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Using data from a large longitudinal sample (N = 1,292) of children and their caregivers in predominantly low-income, nonurban communities, we investigated longitudinal relations between attuned caregiving in infancy, joint attention in toddlerhood, and executive functions in early childhood. The results from path analysis demonstrated that attuned caregiving during infancy predicted more joint attention in toddlerhood, which was in turn associated with better executive function performance in early childhood. Joint attention was a stronger predictor of executive functions for lower-income families. Moreover, joint attention mediated the relation between attuned caregiving and executive functions, and this mediation was amplified for lower-income families. These results highlight joint attention as a key mechanism through which attuned caregiving supports the development of executive functions, particularly for low-income families.

Keywords: joint attention, attuned caregiving, executive function, poverty

Human development in infancy is strongly dependent on social context. Interpersonal coordination between infants and their caregivers creates a shared social environment, marked by dynamic, reciprocal affective and behavioral exchanges, through which the infant develops (Bolis & Schilbach, 2018; Feldman, 2007; Fogel, 1993; Vygotsky, 1975). Evidence for the social origins of cognitive development is documented in research suggesting that sensitive caregiving behaviors practiced during infant–caregiver interactions facilitate cognitive development (for a review, see Hughes & Ensor, 2009). Caregiving is typically studied using broad, global ratings of parenting behaviors; however, little is known about the specific mechanisms within infant–caregiver interactions that may be driving cognitive development. In particular, attuned caregiving, defined here as sensitive and temporally contingent responsive caregiving behaviors, is an important component of the caregiver–infant interaction. Attuned caregiver interactions in infancy are thought to set the foundation for more advanced social exchanges, such as the development of joint attention in the toddler period (Legerstee, Markova, & Fisher, 2007). Here we define and conceptualize joint attention on the dyadic level during the interactions themselves. In joint attention interactions, dyads engage in bouts of coordinated gaze during which caregivers and infants guide each other's attention to stimuli in the environment (Bakeman & Adamson, 1984; Scaife & Bruner, 1975; Seibert, Hogan, & Mundy, 1982). It has recently been proposed that through these shared experiences, joint attention may function as a cognitive scaffolding mechanism, allowing parents to train the essential "building blocks" of higher-order cognitive development, such as executive functions (EFs; Hughes & Devine, 2019; Wass, Clackson, et al., 2018; Yu & Smith, 2016). However, research has yet to examine how the effects of joint attention may function differently depending on environmental factors, such as socioeconomic risk. Thus, longitudinal investigations of the links between caregiver attunement, joint attention interactions in socioeconomically diverse contexts, and higher-order cognitive outcomes are warranted to understand the various social factors that contribute to individual differences and disparities in EF development.

It is well established that various aspects of sensitive parenting behavior longitudinally predict EF development (Bernier, Carlson, & Whipple, 2010; Blair et al., 2011; Fay-Stammbach, Hawes, & Meredith, 2014; Lugo-Gil & Tamis-LeMonda, 2008; Rhoades, Greenberg, Lanza, & Blair, 2011). In particular, attuned caregiving, a sensitive parenting behavior that includes appropriate contingency, responsivity, and matching based on the child's developmental and affective needs, is especially important for cognitive development (Feldman, 2007). Through attuned interactions, caregivers flexibly respond to and regulate their children's behavioral and cognitive cues (Landry & Smith, 2010). This reciprocal "serve and return" of bids and contingent responses offers children the opportunity to test and develop their self-regulatory capacities in a safe environment (Bernier, Carlson, Deschênes, & Matte-Gagné, 2012). Further, attuned interactions provide the foundation for an affiliative parent–child relationship, creating an environment that is conducive to cognitive development (Bornstein & Tamis-LeMonda, 1997). However, attuned caregiving is a broad and

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global construct, yet little research has been devoted to studying the operating dyadic processes that develop from attuned infant–caregiver interactions. Attuned caregiving may be important for promoting cognitive development, particularly EFs, which are known to be critical for academic readiness and self-regulation (Blair & Raver, 2015).

Starting early in infancy, caregivers practice attuned behaviors toward their infants during face-to-face interactions (Tronick & Cohn, 1989). This dyadic interaction is theoretically considered to be a developmental antecedent to more advanced, triadic caregiver–infant reciprocal exchanges, such as joint attention, the coordination of visual attention between individuals to shared objects in the environment (Scaife & Bruner, 1975; Tomasello, 1995; Vygotsky, 1979). In the current study, we focused on joint attention at the dyadic level during interactions with caregivers, emphasizing the simultaneous and concurrent shared attention behaviors of *both* infant and caregiver during the shared social exchanges. This definition differs from individual-level joint attention, which typically emphasizes the infant's ability to respond to and initiate joint attention bids (Mundy & Newell, 2007; Tomasello, 1995). Through the development of joint attention, infants gain a rudimentary social understanding of the cognitive and affective states of others (Reddy & Legerstee, 2007; Trevarthen, 1979). Theoretically, joint attention is considered to be an interpersonal engagement process through which caregivers create shared mental states that form the basis of infant cognitive development (Reddy & Legerstee, 2007). Repeated instances of dyadic attuned caregiving likely set the foundation for triadic joint-attention interactions in which caregivers and infants share attention to other objects in their environment. Therefore, it follows that differences in caregivers' attunement behaviors earlier in infancy could result in differences in joint attention interactions later in development. Indeed, evidence suggests that the development of joint attention is subject to significant individual differences, which have been traced to variability in the quality of caregiver interactions (Raver & Leadbeater, 1995). Specifically, mothers who demonstrate greater reciprocal bidding and affect matching—key characteristics of attuned parenting—have longer bouts of joint attention (Markova & Legerstee, 2006). However, research has yet to explicitly test whether attuned caregiving in early life is a social antecedent to joint attention.

