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Early Intervention and Mediating Processes in Cognitive Performance of Children of Low-Income African American Families

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This longitudinal study of 161 African American children from low-income families examined multiple influences, including early childhood interventions and characteristics of the child and family, on longitudinal patterns of children's cognitive performance measured between 6 months and 8 years of age. Results indicate that more optimal patterns of cognitive development were associated with intensive early educational child care, responsive stimulating care at home, and higher maternal IQ. In accordance with a general systems model, analyses also suggested that child care experiences were related to better cognitive performance in part through enhancing the infant's responsiveness to his or her environment. Maternal IQ had both a direct effect on cognitive performance during early childhood and, also, an indirect effect through its influence on the family environment.

INTRODUCTION

Among children in the United States, those reared in poverty are most at risk of below-average cognitive performance and academic failure (Landesman & Ramey, 1989). Not only are nearly one-fourth of all U.S. children currently growing up in poverty, but the proportion of poor children is increasing (Edelman, 1988; Eggebeen & Lichter, 1991). Furthermore, ethnicity and poverty are confounded, with almost half (45%) of African American children living in a family experiencing economic hardship (Eggebeen & Lichter, 1991). The cognitive development of children reared in low-income families is generally characterized by average performance on standardized tests during infancy, followed by gradual declines during early and middle childhood for U.S. children in general (Belsky & Steinberg, 1978; Etaugh, 1980; Landesman & Ramey, 1989) and for African American children specifically (Burchinal, Lee, & Ramey, 1989). Disproportionately many such children are testing within the low-normal or borderline range by kindergarten age (Ramey & Campbell, 1991). Further, poor children are more likely to experience learning or adjustment problems in the typical classroom than children from more economically advantaged homes (Alexander & Entwisle, 1988). However, whereas both white and African American children from low-income families are disproportionately at risk for impaired cognitive development and academic failure, many of them experience neither (e.g., Alexander & Entwisle, 1988; Elder, 1979; Patterson, Kupersmidt, & Vaden, 1990). Accordingly, a better understanding of the processes underlying cognitive development among economically disadvantaged children is needed (McLoyd, 1990).

The extent to which intelligence tests accurately and fairly reflect children's abilities has been widely debated, but psychologists generally acknowledge that such instruments assess important skills. After a task force appointed by the American Psychological Association completed a comprehensive review of the literature on intelligence, the members noted that cognitive test scores predict school achievement moderately well and accomplishments outside of school modestly well (Neisser et al., 1996). They also concluded, however, that the extent to which characteristics of the child and family influence cognitive performance is still subject to debate because different analytic methods yield varying results. The task force found that one environmental variable that clearly affects cognitive performance is schooling. Attending educational preschool intervention programs or good-quality schools is consistently linked to better cognitive performance. Another variable with clear impact on children's cognitive performance is their parent's cognitive performance. High estimates of heritability in cognitive scores have been observed across a number of studies. The role of other family and child factors on such test scores has been less well demonstrated. The APA task force concluded that intelligence is the joint product of genetic and environmental influences and that further research is needed to identify which environmental factors influence cognitive performance over time and

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the processes (mechanisms) by which they influence development.

Huston, McLoyd, and Garcia-Coll (1994) argued that general systems models are needed to better identify factors that affect outcomes such as cognitive performance over time and to understand the mechanisms through which they operate among children reared in poverty. This involves the identification of different developmental patterns and the determination of the etiology of the differences (Loeber, 1989). General systems theory describes human development as influenced by a hierarchy of factors that can facilitate or impair development, including characteristics of the child, caregivers, family, immediate environment, and the culture in general (Bronfenbrenner & Crouter, 1983; Ramey, MacPhee, & Yeates, 1982; Sameroff, 1983). Such models also describe a multitude of risk and protective factors both for children experiencing poverty and for children in general. Not only do the models identify the levels of influence and risk factors, they also emphasize the dynamic transactions between the child and his or her environment. They describe developmental patterns as a function of the child's innate characteristics and the proximal and distal environment. Development is an iterative process by which the child changes in response to interactions with the environment, which, in turn changes the environment itself. For example, frequent responsive and stimulating interactions with caregivers are believed to facilitate children's cognitive development because responsive interactions should provide scaffolded learning experiences. This should, in turn evoke more responsiveness in the infant to the caregiver, making the interactions between infant and caregiver more rewarding and, thus, increasing the amount of stimulation the infant receives. As this cycle continues, the infant learns increasingly more about his or her world through interacting with the caregiver and by seeking out interactions with others.

Such models serve as useful heuristic devices to explain the influence of the two major determinants of cognitive performance identified by Neisser et al. (1996): the parental cognitive levels and the educational stimulation in the child's environments. General systems theory suggests that the cognitive level of the parent should have a direct effect on the child's intelligence through genetic effects and an indirect influence through its potential impact on caregiving attitudes, interaction styles, and the quality of the family environment (Neisser et al., 1996). Research has documented the direct effects of parental IQ, beliefs, and parenting practices. Except for the infancy period, maternal IQ directly and strongly predicts children's cognitive performance over time both for low-income African American and white children (Martin, Ramey, & Ramey, 1990; Ramey, Yeates, & Short, 1984; Sameroff, Seifer, Baldwin, & Baldwin, 1992) and for U.S. children in general (Furstenberg, Brooks-Gunn, & Chase-Lansdale, 1989; Scarr, 1992). Responsive and stimulating family environments have been positively correlated with children's cognitive test performance in predominantly low-income samples of mixed ethnicity (Bradley, 1985; Bradley et al., 1994). Measures of the responsiveness of the family environment predicted both the mean level of cognitive test scores and the patterns of change over time in such scores among middle-class white children (McCall, Appelbaum, & Hogarty, 1973) and among low-income African American children (Ramey, Lee, & Burchinal, 1989). Indeed, a recent large scale longitudinal study of cognitive performance demonstrated that the responsiveness and stimulation in the family environment largely accounted for obtained differences among different ethnic and poverty groups (Duncan, Brooks-Gunn, & Klebanov, 1994). Furthermore, investigators have shown that authoritarian child-rearing attitudes are negatively correlated with cognitive performance over time for children in general (cf. Miller, 1988) and for predominantly low-income and African American children (Campbell, Goldstein, Schaefer, & Ramey, 1991) and white children (Sameroff et al., 1992). However, there is a need for further study of the alternative or diverse developmental pathways of cognitive performance among minority children and of the ways in which parental beliefs and practices foster differences in such patterns over time (Garcia-Coll, 1990) and to determine the extent to which parental IQ may have indirect effects through parenting beliefs and practices (Neisser et al., 1996).

As predicted under a general systems model, child characteristics also have been shown to be related to cognitive development. Better academic, linguistic, or cognitive outcomes, for example, have been found for females in both middle-class and low-income, white and African American samples of children (Patterson et al., 1990). Several investigators reported that children with easy temperaments had higher cognitive test scores among predominantly middle-class children (Belsky, 1980; Slomkowski, Nelson, Dunn, & Plomin, 1992). Similarly, task orientation during infancy has been related to better cognitive performances among both predominantly middle-class children (DiLalla et al., 1990) and African American lower-class children (MacPhee & Ramey, 1980).

Also consistent with the general systems model, early childhood interventions in a variety of models have been provided for poor children based on the assumption that poverty too often has detrimental effects on the educational value of the early environment. Center-based programs have been implemented based on the assumption that frequent, responsive, and stimulating interactions with caregivers and exposure to a variety of educational materials and experiences will enhance children's cognitive development over time. Program evaluations clearly support this assumption, at least for the duration of the intervention (Haskins, 1989). Compared with controls, low-income children who attended high-quality child care centers display higher cognitive scores during the preschool years (Lazar, Darlington, Murray, Royce, & Snipper, 1982). For the most intensive early childhood programs, such benefits endured into adolescence (Campbell & Ramey, 1994; Garber, 1988). In addition, compared with control children, children who received early interventions were more likely to be promoted in school, to graduate from high school, and to become productive young adults (Lazar et al., 1982; Schweinhart, Weikart, & Larner, 1986). In contrast, control children were more likely to be retained in grade, to be placed in special education, and to drop out of school (Lazar et al., 1982).

