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Child Care in Infancy and Cognitive Performance Until Middle Childhood in the Millennium Cohort Study

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This study used a British cohort ($n = \sim 13,000$) to investigate the association between child care during infancy and later cognition while controlling for social selection and missing data. It was found that attending child care (informal or center based) at 9 months was positively associated with cognitive outcomes at age 3 years, but only for children of mothers with low education. These effects did not persist to ages 5 or 7 years. Early center-based care was associated with better cognitive outcomes than informal care at ages 3 and 5 years, but not at 7 years. Effect sizes were larger among children whose mother had low education. Propensity score matching and multiple imputation revealed significant findings undetected using regression and complete-case approaches.

The majority of children in developed countries receive nonmaternal child-care services during early childhood despite widespread concern about their potentially detrimental impact on children's social and cognitive development (UNICEF, 2008). Furthermore, in recent years, many governments have adopted the explicit goal of expanding child-care coverage, often through publicly funded universal child-care subsidies. Research examining the impact of child care on child developmental outcomes has led to substantially heterogeneous results, and the direction and magnitude of the effects vary according to several important parameters (NICHD ECCRN, 2006). These parameters include the age at which child care is initiated, the use of child care or maternal employment as a predictor of child development, the type of child care under consideration (e.g., formal vs. informal), and whether family characteristics moderate the associations between child care and cognitive outcomes.

In this study, we examine the impact of child care on children's cognitive outcomes at 3, 5, and 7 years with one of the largest data sets available, the British Millennium Cohort Study ($n = \sim 13,000$). Note that the term *impact* is used throughout to simplify the

text and does not imply we are drawing causal interpretations from the data. Given the mixed findings in the literature and the controversies surrounding the impact of the type of child-care services received in infancy, our aim is to use this unique study to examine the role of formal and informal child-care services received in the first 9 months of life and to account for two methodological challenges inherent in longitudinal child-care research: social selection (using propensity score matching [PSM]) and missing data (using multiple imputation [MI]).

Child Care and Children's Cognitive Development: Sources of Variations

Concerns about the impact of nonmaternal care early in life are rooted in the human and nonhuman attachment literatures, which suggest that maternal proximity and availability during infancy are essential to the offspring's healthy development (Belsky, 2001; Bowlby, 1951). Two bodies of literature have quantified the impact of maternal unavailability on child development. In the psychological literature, maternal unavailability is typically associated with the use of child-care services, whereas in the

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economic literature it is associated with maternal employment outside the home (cf. Burchinal & Clarke-Stewart, 2007). Child-care use and maternal employment are only partially overlapping constructs. That is, while the majority of mothers who use child care are in the labor market, a minority are not. In addition, some working mothers may use nonparental child-care services by working night shifts or working from home for example.

Studies examining the role of child-care services on cognitive development generally find positive effects (Loeb, Bridges, Bassok, Fuller, & Rumberger, 2007; NICHD ECCRN, 2000a, 2000b, 2002), although these are often limited to certain types of child-care services or to certain age groups. Specifically, positive impacts were reported for center-based care or formal child-care services and for services initiated in toddlerhood (Hansen & Hawkes, 2009; Loeb et al., 2007; NICHD ECCRN, 2004). Studies that have focused on the type of child care in infancy and later cognitive development find mixed results, with some reporting positive effects (Andersson, 1989; Hansen & Hawkes, 2009; Sylva, Stein, Leach, Barnes, & Malmberg, 2011) and others reporting no effect (e.g., Jaffee, Van Hulle, & Rodgers, 2011; Park & Honig, 1991). Studies on the association between maternal employment and cognitive development often report negative effects of early maternal work (e.g., Baydar & Brooks-Gunn, 1991; Berger, Brooks-Gunn, Paxson, & Waldfogel, 2008; Brooks-Gunn, Han & Waldfogel, 2002; Han, Waldfogel, & Brooks-Gunn, 2001; Ruhm, 2004; Waldfogel, Han, & Brooks-Gunn, 2002). These results are particularly interesting given that maternal employment is generally associated with higher family income, which facilitates greater investment in child inputs. The negative effects are usually detected for maternal employment in the 1st year postbirth and are more pronounced for full-time employment than part-time employment (Baydar & Brooks-Gunn, 1991; Brooks-Gunn et al., 2002; Hill, Waldfogel, Brooks-Gunn, & Han, 2005; Waldfogel et al., 2002).

One potential source of divergence between the child-care and maternal employment literature is the lack of consideration, particularly in many maternal employment studies, of the type of care the child received. One study that did examine the role of child-care services among children of working mothers found a positive effect for center-based services and negative effects for care by a friend or relative (Gregg, Washbrook, Propper, & Burgess, 2005). Formal care is recognized as being, on average, more structured and of better quality than

informal care and previous studies indicate the importance of considering the type of care (e.g., Gregg et al., 2005; Sylva et al., 2011).

Variations by Family Risk

There is evidence to suggest that the impact of child care or maternal employment may vary as a function of family socioeconomic status (SES; Burchinal, Roberts, Zeisel, Hennon, & Hooper, 2006; Côté, Borge, Geoffroy, Rutter, & Tremblay, 2008; Côté et al., 2007; Geoffroy et al., 2007; Votruba-Drzal, Coley, & Chase-Lansdale, 2004). Two main variables have been used to reflect socioeconomic risk—low maternal education and low family income—and three moderating hypotheses have been proposed. Each is reviewed next.

First, there is support for the “compensatory hypothesis,” which suggests that child care may be particularly beneficial for low-SES children as it provides cognitive stimulation and opportunities for learning that may not be available in the home. Consistent with this hypothesis, Geoffroy et al. (2010) showed that children of mothers with low levels of education had scores on school readiness and achievement tests at 6 and 7 years that did not differ from the children of high-educated mothers if they received formal child care. The same compensatory effect was found using either low income (Caughy, DiPietro, & Strobino, 1994) or a composite index including low income, low education, and low occupational prestige as moderators (Geoffroy et al., 2007). Second, there is support for the “loss of resource hypothesis,” which suggests that children from middle- to high-SES families may be deprived of the stimulation and learning opportunities provided by their families in situations of non-maternal care. The loss of resource hypothesis was supported in a child-care study showing that among families providing stimulating home environments, children receiving center-based child care in infancy had lower mathematics scores (Caughy et al., 1994). In addition, maternal employment studies reported negative effects of maternal employment among families of mothers with high levels of education (Brooks-Gunn et al., 2002; Gregg et al., 2005; Han et al., 2001; Harvey, 1999; Hill et al., 2005; Ruhm, 2004). Third, there is some support for the “dual risk hypothesis” suggesting that among children from already impoverished backgrounds, maternal employment may represent an additional risk. For example, Waldfogel et al. (2002) reported negative effects of full-time maternal employment during the 1st year of life on low-income

children's Peabody Picture Vocabulary Test-Revised and Peabody Individual Achievement Test scores at 4 years. Finally, some studies found no or little evidence of an interaction between sociodemographic characteristics of the family and child care, but rather a main effect of high-quality care on child outcomes (Burchinal, Peisner-Feinberg, Bryant, & Clifford, 2000; NICHD & Duncan, 2003; NICHD ECCRN, 2002).

