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Bidirectional Associations Between Parental Responsiveness and Executive Function During Early Childhood

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Abstract

In this study, we examined bidirectional associations between parental responsiveness and executive function (EF) processes in socioeconomically disadvantaged preschoolers. Participants were 534 3- to 5-year-old children (71 percent Hispanic/Latino; 28 percent African American; 1 percent European American) attending Head Start programs. At Time 1 (T1) and 6.5 months later at Time 2 (T2), parents and children participated in a videotaped free play session and children completed delay inhibition (gift delay-wrap, gift delay-bow) and conflict EF (bear/dragon, dimensional change card sort) tasks. Parental warm acceptance, contingent responsiveness, and verbal scaffolding were coded from the free play videos and aggregated to create a parental responsiveness latent variable. A cross-lagged panel structural equation model indicated that higher T1 parental responsiveness significantly predicted more positive gain in delay inhibition and conflict EF from T1 to T2. Higher T1 delay inhibition, but not T1 conflict EF, significantly predicted more positive change in parental responsiveness from T1 to T2. These associations were not explained by several possible confounding variables, including children's age, gender, race/ethnicity, and verbal ability. Findings suggest that parental responsiveness may support EF development in disadvantaged children, with reciprocal effects of delay inhibition on parental responsiveness.

Keywords: parenting; inhibitory control; working memory; early childhood; socioeconomic status

Introduction

Executive function (EF) refers to a set of cognitive processes that are dependent on the prefrontal cortex and support flexible, goal-directed behavior, such as inhibiting an automatic or dominant response, updating information in working memory, and

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flexibly shifting among attentional and behavioral responses (Kane & Engle, 2002). EF develops rapidly during early childhood (Garon, Bryson, & Smith, 2008; Rueda, Posner, & Rothbart, 2005) and thus may be particularly susceptible to environmental influences during early childhood. EF skills are crucial to the acquisition of early literacy and math competencies, which prepare children for academic success once they start school (Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Bull, Espy, & Wiebe, 2008; Clark, Pritchard, & Woodward, 2010; Welsh, Nix, Blair, Bierman, & Nelson, 2010). Early EF difficulties are linked with an increased risk of later emotional and behavioral problems (Espy, Sheffield, Wiebe, Clark, & Moehr, 2011; Kim, Nordling, Yoon, Boldt, & Kochanska, 2013).

During early childhood, parenting quality is thought to play an important role in shaping EF development (Kopp, 1982). In particular, parental responsiveness, which refers to sensitive and contingent responding to children's cues, is theorized to facilitate early EF development (Landry, Smith, & Swank, 2006). In line with theory, recent studies have indicated that higher parental responsiveness significantly predicts greater EF in young children (Fay-Stammbach, Hawes, & Meredith, 2014). However, there are several gaps in this emerging literature. For example, in addition to parental responsiveness shaping children's EF, children's EF may influence parental responsiveness. Although a number of studies have indicated bidirectional associations between parenting factors and young children's disruptive or externalizing behavior (e.g., Combs-Ronto, Olson, Lunkenheimer, & Sameroff, 2009), very few studies have examined bidirectional effects with regard to children's EF. As such, the goal of the current study was to examine bidirectional associations between parental responsiveness and EF processes in preschool children.

Executive Function Processes

Two EF dimensions that have been highlighted in the developmental literature are delay inhibition and conflict EF (Bernier, Carlson, & Whipple, 2010; Carlson, Mandell, & Williams, 2004). Delay inhibition (e.g., delay of gratification tasks) refers to the ability to inhibit a dominant response or control impulses when presented with the prospect of a reward. Conflict EF is the ability to inhibit a dominant response while executing a novel, conflicting response and holding information in working memory, typically not in the context of a reward (Carlson & Moses, 2001; Carlson, White, & Davis-Unger, 2014). Conflict EF tasks include Stroop-like inhibition tasks (e.g., day/night, bear/dragon) and attention shifting tasks [e.g., dimensional change card sort (DCCS)]. For example, in the bear/dragon task (Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996), children are asked to perform actions commanded by a bear puppet but to refrain from performing actions commanded by a dragon puppet. In the DCCS task (Zelazo, 2006), children first sort cards according to one rule (e.g., by shape) and then are asked to switch and sort them according to a conflicting rule (e.g., by color).

