maternal EF</td>
<td>.25</td>
<td>1.80*</td>
<td>.21</td>
<td>.05</td>
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<tr>
<td>Maternal Caregiving Composite (10, 24, 36 months)</td>
<td>.27</td>
<td>2.13*</td>
<td>.25</td>
<td>.06</td>
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Note: One-tailed \( p \)-values for \( t \)-tests and two-tailed \( p \)-values for \( F \)-tests. **\( p \leq .01 \); *\( p \leq .05 \). \( n = 59 \).

### Table 4 Results of hierarchical regression analysis predicting 36-month EF from 24-month EF, maternal education, maternal EF, maternal caregiving, and 36-month verbal ability

<table>
<thead>
<tr>
<th>R</th>
<th>( R^2 )</th>
<th>( R^2 \Delta )</th>
<th>FA</th>
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<td>Step 1</td>
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<tr>
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<td>.08</td>
<td>4.97*</td>
<td>3.68*</td>
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<td>.25</td>
<td>.06</td>
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<td>4.43**</td>
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<tr>
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<td>1.88*</td>
<td>.22</td>
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</table>

Note: One-tailed \( p \)-values for \( t \)-tests and two-tailed \( p \)-values for \( F \)-tests. **\( p \leq .01 \); *\( p \leq .05 \). \( n = 59 \).
EF through maternal caregiving, with a point estimate of 0.10, \( SE = 0.06 \), and 95% CI \([.0141, .2887]\).

Next, we examined maternal contributors to 48-month EF over and above the stability in EF between 36 and 48 months (see Table 6). Step 2 indicated that 36-month EF accounted for an additional 5% of the variance in 48-month EF, above and beyond maternal education and 48-month verbal ability. As can be seen in Step 3, maternal EF and caregiving accounted for an additional 19% of the variance in 48-month EF. The majority of unique variance in 48-month EF, when controlling for stability in EF between 36 and 48 months, was accounted for by maternal caregiving (16%) and 48-month verbal ability (11%). This pattern was similar to our initial 48-month EF model, except that there was no unique contribution of maternal EF when controlling for 36-month EF (see Tables 5 and 6). Mediation analysis revealed a significant indirect effect of maternal EF on the change in EF between 36 and 48 months via maternal caregiving, with a point estimate of 0.11, \( SE = 0.08 \), and 95% CI \([.0158, .3257]\).

Predicting child (24-, 36-, 48-month composite) EF

In the final regression analysis, we used our most reliable measure of child EF – the child EF composite. In order to control for the effects of verbal ability on concurrent EF, we created residualized EF composites with verbal ability removed at each age. Next, we averaged the residualized EF composites across ages to obtain a residualized child EF composite. The results of the regression analysis for residualized child EF are displayed in Table 7. Step 1 was not significant. An additional 23% of the variance in child EF was accounted for when maternal EF and caregiving were included in Step 2. An examination of the regression weights indicated that maternal EF and caregiving accounted for the majority of the unique variance in child EF (i.e. 14% and 5%, respectively). Mediation analysis revealed that the indirect effect of maternal EF on the childhood EF composite was not statistically significant, with point estimate = 0.45, \( SE = 0.04 \), and 95% CI \([-0.0028, .1578]\).

### Table 5  Results of hierarchical regression analysis predicting 48-month EF from maternal education, maternal EF, maternal caregiving, and 48-month verbal ability

<table>
<thead>
<tr>
<th>Dependent variable: 48-month EF</th>
<th>( R )</th>
<th>( R^2 )</th>
<th>( R^2 \Delta )</th>
<th>( \Delta F )</th>
<th>( F )</th>
<th>( \beta )</th>
<th>( t )</th>
<th>( sr )</th>
<th>( sr^2 )</th>
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<tr>
<td>Verbal Ability (48 months)</td>
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<td>.21</td>
<td>.04</td>
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<td>.32</td>
<td>.10</td>
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<td>.02</td>
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<td>.17</td>
<td>.03</td>
<td></td>
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<tr>
<td><strong>Step 2</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Verbal Ability (48 months)</td>
<td>.62</td>
<td>.38</td>
<td>.18</td>
<td>7.46</td>
<td>.28</td>
<td>2.32</td>
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<td>Maternal Caregiving Composite (10, 24, 36 months)</td>
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<td>.10</td>
<td>2.88</td>
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<td>2.88</td>
<td>.31</td>
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Note: One-tailed \( p \)-values for \( t \)-tests and two-tailed \( p \)-values for \( F \)-tests. \(* * \) \( p \leq .001 \); \(* \) \( p \leq .05 \). Only \( sr^2 \) values \( \geq .01 \) are reported. \( n = 57 \).