Given these mixed findings, it is important to systematically test whether children from disadvantaged families benefit more or less from child care than those from nondisadvantaged families. Low income and low maternal education are the most frequently used indicators of disadvantage, yet surprisingly few studies have compared the moderating role of one versus the other. Maternal education and family income are highly correlated but not completely overlapping constructs, and there are good reasons for testing both. For example, from a policy perspective maternal education is a useful indicator that can be used to target populations as it is one of the strongest predictors of children's cognitive development (Peisner-Feinberg et al., 2001; Sameroff, Seifer, Baldwin, & Baldwin, 1993) and can be easily measured. Low family income, although harder to accurately assess than education, is also correlated with family adversity (Caughy et al., 1994; Dearing, McCartney, & Taylor, 2009) and has often been used to target populations for service delivery purposes. One objective of this study is to test the interactions between child care and both maternal education and low income to compare their potentially moderating roles.

Accounting for Social Selection

A major conceptual and methodological issue in child-care research is the possibility that the selection of families into child-care services explains part of the association with children's outcomes. Child-care studies typically control for selection characteristics in ordinary least squares (OLS) regression models. These characteristics generally include parenting and parental cognitive abilities, levels of stimulation in the home, and income. In addition, family characteristics such as ethnicity (Early & Burchinal, 2001; NICHD ECCRN, 1997), whether the child has other siblings (Singer, Fuller, Keiley, & Wolf, 1998), and maternal beliefs about the effects of maternal employment (NICHD ECCRN, 1997) have been suggested as potential selection factors. The decision to use child care may also depend on children's characteristics such as temperament (Lerner

& Galambos, 1986). However, it is rarely possible to account for all potential mediating factors.

Two maternal employment studies have used PSM (Berger et al., 2008; Hill et al., 2005), which is a method designed to reduce selection bias by matching individuals who received a treatment (e.g., child care) with individuals who did not (e.g., maternal care), but have similar probabilities of being treated based on measured characteristics (Dehejia & Wahba, 2002; Rosenbaum & Rubin, 1983; Schneider, Carnoy, Kilpatrick, Schmidt, & Shavelson, 2007). They reported minimal differences between the regression and PSM approaches (Berger et al., 2008; Hill et al., 2005). Apart from one study examining the impact of participation in Head Start (Zhai, Brooks-Gunn, & Waldfogel, 2011), we did not find any published studies using PSM to examine the association between child-care services during infancy and cognitive development. Given that the selection factors for child-care use and maternal employment may differ, child-care studies accounting for social selection with PSM may enrich the debate. One aim of this study is to compare the results obtained with OLS regression and PSM approaches to account for selection biases.

Accounting for Attrition

Attrition is inherent in longitudinal studies and may create a missing value problem as participants lost to follow-up usually differ from those who remain in the study. One strategy to reduce attrition bias is MI, that is, to fill in missing values with multiple predictions based on observed data. There is evidence that MI, as compared to a complete-case approach, can yield different results. For instance, Hill et al. (2005) found that MI reduced the negative impact of maternal employment by supplementing the subgroup in which there was no negative effect—the group of disadvantaged families (Hill et al., 2005). This underlies the importance of carefully accounting for attrition in studies on the long-term impact of child care.

The Setting

The majority of studies on child care and cognitive development have been conducted in the United States. As results may differ in settings with different maternal leave and child-care policies, and where the provision, users, and quality of child-care services differ, it is important to examine whether the pattern of findings differ in other countries. The United States is unique among Western countries in

relation to national parental leave policies. Although a federal policy now mandates a 12-week, job-protected maternity leave, there is no mandatory payment at the national level. In contrast, paid maternal leave is provided in the United Kingdom and is of longer duration. When children in this study were born, mothers in the United Kingdom were allowed 18 weeks of paid leave, and those with 1 year of continuous service could take an additional 13 weeks of unpaid parental leave during the child's first 5 years (Waldfogel, 2001). Not surprisingly, return to work patterns differ markedly across the two countries (Crosby & Hawkes, 2007). In the United Kingdom, approximately 8% of new mothers are back to work within 3 months, whereas the equivalent is 40% in the United States (Berger & Waldfogel, 2004). Furthermore, 70% of U.K. mothers who return by 6 months are employed part-time compared to only 40% in the United States.

Both the U.K. and U.S. governments provide assistance to families using child care in the form of income tax credits and targeted assistance for lower income families. Public expenditures on child care are about 4 times higher in the United Kingdom than the United States as a function of gross domestic product or per child aged younger than 3 years (Organisation for Economic Co-operation and Development [OECD], 2011). Nevertheless, as the cost of formal child care is much higher in the United Kingdom, the net cost of formal child care, as a function of families' income, remains higher in the United Kingdom than in the United States (OECD, 2011). These different policies and the differential patterns of working practices and child-care use point to the need for studies from multiple countries.

Study Objectives

Using data from the British Millennium Cohort Study (MCS), a prospective longitudinal survey of children born between 2000 and 2002, we address three substantive questions and two methodological questions: (a) As compared to parental care, is any form of child care (informal or center based) during infancy associated with better or poorer short-term (age 3 years) and medium-term (5 and 7 years) cognitive outcomes? (b) As compared to informal child care (e.g., care by a family member, neighbor), is center-based child care in infancy associated with better or poorer cognitive outcomes? (c) Is there a differential association between child care and cognitive development as a function of the type of socioeconomic risk (i.e., low maternal education or

low family income)? (d) Does accounting for selection biases using PSM yield results similar to when using OLS regression? (e) Does accounting for attrition with MI affect the results?

Method

Sample and Procedures

The MCS is a nationally representative sample of 18,819 children born in the United Kingdom between September 2000 and January 2002. The sample was clustered geographically by electoral wards and constructed to overrepresent areas of disadvantage, communities with high concentrations of ethnic minorities, and the three smaller countries of the United Kingdom (i.e., Northern Ireland, Wales, and Scotland). The sample was identified through Child Benefit records provided by the Department of Social Security (for more information, see Dex, 2005). The overall response rate was 72% (Plewis, 2004). This study utilizes the first four waves of the survey conducted when the children were 9 months, and 3, 5, and 7 years old.

Dependent Variables: Children's Cognitive Skills at Ages 3, 5, and 7 Years

This study employed two measures of cognitive development at age 3: the Bracken Basic Concept Scale-Revised (BBCS-R) and the British Ability Scale (BAS); two measures at 5 years: the BAS and the Foundation Stage Profiles (FSP); and one measure at 7 years: the BAS. All assessments, apart from the FSP, were conducted in the home by a trained interviewer. The FSP was completed by teachers. For comparison purposes all cognitive outcomes were standardized to have a mean of 100 and a standard deviation of 15.

The BBCS-R (age 3 years). The BBCS-R is a test of academic skills suitable for children aged 2½ and 8 years (Bracken, 1984). It has been used to predict future academic achievement (Panter, 2000). The results of the pilot study and a consultation process led MCS to administer six subtests of the BBCS-R. These tests incorporated 88 concepts of children's knowledge of colors, letter identification, numbers or counting, sizes, comparisons, and shape recognition. The BBCS-R score was available for 13,651 children at age 3.