Successful early intervention programs that involved home visits, where professionals or paraprofessionals regularly visited with the child's parents to work with both the parent and child, have also been reported (Gordon & Guinagh, 1978; Gutelius, Kirsh, MacDonald, Brooks, & McErlean, 1977). Parent or family focused interventions concentrate on changing the parents' expectations for and interactions with their child. It is assumed that more stimulating and responsive interactions between parent and child will enhance the child's cognitive performance over time, and, furthermore, that these changes should be more enduring than those associated with center-based programs because the family's influence will continue after the intervention ends. Family-focused programs have reported successfully changing the quality of parent-child interactions, altering the intellectual stimulus quality of the home, and raising children's cognitive scores over time (e.g., Bradley et al., 1994; McGowan & Johnson, 1984), but not all home visiting programs are successful (Olds & Kitzman, 1993). High-quality programs that involved both home visit and child care interventions have shown large effects on child test performance (Infant Health and Development Program, 1990) and sometimes long-lasting positive effects on educational attainments and life adjustment (Gray & Klaus, 1970; Schweinhart et al., 1986) among children at risk for suboptimal development due to low birthweight, poverty, or both.

Although such evidence is impressive, we need to know more about the underlying processes that account for the successes. Whereas previous research has demonstrated that early childhood programs can enhance cognitive performance, and, in turn, academic outcomes, the processes by which successful interventions change cognitive development have not been adequately documented. The purpose of this study was to examine these issues in secondary data analysis of data from two linked prospective early intervention studies.

Previous research with these samples has demonstrated that a variety of cognitive pathways characterizes performance over time during early childhood among this predominantly African American, economically disadvantaged sample (Ramey et al., 1989). Children thought to be at risk for school failure due to socioeconomic factors were recruited and randomly assigned at birth to receive a child care intervention, a family-focused home-based intervention, or no preschool intervention. The children in the research described here have participated in intervention studies based on a general systems model (Ramey et al., 1982) that emphasizes the role in development of transactions between the child and both the proximal and distal environment (shown in part in Figure 1). Children showing higher cognitive performance over time were most likely to have received child care intervention and have mothers with higher cognitive test scores (Ramey et al., 1989). In contrast, whether the children's cognitive performance increased or decreased during the preschool years was related to the responsiveness and stimulating characteristics of the child's family environment. Similarly, previous cross-sectional and longitudinal research with this sample has demonstrated that attending high-quality child care resulted in higher IQ scores during early childhood (Ramey et al., 1984; Wasik, Ramey, Bryant, & Sparling, 1990), middle childhood (Ramey & Campbell, 1991), and early adolescence (Campbell & Ramey, 1994). In addition, cognitive performance over time has been shown to be positively related to the infant's responsiveness (MacPhee & Ramey, 1980), the mother's IQ (Ramey et al., 1984), the mother's democratic nonauthoritarian parental attitudes (Campbell et al., 1991), and responsiveness and stimulation of the family environment (Ramey, Yeates, & Short, 1984). However, none of the previous analyses has simultaneously examined the associations of child, mother, family environment, and treatment factors with the developmental trajectories of the children.

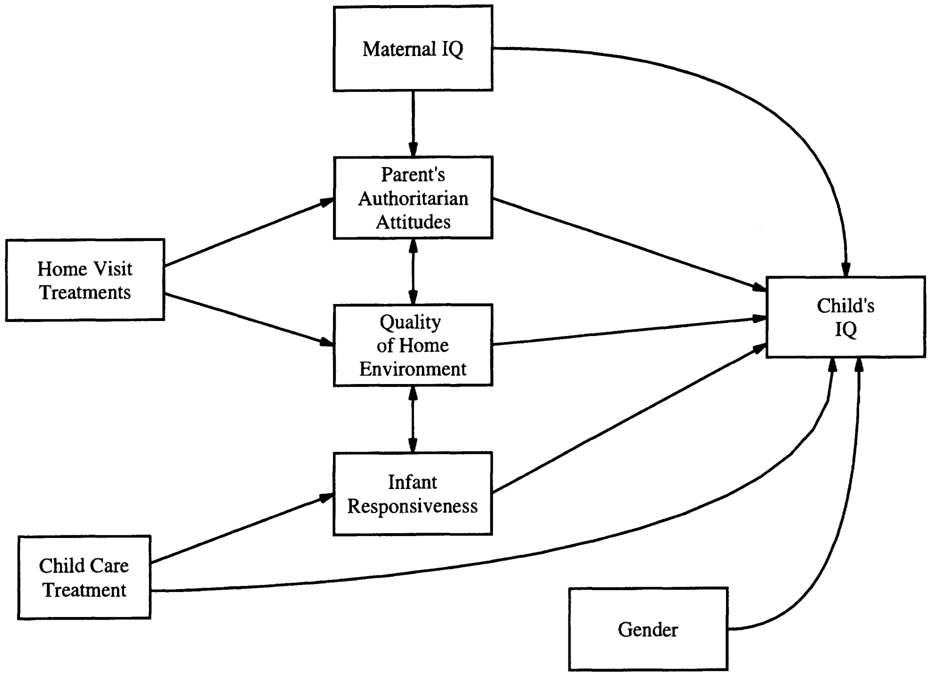

Figure 1 **Proposed model describing cognitive performance over time as a function of quality of caregiving, mediated by infant responsiveness.**

We examined these issues in an analysis of longitudinal assessments of children's cognitive performance from 6 months to 8 years of age, relating individual patterns of cognitive performance over time to characteristics of the child, mother, and family environment. We were interested in testing hypotheses about mediating processes that, in part, account for treatment and maternal IQ effects on cognitive performance over time. We postulate that early intervention affects cognitive performance, in part, through responsive caregiving by child care teachers in the child care intervention or by parents in the home visit intervention, which, in turn, enhances the infant's responsiveness to people and objects in his or her environment. Increased infant responsiveness should encourage more interactions with adults and more engaged interactions with objects. This iterative process should facilitate cognitive performance (see Figure 1 for hypothesized model). In addition, we postulate that maternal IQ will have both direct and indirect effects through its potential impact on the quality of the family environment and parental attitudes. Several interrelated developmental issues were addressed by (1) describing the developmental patterns of cognitive performance exhibited by low-income African American children; (2) identifying interventions that enhance cognitive performance among these children; (3) identifying characteristics of the child, mother, and family environment related to patterns of cognitive performance over time for these children; and (4) identifying factors that may serve as mediators of the impact of early interventions and maternal IQ on cognitive performance over time for these low-income African American children.

METHOD

Participants

Children living in or near a Southeastern university town who were determined to be "at risk" for school failure due to socioeconomic factors were recruited to participate in two consecutive longitudinal studies on the effectiveness of early intervention: the Abecedarian Project (Ramey & Campbell, 1991) and a related study, Project CARE (Wasik, Ramey, Bryant, & Sparling, 1990). Of the 167 children with cognitive data, most children (95%) were African American. Six European American children were deleted from the present analyses to increase the homogeneity of the sample (one child from the 104 children in the Abecedarian Project and five from 63 children in Project CARE).

Of the 161 African American children, 26 children had at least one, but not all, cognitive assessments, and 135 children had complete cognitive data. The children with incomplete cognitive data were children who missed one or more cognitive tests because their family moved out of the area ($n = 10$), the child died during early childhood ($n = 2$), or the child missed at least one testing assessment while continuing to participate in their study ($n = 14$). Comparisons of children with incomplete cognitive data with the 135 children with complete data did not reveal any significant differences on maternal characteristics (income, age, education, marital status, IQ), child characteristics (ethnicity, gender), treatment assignment, or project, so the data were combined to be analyzed with methods that permit some missing data. Thus, subsequent analyses were based on the 161 children with at least some cognitive data over time.

At the birth of the child, mothers of children in both programs tended to be young, single, undereducated, and with low incomes (many reported no earnings at all). There were 85 male children and 76 females. See Table 1 for a listing of the demographic characteristics of the sample.

Intervention Studies

Children were enrolled in one of two sequential studies, the Abecedarian Project or Project CARE. In both projects, children were randomly assigned to treatment or control groups during the first 3 months of life and followed longitudinally. Both studies were conducted in the same community and in the same university-affiliated child development center; they used comparable criteria to determine eligibility for participation (High Risk Index: Ramey & Smith, 1977); and provided similar child care and school-aged treatments. Both studies included an intensive preschool intervention in a child care setting and a family-based school-aged intervention. Project CARE, however, also included a family-based intervention from infancy to school age.