Investigating the precursors to joint attention in early life is critical, given that joint attention is thought to support children's cognitive development. Historically, theory suggests that higher-order cognitive abilities develop *through* social interactions between infants and their caregivers (Bruner, 1999; Cole, John-Steiner, Scribner, & Souberman, 1978; Fogel, 1993). It has been proposed that through joint attention interactions, infants develop the capacity for intraindividual cognitive regulation (Bolis & Schilbach, 2018; Reddy, Hay, Murray, & Trevarthen, 1997). Recent empirical research has begun to test this theory by investigating how normative variations in joint attention relate to cognitive control abilities, concurrently and longitudinally. A seminal study by Yu and Smith (2016) highlighted the importance of the social context in immediate sustained-attention episodes. Specifically, using head-mounted eye trackers to record moment-by-moment eye-gaze patterns in 12-month-old infants, Yu and Smith found that when parents visually attended to an object through joint attention, the duration of the infant's subsequent look toward that object was prolonged. This study suggests that joint attention may be a tool whereby a mature social partner is able to scaffold an infant's visual sustained attention to facilitate attentional control development. Similarly, Wass, Clackson, et al. (2018) found that infant sustained attention toward an object was higher during joint play relative to solo play and that a parent's attention toward objects predicted subsequent infant sustained attention. Both studies highlight the extent to which caregivers are able to contingently prolong infants' sustained attention during real-time interactions. These findings indicate that caregivers may guide the emergence of internalized sustained attention in infants by engaging in joint-attention behaviors during interactions.

Joint attention has been conceptualized neurobiologically as coordination of the posterior orienting attention system and the anterior executive attention system, which are involved in gaze following (or other ostensive signals) and the allocation of volitional, goal-directed attention, respectively (Mundy & Newell, 2007; Posner & Petersen, 1990). Repeated activation of these core attention networks during joint attention interactions likely strengthens their structural and functional connectivity, thus promoting the individual's cognitive abilities over time. Indeed, recent research has demonstrated longitudinal associations between joint attention and the development of cognitive control (Niedźwiecka, Ramotowska, & Tomalski, 2018; Vaughan Van Hecke et al., 2012). Specifically, Niedźwiecka et al. found that at 5 months, mutual gaze during infant–caregiver free-play interactions was positively associated with 11-month infant attentional control, assessed with a gap-and-overlap looking task. These findings highlight the importance of parent–child shared visual gaze on the development of infant attentional control, which is fundamental to higher-order cognitive processes. Complementary research demonstrated that an infant's ability to respond to joint attention around 12 months of age was positively associated with attention-regulation strategies during a delay-of-gratification task at 36 months (Vaughan Van Hecke et al., 2012). Given that joint attention integrates information processing, visual attention orienting, sustaining attention, and disengaging attention, these findings offer initial evidence that joint attention may provide socially anchored scaffolding for executive attention networks that support more complex EF processes. Collectively, the literature suggests that attuned, contingent-responsive parenting behaviors predict joint attention and that joint attention may promote sustained attention in real-time and subsequent development of higher-order cognitive control. Thus, it is plausible that through joint attention, parental attunement in infancy facilitates the basic building blocks of cognition that likely have enduring implications for the development of EFs. However, a cohesive examination of a proposed developmental cascade linking caregiving attunement in infancy with joint attention in toddlerhood to early childhood EF has yet to be empirically investigated.

Thus far, most studies on joint attention have been drawn from relatively small, socioeconomically homogenous samples. Therefore, it is currently unknown how the effects of joint attention may differ depending on the child's environmental context. This is a critical limitation of the existing joint attention literature, given the research demonstrating interactions between the socioeconomic environment and parent–child interactions. Specifically, research has found that sensitive caregiving within low-income households can buffer against some of the detrimental effects of socioeco-

nomic adversity on children's developmental outcomes (Blair & Raver, 2016; Hostinar, Sullivan, & Gunnar, 2014). Theoretically, there is reason to believe that the socioeconomic environment may moderate the effect of joint attention. In low-income households with fewer material resources that may be used to promote EF development, infants may rely more on and reap greater benefits from attuned caregiver interactions to scaffold core cognitive processes (Rosen, Amso, & McLaughlin, 2019). Thus, it is possible that joint attention experiences between caregivers and their infants could buffer against some of the detrimental effects associated with living in poverty. Specifically, given the research demonstrating links between joint attention and later higher-order cognitive abilities, it is possible that joint attention is one important component of caregiver–infant interactions that facilitates EF development, especially for lower-income families. However, because most prior work has used cross-sectional analyses, research is needed to longitudinally investigate the links between attuned caregiving, joint attention, and higher-order cognitive outcomes in a variety of socioeconomic contexts.

Additionally, a related limitation of previous research concerning context is that much of the relevant work has been carried out in less ecologically valid environments, namely, laboratories. More specifically, most research has studied joint attention using standard laboratory-based tasks to elicit joint attention behaviors. However, joint attention is a naturally occurring phenomenon that is spontaneously elicited during everyday parent–child interactions. Furthermore, given the importance of environmental context in shaping caregiving behaviors and infant development, it may be especially important to assess these variables outside of the laboratory, in ecologically valid settings, such as the home, especially when investigating potential socioeconomic differences. Here, we extend the current literature on joint attention by examining naturalistic measures of joint attention and caregiving behaviors measured in the home environment among socioeconomically diverse families.

The Present Study

The aim of the present study was to address four research questions regarding relations between attuned caregiving in early life, joint attention interactions in toddlerhood, and subsequent development of EFs in early childhood. First, how does variability in observed global attuned caregiving behavior during an infant's first year of life predict task-based joint attention at 24 months of age, as well as EF abilities at 48 months? Second, are individual differences in children's engagement in joint attention episodes at 24 months predictive of their EFs at 48 months of age? Third, do relations between joint attention and EFs differ depending on families' income-to-needs ratio (INR)? Fourth, are the associations between attuned caregiver behaviors and early childhood EFs mediated by joint attention? And finally, as an exploratory component of the study, we tested for moderated mediation to investigate whether the interaction between joint attention and INR mediated the relation between attuned caregiving and childhood EFs. Consistent with prior literature, we first hypothesized that higher levels of attuned parenting behaviors during infancy would be predictive of higher EFs in early childhood. Additionally, we hypothesized that attuned caregiving behaviors in early life would be predictive of greater joint attention in toddlerhood. Similarly, we hypothesized that joint attention at 24 months of age would be positively associated with EFs at 48 months of age. Concerning our third question, we hypothesized that the association between joint attention and EFs would be particularly strong for families with lower INRs. Finally, we hypothesized that associations between attuned caregiving behaviors during infancy and EFs in early childhood would be partially explained by joint attention in toddlerhood and that this effect would be amplified for lower-income families.