Studies of preschool-age children have yielded empirical support for separate delay inhibition and conflict EF dimensions (Bernier, Carlson, Deschênes, & Matte-Gagné, 2012; Bernier et al., 2010; Carlson & Moses, 2001; Carlson et al., 2004; Conway & Stifter, 2012; Matte-Gagné & Bernier, 2011). Similarly, findings for preschoolers have indicated distinct 'hot' (affectively salient) and 'cool' (affectively neutral) EF dimensions (Brock et al., 2009; Kim et al., 2013; Mulder, Hoofs, Verhagen, van der Veen, & Leseman, 2014; Willoughby, Kupersmidt, Voegler-Lee, & Bryant, 2011; Zelazo & Carlson, 2012), although not all results have been consistent (e.g., Allan & Lonigan, 2011). Delay inhibition and conflict EF also differ in their developmental course, predictors, and associations with social-emotional and academic outcomes (Allan, Hume, Allan, Farrington, & Lonigan, 2014; Brock et al., 2009; Carlson, 2005; Kim et al., 2013; Lengua et al., 2014; Li-Grining, 2007; Mulder et al., 2014). For instance, preschoolers' delay inhibition but not conflict EF accounted for unique variance in later internalizing and externalizing problems (Kim et al., 2013), whereas conflict EF but not delay inhibition made unique contributions to growth in emergent literacy and mathematics (Allan et al., 2014; Brock et al., 2009; Mulder et al., 2014; Willoughby et al., 2011).

Parental Responsiveness Predicting Children's Executive Function

Young children are thought to internalize EF skills through interactions with their parents, who initially act as sources of external regulation (Kopp, 1982). In particular, parental responsiveness is theorized to predict individual differences in early EF development. As conceptualized across theoretical frameworks, including attachment theory, parental responsiveness includes warm acceptance of the child's needs and interests, sensitive and contingent responses to child signals (Ainsworth, Blehar, Waters, & Wall, 1978), and rich language input attuned to the child's developmental needs (Landry et al., 2006; Vygotsky, 1978). Parental responsiveness is theorized to facilitate emotional security and adaptive stress regulation, which encourages exploration of the environment and engagement in problem-solving activities (Ainsworth et al., 1978; Bernier et al., 2012; Bowlby, 1982; Landry et al., 2006). Parental responsiveness may also ensure that the child gets to play an active role in activities by providing opportunities for the child to take the lead and make choices (Grolnick & Ryan, 1989). At a neurobiological level, parental responsiveness has been found to promote the regulation of stress physiology (Hostinar, Sullivan, & Gunnar, 2014) which in turn is linked with EF development (Blair, 2010; Blair et al., 2011).

Consistent with these theories, recent studies have found that parental responsiveness significantly predicts delay inhibition and conflict EF during early childhood (Bernier et al., 2010; Blair, Raver, Berry, & the Family Life Project Investigators, 2014; Fay-Stammbach et al., 2014; Hackman, Gallop, Evans, & Farah, 2015; Lengua, Honorado, & Bush, 2007; Mileva-Seitz et al., 2015; Razza & Raymond, 2013). For example, parental sensitivity across the first three years was found to predict delay inhibition at 54 months (Razza & Raymond, 2013). In another study, parental sensitivity to infants at ages 12–13 months was found to predict conflict EF, but not delay inhibition, at 26 months (Bernier et al., 2010). However, not all studies have examined these EF dimensions separately or even included delay inhibition as an outcome. In addition, although some studies have controlled for children's verbal ability, which is often correlated with EF (Bernier et al., 2010; Razza & Raymond, 2013), others have not (e.g., Mileva-Seitz et al., 2015). Also, these studies have tended to focus on children from middle- to high-socioeconomic-status (SES) families (e.g., Bernier et al., 2010; Hughes & Ensor, 2009), with some exceptions (Blair et al., 2014). It is important to understand whether these associations generalize to low-SES children, who are at higher risk of negative academic and mental health outcomes (Hackman et al., 2015).

Children's Executive Function Predicting Parenting Quality

According to transactional models, rather than a unidirectional effect of parenting on EF development, there may be reciprocal associations between children's EF and parenting behaviors that contribute to EF development over time (Bell, 1968; Belsky, 1984; Sameroff, 2009; Shaw & Bell, 1993). Empirically, a number of studies have demonstrated changes in parenting quality over time as a function of preschool children's disruptive or externalizing behavior (e.g., Combs-Ronto et al., 2009; Larsson, Viding, Rijsdik, & Plomin, 2008; Smith, Calkins, Keane, Anastopoulos, & Shelton, 2004). Yet, only a few previous studies have investigated bidirectional influences between parenting quality and preschool children's EF. In one study, children's EF skills at 36 months predicted change in parental responsiveness from 36 to 60 months (Blair et al., 2014). In addition, some evidence suggests that self-regulatory constructs similar to EF (e.g., effortful control) may influence parenting quality (Eisenberg et al., 2010; Kiff, Lengua, & Zalewski, 2011; Yates, Obradovic, & Egeland, 2010). For example, lower effortful control at 30 months predicted higher maternal directive teaching strategies a year later (Eisenberg et al., 2010).

Preschool children's delay inhibition and conflict EF may differ in their prediction of parental responsiveness, with delay inhibition a potentially stronger predictor of parental responsiveness. Delay inhibition captures children's inhibitory control in motivationally or emotionally significant contexts similar to the context of parent-child social interactions, whereas conflict EF reflects EF in emotionally-neutral or decontextualized settings. Thus, children high in delay inhibition who are able to overcome temptations and withhold impulsive behavior may elicit higher parental warmth and sensitivity, whereas those exhibiting lower delay inhibition skills potentially elicit more parental stress and controlling behavior. To test this possibility, research is needed that examines the unique contributions of children's delay inhibition and conflict EF to changes in parental responsiveness over time.