The Abecedarian Project recruited children born between 1972 and 1977. At entry to school, half of the children within each of the two randomized preschool groups were randomly assigned to receive a home-school resource teacher program during the first 3 years of elementary school (see Campbell & Ramey, 1994, for more details). Children recruited for Project CARE (Carolina Approach to Responsive Education) were born between 1978 and 1980 and randomly assigned to one of three treatment groups: child care plus home visits, home visits only, or control (see Wasik, Ramey, Bryant, & Sparling, 1990, for more details). All CARE children assigned to either the child care plus home visit or home visit only groups also received the home-school resource teacher treatment during the first 3 years of elementary school. Figure 2 illustrates the services received by the children in these two studies.

Three educational treatments were provided: educational child care from 6 weeks to school entry, home visit from 6 weeks to school entry, and home school resource services during the child's first 3 years of school. They varied in terms of intensity and orientation. The child care treatment was essentially child-centered and offered the most intensive exposure to education. The home visit and home-school treatments were less intensive and were family-oriented, emphasizing the role of the parent as a change agent in the child's development.

The child care treatment involved attending the child care at the child development center from infancy until entry to kindergarten. Children attended 6–8 hours a day, 12 months a year. The center maintained the NAEYC recommended caregiver-staff ratios (i.e., 1:3 for infants and toddlers, 1:4 for 2-year-olds, 1:6 for 3 to 5-year-olds), provided regular in-service training for staff members, and had a specified curriculum (namely, *Learningames;* Sparling & Lewis, 1979, 1984). The curriculum was designed to provide a stable, predictable, intellectually stimulating environment to enhance cognitive, social, and emotional development in low-income children. Teacher education varied from high school to masters level, and all teachers attended semi-annual inservice training.

The preschool home visit treatment involved home visitors who delivered an educational curriculum in the home. The home visitors' educational background ranged from high school to masters' level educators and social workers. Home visitors encouraged and modeled positive parent-child interactions, provided the family with support, served as an advocate for the family, and promoted effective coping skills. The home visitors also used the *Learningames* curriculum (Sparling & Lewis, 1979, 1984) and a problem-solving approach. They demonstrated and described developmentally appropriate activities and helped the family identify home materials suitable for such activities. The problem-solving curriculum (Wasik, Bryant, & Lyons, 1990) involved semistructured discussions between the home visi-

Table 1 Sample Description

Family and Child Characteristics	%	*M*	*SD*	*Range*
Mother's characteristics at birth of child:				
Age in years	...	20.3	4.8	13–44
Education in years	...	10.5	1.7	6–15
% less than high school	67	...	...	...
% high school	34	...	...	...
% more than high school	5	...	...	...
IQ	...	84.8	10.2	50–111
Marital status:				
% married	19	...	...	...
% single, never married	75	...	...	...
% separated or divorced	6	...	...	...
Family characteristics:				
Parental attitudes:				
Authoritarian scale (PARI), 6 months	...	39.5	9.9	16–62
Authoritarian scale (PARI), 18 months	...	37.8	10.0	14–63
Authoritarian scale (PEI), 3 years	...	23.5	5.2	6–32
Authoritarian scale (PEI), 8 years	...	27.4	3.8	16–35
Home Observation Measurement of the Environment (proportion of items passed):				
HOME total (infant version), 6 months	...	.61	.12	.29–.84
HOME total (infant version), 18 months	...	.66	.13	.31–.91
HOME total (infant version), 30 months	...	.67	.13	.36–.96
HOME total (preschool version), 42 months	...	.70	.12	.36–.91
HOME total (preschool version), 54 months	...	.74	.11	.40–.91
HOME total (school version), 8 years	...	.78	.09	.58–.96
Child characteristics:				
Gender (% male)	53	...	...	...
Task orientation (IBR):				
Task orientation factor score, 6 months	...	19.7	4.1	8–28
Task orientation factor score, 12 months	...	21.4	3.4	11–30
Task orientation factor score, 18 months	...	21.5	4.0	10–31
Task orientation mean score	...	20.8	2.6	14–27.5
Cognitive scores:				
Bayley MDI, 6 months	...	105.2	15.3	61–139
Bayley MDI, 12 months	...	109.0	15.1	57–137
Bayley MDI, 18 months	...	99.9	15.8	54–136
Stanford Binet, 24 months	...	90.1	12.3	57–121
McCarthy, 30 months	...	97.8	14.6	65–150
Stanford Binet, 36 months	...	92.7	15.0	53–124
McCarthy GCI, 42 months	...	97.6	12.7	62–126
Stanford Binet, 48 months	...	94.4	12.3	64–128
McCarthy GCI, 54 months	...	95.4	12.9	48–119
WPPSI, 60 months	...	97.2	12.8	68–130
WISC-R, 78 months	...	95.2	12.3	58–127
WISC-R, 96 months	...	94.0	11.7	59–133

tors and the parents regarding ongoing concerns and ways that the parents could use problem-solving strategies to deal with them. Home visits were scheduled weekly during the child's first 3 years and at a schedule chosen by the parents for the child's fourth and fifth year.

School-age intervention involved having a resource teacher who worked between home and school to show parents how to supplement the child's regular education in the classroom. The program was provided for the first 3 years the child was in public school. Resource teachers created for each target child individualized educational activities, based on the child's current needs as identified by the classroom teacher. These activities were then delivered to the family to be used with the child at home. The goal

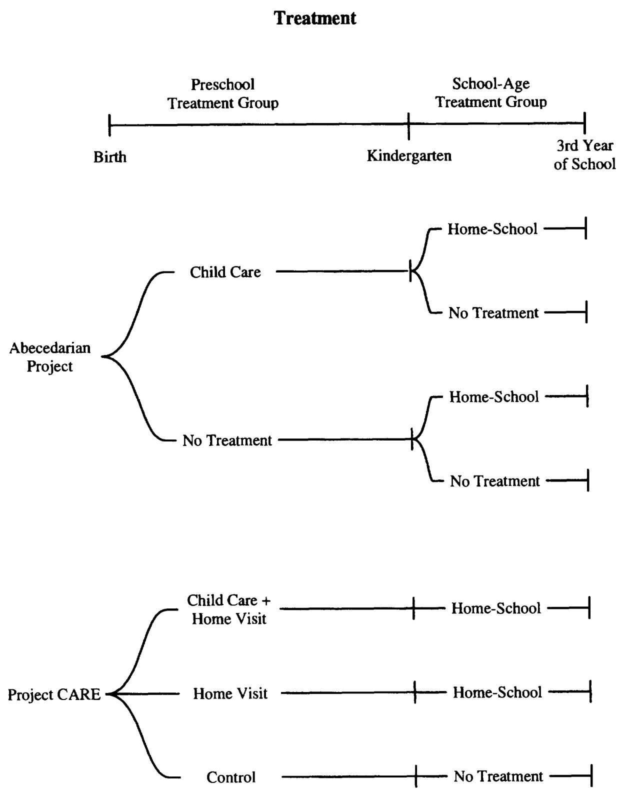

Figure 2 Schematic representation of treatment groups for the two studies.

was to reinforce the child's learning of basic reading and mathematics concepts by fostering parent involvement in the educational process. The resource teacher visited the homes and classrooms on alternative weeks, more often if necessary.

Measures

Predictors included treatments received and characteristics of the child, mother, and family. Outcomes of interest were longitudinal cognitive test scores.

Cognitive assessments. All children were assessed with an age-appropriate, standardized, individually administered intelligence test between the ages of 6 and 96 months: the scores from the Bayley Scales of Infant Development (Bayley, 1969) at 6, 12, and 18 months; the Stanford Binet (Terman & Merrill, 1972) at 24, 36, and 48 months; the McCarthy Scales of Children's Abilities (McCarthy, 1972) at 30, 42, and 54 months; the Wechsler Preschool and Primary Scale of Intelligence (WPPSI; Wechsler, 1967) at 60 months; and the Wechsler Intelligence Scale for Children—Revised (WISC-R; Wechsler, 1974) at 78 and 96 months. All tests used included African American children in their standardization populations, and all report good reliabilities. For example, the average reliability of the WISC-R full-scale IQ was reported as .96, of the full-scale WPPSI IQ ranged from .93 to .96, and of the Stanford Binet IQ as ranging from .91 to .99 across the age range of the test. All tests except the Bayley (1969) have been shown to have good predictive ability using achievement and other cognitive scores as the criterion for European American and African American children and all tests but the Bayley intercorrelate highly (Sattler, 1990).