Method

Participants

The Family Life Project (FLP) is a prospective longitudinal study of families residing in six low-wealth counties in eastern North Carolina and central Pennsylvania (three counties per state) that were selected to be indicative of the Black South and Appalachia, respectively. The FLP adopted a developmental epidemiological design whereby complex sampling procedures were used to recruit a representative sample of 1,292 children whose families resided in one of the six counties at the time of the child's birth. Low-income families in both states and African American families in North Carolina were oversampled. Detailed descriptions of the participating families and communities are given by Vernon-Feagans, Cox, and the FLP Investigators (2013).

Procedure

The data for this analysis were collected in participants' homes at the child ages of 7, 15, 24, and 48 months. This study was approved by the Office of Human Research Ethics at the University of North Carolina (Protocol 05-0201; "Family Life Project: 15- Through 48-Month Participation"). Written informed consent was obtained from all participants. During home visits at each time point, the child's primary caregiver provided information on demographics and numerous aspects of family life and relationships. At 15 months, parenting behaviors were observed during a semistructured parent–child interaction task. Immediately following the home visits, research assistants (RAs) completed ratings of the child's attention during the 2–3 hr of data collection. At 24 months, measures of joint attention and codes for maternal language were derived from a book-reading task between children and their primary caregivers. Finally, at 48 months, children were administered a battery of EF tasks.

Measures

Attuned caregiving. Global caregiving behaviors were observed between infants and their mothers in a 10-min semistructured, dyadic free-play task during the 15-month home visit. In this task, mothers were instructed to play with the infant using a provided set of standardized toys. The interaction was video-recorded and later coded by highly trained coders along several dimensions of caregiving behaviors (Cox & Crnic, 2002; National Institute of Child Health and Human Development Early Child Care Research Network, 1999). The specific dimension of interest for the current analysis was attuned caregiving. Attuned caregiving behaviors were coded using a scale of 1 (*not at all characteristic*)

to 5 (*highly characteristic*) by a team of coders, which included a master coder. Coders underwent training with their master coder until acceptable reliability was established, as determined by intraclass correlation coefficients (>0.80). Once acceptable reliability was established, coders coded in pairs while continuing to complete at least 30% of the videos with their master coder. Each coding pair met biweekly to reconcile scoring discrepancies, and the scores used in the analysis were the final scores arrived at after reconciling. Coders rated attuned caregiving behaviors based on the following criteria: parenting behaviors that included instances of contingent vocalizations by the parent, appropriate attention focusing, evidence of good timing paced to child's interest and arousal level, shared positive affect, and providing an appropriate level of stimulation. Generally, parenting behavior was coded as attuned if parents demonstrated the ability to flexibly adapt contingent-responsive interactions to the child's current affective state and developmental ability. Higher scores are indicative of greater attunement.

Joint attention. Joint attention was assessed at 24 months through a wordless picture book task between the mother and infant using the Early Attention to Reading Situations (EARS) rating system (Feagans, Kipp, & Blood, 1994). At each time point, mothers were given a wordless picture book to review before the session began. The mother was asked to go through the book and talk to the child about the book as she might normally do. Caregivers were assigned to share the books *Just a Thunderstorm* (Mayer & Mayer, 2003) or *The New Baby* (Mayer, 2001) with their children (book assignment was counterbalanced across participants). After approximately 10 min, the RA would ask the mother to stop if the picture book task had not ended. The RA used a laptop computer that was programmed to receive observational ratings every 5 s. The RA coded the child's focus of attention at the 5-s beep into one of five mutually exclusive categories: look at book, look at caregiver, gaze aversion, look at RA/camera, off task, and joint attention. The joint attention category indicated whether the child's eyes were focused on the same page of the book as the mother's eyes or not. For example, when both the mother and child looked at the same page of the book at the same time, this was coded as joint attention. Because we were interested in examining the effects of naturalistically elicited coordinated-attention episodes themselves, we operationalized joint attention broadly and did not delineate child-initiated and child-responded joint attention. This conceptualization of joint attention has been used previously in prior FLP publications (Gueron-Sela et al., 2018).

RAs practiced the rating system with pilot children until acceptable reliability was reached with the master rater (Cohen's kappas of at least .70). Five selected video recordings of the book-sharing activity were then rated by the master rater periodically, to confirm and maintain a Cohen's kappa of at least .70 for each rater. A frequency score indicating the number of instances of joint attention was recorded for each dyad. Because the length of the book-sharing activity varied, raw frequency scores were converted to proportion of time to be used in analyses. Specifically, for the final analysis variable, we created a mean proportion score for each dyad that represented the proportion of 5-s intervals in which joint attention was observed.

Executive functions. At 48 months of age, children were administered an EF battery consisting of two working-memory tasks, three inhibitory control tasks, and one attention-shifting task. Preceding the test trials in each task, RAs administered training trials, and children completed up to three practice trials. RAs discontinued the task for those children who did not demonstrate an understanding of the task. Each task was presented by a RA in an open spiral-bound flipbook with pages that measured 8 in. × 14 in. Details on the tasks and administration procedures, as well as psychometric characteristics, are given by Willoughby, Kupersmidt, Voegler-Lee, and Bryant (2011) and Willoughby, Blair, Wirth, and Greenberg (2010). We provide a brief description of the tasks here.

Working-memory span (working memory). In the span task, children were shown the outline of a house with an animal and a colored dot inside it and were prompted to name the animal and the color of the dot. Then they were shown a blank house and asked to report either the animal or the color they had seen in the previous house. In order to perform correctly, children needed to hold two pieces of information in mind (i.e., the animal and the color) but only needed to recall the prompted feature (e.g., animal).

Pick the picture game (working memory). In this self-ordered pointing task, children were presented with sets of items. For each set, the same items appeared on two sequential pages in a different arrangement. On the first page, children were asked to pick one item. On each subsequent page, children were instructed to pick an item that was not previously picked so that each picture "gets a turn." Difficulty increased as more items, up to six, were added to the sets.