Current Study

In the current study, we examined bidirectional associations between parental responsiveness and EF processes in socioeconomically disadvantaged preschoolers. Participants were 3- to 5-year-old children attending Head Start programs (N = 534). Preschoolers were the focus of this study because considerable evidence indicates that EF can be reliably assessed at preschool-age (Carlson, 2005). At Time 1 (T1) and 6.5 months later at Time 2 (T2), parents and children participated in videotaped free play sessions, and children completed delay inhibition and conflict EF tasks. Parental warm acceptance, contingent responsiveness, and verbal scaffolding were coded from the videotaped parent-child interactions and aggregated to form a parental responsiveness latent variable. In a cross-lagged panel structural equation model (SEM), we examined whether T1 parental responsiveness, delay inhibition, and conflict EF predicted T2 parental responsiveness, delay inhibition, and conflict EF.

We hypothesized that parental responsiveness would predict both delay inhibition and conflict EF, even after controlling for prior levels of these EF processes and simultaneously examining the effects of these EF processes on parental responsiveness. We also examined the unique contributions of delay inhibition and conflict EF to change in parental responsiveness over time, exploring whether delay inhibition may be a stronger predictor of parental responsiveness compared with conflict EF. Analyses controlled for a comprehensive set of potentially confounding variables, including children's age, gender, race/ethnicity, and verbal ability as well as maternal education.

Method

Participants

Recruitment. Participants in the current study were recruited for a study conducted in Houston and Austin, Texas examining the effects of classroom- and home-based interventions on low-SES children's development (Landry et al., 2016). Three cohorts (corresponding to three academic years) of Head Start programs were recruited, and one classroom per center was eligible to participate in each cohort. After teachers signed informed consents, parents of all children in the classrooms were invited to participate and signed informed consents. Six to eight children per classroom were then randomly selected for participation. Classrooms were randomly assigned to receive or not receive The Early Education Model (TEEM; Landry, Swank, Anthony, & Assel, 2011) intervention, which provides teacher training in the use of a responsive style and effective instructional practices, and children were randomly assigned to receive or not receive a responsive parenting intervention called Play and Learning Strategies (PALS; Landry, Smith, Swank, & Guttentag, 2008). Results of the intervention impact study (Landry et al., 2016) indicated that parents who received PALS demonstrated increased responsiveness compared with control parents, and children whose parents received PALS outperformed control children in terms of print knowledge, delay inhibition (gift delay-wrap task), and observed language and social skills. In addition, teachers who received TEEM showed improved instructional practices and responsiveness compared with control teachers. Thus, intervention status (whether or not the parent received PALS) was included as a covariate in analyses.

Sample Characteristics. There were 534 3- to 5-year-old children (50 percent female) who completed one or more of the EF tasks at T1. These children were enrolled in 77 Head Start classrooms located in Houston (79 percent) and Austin, Texas (21 percent). The majority of the children were Hispanic/Latino (71 percent); 28 percent were African American and 1 percent were European American. They were from low-income families, as indicated by their eligibility for Head Start, but specific information about household income was not available. Parents reported having low levels of educational attainment (see Table 1).

Attrition. Out of the 534 children who participated at T1, 381 children participated at T2. This level of attrition was primarily due to children leaving the Head Start center, possibly due to the high risk status of the families in this study (Evans, Kim, Ting, Tesher, & Shannis, 2007). Children who did not participate at T2 did not differ significantly from those who remained in the study in terms of T1 parental responsiveness, T1 delay inhibition, T1 conflict EF, maternal education, age, gender, or race/ethnicity. To further ensure that attrition did not bias the results, we used FIML estimation in analyses.

Procedure

At T1 (September–October) and approximately 6.5 months later at T2 (April-May), parents and children participated in videotaped free play sessions, and children completed assessments of delay inhibition (gift delay-wrap, gift delay-bow), conflict EF (bear/dragon, DCCS), and verbal ability [Expressive One-Word Picture Vocabulary

Table 1. Sample Characteristics (N = 534)

	M **(*****SD*****) or percent**
Child age at Time 1 (years)	4.46 (.52)
Child male	49.91
Child race/ethnicity	
African American	28.02
Hispanic/Latino	70.83
European American	1.15
First main caregiver's relation to child	
Mother	95.31
Father	1.01
Grandmother	3.14
Other	.54
First main caregiver's education	
Less than high school	34.45
High school degree	33.25
Some college	21.77
Associate's degree	3.59
Bachelor's degree	5.50
Some graduate school or master's degree	1.44
Eligible for free/reduced lunch	99.04
Language spoken at home	
English	45.99
Spanish	37.60
Both English and Spanish	16.41

Test (EOWPVT); included as a covariate]. Parent-child free play sessions and child EF assessments were conducted in English or Spanish, depending on which language was preferred by the participant. During the free play session, parents and children were presented with a standard set of toys and asked to play as they normally would for 10 minutes. Videotapes of the parent-child interactions and the gift delay-wrap, gift delay-bow, and bear/dragon tasks were coded in the lab; the DCCS and the EOWPVT were scored by the examiner. To assess interrater reliability, 15–20 percent of the videotapes were double-coded and intraclass correlations (ICCs) were calculated.