Child assessments were conducted by white and African American female examiners who were trained in the assessment of infants and children, but who were not affiliated with the educational program. The WISC-R at 8 years was administered by individuals completely blind to the child's treatment history. The more comprehensive score yielded by each instrument (e.g., full scale IQ) was used in the present analyses.

Academic outcomes. At age 8 years, all children were individually administered the reading and math sections of the Woodcock-Johnson Psycho-Educational Battery, Part 2 (WJ, Woodcock & Johnson, 1977). The WJ subtests that measure reading include letter word identification, word attack, and passage comprehension, whereas the math subtests include applied problems and calculation. Scores on these subtests are combined to create reading and math cluster scores, which may be converted to grade- or age-referenced standard scores or percentiles. The test norms are based on a nationally stratified sample that contained African Americans in proportion to their numbers in the population. The test-retest reliabilities were reported as .98 for reading and .92 for math.

Infant responsiveness. The Infant Behavior Record (IBR) was completed when the infant was 6, 12, and 18 months of age by the examiner who administered the Bayley Scales of Infant Development (Bayley, 1969) to the infant. Factor scores representing the infant's activity level, sociability, and task orientation during the Bayley testing were computed from items on the IBR (MacPhee & Ramey, 1980; DiLalla et al., 1990). The task orientation factor reflects the extent to which the infant is responsive to the examiner and to test materials. The task orientation factor score was included in analyses because this behavioral characteristic has proven to be one of the best infant predictors of later cognitive performance over time (DiLalla et al., 1990) and should be able to serve as a measure of the general responsiveness of the child to his or her environment. Good interrater agreement was obtained ($r > .90$) when a second trained examiner also completed an IBR after observing the testing session for a subset of the infants.

A total IBR task orientation score was created by computing the mean of the task orientation factor scores from the three assessments during infancy.

Maternal measures. Demographic characteristics and maternal IQ (Wechsler Adult Intelligence Scale; Wechsler, 1955, and the WISC-R; Wechsler, 1974, for the few very young mothers) were obtained at entry to the study. Marital status, maternal and paternal age, education, employment status, and family income were recorded during an entry interview. Similar questions were asked during annual interviews for the child's first 5 years and at 8 years.

The mothers' authoritarian caregiving attitudes were measured with the Parent Attitude Research Instrument (PARI; Schaefer & Bell, 1958) when the infants were 6 and 18 months of age and with the Parent as Educator Interview (PEI; Schaefer & Edgerton, 1985) when the children were 3 and 8 years of age. The Authoritarian Control factor from both instruments assesses the extent to which caregivers emphasize rigid obedience and respect in parent-child relations. Test-retest reliabilities for these scales ranging between .44 and .90 have been reported in other samples for Authoritarian Control.

Quality of the family environment. The responsiveness and educational stimulation of the family environment were assessed annually from 6 to 54 months and at 84 months with the Home Observation for Measurement of the Environment (HOME; Caldwell & Bradley, 1979). The three versions of the HOME (infant, preschool, and school-aged) were used with all families. These instruments provide an estimate of the intellectual stimulus value of the family environment and the quality of the parent-child interaction. Items are scored through a combination of systematic observation and interviewing the parent. Because the number of items differ on the three versions of the HOME, the total score from each of these six assessments (at 6, 18, 30, 42, 54, and 84 months) was recomputed as the proportion of items passed. Caldwell and Bradley (1979) reported an estimate of .93 for internal consistency reliability for the entire scale. Bradley (1992) reported that comparable factor structure and predictive validity were obtained with European American and African American samples.

Data Analysis

The relations between the selected preschool child, mother, and family environmental characteristics and patterns of cognitive performance were explored by estimating individual patterns of cognitive performance over time and identifying factors that differentiated children who displayed different patterns. Four sets of models were fit to the longitudinal cognitive data to test the proposed mediating roles of child responsiveness and responsiveness of the family environment using the methods described by Baron and Kenny (1986). The first model included as predictors age, treatment, the mother's marital status, and child gender. The second model included all of these predictors and added maternal IQ. The third model added the mother's authoritarian attitudes and the responsiveness of the family environment to test the hypotheses about the mediating role of the family environment and parental attitudes on the association between maternal and child cognitive performance. The final model consisted of the child's task orientation factor score as well as all factors included in the first three models to test the hypothesis about the mediating role of infant responsiveness on the relations between early intervention and cognitive performance over time.

These successive models were compared by examining the relative fit of the models. Evidence of the mediating effects of the family environment and maternal attitudes on the association between maternal IQ and the child's cognitive performance involved demonstrating that the relative fit was better when the HOME and maternal attitudes scores were included in the model and the parameter estimate for maternal IQ was smaller when those variables were considered. Similarly, evidence of the mediating effects of the infant's task orientation involved demonstrating a better fit when task orientation was added to the model and showing that adding task orientation reduced the magnitude of the parameter estimates for treatment.

These models were fit to the data through growth curve analysis (Bryk & Raudenbush, 1987; Burchinal, Bailey, & Synder, 1994; Francis, Fletcher, Stuebing, Davidson, & Thompson, 1991; Willett, 1989) of the 12 cognitive scores. Growth curve methods permit the examination of individual development patterns and the identification of factors related to those patterns by distinguishing between *within-individual* developmental patterns and *between-individual* differences in those patterns (Burchinal & Appelbaum, 1991). Hierarchical linear models (HLM) estimated individual intellectual growth curves and identified child, family, and treatment characteristics related to patterns of development. As a follow-up analysis of individual differences, the academic achievement at 8 years of age was correlated with indices describing the individual cognitive growth curves.

The HLM analytic method can be viewed as a generalization of the multivariate repeated-measures analysis of variance method that can more optimally examine patterns of individual development and identify factors related to development (Willett, 1989). Individual and population growth curves are estimated simultaneously to describe patterns of change over time and to identify factors associated with those developmental patterns. Specifically, HLM analyses estimate individual and population growth curves from the fixed- and random-effect variables, respectively, specified in the analysis model (Bryk & Raudenbush, 1987; Burchinal et al., 1994). The iterative estimation process is divided into the estimation of the population (i.e., between-subjects) growth curves and the individual (within-subject) growth curves. Time-varying covariates and data from individuals with some missing assessments can be included in HLM analyses because individual growth curves are estimated under the assumption that they vary systematically about group growth curves.

In our HLM, the group and individual growth curves were estimated from the 12 cognitive scores using a cubic polynomial model. Included in the analyses were data for children with any cognitive data ($n = 161$) after analysis indicated the children with and without complete data were not significantly different. The random variables in these HLM analyses included the child-specific intercept and age, thus describing and adjusting for individual differences in overall IQ and the rate of change in IQ over time. A polynomial growth curve model was used to describe the pattern of change in cognitive performance over age by including as independent variables age, age-squared, and age-cubic. Both time-invariant and time-varying predictors were included in the analysis model. The time-invariant predictors included the factors that either did not vary over time (e.g., gender, project, and treatment group) or were only assessed during the child's infancy (e.g., the mother's IQ and the IBR task orientation scores averaged over the three assessments). The treatment predictors included the five treatment groups (child care followed by home-school teacher, home visit followed by home-school teacher, child care only, home-school teacher only, and no treatment), and project (whether the child was part of the Abecedarian Project or Project CARE). The child care and home-school group from the Abecedarian Project and the child care, home visit, and home-school group from Project CARE were combined into a single group when no differences emerged in comparisons. The time-varying predictors were the HOME total scores and the mother authoritarian attitude scores. Whether patterns of change were related to the child's gender, infant task orientation, the mother's IQ or parental attitudes, the HOME, or treatments was examined by fitting interaction terms between those variables and age. Nonsignificant interactions between age and the other predictors were deleted one at a time to enhance interpretation of results due to the high level of correlation among these interaction terms.

