On the Positive Relationship Between Breastfeeding & Intelligence

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A wealth of literature has examined the association between breastfeeding and the development of cognitive abilities in childhood. In particular, at least some evidence exists suggesting that breastfed children perform better on measures of intelligence later in life. Although a correlation appears to be present, fewer observational studies have included appropriate adjustment for potentially confounding variables; maternal intelligence, maternal education, and cognitive stimulation provided by mothers being chief among them. As a result, we analyze a national sample of approximately 790 American respondents to test the association between breastfeeding and intelligence during childhood and adolescence using multiple intelligence tests and controlling for a range of key covariates. Our results suggest that the correlation between breastfeeding throughout the first six months of life and intelligence is statistically significant and consistent, yet of substantively minor impact.

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For decades now, developmental scholars have been interested in determining whether, and to what extent, breastfeeding exerts a causal impact on general intelligence and cognitive functioning (Anderson, Johnstone, & Remley, 1999; Jain, Concato, & Leventhal, 2002; Kanazawa, 2015). To date, some supportive evidence of an association has emerged (Boutwell, Beaver, & Barnes, 2012; Horta, Loret de Mola, & Victora, 2015; Kanazawa, 2015; Mortensen, Michaelsen, Sanders, & Reinisch, 2002), as well as some reason to doubt the relationship (Der, Batty, & Deary, 2006;

Girard, Doyle, & Tremblay, 2017; Ritchie, 2017; von Stumm & Plomin, 2015). Thus, rigorous, often heated, debate lingers about the existence of a possible causal effect. The rancor is not particularly surprising, as a wealth of scholarship has linked intelligence to an array of important life outcomes, ranging from prosocial behavior to longer life expectancy (Beaver et al., 2016; Kanazawa, 2015; Plomin & Deary, 2015; Ritchie, 2015). As a result, scholars have had a longstanding interest in understanding ways in which to positively impact the development of general intelligence via environmental intervention. Breastfeeding would seem a viable avenue, yet several methodological complications prevent consensus on the issue.

Breastfeeding decisions in the general population are not random. To the extent that intelligent and highly educated mothers, for example, are more likely to breastfeed, and also more likely to produce intelligent children, the problem of confounding is likely pervasive in this literature (Barnes, Boutwell, Beaver, Gibson, & Wright, 2014; Kramer et al., 2008; Mortensen et al., 2002). Thus, correcting for key selection factors like maternal education and socioeconomic levels is important. In doing so, Mortensen and colleagues (2002) uncovered positive effects of breastfeeding on intelligence in two samples (analytical sample sizes of roughly 900 and 2,000 subjects; effect sizes of several points for those breastfed for longer time periods) using two different intelligence measures, the Wechsler Adult Intelligence Scale (Wechsler, 1999) and the Borge Priens Prove. Nonetheless, other studies have suggested that correcting for genetic confounding directly eliminates the association between breastfeeding and intelligence (Bartels, Rietveld, Van Baal, & Boomsma, 2002).

To be sure, genetically sensitive models are not always possible due to sample limitations (i.e., not having data from siblings). At

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a minimum, in such cases, studies examining the link between breastfeeding and intelligence would need to control for maternal intelligence (in addition to other key confounders like educational attainment). Kanazawa (2015), analyzing participants in Generation 1 and Generation 2 of the National Child Development Study, examined the issue recently and found that, even when controlling for maternal intelligence, breastfeeding had a positive impact on child intelligence (in Study 2, which controlled for maternal IQ, each additional month of breastfeeding was associated with .16 IQ points gained using an analytical sample of approximately 4,000 children and 2,500 mothers).

Much of the work done on breastfeeding and intelligence is observational, and thus correlational in design. Statistical corrections can be made in observational designs, however, randomized control trials are a preferred mechanism for determining causality. In one of the largest experiments to date, using a treatment intended to promote prolonged breastfeeding, Kramer and colleagues (2008) found evidence of improved cognitive outcomes ranging from 2 to 7 points on various intelligence measures in a sample of Belarusian participants (aligning with other research designs; Anderson et al., 1999). Using a large sample of Irish participants (roughly 8,000), Girard and colleagues (2017) used propensity score matching techniques and unlike the results of Kramer et al. (2008), Girard et al. (2017) uncovered no evidence of a positive effect of breastfeeding on intelligence, once possible confounders were accounted for in the propensity score matching models.