Measures

Parental Responsiveness. Parental responsiveness was coded from the parent-child free play videos using scales developed by the second author and used extensively in previous research (e.g., Landry et al., 2008). Global ratings of warm acceptance, contingent responsiveness, and verbal scaffolding were made using 5-point scales ranging from 1 (*almost never*) to 5 (*almost always*). The warm acceptance scale (T1 ICC = .77; T2 ICC = .81) measured the degree to which the parent praised and encouraged the child, expressed physical affection toward the child, and exhibited acceptance of the child's needs and interests. The contingent responsiveness scale

(T1 ICC = .65; T2 ICC = .72) assessed the extent to which the parent responded promptly, sensitively, and contingently to the child's cues, followed the child's lead and pacing, and engaged flexibly with the child's play interests. The verbal scaffolding scale (T1 ICC = .71; T2 ICC = .78) measured the extent to which the parent provided rich language input attuned to the child's developmental needs (e.g., labeling objects and actions, talk about conceptual connections between objects). Ratings on these three scales, which were correlated significantly at T1 and T2, were used as indicators comprising the latent factor for parental responsiveness at T1 and T2.

Delay Inhibition. In the gift delay-wrap task (Kochanska, Murray, & Harlan, 2000; Li-Grining, 2007), children were told that they would be receiving a present but that they could not peek while the present was being wrapped. Children were then instructed to turn their backs to the examiner as the examiner noisily wrapped the present for 60 seconds. Strategy scores (1 = leaves seat to peek, 2 = turns body in seat to peek, 3 = peeks over shoulder, 4 = does not peek) given for every 15 seconds of the task were averaged to create a total strategy score for the task. Scores for strategy and latency to peek (in seconds), which were strongly correlated ($r = .76$ at T1; $r = .78$ at T2), were standardized and averaged to create a gift delay-wrap total score (interrater reliability: ICC = .94).

In the gift delay-bow task (Kochanska et al., 2000), the wrapped gift was placed on the table in front of the child and the child was told to wait in his/her chair and not to touch or open the gift until the examiner returned with a bow. The delay lasted two minutes. Strategy scores (1 = removes toy from box or touches toy in box, 2 = lifts the lid of the box ≥ 3 inches or takes lid off, 3 = lifts the lid of the box ≤ 2 inches, 4 = touches the box but does not open it, 5 = does not touch the box) given for every 15 seconds of the task were averaged to create a total strategy score for the task. Scores for strategy and latency to touch (in seconds), which were strongly correlated ($r = .62$ at T1; $r = .63$ at T2), were standardized and averaged to create a gift delay-bow total score (interrater reliability: ICC = .99). Gift delay-wrap and gift delay-bow task total scores were significantly correlated at T1 ($r = .39$, $p < .001$) and T2 ($r = .41$, $p < .001$).

Conflict EF. In the bear/dragon task (Carlson, 2005; Garon et al., 2008; Kochanska et al., 1996), children were told to follow the 'nice' bear puppet's commands (e.g., touch your nose) but not the 'mean' dragon puppet's commands. After practicing, there were 12 test trials (two sets of 6 trials, with a reminder of the rules in the middle) with the bear and dragon commands alternating in pseudo-random order. Trial scores ranging from 0 to 2 (0 = no movement, 1 = partial movement, 2 = full movement) were summed for the bear and the dragon separately. Performance on dragon trials (reverse-scored so higher is better) served as an index of conflict EF (interrater reliability: ICC = .99). Internal consistency reliability (Cronbach's α) for the dragon trials was .97 at T1 and .96 at T2.

In the DCCS task (Zelazo, 2006), children were seated at a table facing two boxes, one with a picture of a red rabbit on it and the other with a picture of a blue boat on it. Children were then presented with a series of sorting cards (red and blue rabbits and boats). During the pre-switch phase, they were instructed to sort the cards by shape. There were 10 pre-switch trials, and children were required to get five consecutive trials correct to continue to the post-switch phase. In the post-switch phase (five total trials), children were asked to sort the cards by color. The examiner reminded the child of the sorting rule before each trial. The total number of correct post-switch trials served as the outcome measure. This task is reported to have high interrater reliability, to be sensitive to age, and to be moderately correlated with other established EF measures (Carlson, 2005). Bear/dragon and DCCS task scores were significantly correlated at T1 ($r = .33$, $p < .001$) and T2 ($r = .42$, $p < .001$).