RESULTS

Intervention Analysis Groups

The sample described in this article consisted of the 161 African American children from the two studies with cognitive assessments between 6 months and 8 years of age. The number of children with cognitive assessments ranged from 160 at 6 months to 143 at 6.5 and 8 years. Assignment of the preschool treatment was random for both studies. Assignment to the school-age condition was random for the Abecedarian study and was linked to the child care or home visiting treatments for the CARE study. Of these 161 children, 64 received the child care intervention, 39 received the home visit intervention, and 85 received the school-age intervention. Some children received more than one treatment, as illustrated in Figure 2. The possible combinations included the child care and home-school treatment ($n = 39$), the home visit and home-school treatments ($n = 25$), only the child care treatment ($n = 25$), only the home-school treatment ($n = 21$), or no treatment ($n = 51$).

To justify combining data across these different studies and treatment conditions, a set of analyses was performed to determine whether the selected predictors or the outcomes were significantly different as a function of study or treatment combination. Analyses of variance tested the predictor and outcome variables for mean differences related to whether the child was in the Abecedarian or CARE study or whether the child received the child care, home visit, or home-school intervention(s). An interaction term was added to determine whether the child care intervention had a different impact on Abecedarian than on CARE children. The results of these analyses indicated that only one factor, child care intervention, was substantively related to these variables. Children who received the child care intervention were rated as more task-oriented during infancy, $F(1, 155) = 9.72$, $p = .002$, and as having higher IQ scores at the following ages: 12 months, $F(1, 154) = 8.9$, $p = .003$, 18 months, $F(1, 149) = 62.5$, $p < .001$, 24 months, $F(1, 149) = 36.4$, $p < .001$, 36 months, $F(1, 147) = 34.8$, $p < .001$, 42 months, $F(1, 145) = 19.5$,

$p < .001$, 48 months, $F(1, 146) = 19.0$, $p < .001$, 54 months, $F(1, 143) = 19.4$, $p < .001$, 60 months, $F(1, 142) = 11.9$, $p < .001$, 78 months, $F(1, 137) = 5.6$, $p = .02$, and 96 months, $F(1, 137) = 5.8$, $p = .02$. In addition, the CARE children scored significantly higher than the Abecedarian children at only two of the 12 assessments, at 18, $F(1, 149) = 12.0$, $p < .001$, and 36 months of age, $F(1, 147) = 4.6$, $p = .03$. The project × child care treatment interaction was not significant in any of the analyses. These results, along with the fact that the children had been randomly assigned to treatment and were recruited for the two studies in the same manner from the same community, indicated that combining the data across studies and treatments was appropriate in analyses that include treatment group and study as variables.

Descriptive Analyses

Stability of cognitive performance and risk factors. The across-time correlations of IQ, HOME Total, and the mother's authoritarian scores were examined to assess the stability of IQ and risk factors over time. As shown in Table 2, moderately high stability characterized these longitudinal measures. For example, the 12 longitudinal IQ scores showed moderate to high across-time correlations, except between infant and later assessments. Five of the six longitudinal assessments of the family environment displayed moderate across-time correlations, with somewhat lower correlations between 6-month and later assessments. Modest across-time correlations characterized the four longitudinal measures of authoritarian attitudes. Thus, both the child's cognitive performance and environment tended to be relatively stable during the preschool and middle childhood years when summarized across the entire sample.

Treatment and infant responsiveness. Whether the treatments were related to the degree to which the infants displayed increasing responsiveness to their environments was tested next. Table 3 displays the mean IBR Task Orientation scores at 6, 12, and 18 months for children in the five treatment groups. A repeated-measures analysis of variance indicated that the children who received the child care treatment showed greater increases in task orientation than other children, $F(4, 147) = 3.25$, $p = .01$, and they scored higher at 18 months than other children, $F(4,$

Table 2 Correlations among Repeated Assessments of Cognitive Performance, Family Environment, and Parental Attitudes

	Months										
IQ	12	18	24	30	36	42	48	54	60	78	96
MDI, 6 months	.56	.35	.42	.35	.33	.31	.28	.26	.28	.34	.18
MDI, 12 months		.58	.51	.52	.42	.37	.31	.28	.29	.32	.17
MDI, 18 months			.73	.70	.69	.60	.56	.55	.51	.48	.35
Binet, 24 months				.76	.70	.70	.67	.61	.60	.58	.44
McCarthy, 30 months					.68	.71	.65	.66	.65	.51	.44
Binet, 36 months						.71	.75	.70	.70	.62	.55
McCarthy, 42 months							.77	.77	.78	.67	.58
Binet, 48 months								.79	.76	.72	.68
McCarthy, 54 months									.82	.74	.70
WPPSI, 60 months										.82	.73
WISCR, 78 months											.79

HOME Total	18	30	42	54	96
6 months	.47	.43	.34	.33	.25
18 months		.54	.50	.45	.40
30 months			.56	.57	.48
42 months				.68	.48
54 months					.51

Authoritarian Attitude	18	36	60
PARI, 6 months	.67	.36	.41
PARI, 18 months		.47	.48
PEI, 36 months			.55
PEI, 60 months			

Note: All correlations are significantly different from zero.

Table 3 Treatment Group Means on the IBR Task Orientation Factor from 6 to 18 Months

	Treatment Group				
IBR Task Orientation	Child Care + Home-School (n = 38)	Child Care Only (n = 24)	Home Visit Home-School (n = 24)	Home-School Only (n = 20)	Control (n = 46)
6 months	19.8 (3.5)	19.4 (4.1)	20.4 (4.7)	18.0 (3.9)	20.0 (4.3)
12 months	22.0 (3.3)	21.7 (4.1)	21.5 (3.2)	20.0 (3.9)	21.2 (2.9)
18 months	23.8 (3.2)	22.3 (4.0)	19.0 (2.6)	20.9 (4.3)	20.6 (4.1)

Note: Standard deviations are in parentheses.

147) = 7.40, $p < .001$, but not at 6 months, $F(4, 147) = 1.12$, $p = .35$, or 12 months, $F(4, 147) = 1.27$, $p = .28$.

Growth Curve Analyses

The growth curve analyses examined the general systems model shown in Figure 1. Hierarchical linear model analyses of the cognitive scores were performed to identify linear and nonlinear patterns of cognitive performance. The degree to which stimulating and responsive care at home or in child care served as a mediator in cognitive performance over time was tested. Although there is not a summary statistic that describes the extent of variance accounted for by a given model using analytic methods that include both fixed and random effects, we used the squared correlation between predicted values under the fixed-effects model and the actual IQ scores as our surrogate.

Individual patterns of cognitive performance. Results from all four sets of analyses indicated that significant individual differences in patterns of cognitive performance over time were observed in the overall level of IQ and in the rate of change related to age (see the "Random-Effects Predictors" portion of Table 4). Examination of the individual growth curves also indicated that children with higher IQs tended to show more gains over time, with the mean level and rate of change being positively correlated. The overall pattern of cognitive performance was characterized by cubic change over time, $F(1, 1269) = 94.88$, $p < .001$. That is, the children tended to show a pattern of cognitive performance characterized by changes in direction in the growth curve: average to above average scores during infancy were followed by a marked dip between 18 and 24 months when the tests become more verbal, followed by modest increases in scores during the preschool years and modest declines during the early elementary school years.

Model 1: Cognitive performance and treatment. The first HLM analysis tested the extent to which the three treatments were related to cognitive performance over time. Model 1 in Table 4 lists the estimated IQ mean scores and rates of change over time for the children in the five treatment groups, adjusting for gender and mother's marital status. Figure 3 shows the group growth curves for the five treatment groups. Treatment differences were detected in the overall IQ levels, $F(4, 1269) = 11.76$, $p < .001$, and in patterns of linear, $F(4, 1269) = 5.93$, $p < .001$, quadratic, $F(4, 1269) = 4.81$, $p < .001$, and cubic, $F(4, 1269) = 6.56$, $p < .001$, change over time. Pairwise comparisons were conducted to identify which groups were different.