Silly sounds Stroop (inhibitory control). Children were presented with pictures of cats and dogs and asked to make the sound opposite of that which is typically associated with that animal (e.g., when showed a dog, a correct response would be to make a meowing sound).

Spatial conflict arrows (inhibitory control). In this Simon-like task, children were presented response cards with two black circles ("buttons") on either side of the page and an arrow on either the left or right side of the page. Children were instructed to touch the button corresponding to the side to which the arrow was pointing. The task proceeded in difficulty from displaying left-pointing arrows on the left of the page and right-pointing arrows on the right (congruent trials) to most arrows pointing to the side opposite from which they were positioned (incongruent trials).

Animal go/no-go (inhibitory control). In this standard go/no-go task, children were instructed to click a button (which made an audible sound) every time they saw an animal (go trials) unless the animal was a pig (no-go trials). Varying numbers of go trials appeared prior to each no-go trial, including, in the standard order, 1-go, 3-go, 3-go, 5-go, 1-go, 1-go, and 3-go trials.

Something's the same game (attention shifting). In this task, children were presented with a pair of pictures for matching on a single dimension (e.g., both pictures were the same color). Subsequently, a third picture was presented, and children were asked to identify which of the first two pictures was similar to the new picture. This task requires the child to shift attention from the initial dimension to a new dimension of similarity (e.g., from color to size).

Executive function task scoring and composite formation. Children needed to complete at least 75% of trials for each task in order for their performance to be analyzed. Tasks were scored using item-response theory because this is a more precise way to

estimate children's EF abilities than percent-correct scores. For the purpose of the current study, we were interested in examining EFs unitarily as a measure of higher-order cognitive abilities. As such, expected a posteriori (EAP) scores were derived for each task and averaged to obtain a composite score (Willoughby, Wirth, & Blair, 2011). *Z* scores were calculated to reflect accuracy on each of the six EF assessments. The total score reflected the mean of all completed *z*-scored individual scores. We used a formative composite because it has been found to more appropriately represent the overarching construct of EF than a latent factor, which is limited to measurement of the shared variance among tasks that are only weakly to moderately correlated (Willoughby, Magnus, Vernon-Feagans, Blair, & the Family Life Project Investigators, 2017). The authors chose to composite across the subscales, given the neuroscience-based evidence suggesting that in early childhood, EFs have far less specificity in their neural localization than in adulthood (Bruce Morton, 2010). Moreover, factor analysis supports the unitary structure of EFs in young children (Willoughby, Blair, Wirth, & Greenberg, 2012; Willoughby et al., 2011) as opposed to the three distinct domains (working memory, inhibitory control, and attention shifting) that are seen later in development. Prior studies using this battery with the same population have demonstrated acceptable psychometric properties with the composite EF score (Willoughby et al., 2012). As is typical of EF measures (Willoughby, Holochwost, Blanton, & Blair, 2014), the reliability coefficient for the composite was relatively low, $\alpha = .50$.

Income-to-needs ratio. The INR was calculated using caregiver-reported household income during home visits and corresponding federal poverty threshold values. Specifically, at the 7- and 15-month home visits, primary caregivers were asked to provide detailed information about all sources of household income (e.g., employment income, cash welfare/Temporary Assistance for Needy Families [TANF], Social Security retirement, help from relatives). This total annual income was divided by the federal poverty threshold to create the family's INR. An INR of 1.0 is at the poverty line and indicates that a family may be unable to provide for basic needs. We averaged INR values across the 7- and 15-month time points to obtain a cumulative measure of INR in early life.

Covariates

Individual infant focused attention. To control for the potential confounding of infant individual attention with EF outcomes, we included a variable for infant focused attention in our model. Infant attention was assessed at 24 months of age using the Early Childhood Behavior Questionnaire (ECBQ; Putnam, Gartstein, & Rothbart, 2006), which was reported by the child's parent at the home visit. We included the ECBQ subscale of attention focusing (10 items; e.g., "While looking at picture books on his or her own, how often did [the child] stay interested in the book for 5 min or less?"; $\alpha = .81$). Each item was scored on a scale of 1–7 (*never*, *very rarely*, *less than half the time*, *about half the time*, *more than half the time*, *almost always*, or *always*).

Maternal language. To control for the potentially confounding influence of maternal language during the EARS task on EF outcomes, we included a maternal language input variable. Maternal language was coded from digital video recordings of the same EARS picture-book-sharing task that the joint attention measure was derived from at 24 months of age. The task was transcribed offline by trained graduate students using systematic analysis of language transcripts (SALT; Miller & Chapman, 1985). A graduate student who spent 1 year learning SALT conventions and developing a training manual trained transcribers, who themselves trained for at least 3 months before transcribing videos. To ensure accuracy in the transcription process, coders transcribed 20 cases that were reviewed by the senior transcriber, transcripts were regularly reviewed, and any issues were discussed and resolved with the senior graduate student (Kuhn et al., 2014). For coding purposes, utterances were defined as a sequence of words preceded and followed by a change in conversational turn or a change in intonation pattern. Nonverbal utterances, unintelligible speech, and abandoned utterances were not included. Mean length utterance (MLU) was used in the current analysis as a measure of maternal language input. MLU is a general measure of language complexity and was calculated by dividing the total number of utterances by the total number of morphemes.

Maternal education. Primary caregivers' highest education level was derived from self-reports at the home interview at the 7- and 15-month assessments. The mean level of educational attainment was 14.6 years (standard deviation [*SD*] = 2.8 years), where 14 years reflected having earned a high school diploma. We averaged caregiver education values across the 7- and 15-month time points.

Maternal job prestige. Caregivers' level of job prestige was derived from the home interview at the 7- and 15-month assessments. During this interview, primary caregivers were asked a series of questions about their current job(s), including the job title, employer, and a short description of primary activities and duties. Jobs were given occupational codes according to the characteristics and attributes in the Occupational Information Network (O*Net) database. The O*Net database was used to create five specific occupational characteristics: self-direction, hazardous physical conditions, physical activity, care work, and automation/repetition. Intercoder reliability was adequate, with correlation coefficients ranging from .80 to .92 for the five summary scales. We averaged job prestige scores across the 7- and 15-month time points.