The BAS II (at 3, 5, 7 years). The BAS measures cognitive abilities and educational achievements among children between the ages 2½ and 8 years (Elliott, Smith, & McCulloch, 1996, 1997). Age-specific

combinations of scales were used at different ages. At 3 years, the BAS Naming Vocabulary scale was used. At 5 years, the BAS Naming Vocabulary, Picture Similarity, and Pattern Construction scales were used. There was a moderate intercorrelation between the three domains ranging from $r = .36$ ($p < .001$) to $r = .37$ ($p < .001$). At 7 years, the BAS Reading, Pattern Construction, and Number Skills scales were used. Again, there was moderate to high intercorrelation between the three domains ranging from $r = .33$ ($p < .001$) to $r = .52$ ($p < .001$). For the ages 5 and 7 BAS measures, two overall BAS scores were generated using the mean scores across the three domains at each time point. There were moderate to high correlations between the ages 3, 5, and 7 BAS scores ranging from $r = .47$ ($p < .001$) to $r = .59$ ($p < .001$). The BAS was available for 14,374 children at age 3, 14,698 children at age 5, and 13,105 children at age 7.

The FSP (age 5 years). The FSP was completed by teachers when the children were 5 years old. This period corresponded to the end of the 1st year of school for U.K. children in state schools. Three FSP cognitive domains are included in our analysis: (a) communication, language, and literacy; (b) mathematical development; and (c) knowledge and understanding of the world. Teachers rated children's attainment of specific learning goals on a scale from 0 to 9. An overall FSP score was generated using the mean scores across the three cognitive domains. In England, FSP data were collected for the MCS children by the Department for Children, Schools, and Families, whereas in the other parts of the United Kingdom, the FSP data were collected via postal questionnaire sent to individual teachers. These data were then matched to the records of children in the MCS. The differential data collection methods resulted in English children being matched more successfully to the MCS data. Of the 9,084 children remaining in the (English) sample at 5 years, 8,671 were matched. This represents a success rate of around 95%. Response rates were 59% in Scotland, 54% in Wales, and 68% in Northern Ireland. The difference in administration of the questionnaire is captured by a country indicator that is included in all FSP models.

Independent Variables

Child care. Participation in child care during infancy was measured at 9 months with questions asking the mother who looks after the child when the mother is at work (for working mothers) and who else, other than the mother, looks after the child (for nonworking mothers). Mothers were

provided with 18 response options and asked how many hours per week the child is looked after by someone else. Two dichotomous variables were created using this information. The first distinguished children who received any type of nonparental care (34%) for a minimum of 9 hr per week from those who did not, with the latter group being categorized as having parental care (66%). This was referred to as "any type of child care versus parental care" in the analysis. The second variable distinguished two types of nonparental care: "center-care versus informal care." This comparison was limited to the 34% children who received a minimum of 9 hr of nonparental child care per week and distinguished children receiving center-based care (nurseries or crèches, 20%) from those receiving informal care (80%) by 9 months. Among children receiving informal care at 9 months, 61% received grandparental care, 21% were cared by nanny or child minders, and 18% were cared by neighbors, relatives, or friends.

In the MCS data, 68% of the children whose mothers were in paid employment for more than 9 hr per week at 9 months were in some form of child care for more than 9 hr per week at 9 months. Among those in any form of child care, 21.6% were in center-based care and 78.4% were in informal care for more than 9 hr per week.

Potential confounding variables. We distinguished between two types of variables that could bias the association between child care and cognitive development: (a) those measured at 9 months and that could have influenced the selection of families into child care and (b) those measured at or after 9 months and that could be influenced by child-care decisions. Variables from the first group were used to create the propensity score in the PSM models. All variables from the first and second groups were included as covariates in both the PSM and OLS regression models.

Variables That Could Influence the Child-Care Decision

The following variables were measured via maternal report during the first assessment at 9 months and include a range of child, family, and maternal characteristics. All these variables were found to be significantly associated with participation in child care during infancy, and most of them also distinguished between infants attending center-based versus informal child care, at the $p < .05$ level (see Table 1).

Child characteristics included the child's ethnicity (Mixed Race, Indian, Pakistani and Bangladeshi, Black, Other vs. White) and maternal reports of the

Table 1

Descriptive Statistics for Child, Family, and Maternal Characteristics, and for Cognitive Outcomes by Child-Care Group

	Parental care by 9 months <i>n</i> = 11,074, 66.36% <i>M</i> (<i>SD</i>)/%	Informal care by 9 months <i>n</i> = 4,489, 26.9% <i>M</i> (<i>SD</i>)/%	Center care by 9 months <i>n</i> = 1,124, 6.74% <i>M</i> (<i>SD</i>)/%
Cognitive outcomes			
Bracken School Readiness age 3	98.38 ^a (0.15)	102.80 (0.23)	109.29 ^b (0.40)
British Ability Scale (BAS) age 3	98.49 ^a (0.15)	103.25 (0.23)	106.36 ^b (0.37)
BAS age 5	98.67 ^a (0.15)	102.42 (0.23)	107.26 ^b (0.39)
Foundation Stage Profiles age 5	98.46 ^a (0.15)	102.90 (0.25)	106.98 ^b (0.42)
BAS age 7	98.95 ^a (0.15)	101.71 (0.24)	106.63 ^b (0.42)
Family characteristics			
Annual household income at 9 months (in GBP)	17,841 ^a (142)	25,527 (266)	38,461 ^b (590)
Annual household income at age 3 (in GBP)	20,056 ^a (167)	28,321 (307)	41,473 ^b (659)
Annual household income at age 5 (in GBP)	22,584 ^a (168)	29,876 (294)	43,774 ^b (657)
Annual household income at age 7 (in GBP)	25,342 ^a (213)	33,259 (352)	48,990 ^b (796)
Living in government-subsidized housing (at 9 months)	23.97% ^a	11.41%	2.16% ^b
Home Observation Measurement of the Environment score (at age 3)	11.92 ^a (0.02)	12.27 (0.03)	12.72 ^b (0.04)
Parental time investment (at age 3)			
Reading	-0.02 ^a (0.01)	0.05 (0.01)	0.00 ^a (0.02)
Teaching	-0.04 ^a (0.01)	0.07 (0.01)	0.29 ^b (0.02)
Maternal characteristics			
Education (at 9 months)			
General Certificate of Secondary Education (GCSE) grades D-G	34.65% ^a	18.06%	4.01% ^b
O level/GCSE grades A-C	37.28% ^a	37.48%	21.69% ^b
A/AS/S Levels	8.97% ^a	11.76%	12.88%
Diploma in higher education	7.57% ^a	11.34%	12.80%
First degree	9.25% ^a	17.15%	37.11% ^b
Higher degree	2.28% ^a	4.22%	11.51% ^b
Employment			
Employed at 9 months	23.90% ^a	84.75%	96.57% ^b
Employed at age 3	35.20% ^a	78.41%	90.83% ^b
Employed at age 5	43.56% ^a	77.55%	86.28% ^b
Employed at age 7	50.56% ^a	78.48%	88.50% ^b
Age at child's birth	27.97 ^a (0.06)	28.57 (0.09)	31.58 ^b (0.14)
Single at child's birth	10.74% ^a	7.41%	4.11% ^b
Planned pregnancy	51.00% ^a	57.29%	75.76% ^b
Smoked when pregnant	27.54% ^a	20.66%	12.16% ^b
Attended antenatal classes	28.41% ^a	44.75%	60.40% ^b
Ever breastfed	65.68% ^a	67.44%	84.22% ^b
Attachment score (at 9 months)	24.77 ^a (0.03)	24.48 (0.04)	23.82 ^b (0.07)
Self-esteem score (at 9 months)	18.51 ^a (0.03)	18.82 (0.04)	19.02 ^b (0.09)
High social class (at 9 months)	19.16% ^a	38.00%	72.52% ^b
Literacy difficulties (at 9 months)	11.45% ^a	8.49%	5.39% ^b
Long-term chronic illness (at 9 months)	22.85% ^a	19.34%	16.27% ^b
Child characteristics			
Female	49.05%	48.98%	47.45%
Ethnic group (% Non-White)	20.53% ^a	11.92%	6.86% ^b
Birth weight (in kg)	3.34 ^a (0.01)	3.38 (0.01)	3.44 ^b (0.02)
Days/weeks of gestation	277.10/39.59 ^a (0.14/0.02)	277.61/39.66 (0.21/0.03)	278.36/39.77 (0.380/0.05)