Reduction of EF Data. At T1, principal components analysis (PCA) with promax rotation yielded two factors with eigenvalues > 1, and they accounted for 69 percent of the total variance. Gift delay-wrap (.67) and gift delay-bow (.90) loaded on the delay inhibition factor, and bear/dragon (.69) and DCCS (.89) loaded on the conflict EF factor. No cross-loadings (>.35) were observed, and the correlation between the two factors was .26 ($p < .001$).

Similarly, at T2, PCA yielded two factors with eigenvalues > 1, and they accounted for 71 percent of the total variance. Gift delay-wrap (.81) and gift delay-bow (.87) loaded on the delay inhibition factor, and bear/dragon (.83) and DCCS (.86) loaded on the conflict EF factor. No cross-loadings were observed, and the correlation between the two factors was .19 ($p < .001$). Accordingly, scores on the gift delay-wrap and gift delay-bow tasks were standardized and averaged to compute a delay inhibition composite. Scores on the bear/dragon and DCCS tasks were standardized and averaged to compute a conflict EF composite.

Verbal Ability. In the Expressive One-Word Picture Vocabulary Test (EOWPVT; Brownell, 2000), examinees are presented with a series of illustrations depicting an object, action, or concept and asked to name each illustration (e.g., *What's this?*). Testing stopped when children made six consecutive errors. In the current sample, internal consistency (Cronbach's α) of the EOWPVT was .97 at T1. Given that some children also completed the EOWPVT-Spanish Bilingual Edition (EOWPVT-SBE; Brownell, 2001), separate analyses were run controlling for EOWPVT scores and controlling for EOWPVT-SBE scores. Because results were the same, we report results of analyses that controlled for EOWPVT scores.

Data Analytic Plan

Main analyses were conducted in Mplus (version 7; Muthén & Muthén, 1998–2012) using full information maximum likelihood (FIML) to account for missing data. Measurement models were estimated to examine whether the observed parental responsiveness indicators loaded on the parental responsiveness latent factor and to evaluate factorial invariance over time. Evidence of factorial invariance is necessary for longitudinal comparisons to rule out the possibility that changes are due to a change in the construct over time. To test factorial invariance, we used a series of nested confirmatory factor analysis (CFA) models (Widaman, Ferrer, & Conger, 2010) with criteria for the equivalent fit of nested models being that the decrease in the comparative fit index (CFI) was ≤ .01 and the increase in the root-mean-square error of approximation (RMSEA) was ≤ .015 (Chen, 2007; Cheung & Rensvold, 2002).

A cross-lagged SEM was used to examine bidirectional associations among parental responsiveness, delay inhibition, and conflict EF. This model included autoregressive paths of the variables across time, concurrent covariances between the variables, and cross-lagged regression paths from T1 parental responsiveness to T2 EF skills and from T1 EF skills to T2 parental responsiveness. Models were evaluated for overall fit using the chi-square goodness-of-fit test, RMSEA, CFI, and standardized root mean squared residual (SRMR). Adequate model fit is traditionally indicated by a non-significant chi-square; however, with larger samples, it is possible to get significant chi-squares even for models that fit the data well. An RMSEA $\leq .06$, a CFI $\geq .95$, and an SRMR $< .08$ indicated good model fit (Brown, 2006; Hu & Bentler, 1999).

Multilevel modeling was used to account for the nesting of children within classrooms (Raudenbush & Bryk, 2002). Specifically, there was an average of 5.6 ($SD = 1.31$, range = 2–8) children per classroom. Intraclass correlations (ICCs) indicated that 17 percent ($p = .002$) of the total variability in T2 conflict EF was attributable to differences between classrooms. ICCs were .01 (ns) and .03 (ns) for T2 delay inhibition and T2 parental responsiveness, respectively. At T1, ICCs were .07 ($p = .04$), .14 ($p = .002$), and .16 ($p < .0001$) for parental responsiveness, delay inhibition, and conflict EF, respectively. Inspection of the distributional qualities of the variables used in the main analyses indicated that they did not deviate from normality (e.g., skew ranged from −1.14 to .48; kurtosis ranged from −1.32 to .76).

Results

Age, gender, and maternal education showed multiple significant correlations with the parental responsiveness and EF variables, but race/ethnicity did not. Children's T1 verbal ability was significantly associated with T1 parental responsiveness, T1 delay inhibition, and T1 and T2 conflict EF ($r = .12$–$.35$, $p < .05$–$.001$) but not significantly associated with T2 parental responsiveness or T2 delay inhibition ($r = .04$–$.09$, ns). Thus, age, gender, maternal education, T1 verbal ability, site, cohort, and parenting intervention status were included as covariates in the main analyses.

Descriptive Statistics

As shown in Table 2, parents displayed moderate levels of warm acceptance, contingent responsiveness, and verbal scaffolding, and the full range of the rating scales was observed. As shown in Table 3, there were significant correlations across time points for parental responsiveness, delay inhibition, and conflict EF. There was a small but significant decrease in parental responsiveness from T1 to T2, paired $t(336) = -2.29$, $p < .05$. There were significant increases in delay inhibition, paired $t(334) = 5.39$, $p < .001$, and conflict EF, paired $t(379) = 12.55$, $p < .001$, from T1 to T2. Delay inhibition and conflict EF were significantly correlated at T1 and T2.