Demographics. The state of residence (PA = 0, NC = 1), sex (0 = Male, 1 = Female), and race (0 = not African American, 1 = African American) of the child were included as covariates to control for site and demographic differences in study variables.

Data Analysis

The total sample size recruited at study entry was 1,292, with 1,204 children seen at age 7 months, 1,169 at 15 months, 1,144 at 24 months, and 1,066 at 48 months. First, data were screened for outliers and normality of distributions. To avoid bias in estimates associated with listwise deletion, we used full information maximum likelihood (FIML) for all analyses. To address our main research questions, we used path analysis. In our hypothesized model (see Figure 1), we were specifically interested in measuring the following: (a) the direct paths from attuned caregiving at 15 months to joint attention at 24 months (Path *a*) and EFs at 48 months (Path *c*), (b) the direct paths from joint attention at 24 months to EFs at 48 months (Path *b*), (c) moderation of the path

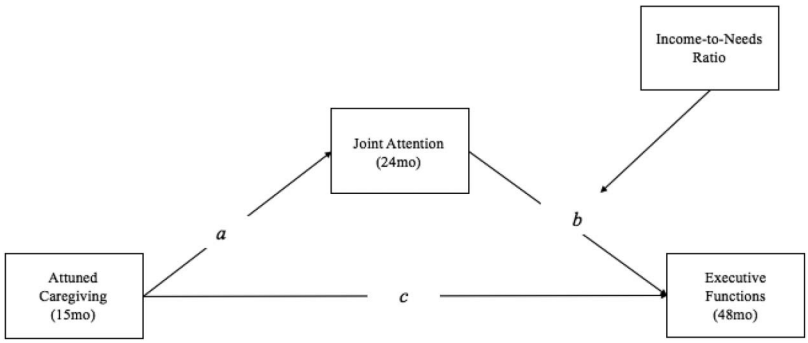

Figure 1. The hypothesized moderated-mediation model relating attuned caregiving to joint attention and executive outcomes, conditional on income-to-needs ratio (INR). Covariates are not shown.

from joint attention at 24 months to EF at 48 months by INR, (d) indirect paths from attuned caregiving to EFs through joint attention, and (e) moderated mediation of the indirect path from attuned caregiving to EFs via conditional relations between joint attention and INR. Tests of statistical mediation employed bootstrapping with 5,000 samples to generate bias-corrected confidence intervals for indirect effects (Shrout & Bolger, 2002). To test moderation, grand-mean-centered scores were used to compute the interaction term, and we probed statistically significant interactions at 1 *SD* below (i.e., lower INR) and 1 *SD* above (i.e., higher INR) the INR mean (Aiken & West, 1991). To control for the effect of infant attention and maternal language during the joint attention task on subsequent EFs, we included infant focused attention and maternal language input as a covariate on Path *b*. Finally, we controlled for caregiver education, job prestige, sex, state of residence, and race on all paths in our model. All analyses were conducted in the R environment (R Core Team, 2013) using the lavaan package (Rosseel, 2012). All parameter estimates are standardized estimates and thus indicate how much the dependent variable would be expected to change for a single-standard-deviation change in the predictor variable.

Results

Descriptive Statistics

Table 1 shows descriptive statistics, and Table 2 displays correlations among the variables in the analysis. Table 2 indicates a positive association between attuned caregiving and joint attention, EFs, infant focused attention, and maternal language. Further, attuned caregiving was positively correlated with INR, maternal education, and job prestige. Joint attention was positively associated with EFs, infant focused attention, maternal language, INR, maternal education, and job prestige. EFs were positively correlated with infant focused attention, maternal language, INR, maternal education, and job prestige. The reported correlation coefficients were in the hypothesized directions, thus providing support for subsequent analyses.

Preliminary Analyses: Attuned Caregiving and Executive Functions

To assess the direct effects of attuned caregiving on EF (without joint attention in the model), we constructed a regression of EFs at 48 months on attuned caregiving at 15 months, controlling for all covariates. As hypothesized, attuned caregiving was positively associated with EFs at 48 months ($\beta = .09$, standard error [*SE*] = .02, $p = .007$).

Path Analysis

To test our main hypotheses, we first examined the direct effects of attuned caregiving on joint attention and EFs. Second, we examined the direct effects of joint attention on EFs and explored the moderating role of INR while controlling for infant focused attention and maternal language input during the joint attention task. Third, we examined the indirect effects of attuned caregiving on EFs via joint attention and its interaction with INR. All effects

Table 1
Descriptive Statistics

Variables	*N*	*M*	*SD*	Minimum	Median	Maximum
Attuned caregiving, 15 months	1,100	2.7	0.8	1.0	3.0	5.0
Joint attention, 24 months	1,078	0.4	0.2	0.0	0.4	1.0
Executive function, 48 months	1,009	−0.1	0.5	−2.1	−0.1	1.2
Maternal education, 7–15 months	1,225	14.48	2.8	6.0	14.0	22.0
INR, 7–15 months	1,228	1.8	1.6	0.0	1.4	16.6
Job prestige, 7–15 months	1,119	40.0	11.2	16.8	38.9	86.0
Infant focused attention, 24 months	1,086	4.1	0.7	3.7	4.1	6.3
Maternal language input, 24 months	1,047	3.1	0.9	1.1	3.0	8.8

Note. INR = income-to-needs ratio.

Table 2
Correlation Matrix

Variables	1	2	3	4	5	6	7	8
1. Attuned caregiving, 15 months	1							
2. Joint attention, 24 months	0.18**	1						
3. Executive function, 48 months	0.28**	0.23**	1					
4. INR, 7–15 months	0.37**	0.15**	0.27**	1				
5. Maternal education, 7–15 months	0.41**	0.16**	0.30**	0.54**	1			
6. Job prestige, 7–15 months	0.31**	0.13**	0.24**	0.52**	0.56**	1		
7. Infant focused attention, 24 months	0.09*	0.06*	0.16**	0.13**	0.11**	0.08*	1	
8. Maternal language input, 24 months	0.15**	0.08**	0.08*	0.06	0.12**	0.06	0.01*	1

Note. INR = income-to-needs ratio.
* $p < .05$. ** $p < .01$.

are reported as standardized coefficients, as shown in Table 3 and Figure 2.