Table 1
Continued

	Parental care by 9 months <i>n</i> = 11,074, 66.36% <i>M</i> (<i>SD</i>)/%	Informal care by 9 months <i>n</i> = 4,489, 26.9% <i>M</i> (<i>SD</i>)/%	Center care by 9 months <i>n</i> = 1,124, 6.74% <i>M</i> (<i>SD</i>)/%
Birth by c-section	10.73% ^a	14.17%	16.67% ^b
Birth order	2.13 ^a (0.01)	1.65 (0.01)	1.49 ^b (0.02)

^aSignificant difference between "parental care" and "any child care," at $p < .05$. ^bSignificant difference between "informal child care" and "center-based child care," at $p < .05$.

child's birth weight (in kilograms) and the number of days in gestation. Finally, a binary indicator representing whether the child was delivered by emergency cesarean section was also included.

Family characteristics included the child's rank by age among his or her natural siblings (birth order) and a dummy variable distinguishing families living in government-subsidized housing.

Maternal characteristics and maternal behavior variables included the mother's age at the time of the cohort child's birth, whether the mother was single at the time of the child's birth, and whether the mother had a long-term chronic illness, defined as an illness, disability, or infirmity for a long period of time. In addition, variables indicating the mother's socioeconomic class were included. Mothers who are employed, or who have previously been employed, in higher or lower management or professional jobs were classified as high social class as compared to lower employment classes. Three questions asked the mother if she had difficulties with reading, filling out forms, or calculating change. If she indicated difficulty on any of these tasks, she was characterized as having literacy difficulties. Maternal education was measured using a six-level categorical variable indicating whether the mother's highest educational qualification was a (a) General Certificate of Secondary Education (GCSE) with grades D–G, which is equivalent to 11 years of education; (b) GCSE with grades A–C, which is equivalent to 11 years of education; (c) Advanced Level General Certificate of Secondary Education (A Level), which is equivalent to 13 years of education; (d) diploma in higher education, which is equivalent to 14/15 years of education depending on length of diploma; (e) first degree, which is equivalent to 16 years of education; or (f) a higher degree (e.g., M.A. or Ph.D.), which is equivalent to 17–21 years of education depending on degree type. A number of pregnancy and birth-related variables were also controlled for, including

whether the pregnancy was planned, whether the mother smoked during pregnancy after the pregnancy had been confirmed, and whether she attended any antenatal classes during pregnancy. Finally, an indicator of whether the child was ever breastfed was also included.

Variables That Could Be Influenced by the Child-Care Decision

The following variables were also used as covariates in the OLS and PSM models, yet they were not used to generate the propensity scores as they may have been influenced by the child-care decision in infancy. These included a dummy indicator of low income at 9 months, a dummy indicator of maternal employment at 9 months, and household income and maternal employment measured at the same time as the cognitive assessments (i.e., 3, 5, and 7 years). Annual household income was assessed and calculated using the same method at each of the four data collection waves. Respondents were asked to state their net household income from all sources and earnings, after deductions for tax, national insurance, and so forth, from a list of 18 possible income brackets. This information was used to generate a pseudocontinuous measure by taking the midpoints of each income bracket to approximate total household income. There was a high correlation in household income across the four time periods ranging from 0.66 to 0.77 ($p < .01$). A dummy was used for low income at 9 months to facilitate interpretation of child care by low-income interactions (see below for how the variable was derived). Maternal employment was measured at each data collection wave and was coded 1 if the mother said she was in part- or full-time employment and 0 otherwise. Maternal attachment and self-esteem were assessed at 9 months using a short form of the Condon Maternal Attachment Scale (Condon & Corkindale, 1998) and a

short form of the Rosenberg Self-Esteem Scale (Rosenberg, 1965), respectively. Higher scores indicated greater attachment and self-esteem.

Additional variables included continuous scores on the Home Observation Measurement of the Environment (HOME) scale (Caldwell & Bradley, 1984), which assessed the quality and quantity of stimulation and support available to a child in their home at age 3 years. A measure of parental time inputs at age 3 included seven items related to how often someone in the home taught the child to learn the alphabet, count, sing, draw, play sports, and how often someone read to the child and took the child to the library. Principal component factor analysis, conducted with the seven items, revealed two independent factors representing reading and teaching, respectively. This information was used to generate two parental investment variables: "Parental time investment: reading" represents the mean of the alphabet, count, sing, draw, sports measures, and "parental time investment: teaching" represents the mean of the reading and library measures.

An indicator of country of residence at the first wave (England, Scotland, Wales, or Northern Ireland) was included in the analysis of the FSP models to account for the differing method of FSP data collection in each country. Finally, the gender of the child and the child's age in months at the time of each cognitive assessment were also included.

Subsequent Child-Care Experiences

The OLS and PSM models (but not the model used to generate the propensity score) also controlled for all subsequent preschool child-care experiences up to ages 3 and 5 years. By age 5 the majority of the sample had started school. The measures of subsequent child-care experiences were retrospective measures collected at the age 5 data collection wave. Mothers were asked at what age the child started informal care (child minder) or center-based care (e.g., nursery school, playgroup, preschool, or day nursery), and for how many hours. This information was used to generate dichotomous variables indicating whether the child had been in any form of child care for at least 9 hr a week by ages 3 (67%) and 5 (95%) years and, for those who have been in child care, whether they received center-based care versus informal care by ages 3 (63% vs. 37%) and 5 (95% vs. 5%) years.

Socioeconomic moderator variables. Maternal education and family income were tested as potential moderators of the relations between child care dur-

ing infancy and cognitive outcomes. The moderator variables were dichotomized as previous studies identified associations between child care and cognitive development for the lower end of the socioeconomic distribution (e.g., Côté et al., 2007; Geoffroy et al., 2010; Peisner-Feinberg et al., 2001; Waldfogel et al., 2002). Low maternal education indicated that the mother had obtained a GCSE with grades D–G or less (i.e., having the minimum mandatory level of education, approximately equivalent to a high school degree in the United States). Using this definition, approximately 28% of all mothers in the MCS were considered to have low levels of education. Low income indicated that the total annual household income was at or below the U.K. poverty threshold (60% of the median income within the sample adjusted for weighting). With this definition, 28% of the sample had low income. There was a significant overlap between low maternal education and low family income, $F(1, 1893.5) = 1222.96$, $p < .0001$. Whereas 58% of the sample had neither low income nor low education, just 14% had both low income and low education, 14.1% had low income only, and 13.9% had low education only.

Analyses

Comparing child-care conditions. We conducted two main sets of analyses. In the first, we compared the cognitive outcomes of children who received "any type of child care" with those of children who received "parental care" during the first 9 months of life. In the second, we compared the cognitive outcomes of children who received "center-based care" with those of children who received "informal care" during the first 9 months of life. Separate models were used to predict performance on five cognitive tests: the Bracken School Readiness (BSR) and the BAS at age 3, the BAS and the FSP at age 5, and the BAS at age 7 years.