Parental Responsiveness Confirmatory Factor Analyses and Factorial Invariance

The parental responsiveness latent factor model fit the data well at both T1, $\chi^2(3) = 4.52$, ns, RMSEA = .03, CFI = 1.00, SRMR = .02, and T2, $\chi^2(3) = 1.38$, ns, RMSEA = .00, CFI = 1.00, SRMR = .01. Factor loadings for the parental responsiveness factor for warm acceptance, contingent responsiveness, and verbal scaffolding were .99, .66, and .51, respectively, at T1 and .96, .80, and .65, respectively, at T2.

Table 2. Descriptive Statistics for Parental Responsiveness and EF Variables

	Time 1			Time 2		
Scale/task	*M*	*SD*	Range	*M*	*SD*	Range
Parental warm acceptance	3.62	.96	1–5	3.51	1.02	1–5
Parental contingent responsiveness	3.37	.96	1–5	3.39	1.00	1–5
Parental verbal scaffolding	3.16	1.03	1–5	2.92	1.08	1–5
Gift delay-wrap						
Latency	32.94	25.63	0–60	44.47	22.32	0–60
Strategy	3.47	.67	1–4	3.75	.44	1.5–4
Gift delay-bow						
Latency	73.73	49.40	0–120	78.85	49.48	0–120
Strategy	4.59	.79	1–5	4.69	.61	1–5
Bear/dragon	6.89	5.45	1–13	9.58	4.91	1–13
DCCS	2.94	1.31	0–5	3.59	1.41	1–5

Note: DCCS = dimensional change card sort. Bear/dragon scores were reverse-scored, so higher is better for all EF tasks.

We then examined factorial invariance to assess whether the contribution of individual rating scales to the underlying parental responsiveness latent factor changed across time. Analyses supported configural invariance (the same pattern of fixed and free factor loadings across time), $\chi^2(20) = 12.68$, ns, RMSEA = .00, CFI = 1.00, SRMR = .03, weak factorial invariance (i.e., metric invariance; factor loadings were invariant across time), χ^2 (22) = 16.88, ns, RMSEA = .00, CFI = 1.00, SRMR = .04, and strong factorial invariance (i.e., scalar or intercept invariance; factor loadings and intercepts were invariant across time), $\chi^2(25) = 36.16$, $p < .10$, RMSEA = .03, CFI = .99, SRMR = .04, based on the small amount of change in CFI across models (Chen, 2007).

Bidirectional Associations between Parental Responsiveness and Children's EF

Results indicated that the SEM fit the data well, $\chi^2(91) = 139.30$, $p < .001$, RMSEA = .03, CFI = .97, SRMR = .05. As shown in Figure 1, higher T1 parental responsiveness significantly predicted greater gains in both delay inhibition and conflict EF from T1 to T2. In addition, T1 delay inhibition significantly predicted change in parental responsiveness from T1 to T2, but T1 conflict EF did not.

Covariates. Gender significantly predicted T2 delay inhibition, such that girls outperformed boys, $\beta = .15$, $p < .01$. Also, parents who received PALS had higher T2 parental responsiveness than those in the control group, $\beta = .36$, $p < .001$ (as reported in Landry et al., 2016). Higher T1 verbal ability significantly predicted higher T2 conflict EF, $\beta = .12$, $p < .05$, and older children had higher T2 conflict EF than younger children, $\beta = .19$, $p < .01$.

Supplemental Analysis. We re-ran this SEM in a sample restricted to children whose parents did not receive the parenting intervention (n = 260). Results indicated that

Table 3. Zero-Order Correlations Between Demographic, Parental Responsiveness, and EF Variables

	Demographics				T1 variables					T2 variables				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Age	–													
2. Gender	.01	–												
3. Race/ethnicity	−.03	−.06	–											
4. Maternal education	.04	−.06	.35***	–										
5. T1 parental warm acceptance	−.06	.01	−.01	.05	–									
6. T1 parental contingent responsiveness	−.02	.02	.02	.14**	.65***	–								
7. T1 parental verbal scaffolding	−.05	−.06	.08	.11*	.50***	.34***	–							
8. T1 delay inhibition	.27***	.19***	−.09	−.01	.02	.03	−.02	–						
9. T1 conflict EF	.47***	.05	.05	.12*	.03	.10*	.05	.31***	–					
10. T2 parental warm acceptance	−.07	.07	−.05	.02	.26***	.15**	.22***	.07	−.06	–				
11. T2 parental contingent responsiveness	−.06	.08	−.05	.01	.21***	.15**	.16**	.11	−.03	.77***	–			
12. T2 parental verbal scaffolding	−.06	-.05	.04	.11*	.19***	.10	.34***	.08	−.04	.62***	.52***	–		
13. T2 delay inhibition	.04	.26***	−.02	−.01	.09	.06	.06	.43***	.11*	.11*	.10	.06	–	
14. T2 conflict EF	.51***	.15**	−.02	.09	.08	.09	.13*	.33***	.59***	.02	.03	−.01	.19***	–

Note: EF = executive function; T1 = Time 1; T2 = Time 2. Gender, 0 = male, 1 = female; Race/ethnicity, 0 = Hispanic/Latino, 1 = African American. In analyses of racial/ethnic differences including European American children, there were also no significant group differences for parental responsiveness or children's EF.