These comparisons indicated that children in the child care and home-school and the child care only treatment groups tended to have higher scores across time and displayed less change over time. As can be seen in Figure 3, the children in either treatment group that included the child care intervention tended to show higher, more stable cognitive scores beginning during late infancy than the children in the other three treatment groups. On average, the children in the two child care groups also showed less linear change and less curvature to their cognitive curves. They showed less decline in scores when the cognitive tests become more verbal during late infancy, and a slower decline in the early school years, accounting for the significant group × age-squared and group × age-cubed interactions. All pairwise comparisons involving the two child care groups and the other three groups indicated significant differences except for the comparison of the cubic age terms between the child care only and control groups, which did not quite reach significance. Pairwise comparisons of the home visit and home-school group, the home-school only group, and the control group indicated that the groups did not differ in terms of across-time mean IQ scores or the linear, quadratic, or cubic rates of change over time.

In addition, analyses indicated that cognitive performance was significantly associated with the mother being married, $F(1, 1269) = 7.12$, $p = .008$, but

Table 4 Growth Curve Analysis: Predicting Patterns of Cognitive Performance from Child, Family, and Treatment Factors

	Individual Growth Curves							
	Model 1		Model 2		Model 3		Model 4	
Random Effect Predictors	Variance	*SE*	Variance	*SE*	Variance	*SE*	Variance	*SE*
Degree of individual differences:								
Overall IQ (intercept)	80.96***	10.55	68.01***	9.02	62.80***	8.53	50.78***	7.23
Rate of change (age slope)	3.13***	.64	2.72***	.58	2.81***	.59	2.08***	.51
Covariance-intercept, age	2.96	1.86	.82	1.61	1.23	1.59	4.55**	1.45
	"R^2" = .10		"R^2" = .28		"R^2" = .31		"R^2" = .41	

	Group Growth Curves								
	Model 1		Model 2		Model 3		Model 4		
Fixed Effect Predictors	*B*	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*	Contrasts
Early interventions:									
Treatment (mean level at 4 years)[a]	***		***		***		***		
Child care and home-school	104.40	1.49	103.93	1.40	103.62	1.35	101.76	1.21	(CC+HS, CC)>
Child care only	102.22	2.02	103.33	1.91	103.06	1.85	102.42	1.61	(HV+HS, HS,
Home visit and home-school	91.51	2.30	91.09	2.17	91.52	2.09	92.45	1.81	Control)
Home-school only	91.74	2.16	91.72	2.03	91.76	1.95	93.53	1.71	
Control	95.34	1.34	95.31	1.26	95.57	1.21	95.86	1.07	
Project (CARE = 1)	3.40	2.09	3.21	1.97	2.84	1.89	2.55	1.60	
Treatment × age (linear change)[a]	***		***		***		***		
Child care and home-school	−1.27	.63	−1.38	.62	−1.64	.63	−1.22	.62	CC+HS<
Child care only	.43	.82	.70	.81	.18	.82	.32	.80	(HV+HS, HS,
Home visit and home-school	2.54	.84	2.48	.82	2.32	.82	2.05	.80	Control)
Home-school only	3.06	1.83	3.08	.82	2.88	.83	2.53	.81	
Control	1.45	.60	1.47	.59	1.10	.60	1.01	.58	
Treatment × age^2 (quadratic change)[a]	***		***		***		***		
Child care and home-school	.36	.10	.35	.10	.47	.10	.42	.10	(CC+HS, CC)<
Child care only	.29	.12	.30	.12	.37	.13	.35	.13	(HV+HS, HS,
Home visit and home-school	.85	.14	.84	.14	.96	.15	.99	.15	Control)
Home-school only	.69	.12	.70	.12	.79	.13	.89	.13	
Control	.76	.09	.77	.09	.87	.09	.88	.10	
Treatment × age^3 (cubic change)[a]	***		***		***		***		
Child care and home-school	−.07	.05	−.06	.05	−.05	.05	−.05	.05	(CC+HS, CC)>
Child care only	−.17	.06	−.18	.06	−.13	.06	−.12	.06	(HV+HS, HS)
Home visit and home-school	−.46	.07	−.46	.07	−.45	.07	−.43	.07	
Home-school only	−.33	.07	−.33	.07	−.31	.07	−.31	.07	CC+HS >
Control	−.26	.05	−.26	.05	−.23	.05	−.22	.05	Control
Mother characteristics:									
Mother's marital status (married = 1)	2.69**	1.01	2.80**	.98	2.18*	.98	2.09*	.92	
Mother's IQ (WAIS)									
Mean level			.37***	.07	.29***	.07	.24**	.07	
Mother's IQ × age			.05**	.02	.06***	.02	.08***	.02	
Parental attitudes (PARI/PEI)					−.80	.47	−.57	.44	
Family environment:									
Family environment (HOME):									
Mean level					16.32***	3.76	17.00***	3.72	
Family environment × age					−3.53*	1.60	−3.74*	1.55	
Family environment × age^2					−1.30**	.50	−1.66***	.49	
Child characteristics:									
Gender (male = 1, female = 0)	−1.78	1.51	−1.89	1.41	−1.86	1.36	−1.25	1.16	
Task orientation (IBR):									
Mean level							1.07***	.27	
Task orientation × age							−.32***	.07	
Task orientation × age^2							.07***	.02	

[a] Reported is the significance level of the test of differences among the five treatment groups.
* $p < .05$; ** $p < .01$; *** $p < .001$.

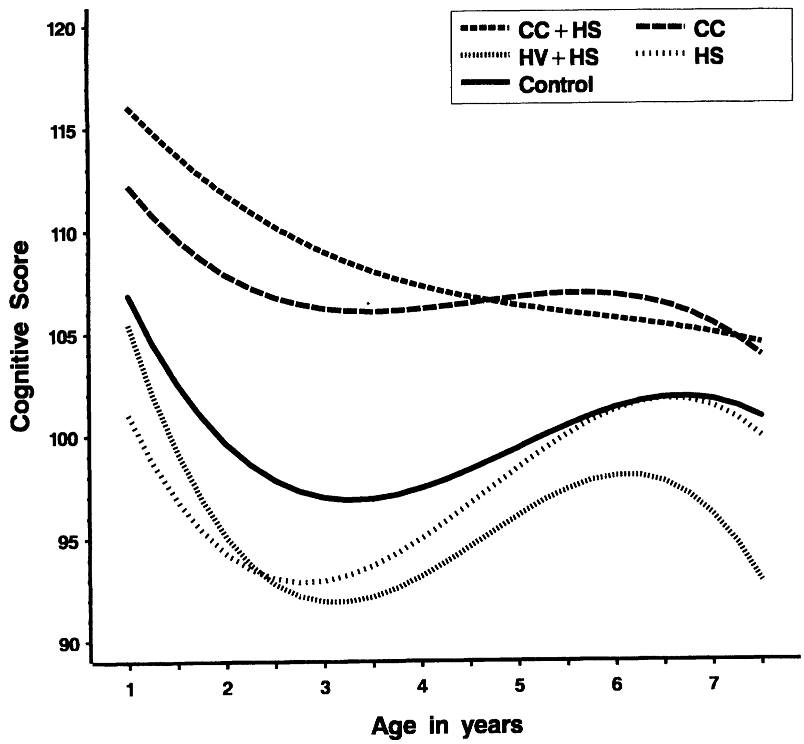

Figure 3 Growth curves of cognitive performance scores by intervention groups

not with child gender or whether the child participated in the Abecedarian or CARE projects. Children with married mothers tended to score slightly higher than children with unmarried mothers.

Model 2: Adding maternal IQ. The second HLM model added maternal IQ as a fixed effects predictor to the analysis model (see Model 2 in Table 4 for parameter estimates from this model). Maternal IQ was clearly a significant predictor of the mean level of cognitive performance, $F(1, 1269) = 27.89$, $p < .001$, and to patterns of linear change over time, $F(1, 1269) = 10.18$, $p = .002$. Higher maternal IQ was associated with higher cognitive performance over time and a pattern of increasing scores between 6 months and 8 years of age. Treatment groups and mother's marital status continued to be significantly related to cognitive performance in Model 2, showing similar patterns of association with cognitive performance as was obtained with Model 1.