Addressing selection biases. We estimated both OLS and PSM models. First, we estimated OLS models controlling for all covariates listed in the Measures section: gender and age of the child, ethnicity, days of gestation, birth weight, cesarean section, birth order, breastfed, planned pregnancy, antenatal classes, smoked during pregnancy, mother's age, mother single at the birth of the child, mother's education, mother's literacy difficulties, mother's social class, mother has a long-term chronic illness, mother's employment at 9 months, low household income at 9 months, mother's employment and household income at the time of

the cognitive assessment, maternal attachment at 9 months, maternal self-esteem at 9 months, living in government-subsidized housing, HOME score at 3 years, parental time investment at 3 years, subsequent child-care use up to age 3 for models of cognitive outcomes at age 3, and up to age 5 for models of cognitive outcomes at ages 5 or 7. The FSP models also included a country dummy.

Second, we estimated PSM models. Propensity scores were estimated for each child to represent the probability of being in any form of child care during infancy and, among those children, their probability of being in center-based versus informal child care. Probit regression models were used, with child-care status as the binary outcome indicator and the variables that preceded the child-care experience as the predictor variables—mother's age at time of child's birth, whether the mother was single at the time of the child's birth, whether the mother had a long-term chronic illness, social class, maternal literacy difficulties, maternal education, planned pregnancy, maternal smoking during pregnancy, attending antenatal classes, breastfeeding, child's ethnicity, birth order, child's birth weight, number of days in gestation, cesarean section delivery, and government-subsidized housing. From the probit models, a predicted score was calculated for each child. This propensity score could theoretically range from 0 to 1 and represented the probability that the child received the child-care "treatment" of interest. We then used a radius matching algorithm to match each child who participated in child care (or in center-based child care for the second set of analyses) with all children who did not, but whose propensity scores lay within a chosen distance (caliper). With radius matching, all untreated individuals within the caliper distance are matched to a treated individual and are weighted equally (i.e., rectangular kernel). As an example, if four untreated individuals are within the specified caliper distance, each is matched to the treated individual and is assigned a weight of .25. With radius matching, an untreated individual may be used as a match for more than one treated individual (akin to matching with replacement). Untreated individuals who are matched to multiple treated individuals consequently have greater overall weight in the analysis compared to those who are matched to fewer treated individuals. Treated individuals for whom no untreated individuals are available within the caliper are excluded from the analysis as this indicates insufficient overlap in the propensity scores to find a suitable "counterfactual." The radius matching procedure often results in more precise estimates of treatment effects than a 1:1

matching algorithm (i.e., nearest neighbor matching), as it allows the use of information from a larger number of untreated participants.

The main advantage of PSM over OLS is that it allows more flexibility in the functional form. Given that the matching estimator simply compares the outcomes of individuals who are observationally similar to one another in terms of covariates (yet who differ in their child-care type), the matching estimator is less parametric in the sense that it imposes little structure in the relation between the covariates, treatment, and the dependent variable. Nevertheless, PSM still does not guarantee causal estimates just as in the case of OLS. In particular, matching estimators only provide causal inference in the cases when (a) selection is on observable child and family characteristics, or (b) balancing the observable covariate distribution also balances the unobservable covariate distribution, in the case where unobservable factors also contribute to selection of child care.

The quality of the matching process was evaluated by comparing the child-care (treated) and matched comparison (untreated) groups on all observed pretreatment characteristics, using the complete-case sample (i.e., before MI). As recommended, we aimed to obtain a difference between the two groups smaller than 5% of a standard deviation (standardized bias; see Caliendo & Kopeinig, 2008). A caliper of 0.1 was found to best balance the treated and untreated groups, for both sets of analyses (any child care vs. parental care, and center-based vs. informal child care).

The OLS and PSM models used to test the association between infancy child care and cognitive outcomes included all covariates (from the first and the second set of variables), to reduce the likelihood of any additional bias not controlled for by the matching and to improve efficiency (Rubin, 1973; Rubin & Thomas, 2000). To test whether child care had a greater or lesser impact on the cognitive development of high-risk children, the OLS and PSM models were estimated three times, first excluding any SES interactions and then including either an interaction between the infancy child-care variable and low maternal education or between the infancy child-care variable and low family income at 9 months.

Note that we do not use sampling weights in the analysis as our matching approach estimates the "average treatment effect on the treated." Therefore, as we do not make inferences about the whole U.K. population, the sample weights are not required.

Addressing biases due to missing data. Deletion of cases or variables due to missing data can lead to substantial bias (Hill et al., 2005). To examine the impact of missing data on our estimations, we estimated our models with and without MI. MI is particularly useful when the data are missing completely at random or when the missing data can be fully described by observed variables in the data set. If unobserved child and family characteristics contributed to generating missing data, then MI may result in some bias of estimates. As Wayman (2003) notes, however, the goal of MI is to capture as much of the mechanism that produced the missing data through observed variables, and these results will likely be better than those produced by listwise deletion (i.e., excluding children with missing data). It should be noted that the estimates produced with MI only have a causal interpretation if selection into child care is based on observable characteristics. Thus, in the event that selection into child care is affected by unobserved child characteristics, even if the mechanism that generated missing data can be fully captured by observed variables, the derived estimates represent correlations, rather than a causal estimates. Although we use multiple observable characteristics of the respondents in the imputation process, it is possible that we are not fully capturing all factors influencing attrition; therefore, our MI results cannot be interpreted as causal effects.

We performed MI by chained equations, using the *mi* command in Stata 11.0. Missing values were imputed 50 times using the MCS sampling weight and 78 individual items used to generate the variables included in our models, with the original 18,552 participants. Analyses were run with the resulting 50 "completed" data sets and then pooled with Rubin's combination rules (Rubin, 1987), using *mi estimate*. For the PSM approach, the balance between the data sets was assessed in the nonimputed data, that is, in the original data, by comparing the child-care (treated) and matched comparison (untreated) groups on all observed pre-treatment characteristics. If the matching process was successful at balancing the covariate distributions across the two groups, the size of the difference should be smaller than 5% of a standard deviation. Once the appropriate matching algorithm was identified using the nonimputed data, the same one was used for the imputed data. All tables and figures reported in this study are based on the pooled imputed values. Note that MI was only conducted for children who had participated in at least one of the cognitive assessments at ages 3, 5, or

7 years ($n \sim 13,000$). An overview of the results using the nonimputed data is presented in the Results section.

Calculation of effect sizes. Cohen's d effect sizes were calculated to describe the magnitude of the effects (in standard deviation units) of child-care use on cognitive outcomes for children of mothers with low and high education (Cohen, 1988). Cohen's d was designed for use where the scores being compared are continuous and normally distributed, a condition that is met in this study. For instance, effect sizes comparing "any type of child care" with "parental care" were calculated as: $d = (X_{\text{child care}} - X_{\text{parental care}}) / s_{\text{pooled}}$. Where $s_{\text{pooled}} = \sqrt{\{(n_{\text{child care}} - 1)(s_{\text{child care}}^2) + (n_{\text{parental care}} - 1)(s_{\text{parental care}}^2)\} / (n_{\text{child care}} + n_{\text{parental care}} - 2)}$. Positive d s indicated higher cognitive scores in the child-care than the parental-care group.