Relations Between Attuned Caregiving, Joint Attention, and Executive Functions

First, tests of direct effects demonstrated a significant positive association between attuned caregiving in infancy and EFs in early childhood ($\beta = .07$, $SE = .02$, $p = .036$). Compared with the preliminary model without joint attention, the coefficient was reduced by 22%, suggesting partial mediation through joint attention. Further, the model demonstrated a significant positive direct effect of attuned caregiving in infancy on joint attention in toddlerhood ($\beta = .11$, $SE = .01$, $p = .001$). Second, a significant direct effect was present between joint attention in toddlerhood and EFs in early childhood, such that joint attention was positively associated with EFs ($\beta = .13$, $SE = .07$, $p < .001$). There was also a significant association between infant focused attention and EFs ($\beta = .10$, $SE = .02$, $p < .001$) and for maternal language input during the joint attention task and EFs ($\beta = .07$, $SE = .02$, $p = .03$).

Income-to-Needs Ratio as a Moderator of Joint Attention

To examine the moderating role of INR on the relation between joint attention in toddlerhood and EFs in early childhood, we estimated a second path model that included an interaction term for joint attention and INR as a predictor of EFs. Tests of moderation demonstrated a significant interaction effect, such that the relation

Table 3
Regression Results

Predictors	Standardized estimates (*SE*)
Direct paths	
Executive function, 48 months	
Attuned caregiving, 15 months	0.07 (0.02)**
Joint attention, 24 months	0.13 (0.07)**
INR, 7–15 months	0.01 (0.01)
INR, 7–15 Months × Joint Attention, 24 Months	−0.07 (0.04)**
Maternal education, 7–15 months	0.14 (0.01)**
Job prestige, 7–15 months	0.06 (0.02)
Infant focused attention, 24 months	0.10 (0.02)**
Maternal language input, 24 months	0.07 (0.02)*
Sex	−0.14 (0.03)**
State	−0.17 (0.04)**
Race	−0.14 (0.04)**
Joint attention, 24 months	
Attuned caregiving, 15 months	0.11 (0.01)**
INR, 7–15 months	0.04 (0.01)
Maternal education, 7–15 months	0.04 (0.01)
Job prestige, 7–15 months	0.05 (0.01)
Sex	−0.06 (0.01)
State	−0.10 (0.02)**
Race	0.05 (0.02)
Indirect paths	**Estimate (95% CI)**
AC → JA → EF	0.014 (.003, .017)
AC → JA × INR → EF	−0.008 (−.007, −.001)

Note. INR = income-to-needs ratio; AC = attuned caregiving; JA = joint attention; EF = executive function.
* $p < .05$. ** $p < .01$.

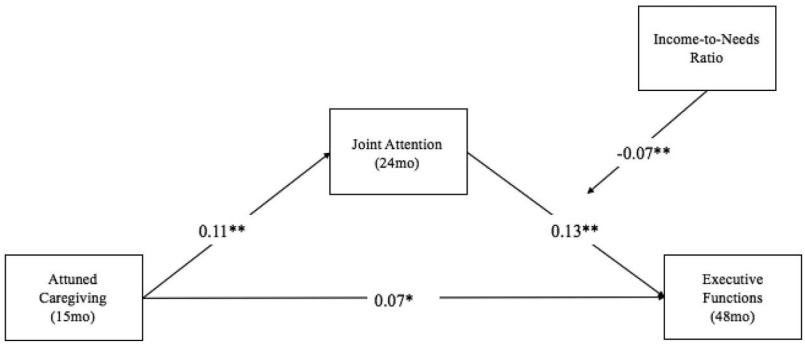

Figure 2. The observed mediation model relating attuned caregiving to joint attention and executive outcomes, including moderation by income-to-needs ratio (INR). All coefficients are standardized (β). On the *a* path, we controlled for INR, maternal education, and job prestige at 7–15 months, as well as sex, state, and race. On the *b* path, we controlled for infant focused attention and maternal language input at 24 months; INR, maternal education, and job prestige at 7–15 months; and sex, state, and race. * $p < .05$. ** $p < .01$.

between joint attention and EFs was moderated by INR ($\beta = -.07$, $SE = .04$, $p = .01$). As shown in Figure 3, analysis of simple slopes indicated that the positive relation between joint attention and EFs was stronger for families with lower INR (mean −1 *SD*: $\beta = .20$, $SE = .08$, $p < .001$). In contrast, for those with higher INR, the relation between joint attention and EFs was smaller yet still significant (mean + 1 *SD*: $\beta = .06$, $SE = .08$, $p = .02$). These results indicate that the relation between joint attention and EFs was approximately 3 times larger for low-income relative to high-income families.

Test of Mediation Through Joint Attention

To test for mediation in our model, we estimated the indirect effects of attuned caregiving in infancy to EFs in early childhood through joint attention in toddlerhood. The results from tests of indirect effects unconditional on INR (see Table 3) indicated that joint attention partially mediated the relation between attuned caregiving and EFs ($\beta = .014$, 95% confidence interval [CI] [.003, .017]).

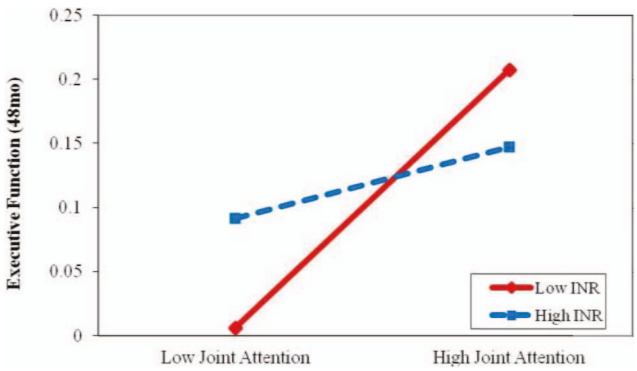

Figure 3. Family income-to-needs ratio (INR) moderates the association between joint attention at 24 months and executive function at 48 months. Model-estimated simple slopes are plotted at values of 1 standard deviation above (high) and below (low) the respective variable's mean. See the online article for the color version of this figure.