Although we are unable to examine results from a randomized trial, the current study represents an effort to replicate and extend the recent observational results of Kanazawa (2015) using a large national sample of American respondents. The value of our study is derived from our ability to examine breastfeeding effects across more than a decade of the life course (rather than the first 5 to 6 years; Girard et al., 2017; Kramer et al., 2008) when using multiple measures of intelligence. Moreover, we use a latent variable approach, allowing us to account for measurement error that might further diminish effect sizes in the analyses. In accordance with prior work (Kanazawa, 2015) we are also able to include appropriate controls for maternal intelligence, as well as controls for cognitive stimulation/maternal interaction recommended by Horta et al. (2015), along with a range of other possible confounder variables. Although some previous evidence has controlled for these items individually (Kanazawa, 2015), few have been able to include all of them in a single analysis.¹ Below we present our data, along with our findings, regarding the potential influence of breastfeeding on intelligence from late childhood through middle adolescence.

Method

Participants

To investigate the association between breastfeeding and child intelligence, we analyzed participants drawn from the National Institute of Child Health and Human Development's Study of Early Child Care and Youth Development (SECCYD),² conducted from 1991 through 2007. Families were recruited from hospitals located across 10 cities (for more detailed description, see a publication by the NICHD Early Child Care Research Network,

2001). It is important to note that the data cannot be considered nationally representative, yet the selected sites represent a diverse set of cities. From eligible families, 3,015 families were conditionally randomly sampled.³ These families were contacted for an interview 2 weeks after the birth of the target child but some could not be reached or refused to participate, whereas others experienced circumstances that interfered with participation (e.g., the child remained in the hospital for an extended period). In total, 1,526 eligible families agreed to take part in the study. Approximately 1 month after the focal child was born, 1,364 (89%) families completed the first interview. For the next decade and a half (15 years) data were collected from the parents and children, and eventually teachers provided data as well relevant to the focal children. For the current study, we use data up to and including the final assessment at age 15.

Because of attrition, 1,009 of the 1,364 families remained in the study by the time children reached age 15. As an additional point of emphasis, our analyses make use of data reported on by mothers (e.g., breastfeeding) and standardized laboratory assessments that required travel away from home to complete (i.e., child intelligence). Although beneficial from an analytical standpoint, the use of multimethod data contributes to missing data. As a result of attrition and missing data, the sample size of the models we estimate is 793 based on the availability of complete information on the indicators of intelligence. However, we use imputation of missing data (described in below) for our predictor variables.⁴

Measures

Breastfeeding. Information on breastfeeding was drawn from the 1-month and 6-month interviews conducted with mothers. At the 1-month interview mothers were asked if they were currently breastfeeding. If the mother answered yes, then that response was noted. If the mother answered no, she was asked if she breastfed at all during the first month and, if so, during which week of the month she stopped breastfeeding. Similar questions were asked of mothers at the 6-month interview, with the difference being that mothers who reported stopping breastfeeding prior to the 6-month interview were asked in which month (rather than which week) they stopped. Using this information on breastfeeding during the first 6 months of the child's life, we constructed four dummy variables. Descriptive statistics for these variables, and all other variables to be described, are presented in Table 1 (and a full correlation matrix is available in the supplementary files).

Child/adolescent intelligence. At multiple points during the SECCYD, children completed a variety of tests during laboratory visits, some that gauge intelligence. In particular, when study children were in third grade, fifth grade, and when they were 15

¹ Our study also is noteworthy in that we are able to measure breastfeeding duration using data collected at the time of breastfeeding, as opposed to lengthy retrospective reports (e.g., Kanazawa, 2015).

² Analysis of the SECCYD data was granted IRB exempt status by Florida International University for an initial proposal entitled *Parental Stability and Delinquency: Assessment, Explanations, and Implications*. (FIU IRB exemption # 082610-00).

³ The conditioning assured representation (at least 10% marginally) of single-parent households, mothers with less than a high school education, and ethnic minority mothers.

⁴ See online supplementary files for a detailed treatment of missing data for any models not using FIML imputation.