*$p < .05$, **$p < .01$, ***$p < .001$.

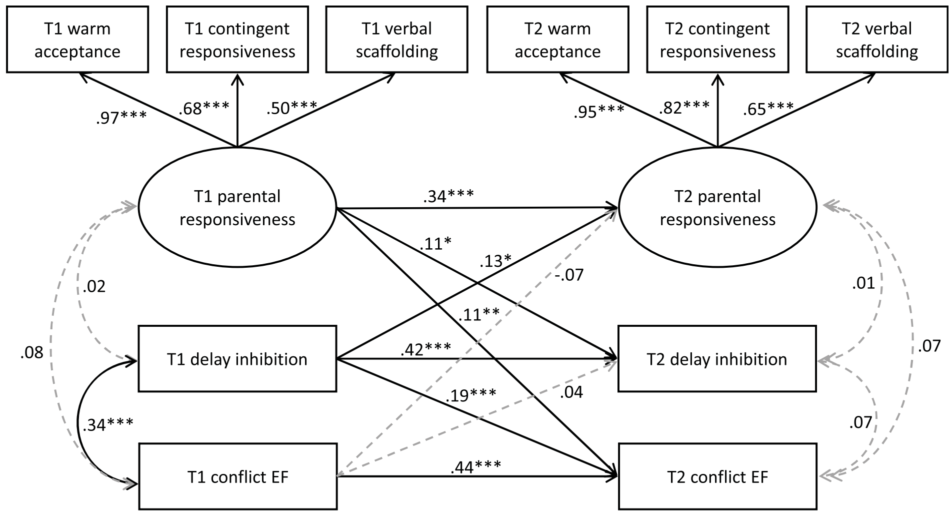

Figure 1. Longitudinal Associations Among Parental Responsiveness, Delay Inhibition, and Conflict EF. Estimates are Standardized Regression Coefficients. Bold Lines Represent Significant Paths and Dashed Lines Represent Non-Significant Paths.
T1, Time 1; T2, Time 2; EF, executive function
* $p < .05$, ** $p < .01$, *** $p < .001$

the model fit the data well, $\chi^2(78) = 106.74$, $p < .05$, RMSEA = .04, CFI = .97, SRMR = .05. Higher parental responsiveness significantly predicted greater gains in both delay inhibition ($\beta = .17$, $p < .05$) and conflict EF ($\beta = .13$, $p < .05$) over time. However, delay inhibition no longer significantly predicted change in parental responsiveness over time ($\beta = .06$, ns).

Discussion

The goal of this study was to examine bidirectional associations between parental responsiveness and EF in low-SES preschoolers. Delay inhibition and conflict EF are two distinct EF dimensions that play essential roles in shaping children's academic and social-emotional outcomes (Welsh et al., 2010; Zelazo & Carlson, 2012). Results indicated that higher parental responsiveness predicted more positive change in both delay inhibition and conflict EF over time, independent of a comprehensive set of potentially confounding variables (e.g., age, gender, race/ethnicity, maternal education, verbal ability). Specifically, preschoolers who experienced more responsive interactions with their parents had higher delay inhibition and conflict EF 6.5 months later. Interestingly, these results were found despite the relatively weak zero-order correlations between parental responsiveness indicators and EF task scores (see Table 3), suggesting that adjusting for the covariates allowed stronger associations between parental responsiveness and EF to emerge. These results align with findings from prior studies (Bernier et al., 2010; Lengua et al., 2007) and suggest that parental responsiveness may promote the development of both delay inhibition and conflict EF in low-SES preschoolers. High levels of parental responsiveness may maintain the child's secure attachment to the parent (Ainsworth et al.,

1978) and ensure that the child has opportunities to make choices and take the lead, which promote autonomy and a sense of volition (Grolnick & Ryan, 1989). At a neurobiological level, parental responsiveness may provide external regulation of the child's physiological stress-response systems, which in turn supports EF development (Blair, 2010).

It is important to note that effect sizes for the pathways from parental responsiveness to children's EF skills were relatively small. Parental responsiveness is likely one of many factors that contribute to preschoolers' EF development, with other factors including genetic background, prenatal care, nutrition, other aspects of parenting quality and the home environment, as well as preschool and neighborhood quality (e.g., Baptista et al., 2016; Cuevas et al., 2014). It is also possible that parental responsiveness measured when children were younger would have played a larger role in shaping preschoolers' EF development. Parental responsiveness may be especially crucial during infancy and toddlerhood when children are particularly dependent on their parents.