Moreover, the tests of indirect effects conditional on INR demonstrated that the interactive effects between joint attention and INR partially mediated relations between attuned caregiving and EFs ($\beta = -.01$, 95% CI [–.007, −.001]), such that the role of joint attention as a mediator was amplified among families with lower INR (mean −1 *SD*: $\beta = .02$, 95% CI [.003, .023]) relative to individuals with higher INR (mean +1 *SD*: $\beta = .006$, 95% CI [–.001, .013]).

Discussion

In the current study, we assessed longitudinal relations between attuned caregiving, joint attention, and EFs among families living in predominately rural, low-income environments. Specifically, we investigated joint attention during toddlerhood as a mediator between the relation of attuned caregiving during infancy to EFs in early childhood and the extent to which income moderated this mediation. This research was motivated by the theory of joint attention as a guided-attention mechanism that parents engage in with their infant to promote the basic building blocks of infant cognitive control. This foundational set of cognitive abilities may have long-term developmental implications, particularly for children living in socioeconomic risk. We found evidence in support of our hypothesis that joint attention may be one operating mechanism by which attuned caregiver behaviors predict the development of higher-order cognitive abilities. Further, our findings support the hypothesis that the effect of joint attention would be amplified for children living in elevated poverty. Although previous research has demonstrated associations between attuned caregiving and EFs (Bernier et al., 2010; Blair et al., 2011; Lugo-Gil & Tamis-LeMonda, 2008), we build upon these findings by examining joint attention in infancy, a particular contingent-responsive dyadic exchange, as a predictor of EFs in early childhood, over and above individual infant focused attention and maternal language input. Collectively, our findings presented here, in conjunction with other empirical research, support theories suggesting that it is through social interactions that infants develop the capacity for higher-order cognition and self-regulation (Cole et al., 1978; Fogel, 1993).

Attuned Caregiving and Joint Attention

The results from our first path of interest demonstrated that attuned caregiving during infancy positively predicted joint attention in toddlerhood. Although little research has been devoted to the longitudinal study of early social influences on the development of joint attention, our findings are substantiated by theory and emerging empirical research. In particular, joint attention has theoretically been conceptualized as a behavioral manifestation of contingent-responsive synchrony between infants and caregivers that develops over time (Bolis & Schilbach, 2018). Attuned caregiver behaviors are characterized by adaptive and flexible affect, attention, and responsiveness to the infant. These practices are especially important in the first months of an infant's life, before the mature development of self-directed joint attention. The association between attuned caregiving in early life and joint attention in early toddlerhood provides empirical evidence that behaviorally attuned caregiving qualities may set the foundation for the development of joint attention. Specifically, throughout infancy, the caregiver and infant engage in a "dance" of attention and affect matching during face-to-face interactions (Tronick & Cohn, 1989) that developmentally precedes the onset of joint attention. Moreover, the development of shared visual attention toward objects may depend on the history of the dyad's reciprocity and attentional attunement, which is co-constructed early in life during sensitive caregiver interactions (Raver & Leadbeater, 1995). Here we find empirical evidence to support this theory, given that our measurement of attuned caregiving is characterized by highly attuned, affective, and attentive behaviors during interactions. This inference is empirically supported by evidence that attuned mothers are more sensitive and responsive to their infants by providing a higher quality and greater quantity of affective and intentional cues, thus setting the stage for contingent gaze following during joint attention (Legerstee et al., 2007). A caregiver's sensitivity to their infant's cues likely contributes to their ability to capture and guide their infant's attention, thereby scaffolding the infant's training of shared social attention, which may further contribute to the development of joint attention over time. Through this dynamic, interpersonal process, caregivers and infants coconstruct the building blocks of cognition.

Joint Attention and Executive Functions

The results from our second path of interest indicated that greater joint attention at 24 months longitudinally predicted greater EF abilities at 48 months while also controlling for attuned caregiving in early life, infant focused attention, and maternal language input during the joint attention task. This finding adds to a recent, growing body of literature suggesting that joint attention may be an important mechanism whereby infants develop higher-order cognitive abilities (Niedźwiecka et al., 2018; Vaughan Van Hecke et al., 2012). In other words, it is not only attuned caregiving alone that predicts EFs; there is an additional, unique effect of joint attention. One possible explanation for these findings is that joint attention between infants and caregivers functions as a guided-attention mechanism whereby parents scaffold basic components of cognitive control with their infants. This idea is supported by empirical evidence from gaze-tracking research, which has demonstrated that infants prolong sustained gaze toward objects when their parents have focused attention on the same object (Wass, Noreika, et al., 2018; Yu & Smith, 2016). In essence, parents may be training and fine-tuning attentional control in infancy through joint attention, thus setting the foundation for higher-order cognitive abilities in early childhood. Recent evidence from neuroscience supports the theory of socially constructed development of cognitive control. Specifically, Wass, Clackson, et al. (2018) demonstrated that increases in the caregiver's theta power (a biomarker of attention measured by electroencephalogram [EEG]) during a bout of joint attention predicted subsequent infant gaze duration directed toward the same object. In other words, an infant's sustained attention is potentiated in joint attention contexts when the mature dyadic partner allocates greater neurophysiological resources to the shared object. These findings provide neural evidence for the process by which joint attention scaffolds and trains higher-order attentional control.

Our mediational findings support our central hypothesis that joint attention is a specific operating mechanism of attuned caregiver interactions that scaffold early cognitive abilities. This finding is well situated within a rich body of literature linking sensitive parenting practices to EF outcomes in early childhood (Bernier et al., 2010; Blair et al., 2011; Lugo-Gil & Tamis-LeMonda, 2008). Moreover, these findings are consistent with broader theory emphasizing the role of social interactions in the development of EFs (Cole et al., 1978; Fernyhough, 2010; Hughes & Ensor, 2007; Lewis & Carpendale, 2009; Perry, Braren, Blair, & the Family Life Project Key Investigators, 2018). Given that we assessed and defined joint attention on the level of the dyad during a structured social interaction, our findings point to the interactional process of joint attention as a specific component of attuned caregiving that scaffolds EF development (Rosen et al., 2019). Importantly, because our analysis was longitudinal, we can also claim that earlier attuned caregiving may support the development of joint attention, and in turn, this joint attention may support the development of EFs. That is, caregiver attunement in infancy may foster the development of joint attention in toddlerhood, which supports EF in early childhood. Further, it is not merely attuned caregiving alone that supports EF but attuned caregiving *through* joint attention. This further highlights the idea that although caregivers contribute significantly, it is not the caregiver alone supporting EF development but the interactional nature of exchanges between *both* the caregiver and the child. Reciprocally, the ability to attend to social cues is advantageous for infants as they develop social-communicative abilities (Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998; Miller & Gros-Louis, 2013). As such, the development of attention in infancy may be coconstructed through attuned social interactions with caregivers during which the caregiver's and child's attention processes are attuned or synchronous with each other. We propose that it is through these repeated instances of joint attention or attentional synchrony that infants are able to develop their own ability for independent cognitive control and EFs. Future longitudinal research is needed to empirically test this hypothesis.