Table 1
Descriptive Statistics

Variable	<i>n</i>	<i>M/proportion</i>	<i>SD</i>	Min	Max
Breastfeeding dummy variables					
Never breastfed (= 1)	789	.24	—	0	1
Stopped before end of first month (=1)	789	.15	—	0	1
Stopped before end of 6 months (=1)	789	.29	—	0	1
Breastfed through 6-month interview (=1)	789	.32	—	0	1
Child/adolescent intelligence measures					
Grade 3 WJ-R Picture Vocabulary	793	31.90	3.03	19	41
Grade 3 WJ-R Passage Comprehension	793	22.07	4.33	2	33
Grade 3 WJ-R Applied Problems	793	32.79	3.80	8	43
Grade 5 WJ-R Picture Vocabulary	793	34.50	3.30	18	46
Grade 5 WJ-R Passage Comprehension	793	25.34	4.13	1	38
Grade 5 WJ-R Applied Problems	793	36.92	4.05	16	50
Age 15 WJ-R Picture Vocabulary	793	38.21	3.96	24	52
Age 15 WJ-R Passage Comprehension	793	30.74	4.35	10	41
Age 15 WJ-R Applied Problems	793	41.94	5.74	19	59
Covariates					
Maternal Intelligence (PPVT-R)—3 Years	757	100.09	18.32	40	159
Maternal Education	793	14.46	2.38	7	21
Stimulation of Cognitive Development—6 Months	778	2.62	.67	1	4
Home Enrichment—6 Months	781	6.62	1.89	0	9
Male (=1)	793	.49	—	0	1
Non-White (=1)	793	.18	—	0	1
Family structure (2-parent nuclear = 1, others = 0)	793	.74	—	0	1
Maternal age at birth of child	793	28.69	5.53	18	46
Birth order	793	1.79	.90	1	7
Maternal working hours	793	2.47	8.72	0	94
Family receives public assistance (=1)	793	.15	—	0	1
Maternal depression	793	11.07	8.64	0	53
Planned pregnancy	793	1.19	.92	0	2

Notes. WJ-R = Woodcock Johnson—Revised; PPVT-R = Peabody Picture Vocabulary Test—Revised.

years old they completed a number of different Woodcock-Johnson Psycho-educational Battery—Revised (WJ-R; Woodcock & Johnson, 1989) tests. Three of the WJ-R tests were administered consistently at third grade, fifth grade, and at age 15, and they are used in the current study as indicators of general intelligence: picture vocabulary (PV), passage comprehension (PC), and applied problems (AP).⁵ Using the raw scores for each of the three tests, we constructed a latent variable to measure intelligence at each of the three assessment periods. It is also worth noting that WJ-R scores generally (though not entirely) capture variation in crystallized intelligence (see Duckworth, Quinn, & Tsukayama, 2012; Ritchie, 2015).

Covariates

As previously discussed, a primary concern when investigating whether breastfeeding is associated with child/adolescent intelligence is that breastfeeding is not randomly distributed across the population of mothers with newborns. Given this fact, observed indicators of factors which could confound the association must be controlled. Fortunately, the richness of the SECCYD data enables us to account for a number of important factors, each of which is described below.

Maternal intelligence and education. We control for maternal intelligence using standardized scores for the Peabody Picture Vocabulary Test—Revised (PPVT-R; Dunn & Dunn, 1981), completed by mothers when their children were three years old. The PPVT-R assesses verbal intelligence through measuring an individual's receptive knowledge of vocabulary (D'Amato, Gray, &

Dean, 1988). It would have been more ideal if maternal intelligence had been assessed when children were newborns or infants, but we have little reason to believe that substantive changes in maternal intelligence would have taken place between the time the children were born and the assessment at age three when mothers completed the PPVT-R. Mothers reported on their current educational attainment when the focal child was 1 month old. Maternal education was measured on an ordinal scale ranging from a low score of 7 (7th grade) to a high score of 21 (doctoral degree).