Results

We focus on the results obtained using MI. Table 1 presents the percentages or means and standard deviations for the dependent variables and the covariates by child-care status. Table 1 also presents bivariate associations for each measure indicating statistical differences between the "any child care" and "parental care" groups, and the "center-based care" and "informal care" groups.

There were significant differences across all five dependent variables by child-care status, with children in center-based care typically having higher cognitive scores than those in informal care, and those in informal care having higher scores than children in parental care. In general, children who were in any form of child care during infancy experienced less risk on almost all observed child, family, and maternal characteristics, compared to those in parental care. Similarly, those in center care experienced less risk than those in informal care.

Associations Between Infancy Child-Care Use and Cognitive Outcomes at 3, 5, and 7 Years

The differences in children's cognitive outcomes by child-care status presented in the descriptive statistics suggested that child care, and particularly center-based child care, was associated with higher cognitive scores. However, the observed differences in family, maternal, and child characteristics across child-care groups indicated that social selection into child care may account for this relation. In the next set of analyses, we estimated OLS and PSM models

of the association between child care during infancy and cognitive outcomes at 3, 5, and 7 years, and then included an interaction between child care and either low maternal education or low income.

Any type of child care versus parental care. We found no main effects of child care on any of the five cognitive tests, using either the OLS or PSM approaches. In addition, we found no significant interactions between child-care participation and low income using either approach; however, we did identify significant interactions with maternal education for two of the cognitive outcomes. Therefore, we only present the OLS and PSM results of models that included the child care by low maternal education interaction (Table 2). For clarity in the presentation, we omit presenting the coefficients for the control variables and present only the coefficients for child care during infancy, maternal education, and the child care during infancy by low maternal education interaction (full results are available in the online supporting information Appendix S1). The F test for each model was statistically significant at the .01 alpha level. All effect sizes are computed from the adjusted means obtained from the PSM models.

The two significant interactions in both the OLS and PSM models indicated that the effect of child care on age 3 test scores (BSR and BAS) varied as a function of maternal education. The association between child care and the BSR at 3 years was larger among children of less educated mothers, $d = 0.34$, 95% CI [0.26, 0.43], than among children of more highly educated mothers where it was not significantly different from zero, $d = 0.04$, 95% CI [0.00, 0.08]. Similarly, the association between child care and the BAS at age 3 years was larger among children of less educated mothers, $d = 0.27$, 95% CI [0.19, 0.36] than among children of more highly educated mothers, $d = 0.10$, 95% CI [0.06, 0.13]. Children in any form of child care did not differ from those in parental care on the ages 5 or 7 years cognitive tests, regardless of maternal education levels.

Center-based child care versus informal care. The OLS and PSM approaches yielded partially different results regarding the effects of center-based versus informal child-care attendance on future cognitive outcomes. Both approaches detected main effects of center care on BSR at 3 years and BAS at 5 years. The effect size for center-based child care versus informal child care, across children attending child care during infancy, was $d = 0.42$, 95% CI [0.34, 0.49] on the BSR at age 3 years and $d = 0.31$, 95% CI [0.24, 0.38] on the BAS at age 5 years.

In addition to the main effect of center-based child care on the BSR at 3 years, there was a Center-Based Child Care $\times$ Low Maternal Education interaction in the PSM model only. The association between center-based child care and scores on the BSR at 3 years was larger among children of less educated mothers, $d = 1.15$, 95% CI [0.80, 1.50], than among children of more highly educated mothers, $d = 0.40$, 95% CI [0.32, 0.47].

Finally, there was a significant interaction between center-based child care and maternal education on the FSP at 5 years in the PSM model. The association between center-based child care and the FSP at 5 years was larger among children of less educated mothers, $d = 0.93$, 95% CI [0.53, 1.33] than among children of more highly educated mothers, $d = 0.09$, 95% CI [0.09, 0.17]. Children in center-based child care did not differ from those in informal child care on the BAS at ages 3 or 7, regardless of maternal education level.

With both approaches, we found no significant interactions between child-care participation and low income on any of the five outcomes. However, the PSM approach detected two significant interactions between center-based child-care participation and low maternal education that were not detected with the regression approach. In Table 3, we only present the results of models that included the Center-Based Child Care by Low Maternal Education interaction, with the coefficients for center-based child care during infancy, maternal education, and the Center-Based Child Care During Infancy $\times$ Low Maternal Education interaction, omitting coefficients for other control variables (full results are available in online supporting information Appendix S1). The F test for each model was statistically significant at the .01 alpha level.

Comparison of results with and without MI. The estimates obtained using listwise deletion (or complete-case analysis) and MI were in the same direction; however, some effects reached statistical significance only with the MI approach. First, there were no differences in the results from the main effect models estimated with the imputed and listwise deletion samples. Second, regarding the interaction models, the same pattern of results was found for the BSR at age 3, BAS at age 5, FSP at age 5, and BAS at age 7 models comparing any type of child care with parental care. However, the interaction effect observed between any form of child care and low maternal education in the BAS age 3 OLS model was not significant when estimated with listwise deletion, yet there was no difference for the PSM models. Third, the same pattern of results was

Table 2
Associations Between the Use of Any Type of Child Care in Infancy, Maternal Education, and Their Interaction, With Cognitive Outcomes at 3, 5, and 7 Years From Ordinary Least Square (OLS) Regression and Propensity Score Matching (PSM) Model

	Age 3 years				Age 5 years				Age 7 years	
	Bracken School Readiness Scores (<i>n</i> = 13,652)		British Ability Scale (BAS; <i>n</i> = 14,374)		BAS (<i>n</i> = 14,793)		Foundation Stage Profile (FSP; <i>n</i> = 11,708)		BAS (<i>n</i> = 13,464)	
	OLS	PSM	OLS	PSM	OLS	PSM	OLS	PSM	OLS	PSM
Any child care in infancy	-0.51 (0.34)	-0.38 (0.38)	-0.73* (0.33)	-0.37 (0.37)	-0.10 (0.35)	0.06 (0.37)	0.05 (0.39)	0.31 (0.40)	-0.50 (0.37)	-0.44 (0.41)
Maternal education ^a										
O level/General Certificate of	2.30** (0.33)	2.72** (0.40)	2.15** (0.33)	2.39** (0.39)	2.33** (0.35)	2.27** (0.42)	2.59** (0.38)	2.89** (0.45)	2.68** (0.38)	3.32** (0.45)
Secondary Education (GCSE) grades A–C										
A/AS/S Levels	3.50** (0.46)	4.09** (0.54)	2.89** (0.45)	2.89** (0.52)	2.53** (0.49)	2.48** (0.56)	3.91** (0.54)	3.73** (0.58)	4.27** (0.52)	4.81** (0.58)
Diploma in higher education	3.77** (0.48)	4.27** (0.53)	3.56** (0.46)	3.55** (0.51)	3.45** (0.52)	3.32** (0.54)	3.14** (0.55)	3.02** (0.60)	3.28** (0.55)	3.88** (0.59)
First degree	5.17** (0.49)	5.61** (0.56)	4.38** (0.47)	4.42** (0.53)	4.78** (0.52)	4.83** (0.55)	4.76** (0.56)	5.03** (0.58)	5.88** (0.54)	6.90** (0.60)
Higher degree	5.31** (0.69)	5.71** (0.75)	4.14** (0.67)	4.05** (0.75)	4.85** (0.73)	4.86** (0.73)	4.44** (0.80)	4.67** (0.77)	6.31** (0.76)	7.18** (0.80)
Low Maternal Education × Any Child Care	1.32* (0.62)	1.70** (0.64)	1.41* (0.61)	1.46* (0.63)	0.42 (0.65)	0.41 (0.70)	-0.53 (0.71)	-0.42 (0.80)	0.13 (0.69)	0.71 (0.76)