Moderation by Income-to-Needs Ratio

Our findings also contribute to growing literature on joint attention and EF development by assessing the moderating role

of INR. Specifically, we found that the relation between toddler joint attention and early childhood EFs was moderated by INR such that the positive association between joint attention and EFs was greater for families with lower INRs. This relation indicates an amplifying effect whereby the positive effects of joint attention on EFs provide an additional boost for low-income children. We posit that this could reflect the critical effects of insufficient materials and resources in the home environment for families living with low incomes. In other words, lower-income families may have fewer financial resources to invest in learning materials, such as toys and books. Thus, in homes with fewer cognitively enriching material resources, the child may reap more benefits from social interactions involving joint attention to scaffold the foundational building blocks of cognition (Rosen et al., 2019). Further evidence for this hypothesis comes from our moderated-mediation finding demonstrating that the role of joint attention as a mechanism through which attuned caregiving relates to EF was particularly strong for low-income families. Therefore, in low-income homes that may be strained by a lack of resources, children may rely more on social interactions and reap more of the cognitive benefits associated with joint attention from attuned caregivers. These findings highlight the importance of fostering well-resourced, supportive, and low-stress environments that are conducive to attuned caregiving and joint attention, particularly for low-income families and during early life, when the brain is especially plastic and susceptible to social influence (Cerqueira, Mailliet, Almeida, Jay, & Sousa, 2007; Grossmann, 2013; Hodel, 2018).

One of the strengths of the current study is the longitudinal analysis, which allowed us to establish temporal precedence that may support a causal relation. Although the reported pathways are correlational, establishing temporal precedence strengthens our ability to infer a potential causal relation in which joint attention operates as a causal mechanism by which attuned caregiving affects EF. Intervention research efforts have offered preliminary support for a casual role of dyadic, shared-attention experiences in the development of higher-order cognitive abilities. Specifically, a randomized controlled trial intervention conducted by Cooper et al. (2014) implemented a book-sharing intervention for 14- to 16-month-old infants and caregivers living in impoverished South African communities. After 8 weeks of the book-sharing intervention, infants demonstrated gains in sustained attention relative to the infants in the control group. Although this work did not specifically target joint attention, book reading allows for opportunities for joint attention, as observed in the current study, and likely may have contributed to the observed gains in sustained attention. Collectively, not only do these findings highlight a potential casual role for shared attention, but they also invite future research efforts to explore joint attention as a point of leverage for intervention research aimed at lower-income, at-risk populations. Additionally, because we found joint attention to be an important process likely supporting the development of EFs, especially for lower-income families, interventions targeting joint attention may be particularly useful for attenuating the disparities in EFs associated with socioeconomic status.

Limitations and Future Directions

Although this study expands the literature, there are several limitations that should be addressed to inform future research efforts. First, our operationalization of joint attention was relatively broad, given that a moment of joint attention was defined as the caregiver and infant both looking at a book. From this coding scheme, we are unable to glean detailed information as to whom initiated joint attention or when gaze following occurred. However, this is an inherent limitation of collecting data in the field. Thus, we suggest that this shortcoming was offset by the fact that we assessed joint attention in a naturalistic interaction and ecologically valid context (in the home). Similarly, our measurement of attuned caregiving used a global coding scheme of behaviors. Future research examining attuned caregiving and joint attention could aim to microanalyze the moment-to-moment dyadic behaviors as they unfold within the interaction. Further, analyses of joint attention would be bolstered by the inclusion of eye-tracking or dual neurophysiology measures to better understand the nuanced but rich features within joint attention interactions that may be particularly important for guiding attention. In addition, future research could investigate if joint attention is more strongly predictive of specific domains of EF (i.e., working memory, inhibitory control, or attention shifting). Similarly, future research is needed to disentangle the factors from low-income environments that might be contributing to moderation of the relation between joint attention and EFs. Importantly, the longitudinal model presented here is correlational. Although the consideration and inclusion of infant focused attention and maternal language covariates improve our ability to draw inferences, causal conclusions about the relations between variables are not possible. Therefore, future experimental research is needed to evaluate causality regarding the links between caregiver behaviors, joint attention, and the development of EFs. Lastly, it is important to note that the effect sizes in our main analyses were relatively small. However, despite small effect sizes, we emphasize that the observed associations are reliably estimated, given that we had a large sample size. Indeed, one of the strengths of a larger sample, such as the FLP, is the increased statistical power to detect small but meaningful associations between constructs, which is inherently difficult in collecting longitudinal data in the field.

Despite these limitations, the present study has a number of strengths. To the best of our knowledge, this is the first study to highlight joint attention as a key operating mechanism connecting caregiver attunement to the development of EFs among families living in socioeconomic-related risk. Moreover, we used an ecologically valid measure of joint attention as it might naturally occur in the home environment during a book-reading task. This expands the literature, given that joint attention is typically studied within lab environments. However, it is through experiences like book-reading activities or prolonged play opportunities in the home environment that infants develop and begin to demonstrate sustained and executive attention. We consider the possibility that the developmental process of joint attention between infant–caregiver dyads is a mechanism by which infants learn to regulate their attentional control through a guided-attention process. Further, we propose joint attention

to be an important process of social regulation in which caregivers scaffold an infant's abilities, but *together*, both the caregiver and the child co-construct higher-order cognitive processes, such as EF.

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