Promotion of cognitive development. As recommended by Horta and colleagues (2015) we control for two indicators tapping the extent to which the home environment provides stimulation that would aid in cognitive development, each assessed when children were 6 months old. The first indicator is based on a semistructured videotaped mother–child interaction task completed in the home consisting of sessions of 15 min of free play between the mother and the child, divided into two episodes. During the first episode of 7–8 min, mothers were asked to play as they normally might with their child, using toys of their own choosing. The second episode was followed by 7–8 min where mothers were provided with a standard set of toys with which to engage their infants in play. From these videotaped episodes,

⁵ Other WJ-R tests were administered at each of the assessment periods, but only these three tests were common across each assessment period. As such, to maintain a consistent measure of intelligence, we did not make use of data from other WJ-R tests that were administered.

trained raters scored the quality and frequency of the mother's effort to facilitate the child's cognitive development on a scale from one to four. Indicative of its construct validity, this measure of stimulation of cognitive development is positively correlated with ever having breastfed ($r = .22$).

The second indicator reflects the extent to which the home environment promotes cognitive development. During the same home visit where the mother-child interaction task just described took place, trained observers recoded information using the Home Observation for Measurement of the Environment (HOME; Caldwell & Bradley, 1984). From this inventory, the SECCYD researchers constructed a nine-item home enrichment variable tapping into such things as whether the child has three or more books of his or her own; whether the mother structures play periods; whether the mother reads to the child at least three times weekly; the presence of complex eye-hand coordination toys; and the presence of toys for literature and music. Each item was scored as a dichotomy (yes = 1, no = 0), and the scores were added together to create an index ranging from 0 to 9. The current home enrichment measure—derived from the original HOME inventory—is positively correlated with ever having breastfed ($r = .31$). It is also positively correlated with the above measure for stimulation of cognitive development ($r = .30$).

Other covariates. We controlled for nine other variables based on information collected when children were 1 month old. First, dichotomous measures for the child's race (non-White = 1, all others = 0) and gender (Male = 1, Female = 0) were included. Second, family structure was measured dichotomously, with two-parent nuclear families assigned a score of 1 and all other family types assigned a score of 0. In addition, we controlled for the mother's age at the birth of their child (in whole years); the child's birth order; the number of hours per week mothers reported they were working; if the family was receiving public assistance (Yes = 1, No = 0); maternal depression (based on scores from the Center for Epidemiological Studies Depression Scale); and an ordinal measure for whether the pregnancy was planned (0 = neither parents were planning, 1 = one parent was planning, 2 = both parents were planning).

Analytic Plan

To examine the effect of breastfeeding on the development of intelligence over time, there are several possible modeling strategies that can be useful. Earlier versions of the article assumed a straightforward approach of ordinary least squares (OLS) regression to test the association between variables (available in Supplemental Tables S1 and S2 in the [online supplemental material](#)). Although informative—and producing results that generally aligned with those presented herein—this failed to fully capitalize on the longitudinal nature of the data, thus we examined second-order growth curve models or curve of factors models (Duncan, Duncan, & Strycker, 2006) which use the first-order factors for intelligence as indicators for the structural parameters of the second-order model (i.e., intercept and slope).⁶ One of the strengths of the second-order model is that by using multiple indicators, measurement error is removed from the construct, allowing for more precise estimating of the growth parameters (Ferrer, Balluerka, & Widaman, 2008). An additional advantage of

the second-order model is the ability to test for measurement invariance of the manifest indicators of the latent variable.

Following the approach outlined by Wickrama, Lee, O'Neal, and Lorenz (2016; see also Muthén & Muthén, 1998–2011), we estimated a sequence of models to assess measurement invariance. The fit criteria for these models are shown in Supplemental Table S3. We first estimated an unconstrained model for the first-order latent factors of intelligence across the three measurement occasions. This model serves as a comparison for whether the imposition of constraints worsens the fit of the model, thereby indicating measurement variance. In the next step, we estimated a weak invariance model by constraining the factor loadings to be equal. We then estimated a strong invariance model in which the indicator means and factor loadings are constrained to be equal over the measurement periods. The results indicated that the intelligence factor shows clear measurement variance for the factor loadings and the intercepts and suggest that while the factors do measure growth, they nonetheless demonstrate clear signs of measurement variance (Ferrer et al., 2008). As a consequence, we were not fully comfortable presenting the results for the second-order growth model as the primary findings of the article (see Joop & Reinoud, 2005).