^aOmitted level: GCSE grades D–G. Coefficients for covariates are reported in the online supporting information Appendix S1. The following variables were included in the propensity score for the PSM models and as covariates in the OLS models: child ethnicity, number of weeks of gestation, birth weight, birth by cesarean section, birth order, ever breastfed, planned pregnancy, attendance at antenatal classes, smoked during pregnancy, mother's age at the child's birth, mother was single at the birth of the child, mother's education level, mother's literacy difficulties, mother's social class, mother had a long-term chronic illness, and local authority housing at 9 months. The following control variables were included as covariates in all the models: any child care before age 3, center child care before age 3, any child care before age 5 (in BAS5, BAS7, FSP7 models only), center child care before age 5 (in BAS5, BAS7, FSP7 only), child age (at time of assessment), child gender, maternal attachment at 9 months, maternal self-esteem at 9 months, Home observation measurement of the environment score at 3 years, the reading and teaching factors of parental time investment at 3 years, household income (at time of assessment), and maternal employment (at time of assessment). The FSP models also include a country dummy.

p* < .05. *p* < .01.

Table 3
Associations Between the Use of Center-Based Child Care in Infancy, Maternal Education, and Their Interaction, With Cognitive Outcomes at 3, 5, and 7 Years From Ordinary Least Square (OLS) Regression and Propensity Score Matching (PSM) Models

	Age 3 years			Age 5 years			Age 7 years		
	Bracken School Readiness Scores (<i>n</i> = 4,260)		British Ability Scale (<i>BAS</i> ; <i>n</i> = 4,456)	Foundation Stage Profile (FSP; <i>n</i> = 3,641)		BAS (<i>n</i> = 4,634)	BAS (<i>n</i> = 4,304)		
	OLS	PSM	OLS	PSM	OLS		OLS	PSM	
Center-based child care	1.15* (0.53)	1.45** (0.54)	-0.55 (0.49)	-0.24 (0.49)	0.63 (0.57)	1.91** (0.53)	0.58 (0.55)	0.71 (0.55)	
Maternal education ^a									
O level/General Certificate of Secondary Education (GCSE) grades A-C	1.27 (0.65)	1.37 (0.78)	1.27* (0.61)	1.44 (0.79)	2.90** (0.71)	2.14* (0.66)	2.51** (0.69)	2.62** (0.88)	
A/AS/S Levels	2.71** (0.82)	3.09** (0.92)	2.21** (0.77)	2.85** (0.92)	3.72** (0.90)	2.68* (0.83)	3.89** (0.87)	3.99** (1.04)	
Diploma in higher education	2.98** (0.82)	2.37* (0.99)	2.43** (0.77)	2.55** (0.94)	2.55** (0.91)	2.66** (1.00)	2.10* (0.88)	2.26* (1.03)	
First degree	4.02** (0.83)	4.36** (0.92)	2.83** (0.78)	3.69** (0.92)	4.33** (0.92)	3.87** (1.00)	4.84** (0.88)	4.68** (1.03)	
Higher degree	3.67** (1.08)	3.90** (1.17)	3.32** (1.01)	4.42** (1.18)	4.45** (1.17)	3.87** (1.18)	6.97** (1.13)	6.53** (1.23)	
Low Maternal Education × Any Child Care	4.09 (2.14)	3.94* (1.80)	1.67 (2.02)	1.77 (1.67)	4.57 (2.55)	2.57 (2.37)	1.90 (2.40)	1.85 (2.71)	

^aOmitted level: GCSE grades D-G. Coefficients for covariates are reported in the online supporting information Appendix S1. The following variables were included in the propensity score for the PSM models and as covariates in the OLS models: child ethnicity, number of weeks of gestation, birth weight, birth by cesarean section, birth order, ever breastfed, planned pregnancy, attendance at antenatal classes, smoked during pregnancy, mother's age at the child's birth, mother was single at the birth of the child, mother's education level, mother's literacy difficulties, mother's social class, mother had a long-term chronic illness, and local authority housing at 9 months. The following control variables were included as covariates in all the models: any child care before age 3, center child care before age 3, any child care before age 5 (in BAS5, BAS7, FSP7 models only), center child care before age 5 (in BAS5, BAS7, FSP7 only), child age (at time of assessment), child gender, maternal attachment at 9 months, maternal self-esteem at 9 months, Home observation measurement of the environment score at 3 years, the reading and teaching factors of parental time investment at 3 years, household income (at time of assessment), and maternal employment (at time of assessment). The FSP models also include a country dummy.

p* < .05. *p* < .01.

found regarding BAS at ages 3, 5, and 7 in the center-based versus informal-care models that included the interaction between center-based child care and low maternal education. However, the interaction effects observed for the BSR age 3 and FSP age 5 PSM models were not significant when estimated with listwise deletion, yet there was no difference in the OLS models. For almost all estimated models, both the coefficients and the standard errors were larger in the listwise deletion results compared to the imputed results reported in Tables 2 and 3. Regarding the three models where differences were observed between listwise deletion and MI, in all cases, both the coefficients and standard errors were lower in the models estimated with the imputed data. The listwise deletion results are available from the authors upon request.

Discussion

The aim of this study was to investigate whether nonparental child care received in infancy was associated with cognitive outcomes at 3, 5, and 7 years among a large ($n \sim 13,000$) sample of children born in the United Kingdom between 2000 and 2002. We found that child-care use at 9 months was associated with better cognitive development for certain outcomes, yet the effects depended on the level of maternal education. The significant effects of any type of child care were small to moderate and were limited to children of mothers with low levels of education and to the preschool years (i.e., age 3 years). We found that center-based care, compared to informal care at 9 months, was associated with better cognitive development for certain outcomes, and again the effects varied as a function of maternal education. The significant effects were moderate overall and large for children of mothers with low education. The effects for center-based child care extended until school entry (5 years), but not beyond (age 7 years). The results inform the ongoing debates about the use of child-care services in infancy by indicating that services received at this early stage of life did not carry risk, but rather made no difference or contributed positively to children's cognitive development, in the case of children of mothers with low levels of education.

Although we found a short-term advantage of participating in any type of child care for children of mothers with low education, our results suggest that center-based child care increases further the likelihood of beneficial effects for these children. The characteristics of center-based settings may

make them more likely than those of informal-care settings to foster cognitive abilities. Informal care is usually family based and aimed at providing a "home-like" setting that involves mostly free play. Infants receiving informal care are exposed to an environment with less focus on structured activities than children in center-based care. Center care is usually provided to groups of children of similar ages and there is evidence that age segregation may promote higher quality care and education (NICHD ECCRN, 2004). Indeed, in groups of children of similar ages, the type of care and activities are more easily targeted to children's developmental needs. For instance, in mixed-age settings, younger children (i.e., toddlers) were shown to receive less sensitive and supportive care than older ones (i.e., preschoolers; Kryzer, Kovan, Phillips, Domagall, & Gunnar, 2007). Thus, children who experience center care have more exposure to an environment designed as an educational setting and have access to a greater number and variety of toys and materials for children (Kisker & Maynard, 1991). Our results suggest that the characteristics of center-based care provide an advantage even when child care is initiated during infancy. Our results are consistent with previous studies reporting a positive effect for center-based services in infancy (e.g., Gregg et al., 2005; Hansen & Hawkes, 2009; Sylva et al., 2011), but contrary to some of these studies (e.g., Gregg et al., 2005; Sylva et al., 2011), we did not find a negative effect of informal care and even found an overall positive effect of child care for children of mothers with low education. However, these studies did not examine maternal education as a moderator of informal child care.