### Table 6  Results of hierarchical regression analysis predicting 48-month EF from 36-month EF, maternal education, maternal EF, maternal caregiving, and 48-month verbal ability

<table>
<thead>
<tr>
<th>Dependent variable: 48-month EF</th>
<th>( R )</th>
<th>( R^2 )</th>
<th>( R^2 \Delta )</th>
<th>( \Delta F )</th>
<th>( F )</th>
<th>( \beta )</th>
<th>( t )</th>
<th>( sr )</th>
<th>( sr^2 )</th>
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<tr>
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<td>.24</td>
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<td>.16</td>
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<td>.03</td>
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<td>.17</td>
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<td>.05</td>
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<td>.09</td>
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<tr>
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<td>-0.01</td>
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<td>.06</td>
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<td>Maternal Caregiving Composite (10, 24, 36 months)</td>
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<td>-.47</td>
<td>4.12</td>
<td>-.40</td>
<td>.16</td>
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</table>

Note: One-tailed \( p \)-values for \( t \)-tests and two-tailed \( p \)-values for \( F \)-tests. \(* * \) \( p \leq .001 \); \(* \) \( p \leq .05 \). Only \( sr^2 \) values \( \geq .01 \) are reported. \( n = 55 \).
In sum, with the exception of the 24-month analysis, all analyses revealed unique contributions of maternal EF and maternal caregiving to early childhood EF above and beyond child verbal ability and maternal education. Furthermore, there was evidence that maternal EF had significant indirect effects on changes in child EF through maternal caregiving.

Discussion

These data provide the first concurrent analysis of the relative contributions of maternal EF and caregiving in predicting child EF. As hypothesized, we found that negative caregiving behaviors were negatively associated with child EF as well as maternal EF. This finding supports previous evidence from a predominately low-income sample of links between negative caregiving behaviors and child EF at 36 months (Rhoades et al., 2011), and reveals that these associations are also present in nonadverse contexts. In the present study, regression analyses revealed that by 36 months of age, maternal EF and negative caregiving (i.e., a composite from 10, 24, and 36 months) each accounted for unique variance in child EF, above and beyond maternal education (a correlate of socioeconomic status and verbal intelligence) and child verbal ability (a potential indicator of verbal or crystallized intelligence). These findings were confirmed when using an early childhood EF composite, our most reliable measure of EF. Thus, measures of maternal EF and negative caregiving, although related, provide unique information about the development of child EF.

Mediation models revealed that the links between maternal EF and child EF at 36 and 48 months of age were at least partially explained by associated variations in caregiving behaviors. Likewise, maternal EF had statistical indirect effects on changes in child EF (from 24 to 36 months and from 36 to 48 months) through maternal caregiving. These findings are consistent with a growing body of research demonstrating associations between maternal EF and caregiving behaviors (see review by Barrett & Fleming, 2011; Deater-Deckard et al., 2012b). Furthermore, our findings confirm that maternal caregiving is an important mediator between familial measures, such as socioeconomic status (Rhoades et al., 2011), and child EF, and extend these mediated findings to include maternal EF–child EF associations. Based on Calkins’ (2011) psychobiological framework, we posit that maternal EFs are critical to regulating maternal caregiving behaviors, especially negative caregiving behaviors such as those examined in the present study.

Although 24-month EF was associated with maternal EF, we found no link between negative caregiving behaviors and child EF prior to 36 months. This null result contrasts with evidence of associations between positive maternal caregiving behaviors and 24-month EF (Bernier et al., 2010; Bibok et al., 2009; Hughes & Ensor, 2009). To help understand this pattern, we (a) confirmed that the 10- and 24-month negative caregiving composite was associated with EF at 36 and 48 months (i.e., the null result does not appear to be related to the number of caregiving assessments or the informative value of infant and toddler negative caregiving behaviors); and (b) completed exploratory analyses of both individual and composite caregiving and EF measures to ensure that we had not overlooked a potential association at 24 months. One potential explanation for the lack of association between 24-month EF and negative caregiving behaviors would be that the effects of the potential mechanisms that underlie this association (reviewed below) are not substantial enough to be manifested in the rudimentary forms of EF that are present at 2 years of age. Furthermore, challenging child behaviors (e.g., noncompliance) associated with children’s autonomy are exhibited increasingly during the first 3 years. Perhaps opportunities for negative (as compared to positive) interactions may be only recently on the 24-month horizon, and associations between negative caregiving behaviors and child EF might be less immediately