An alternative modeling strategy we also used is the factor of curves model in which growth factors are estimated for each individual measure of intelligence and then second-order growth factors are estimated from the first-order factors. This model does not require measurement invariance. Following this strategy, we first estimated separate growth curve models for each measure of intelligence over the three measurement occasions. The growth curves for the picture vocabulary (PV) and passage comprehension (PC) measures of intelligence showed acceptable model fit, but the model for the applied problems (AP) measures required us to constrain the slope variance to 0 to identify the model. As a consequence, the model fit less well. Model fit statistics for each separate measures of intelligence are presented in Supplemental Table S4 in the [online supplemental material](#). Building on these individual growth curve models, a factor of curves model was estimated to explore the covariance between the growth parameters for each measure of intelligence. From this model, we then estimated the effects of our covariates of interest on the intercept and slope of the global factors. The model fit was poor for this model (again, see Supplemental Table S4), but the estimates are shown in Supplemental Tables S5 and S6 in the [online supplemental material](#). In particular, the effects of any amount of breastfeeding was $b = .498$ ($p = .008$); presented, along with the findings associated with the slope for intelligence models, in Supplemental Table S5). In addition, the effects for the alternative coding measures assessing length of breastfeeding were as follows: stopped before the end of the first month $b = .322$ ($p = .170$), breastfeeding stopped before the end of the sixth month $b = .579$ ($p = .007$), and breastfeeding continued to six months: $b = .584$ ($p = .010$); full results, including coefficients for the slope for intelligence models, presented in Supplemental Table S6).

⁶ We should note that the adaptation of the analysis plan over time was the result of anonymous reviewer feedback on prior iterations of the manuscript, which initially began with a focus on OLS regression and morphed into more complex longitudinal designs.

As these two approaches (i.e., curve of factors and factor of curves) produced models that were not ideal representations of the data and might ultimately undermine our ability to accurately assess the association between breastfeeding and indicators of intelligence, we opted to present estimates from a structural equation model with autoregressive paths for intelligence, as opposed to trying to more directly model the growth structure of intelligence. As the breastfeeding variable is measured prior to the measurement occasions of intelligence, it acts as a time-stable covariate in the model. Essentially, then, we are examining whether breastfeeding has an effect on intelligence at each time point, net of the additional covariates. Further, by including the autoregressive terms, and accounting for measurement error, we are assessing the effect of breastfeeding on the change in intelligence between the measurement occasions.

Thus, we estimated two structural equation models. Each of the two models include autoregressive terms for intelligence between each of the measurement occasions allowing us to discern the effect of breastfeeding on the change in intelligence between the measurement occasions. The breastfeeding variable(s) and additional covariates are modeled as exogenous predictors of intelligence at each measurement occasion. The first model uses a dichotomous indicator reflecting whether mothers did or did not ever breastfeed as the key independent variable (never breastfed = 0, ever breastfed = 1). This model assesses, then, whether any amount of breastfeeding is associated with higher scores for child/adolescent intelligence. The second model uses the three dummy variables tapping the duration of breastfeeding by mothers (never having breastfed is the reference category), enabling us to assess whether longer durations of breastfeeding (up to 6 months) are more strongly associated with child/adolescent intelligence.

Several fit indices are used to evaluate model fit. In addition to the conventional χ^2 test statistic, the root mean squared error of approximation (RMSEA; Steiger, 1990) is used because it takes into account the sample size to correct for the tendency of the χ^2 to reject models with large samples. Values less than 0.05 are good, values between 0.05 and 0.08 are acceptable, and values greater than 0.10 indicate poor model fit. The nonnormed fit index (NNFI; Bentler & Bonett, 1980) takes into account the number of parameters in a model to adjust for the tendency for fit indices to increase as the size of the model increases. Values of 0.90 to 0.95 are considered acceptable and values greater than 0.95 are considered good. The comparative fit index (CFI; Bentler, 1990) has the same goodness of fit criteria as the NNFI.

Although complete data on each of the indicators of child intelligence is available for 793 cases, missing data exists for some of the predictor variables (e.g., maternal intelligence). Missing data were handled by using full information maximum likelihood to estimate the models. It should be noted that estimation of the models based on complete listwise deletion ($N = 738$) produces substantively identical results. All analyses were conducted using Mplus 6.0 (Muthen & Muthen, 1998–2011).