Another objective of this study was to test the extent to which there was a differential effect of child care, and the type of child care, according to socioeconomic risk. We examined both low maternal education and low income as potential moderators to shed light on previously divergent results in studies using one or the other moderator. We found differential impacts of child care and the type of child care according to maternal education. All four significant interactions revealed the same pattern, whereby children of mothers with low education particularly benefited from child-care services, particularly from center-based rather than informal child care, whereas children of mothers with higher levels of education benefited modestly, moderately, or not at all. Indeed, we found that children of mothers with low levels of education receiving any type of child care had higher scores on the BSR and on the BAS at 3 years compared to children of

mothers with low education receiving parental care. The effect sizes were moderate. Children of mothers with low education in center-based child care had higher scores on the BSR at 3 years and on the FSP at 5 years compared to children of mothers with low education receiving informal child care, and the effects sizes were large. Although the effect sizes were smaller (i.e., small to moderate), center-based care was also found to be associated with higher scores on some cognitive tests at 3 and 5 years among children of mothers who did not have low levels of education. These results are consistent with a previous study of Canadian children (Geoffroy et al., 2010) and suggest that child care, particularly center-based child care, may attenuate the cognitive disadvantage associated with growing up in a family where the mother has low education.

Despite the significant overlap between low maternal education and low family income in this study, $\chi^2(1) = .0014$, $p < .0001$, differential effects of child care were not found when low income was used as the moderator. This suggests that child care may serve to partially compensate for a lack of stimulation (low maternal education) rather than material deprivation (low income). These results underscore the importance of distinguishing the moderating role of low maternal education and low income in child-care studies and suggest that children of mothers with low levels of education may benefit from child-care services more than children of low-income families.

Accounting for Methodological Biases

Given the previously documented impact of social selection and attrition in longitudinal child-care studies (Hill et al., 2005), we carefully addressed these biases using PSM and MI. PSM and MI yielded significant findings that were undetected using the regression and complete-case approaches. In addition, we controlled for maternal employment, a variable often omitted in child-care research.

There were strong selection effects in the use of child care. Children exposed to higher levels of family and maternal risk characteristics were much more likely to receive parental-care or informal child-care services. The magnitudes of the effects obtained with OLS regression analyses were largely consistent with those obtained with PSM analyses. However, in two instances, we detected significant interactions between maternal education and center-based child care using PSM that we did not detect using OLS. This suggests that the assumptions of OLS may not be tenable in the presence of

strong selection effects and may conceal group differences.

We also observed differences when we compared the results from listwise deletion (i.e., complete-case approach) with those obtained with MI. Some of the Maternal Education $\times$ Child-Care interactions detected with MI did not reach significance using the complete-case approach. The MI approach brought more of the disadvantaged children (who are typically disproportionately affected by attrition) into the analyses and therefore provided adequate power for testing SES interactions, particularly for the center-based versus informal-care analyses. This pattern of results is consistent with Hill et al. (2005) who reported that MI reduced the negative effect of maternal employment (compared to the nonimputed results).

Strengths and Limitations

This study has a number of considerable strengths. First, it is based on one of the largest samples available to examine the association between child care and cognitive outcomes. As noted by Berger et al. (2008), sample size is an important limitation of child-care studies. The MCS is more than 10 times larger than the state-of-the-art studies and thus allows for more precise estimations of the associations between child care and cognitive development. The second strength concerns the extensiveness of the cognitive assessments: (a) variety of cognitive domains: school readiness, vocabulary, communication, mathematical skills, knowledge of the world, reading, number skills, and pattern construction; (b) developmental scope: 3, 5, and 7 years; and (c) source of assessment: formal testing and teacher ratings. A third strength is found in our use of PSM and OLS to control for selection into child care based on observed characteristics. A fourth strength is the fact that our results allow us to distinguish the role of child care from that of maternal employment as we control for maternal employment. Indeed, we found that child care still had an impact on cognitive development while controlling for maternal employment. Finally, our use of MI reduced the biases associated with differential attrition that can be accounted for by observed characteristics.

There are also limitations to our study. First, we could not account for the quality of child care. As with other large-scale studies designed to examine the role of numerous factors in child development, detailed measures of child-care quality and family processes were not available. Previous studies suggest that child-care type is associated with child-care quality, although important variations in quality

within each child-care type were noted (Japel, Tremblay, & Côté, 2005). Second, MI only corrects the bias due to differential attrition if the missing values can be fully described by observed variables, as discussed above. Thus, if unobserved characteristics affect the mechanism generating missing values, then some bias is still likely to remain. Third, despite our sample being one of the largest available to study child care and child development, our capacity to study interactions between maternal education and the use of center-based child care in infancy was limited (due to low numbers of mothers with low levels of education using center care). Caution is required in interpreting these results. However, the fact that we detected two significant interactions suggests that this is a meaningful association and that it should be the subject of further investigations. Finally, as mentioned previously, PSM is a method for dealing with selection on observable family and child characteristics in a manner that is more flexible than OLS in terms of the functional form; it generally does not control for selection on unobservable (or unmeasured) characteristics. It is possible that there are additional factors that influence both the decision to use child care and children's cognitive development that were not observed, such as parental intelligence, motivation, personality, and educational beliefs. To the extent that such variables were not accounted for by PSM, the results may still be affected by selection bias, thus the estimates do not have a causal interpretation. To minimize the likelihood of unaccounted selection into child care, many additional covariates were included in this analysis. Other methods such as instrumental variables, fixed-effects, or within-family models, which can control for selection on both observable and unobservable characteristics, could not be used in this study. Using a sibling comparison design, Jaffee et al. (2011) found that whereas between-family comparisons showed a positive impact of early child care on childhood and adolescence achievement scores, within-family comparisons failed to detect these effects. This suggests the existence of unmeasured characteristics that may not be adequately controlled for in an OLS model. A study using a sibling comparison design with both OLS and PSM is needed to determine whether the results with PSM converge with those of the sibling comparison.

In sum, we did not detect detrimental effects on cognitive development of early nonparental child care, or of center-based versus informal child care, as provided in the United Kingdom between 2000 and 2003. To the contrary, we showed improved short-

term outcomes for children of mothers with low levels of education who received nonparental care during infancy. Center-based care had positive effects over informal care, and these benefits lasted longer and extended to children of educated mothers. Our findings suggest that social programs aimed at providing child-care services to vulnerable populations should target low maternal education rather than low family income. Experimental studies comparing the effect of early child care for children of mothers with low-education versus those of low-income families would prove informative regarding the feasibility of this approach and the potential additional benefits of targeting services based on the strongest predictor of cognitive development—maternal education.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's website:

Appendix S1. Coefficients for Models of the Associations Between the Use of Child Care in Infancy, Maternal Education, and Their Interaction, With Cognitive Outcomes (for Ordinary Least Squares Regressions and Propensity Score Matching Models).