Model 3: Family environment as a mediator. The third HLM analysis added measures of caregiving attitudes (maternal authoritarian score) and quality of the family environment (HOME score) and their interactions with age to the set of fixed effect predictors in the analysis model (see Model 3 in Table 4 for the parameter estimates and their standard errors). The HOME total score was significantly related to overall cognitive performance, $F(1, 1265) = 18.86$, $p < .001$, and to linear, $F(1, 1265) = 4.85$, $p = .03$, and quadratic rates of change over time, $F(1, 1265) = 6.84$, $p < .001$. Higher HOME scores were related to higher overall cognitive performance over time. The age × home interactions reflected the reduction over time in the linear association between the HOME and cognitive performance, with HOME scores being a stronger predictor of cognitive performance at younger ages than at older ages. The age-squared × home interaction occurred because children with higher HOME scores tended to show more curvature in their growth curves. In contrast, the mother's authoritarian attitude was not significantly related to cognitive performance in this model. In addition, cognitive performance continued to be significantly related to treatment and mother's marital status in this analysis.

Comparison of the results of Models 2 and 3 provided some evidence that the quality of the home environment, in part, mediated the relations between maternal IQ and child cognitive performance. The parameter estimate for maternal IQ decreased from $B = .37$ to $B = .29$ when these home and attitude variables were also considered, providing evidence that some of the variance accounted for by maternal IQ in Model 2 was also accounted for by these distal measures of parenting in Model 3.

Model 4: Infant responsiveness as a mediator. The final HLM analysis was performed to test the hypothesis that infant responsiveness mediated treatment effects on cognitive performance over time. The overall measure of infant task orientation was positively associated with overall cognitive performance (see Model 4 in Table 4 for parameter estimates and standard errors). Higher overall cognitive performance was observed among children with higher task orientation scores, $F(1, 1264) = 16.10$, $p < .001$. The interaction between age and task orientation reflects a trend of decreasing levels of association over time, with task orientation having a stronger relation with early assessments of cognitive performance than later assessments, $F(1, 1264) = 24.02$, $p < .001$. The interaction between age-squared and task orientation occurred because children with higher task orientation scores tended to have more curvature in the trajectories over time, $F(1, 1264) = 15.72$, $p < .001$.

Shown in Table 4, the results of the model with and without the hypothesized mediator were compared (Models 4 and 3, respectively). Comparisons of the two models in terms of the relative overall fit and magnitude of treatment effects suggest that infant responsiveness may mediate the impact of the child care intervention and maternal IQ, but not the HOME, on cognitive performance. Adding the child's IBR Task Orientation score increased the fit of the model from .31 to .41. In addition, both the predictors, child care treatment and maternal IQ, and the mediator, infant responsiveness, were significantly related to cognitive performance over time. Furthermore, the repeated-measures analyses reported above revealed that children who received the child care treatment showed a pattern of increasing scores on the task orientation scale during infancy compared with children in the home visit or control groups. Finally, the parameter estimates for treatment and for the interaction between age and treatment as estimated in models with the infant responsiveness mediator were smaller than those parameter estimates in the models without the mediator. The effect size of the child care treatment under Model 3 was 1.2 standard deviations ($SD = 8.8$) and under Model 4 was 0.9 standard deviations ($SD = 8.8$). Similarly, the parameter estimate for maternal IQ reduced from $B = .29$ to $B = .24$. In contrast, the parameter estimates for the HOME total score did not change much from Models 3 and 4. In summary, as suggested by Baron and Kenny (1986), these analyses provide evidence of mediation because the overall fit of the model improves with the inclusion of the mediator, the predictor and mediator both are related to the dependent variable, and the magnitude of the relation between the child care intervention and cognitive performance over time is clearly significant in the analysis without the mediator but is weaker when the mediator is added to that regression model.

Partial correlations between the child's cognitive scores, the child's average IBR Task Orientation score, the HOME total scores, and the mother's cognitive score were computed to provide a measure of effect sizes in the final model. This descriptive analysis involved computing the mean scores across time for each child on each of the analysis variables and then computing the partial correlations between pairs of variables. All of the other predictors in the final analysis model including treatment group were included as covariates when these partial correlations were computed. Results indicated that children's across time average cognitive scores were moderately correlated with their average IBR Task Orientation scores, $r(148) = .50, p < .001$, and modestly correlated with the average HOME scores, $r(148) = .25$, $p = .002$, and maternal IQ, $r(148) = .21, p = .008$. Consistent with the mediational model proposed, maternal IQ was also modestly correlated with the average HOME scores, $r(148) = .25$, $p = .002$.

Moderators of child care treatment effects. A post hoc analysis was conducted to determine whether any of the selected characteristics of the child, mother, or family environment moderated the impact of the child care treatment on cognitive performance. The child care treatment was the only treatment examined in this analysis because the other treatments were not significantly related to cognitive performance. Model 4 was modified to include child care as the only treatment. In addition, all interactions between the child care treatment and the other predictors were also estimated. The three-way interaction among the IBR Task Orientation mean, the child care treatment, and age-squared was the only interaction term significantly related to cognitive performance, $F(1, 1263) = 4.62, p = .03$, indicating that task orientation was associated with more curvature in the cognitive growth curves for children receiving the child care treatment. All other predictors showed similar patterns of association with cognitive performance as reported for Model 4.

Individual cognitive performance and academic achievement. In the last set of analyses, we asked whether the individual differences in cognitive growth curves related to the child's academic performance at 8 years. The estimated intercept and rate of change over time from each child's individual cognitive growth curve were correlated with their Woodcock-Johnson reading and math achievement scores. These analyses tested the extent to which individual patterns of cognitive performance contributed when the influences of the selected child, family, and intervention characteristics on cognitive performance were controlled. The across-time mean IQ level was a moderate predictor of both reading, $r(140) = .36$, $p < .001$, and math, $r(141) = .46$, $p < .001$, at 8 years, whereas the individual rate of change was only a modest predictor of reading, $r(140) = .24$, $p = .004$, and math, $r(141) = .32$, $p = .001$.

DISCUSSION

These results suggest that the cognitive performance over time of African American children from low-income families is enhanced by intensive high-quality early intervention and by specific child, maternal, and family environment factors. The impact of the child care intervention appeared to be, in part, mediated by the responsiveness of the infant to his or her environment. The child care intervention was linked to increased child responsiveness, which, in turn, was related to more optimal patterns of cognitive performance during the first 8 years of life. In addition, maternal IQ appeared to have both direct effects on the child's cognitive performance during early and middle childhood and indirect effects through its impact on the quality of the family environment and perhaps on infant responsiveness. These results are consistent with a general systems model that describes development as related to the transactions between the child and his or her environment.

Growth curve analyses are ideally suited for analyses of longitudinal data in which investigators seek to describe patterns of change over time and to identify correlates of those patterns, because they distinguish between intraindividual patterns of change and interindividual differences of developmental patterns by estimating both individual and group growth curves (Bryk & Raudenbush, 1987). Growth curve analysis was selected to analyze these longitudinal data instead of other approaches such as structural equations analysis (Willett & Sayer, 1994) or multivariate repeated-measures analysis of variance (O'Brien & Kaiser, 1985) for several reasons. Although all three methods estimate both group and individual growth curves from longitudinal data, HLMs offer two other advantages. Only the HLM approach allows for inclusion of data from individuals with some missing values without imputing those missing data. The group curves are estimated with HLM from weighted combinations of the parameter estimates from individual curves such that individuals with fewer observations or more unusual data are given less weight than individuals with more data or more typical data. As such, outliers are less likely to influence the estimation of the group growth curve with HLM. In addition, HLM easily incorporates repeated assessments of variables as predictors. Combined with the approach described by Baron and Kenny (1986) for examining the effects of mediating and moderating variables, we believe that the HLM approach provides the most appropriate analyses to examine our questions about longitudinal patterns of cognitive performance, factors related to those patterns, and potential mediators.