Results

Figure 1 presents a graphical display of the analysis plan and Table 2 shows the structural equation model when using the binary measure of breastfeeding. The first column shows that mothers who engaged in any amount of breastfeeding were more likely to

Figure 1. Path diagram for the autoregressive model.

have children with higher intelligence scores at grade three ($b = 0.467, p = .010$). Several of the covariates are associated with this initial measurement of intelligence as well. Maternal intelligence ($b = 0.045, p = .001$), maternal education ($b = 0.284, p = .001$), maternal age at birth ($0.043, p = .011$), and a planned pregnancy ($b = 0.175, p = .031$) are each positively associated with intelligence at third grade, whereas birth order ($b = -0.476, p = .001$) and being non-White ($b = -0.512, p = .017$) are negatively associated.

The second column shows that any amount of breastfeeding has no effect on intelligence at grade five when accounting for intelligence at grade three. Of the predictor variables, only intelligence at third grade ($b = 1.021, p = .001$), maternal intelligence ($b = 0.010, p = .014$), and stimulation of cognitive development ($b = 0.166, p = .039$) are statistically significant. The final column in Table 2 shows that any amount of breastfeeding has no effect on intelligence at age 15 when accounting for intelligence at Grade 5. Only intelligence at Grade 5 ($b = 1.091, p = .001$) and being male ($b = 0.358, p = .012$) are significantly associated with intelligence at age 15.

It is important to consider, however, that the duration of breastfeeding may influence the strength of its association with intelligence. This possibility is examined in Table 3 by discretely categorizing breastfeeding based on duration, up to 6 months. The first column reveals significant effects of breastfeeding for longer than 1 month but stopping before 6 months ($b = 0.527, p = .017$) and for breastfeeding throughout the first 6 months of a child's life ($b = 0.588, p = .004$) on intelligence at Grade 3. No significant effect is found for breastfeeding only during the first month. Several covariates were predictive of intelligence at grade three. Maternal intelligence ($b = 0.044, p = .001$), maternal education ($b = 0.291, p = .001$), maternal age at birth ($b = 0.044, p = .010$), and a planned pregnancy ($b = 0.191, p = .019$) were each positively associated with intelligence at third grade. Birth order ($b = -0.484, p = .001$) and being non-White ($b = -0.511, p = .017$) were negatively associated.

The second column shows that breastfeeding throughout the first 6 months of a child's life is significantly associated with intelligence at Grade 5 ($b = 0.344, p = .028$), even when accounting for intelligence at Grade 3. In addition, intelligence at grade three ($b = 1.011, p = .001$), maternal intelligence ($b = 0.009, p = .018$), and stimulation of cognitive development ($b = 0.184, p =$

Table 2

Structural Equation Model of Intelligence—Breastfeeding Binary Measure (N = 793)

Variable	Intelligence Grade 3			Intelligence Grade 5			Intelligence Age 15		
	b	SE	p value	b	SE	p value	b	SE	p value
Breastfeeding (never breastfed is reference)									
Any breastfeeding	.467**	.180	.010	.163	.131	.214	.164	.186	.379
Autoregressive terms									
Intelligence Grade 3	—	—	—	1.021***	.038	.001	—	—	—
Intelligence Grade 5	—	—	—	—	—	—	1.091***	.049	.001
Additional covariates									
Maternal intelligence	.045***	.005	.001	.010**	.004	.014	.005	.006	.406
Maternal education	.284***	.084	.001	.070	.061	.244	.123	.085	.148
Stimulation of cognitive development	.060	.113	.598	.166*	.081	.039	-.046	.113	.687
Home enrichment score	.067	.041	.105	.020	.030	.490	.044	.042	.290
Male	-.136	.139	.328	-.063	.100	.529	.358**	.143	.012
Non-White	-.512**	.214	.017	.046	.155	.768	-.256	.218	.240
Two-parent household	.320	.196	.103	-.005	.141	.973	.259	.198	.191
Maternal age at birth	.043**	.017	.011	-.018	.012	.128	.003	.017	.861
Birth order	-.476***	.084	.001	-.080	.061	.191	.015	.088	.861
Maternal working hours	.001	.008	.953	.003	.006	.585	-.001	.008	.858
Public assistance	-.081	.225	.718	.021	.162	.897	.022	.225	.921
Maternal depression	.003	.008	.697	-.01	.006	.101	.003	.009	.724
Planned pregnancy	.175*	.081	.031	.043	.059	.464	.078	.082	.344
Model fit									
Chi-square					535				
Root mean square error of approximation					.061				
Nonnormed fit index					.908				
Comparative fit index					.941				

* $p < .05$. ** $p < .01$. *** $p < .001$ (two-tailed).