Reciprocal associations of children's EF predicting parental responsiveness were also found. In particular, higher delay inhibition predicted increases in parental responsiveness over time, whereas conflict EF did not significantly relate to later parental responsiveness. This finding is consistent with prior studies indicating that these EF dimensions often differentially predict developmental outcomes (Brock et al., 2009; Kim et al., 2013; Li-Grining, 2007). Children's performance on delay inhibition tasks reflects their impulse control or ability to withhold automatic responses in the context of a reward. Thus, lower delay inhibition may elicit lower parental warmth and higher controlling or intrusive behavior (e.g., more directives), whereas higher delay inhibition may elicit higher parental warmth and lower controlling behavior (e.g., more autonomy granting). Taken together, these findings suggest that there may be reciprocal influences of parental responsiveness and preschoolers' delay inhibition on each other over time, consistent with transactional models of development (Bell, 1968).

In contrast to delay inhibition tasks, conflict EF tasks have limited emotional or motivational significance and thus require a more abstract or decontextualized form of self-regulation. Consequently, conflict EF may be less reflective of preschoolers' EF capacities in social-emotional contexts, such as interactions with their parents. The differential associations of delay inhibition and conflict EF with parental responsiveness could also be due to other differences between the two EF dimensions, such as the higher working memory demands of conflict EF tasks compared with delay inhibition tasks.

On the whole, there were some signs that the path from children's EF to parental responsiveness was weaker relative to the reverse direction of associations. As mentioned, only delay inhibition predicted parental responsiveness, and this effect was relatively small in size. Given that the children in our sample varied by intervention status (Landry et al., 2016), we controlled for parenting intervention status in our analyses, which is similar to the approach taken in multiple prior studies (e.g., Trentacosta et al., 2008; Waller et al., 2012). We also re-ran our main model among children whose parents did not receive PALS, which indicated that parental responsiveness significantly predicted both delay inhibition and conflict EF, but delay inhibition no longer significantly predicted parental responsiveness. Although these additional findings were hindered by a smaller sample size, they support the pathway from parental responsiveness to children's EF development over time and are consistent with the idea that reciprocal effects of children's EF on parental responsiveness may be relatively weaker, at least at preschool-age.

These results suggest that perhaps parental responsiveness contributes more to shaping preschoolers' EF than preschoolers' EF does to shaping parental responsiveness. Indeed, there are certainly other factors that may have a larger influence on the level of responsiveness demonstrated by the parent; for instance, environmental stressors, parenting beliefs, and parental mental health have all been found to influence parenting style (Bornstein, Hahn, & Haynes, 2010; Smith, 2010). The weak pathways from children's EF to parental responsiveness could also be due in part to the coding of parental responsiveness in a free play context. It is possible that observations made in another context, such as a problem-solving or teaching activity, may have yielded a more sensitive measure of parental responsiveness.

Findings from this study suggest that interventions that target parental responsiveness may promote EF development among low-SES preschoolers. Recent studies, including findings from the current sample (Landry et al., 2016), have found positive effects of responsiveness-focused interventions on delay inhibition development in young children. For example, in one study, improving caregiver responsiveness in family child care homes was associated with gains in delay inhibition but not conflict EF for the youngest preschoolers in the sample (Merz, Landry, Johnson, Williams, & Jung, 2016). Findings from these initial investigations suggest that there may be benefits of enhancing caregiver responsiveness in children's early environments for delay inhibition development. More research is needed to inform the design of effective interventions and understand which children benefit the most from them. Effective parenting interventions that include responsiveness training could also be added as supplements to interventions implemented in Head Start classrooms that have been found to improve children's EF (e.g., Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008; Raver et al., 2011). This approach would provide comprehensive support for EF development across both the home and preschool environments.

This study had a number of strengths including a large sample size and a longitudinal design. Parental responsiveness was measured through direct observations of multiple responsive behaviors and modeled as a latent factor. Rigorous statistical methods were used with a comprehensive set of covariates, including verbal ability. EF tasks used in this study demonstrated strong reliability and validity both in the current study and in previous research (Carlson, 2005). The use of multiple methods of assessment (e.g., direct observations, structured tasks) precluded the possibility of shared method variance inflating associations between parenting and EF.

There were also several limitations of this study that should be taken into account when interpreting the findings. The focus of this study on a low-SES sample may limit the generalizability of the findings to higher-SES populations. Given that this study had only two time points, future studies should assess parenting and EF across three or more time points to analyze more complex patterns of bidirectional change across time. In addition, we only had two tasks per EF dimension, whereas the use of more measures would have facilitated modeling delay inhibition and conflict EF as latent constructs.

Findings from this study indicated bidirectional associations between parental responsiveness and EF processes in low-SES preschoolers. Specifically, higher parental responsiveness predicted greater gains in both delay inhibition and conflict EF over time. In addition, higher delay inhibition, but not conflict EF, predicted increases in parental responsiveness over time. These findings suggest that responsive parenting interventions may be an effective means of improving EF development in low-SES preschoolers.

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