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Table 7 Results of hierarchical regression analysis predicting child EF (a composite of 24-, 36-, and 48-month assessments) from maternal education, maternal EF, and maternal caregiving

<table>
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<tr>
<th>Step</th>
<th>R</th>
<th>R²</th>
<th>R²A</th>
<th>FA</th>
<th>F</th>
<th>β</th>
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<td>.25</td>
<td>1.96*</td>
<td>.25</td>
<td>.06</td>
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<td>.23</td>
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<td>.23</td>
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<td>.04</td>
<td>.16</td>
<td>1.38</td>
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<td>.22</td>
<td>.05</td>
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</table>

Note: One-tailed p-values for t-tests and two-tailed p-values for F-tests. ***p ≤ .001; *p ≤ .05. n = 62.
detectable. This null finding highlights the importance of including multiple maternal measures when assessing associations with toddler EF.

At 3 and 4 years of age, maternal EF and negative caregiving accounted for an additional 16–18% of the variance in child EF, above and beyond maternal education and child verbal ability. We also found that, at both ages, negative caregiving behaviors mediated the association between maternal EF and child EF.\(^3\) When examining the amount of unique variance accounted for by each maternal measure, we see different patterns at each age. Maternal EF and negative caregiving accounted for approximately the same amount of variance in 36-month EF (6% and 4%, respectively) even when controlling for stability in EF (4% and 5%, respectively). For 48-month EF, on the other hand, negative caregiving accounted for more unique variance (10%) than maternal EF (3%) and controlling for stability in EF enhanced this pattern with unique contributions of negative caregiving only (16% of the variance). Taken together with the 24-month null findings, we see a pattern of negative caregiving accounting for more unique variance in EF throughout early childhood.

To better understand this trend, we begin by considering the specific behaviors that were coded as mothers played games/puzzles with their children. Negative caregiving included behaviors that were high in intrusiveness and negative affect/physical stimulation and low in facilitating attention. This pattern of interaction during a relatively stress-free interaction (i.e. age-appropriate games that were not intended to elicit frustration) does not appear conducive to promoting child learning and autonomy. For instance, when mothers are intrusive, the interaction becomes focused on meeting the mother’s needs and goals as compared to facilitating the needs and goals of the child by providing appropriate attentive responses.

An examination of negative intrusive parenting behaviors revealed that the rate of growth in language development between 18 and 36 months was associated with the amount of negative caregiving behaviors (Pungello, Iruka, Dotterer, Mills-Koonce & Reznick, 2009). The authors concluded that such caregiving behaviors do not support autonomy and development of the child. Although we controlled for child verbal ability in the present study, we found a similar pattern of negative caregiving behaviors accounting for the growth in early childhood EF. It has been posited that because EF development exhibits a linear trend, small changes in early EF can shift the entire developmental trajectory (Moffitt, Arseneault, Belsky, Dickson, Hancox, Harrington & Caspi, 2011). This hypothesis was directed towards potential EF interventions, but the same concept can be applied to factors that potentially hinder early EF.

Bio-social mechanisms – both genetic as well as co-occurring socialization experience (environment) – are theorized to support optimal regulatory development (Rueda, Posner & Rothbart, 2004). There is evidence that EF is heritable (Friedman, Miyake, Young, DeFries, Corley & Hewitt, 2008; Jester et al., 2009; Polderman et al., 2006), and we cannot discount this potential genetic mechanism underlying maternal–child EF associations. Furthermore, the prefrontal cortex is critical to EFs, and it is the most likely candidate through which mechanisms associated with maternal EF and caregiving influence early childhood EF. The development of the prefrontal cortex is protracted, and there are many aspects of development (e.g. synaptogenesis, dendritic and axonal growth, myelination, glucose metabolism) that could potentially be influenced by bio-social mechanisms (Chugani, Phelps & Mazziotta, 1987; Deoni, Mercure, Blasi, Gasston, Thomson, Johnson, Williams & Murphy, 2011; Huttenlocher & Dabholkar, 1997; Tsekhmistrenko Vasil’eva, Shumeiko & Vologirov, 2004). Empirical evidence for parenting having an effect on children’s brain development has focused on rodents (Barrett & Fleming, 2011) or on maltreated children (Belsky & de Haan, 2011; Hughes, 2011).