The growth curve analysis illustrated a general downward trend in performance for all high-risk groups over time but also showed the positive impact of early center-based intervention. Although marked individual differences characterized the longitudinal patterns of change among these children, the general tendency in these data was nevertheless similar to that described for other such study samples (Etaugh, 1980; Golden et al., 1978)—normal cognitive performance during infancy and somewhat below-normal cognitive performance during preschool and early elementary school years. It is important to note, however, that intensive early intervention lessened the detrimental effects of poverty on longitudinal patterns of change in cognitive scores. Children who received the child care treatment showed both higher cognitive scores and less decline over time in their scores, especially late in infancy as the cognitive tests become more verbal. Random assignment to treatment permits us to conclude that the high-quality child care early intervention program enhanced cognitive performance over time. By demonstrating how patterns of development are changed by center-based child care experiences, even when influential child and family characteristics are considered, these findings build on previous reports that high-quality, intense interventions enhance cognitive performance of low-income children (Lazar et al., 1982).

The impact of the child care intervention on the longitudinal cognitive performance appeared to be mediated, in part, by the intervention's impact on the infant's responsiveness to his or her environment. This finding addresses one of the key questions raised by Neisser and his colleagues (1996) in their review of the intelligence literature, namely, how environmental factors such as early intervention influence children's cognitive development. The present longitudinal analyses suggested that the infants assigned to the child care treatment become increasingly more responsive to the people and objects in their environment during the first 18 months of life when compared to the infants randomly assigned to other groups. We assume this resulted from frequent interactions with responsive adults in the child care center. The HLM results further suggest that increased infant responsiveness is clearly related to better cognitive performance during infancy, early childhood, and into middle childhood and that increased responsiveness may account, in part, for the child care treatment effect on cognitive performance. These findings are consistent with general systems models that indicate that responsive care by caregivers should increase infant responsiveness, which, in turn, should affect caregiver's reactions to the infant, leading to more adult-child interactions, which ultimately enhance the infant's development. They are consistent with previous research suggesting that this IBR factor is one of the best infant predictors of later cognitive performance over time (DiLalla et al., 1990). This finding provides further evidence that behavioral differences are related to cognitive performance over time in a low-income, African American group as well as in a middle-class sample (DiLalla et al., 1990).

These results also suggest that successful generalization of these child care intervention results into community child care or other early intervention programs for children from poor families should focus on ensuring that children, beginning in infancy, receive care from responsive adults. Such care requires good adult-child ratios as recommended by the National Association for the Education of Young Children to permit the extensive teacher-child interactions that promote infant responsiveness to people and objects. More extensive training of teachers in infant classrooms is also needed to ensure that their interactions styles are responsive, contingent, and positive when they interact with infants and toddlers. These results in conjunction with results from other intervention studies suggest that responsive care beginning in infancy and continuing through entry to kindergarten may be necessary to achieve long-term child care effects on cognitive outcomes. The results from this study indicate that the children in the child care intervention had cognitive trajectories adequate for continued growth and development as early as 18 months of age. This study could not test how later entry or earlier ending of care would have changed the developmental trajectories, but the long-term child care effects are not obtained if the intervention ends at 3 years (Infant Health and Development Program, 1997).

In this study, less intensive, family-focused interventions were not related to improved patterns of intelligence test scores over time. Although quality of the family environment was a powerful predictor of such scores across time, neither the preschool home visit treatment nor the home-school resource teacher treatment was significantly associated with improved patterns of cognitive performance. Unexpectedly, the preschool home visit program was related neither to the quality of the family environment nor to the child's cognitive performance. The focus of the home visit program, supporting parenting skills and enhancing the quality of the family environment, should relate to cognitive outcomes, but the intervention was unsuccessful in changing the family environment. One explanation for this finding is that a weekly home visit intervention may not be intense enough to yield effects, at least not in the domains we measured. Indeed, in a comprehensive review of home-visit programs, Olds and Kitzman (1993) noted many home visit studies with few or no effects.

Other developmental processes underlying the cognitive performance over time of these children can be inferred indirectly from the present growth curve analyses. The results were consistent both with our general systems model (Figure 1) and with McLoyd's (1990) person-context-process theory, suggesting that quality of caregiving was a strong determinant of cognitive performance over time among these low-income children. Analyses supported much of the model depicted in Figure 1 by supporting hypothesized direct lines from maternal IQ, quality of the family environment, and the child care intervention to cognitive performance during early childhood and the mediating effects of maternal IQ on the quality of the family environment and of the child care intervention through infant responsiveness. These analyses indicate that, from infancy through age 8, cognitive performance was strongly associated with the degree of responsive, stimulating care available to the child at home or in child care. Early childhood education in a quality child care facility and the quality of the family environment were both related to higher child test scores over time, even after adjusting for maternal IQ. Consistent with previous work, maternal ability showed increasingly positive correlations with child IQ as the child grew from infancy into the preschool and early school-age years and also showed that mothers with higher intelligence test scores tended to have children with higher intelligence test scores, who showed more gains in their scores across the preschool years (Benson, Cherny, Haith, & Fulker, 1993; McCall, 1977). Furthermore, as expected under a general systems model, we found evidence that maternal IQ has both a direct effect on the child's cognitive performance and an indirect effect through its association with the quality of the family environment and, perhaps, its association with the infant's responsiveness.

The goal of the final post hoc analysis was to predict which children might benefit most from the child care intervention. Results indicated that neither the selected characteristics of the mother or family environment moderated the child care intervention effects. Higher cognitive scores over time were associated with higher maternal IQ and HOME scores for children who did and did not receive the child care intervention. Infant responsiveness was the only factor identified that potentially could be used to determine which children might most benefit from the child care intervention. However, the repeated-measures analysis of variance of the treatment and time differences in IBR scores during infancy suggests that a more likely explanation for this finding is that the child care intervention had its impact by making infants more task oriented.

These results provide further evidence of the malleability of cognitive performance during early childhood. They also address several of the nature-nurture issues raised in the comprehensive review of the literature by Neisser and colleagues (1996). Like previous work, we did find that the magnitude of the association between cognitive performance and the family environment decreased from infancy to middle childhood whereas the association between maternal and child test performance increased. In contrast to much of the previous work, the family environment and the child care intervention both remained substantial predictors in the analysis models even at the last assessment at 8 years of age. In conjunction with other Abecedarian and CARE project papers, the results from these projects provide clear evidence that intensive, high-quality, child care interventions can change the developmental trajectories of cognitive performance and enhance academic outcomes for African American children from low-income families. As such, they provide further evidence related to educability by demonstrating that intelligence test scores of African American children from low-income families can be increased through changing the child's experiences during early childhood and that these changes can be enduring. Furthermore, these results suggest that the family environment appears to be a substantial predictor of cognitive development within this population, even after adjusting for direct and indirect effects of maternal IQ. Indeed, within this sample, the association between children's cognitive development and the quality of the home environment as measured by the HOME is as strong as or stronger than the association with maternal IQ. This result differs from those of other studies that contrasted the genetic and environmental effects on cognitive performance among predominantly middle-class families (cf. Neisser et al., 1996). This discrepancy suggests that between-family differences, such as those in the home environment, perhaps can have more long lasting consequences for low-income African American children than for middle-class children.

Several limitations should be considered. First, we did not include in the analysis any proximal process-oriented measures of caregiver-child interactions. Instead, we had available only measures of the family environment and of the mother's attitudes toward parenting as measures of parenting, and assignments to treatment group as our measure of intervention. Second, it is clear that IQ tests provide a reliable measure of one aspect of intelligence, but they clearly do not describe all aspects of intelligence (Neisser et al., 1996). This study has examined only those aspects of intelligence that are measured by standardized infant cognitive and child IQ tests. Third, we cannot examine specific aspects of the interventions such as number of home visits or the impact of specific characteristics of child care teachers because such data are not readily accessible or were not collected. Fourth, although we believe that the child care intervention would be effective with other low-income populations, this sample included only African American children. Future research in which longitudinal patterns of children's cognitive performance are examined should include better measures of caregiving styles of the parents and other caregivers; measures of factors such as motivation, self-efficacy, and family functioning; measures of other aspects of intelligence; and more diversity in the populations sampled.

In conclusion, these analyses revealed developmental diversity among low-income African American children and related alternative developmental pathways to environmental influences. More optimal patterns of cognitive performance over time were associated with higher maternal IQ, responsive and stimulating care at home, and the provision of intensive early educational child care. The impact of intensive, educational child care on cognitive performance appeared to be mediated through the enhancement of infant responsiveness to people and objects among children attending the intervention child care center.

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