One potential way in which maternal caregiving and EF could influence child EF is via stress reactivity. Stress hormone levels affect synaptic plasticity in PFC neurocircuitry (Mizoguchi, Ishige, Takeda, Abrurada & Tabira, 2004), which is critical for EF. Accordingly, there is evidence that stress hormone levels are related to EF during early childhood (Blair, Granger & Razza, 2005; Davis, Bruce & Gunnar, 2002). Using a predominately low-income sample, Blair and colleagues (Blair, Granger, Willoughby, Mills-Koonce, Cox, Greenberg, Kivlighan, Fortunato & FLP Investigators, 2011) found evidence that associations between caregiving behaviors and child EF at 36 months were mediated by stress hormone levels. Surprisingly, the mediated association was only found for positive caregiving behaviors (i.e. lower levels of stress hormones in children; higher 36-month EF). It is plausible that the link between negative caregiving behaviors and child EF in children not subjected to economic adversity (similar to the present sample) might be mediated by stress hormone levels. Clearly, additional research is necessary to understand how stress reactivity mediates associations between caregiving and child EF across a variety of familial contexts.

\(^3\) Although mediation was not present in our childhood EF composite, this finding is likely related to the lack of association between 24-month EF and negative caregiving behaviors (see previous paragraph).
From the perspective of the mother, stress physiology is also related to caregiving behaviors and maternal EF. An examination of maternal stress hormone levels and maternal vagal stress reactivity revealed that these measures were associated with negative intrusive caregiving behaviors, but not positive caregiving behaviors (Mills-Koonce, Propper, Gariepy, Barnett, Moore, Calkins & Cox, 2009). Other evidence, however, has found that maternal sensitivity is related to maternal stress hormone levels (Gonzales, Jenkins, Steiner & Fleming, 2012). Furthermore, this research revealed that the maternal stress hormone-caregiving link was mediated by maternal EF. Together, these findings suggest that stress reactivity in both mother and child could potentially underlie associations among maternal caregiving, maternal EF, and child EF.

Research focusing on the genetic underpinnings of EF has revealed that polymorphisms in multiple genes associated with the production and utilization of the neurotransmitter dopamine, which is associated with EF, are likely related to individual differences in early childhood EF (for reviews see Barnes, Dean, Nandam, O’Connell & Bellgrove, 2011; Bell & Deater-Deckard, 2007; Deater-Deckard & Wang, 2012). A potential mechanism for the influence of early life experiences on child EF would involve epigenetic changes, such as DNA methylation (for review see Szfy & Bick, 2013). In this way, genes in the central and peripheral nervous systems could be ‘activated’ and ‘inactivated’ by changes in methylation. In rodents, typical variations in maternal care have been associated with alterations in stress hormone receptors in the hippocampus as well as changes in DNA methylation of associated genes (for review, see Jensen Pena & Champagne, 2012); thus, providing a potential mechanism via which early life experience could have long-lasting effects on stress sensitivity, neurodevelopment, and behavior. Although we still have much to learn about epigenetics and its relation to EF, it is a potential mechanism that should not be overlooked. Will epigenetic changes related to EF only occur in genes associated with stress reactivity or will they also be found in genes associated with dopamine?

Although our sample varied in verbal ability and maternal education, our sample was predominately Caucasian and all mothers graduated from high school. A test of whether this effect is consistent across ethnic groups and across the full socioeconomic spectrum is essential in determining the generalization of our findings. Furthermore, maternal education is only a single component of socioeconomic status, and additional indicators (i.e. income, occupation) are essential to establishing a reliable indicator of socioeconomic status.

Consistent with classical applications of probability theory, we used one-tailed p-values because we had directional hypotheses for effects. Although it has become common for researchers to use two-tailed p-values when testing directional hypotheses, this practice nevertheless can inflate type-II error by reducing statistical power (e.g. Hays, 1988, pp. 276–277).

In sum, these data reveal that maternal EF and negative caregiving behaviors are uniquely associated with EF during early childhood, and suggest that associations with negative caregiving are increasingly manifested during early childhood. Importantly, these associations were present in the context of ‘typical’ parenting behaviors as compared to severe adverse environments. Our findings suggest that regardless of maternal EF and education, an environment that is low in negative caregiving behaviors will help promote optimal EF development.

Acknowledgements

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References


Polderman, T.J.C., Gosso, M.F., Posthuma, D., van Beesterveldt, T.C.E.M., Heutink, P., Verhulst, F.C., & Boomsma,


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