.020) are positively associated with intelligence at Grade 5. The final column in Table 3 again shows that breastfeeding throughout the first 6 months of a child's life is significantly associated with intelligence at age 15 ($b = 0.493$, $p = .028$) when accounting for intelligence at Grade 5. Of the other predictors, only intelligence at Grade 5 ($b = 1.085$, $p = .001$) and being male ($b = 0.367$, $p = .010$) are significantly associated with intelligence at age 15.

Discussion

As all researchers understand, inferring causal effects is difficult (Rothman & Greenland, 2005). Using the analogy of turning on a light switch as representing the cause of the bulb lighting up, Rothman & Greenland (2005, p. S144) note, "When all other factors are in place, turning the switch will cause the light to go on, but if one or more of the other factors is lacking, the light will not go on." Precisely the same difficulty exists in identifying causal effects of breastfeeding on intelligence. For the current study, the association between prolonged (for a full 6 months) breastfeeding and intelligence across more than a decade of life withstood the inclusion of autoregressive measures of intelligence and a range of factors that could confound the correlation; particularly maternal intelligence, maternal education, and cognitive enrichment variables.⁷ Moreover, the correlation of prolonged breastfeeding with intelligence indicators survived correction for intelligence at prior ages, thus suggesting an association between longer breastfeeding time and changes in scores on intelligence measures. In short, various analytical approaches, including longitudinal designs assessing changes in intelligence correlated with prolonged breastfeeding, all seemed to suggest the existence of at least some

correlation between breastfeeding and higher scores on measures of intelligence.

Nonetheless, a correlation between breastfeeding and intelligence reveals virtually nothing about a possible pathway leading from the ingestion of breastmilk to ultimately improved intelligence. In other words, the actual causal effect—should one even exist—may come not from breastfeeding directly but from some "downstream" effect. For instance, we were unable to consider the mediating (or moderating) effect of genes associated with the metabolism of fatty acids in breast milk, which are thought to provide some of the actual cognitive benefits (e.g., Caspi et al., 2007). Relatedly, though we control for maternal intelligence, this is not the same thing as controlling for unmeasured heritable influences of general intelligence (see Barnes et al., 2014 for a discussion). As we have discussed, the "gold-standard" approach in this case would include a randomized trial, such as the one conducted by Kramer and colleagues (2008) who assessed scores on the Wechsler Abbreviated Intelligence Scale roughly 6 years into the life course. Their results revealed increases in intelligence for those breastfed longer in a sample of Belarusian participants. Our results reveal similar findings using American participants examining a longer period of the life course and utilizing alternative measures of intelligence. Nonetheless, our results are associational in nature and, as Barnes et al. (2014) noted, two variables correlated at a moderate effect size are vulnerable to genetic confounding when the heritability of both variables is at least

⁷ See also Gurka, LoCasale-Crouch, and Blackman (2010) for an analysis that intersects with ours using the same sample of participants.

Table 3

Structural Equation Model of Intelligence - Breastfeeding Dummy Variables (N = 793)

Variable	Intelligence Grade 3			Intelligence Grade 5			Intelligence Age 15		
	b	SE	p value	b	SE	p value	b	SE	p value
Breastfeeding (never breastfed is reference)									
Stopped before end of first month	.243	.227	.284	.013	.165	.942	.029	.233	.901
Stopped before end of the sixth month	.527*	.207	.017	.031	.149	.834	.091	.212	.668
Continued to sixth month	.588**	.220	.004	.344*	.157	.028	.493*	.225	.028
Autoregressive terms									
Intelligence Grade 3	—	—	—	1.011***	.038	.001	—	—	—
Intelligence Grade 5	—	—	—	—	—	—	1.085***	.049	.001
Additional covariates									
Maternal intelligence	.044***	.005	.001	.009*	.004	.018	.002	.006	.684
Maternal education	.291***	.084	.001	.087	.060	.149	.128	.085	.131
Stimulation of cognitive development	.056	.114	.626	.184*	.080	.020	.062	.113	.585
Home enrichment score	.066	.041	.109	.022	.030	.492	.038	.042	.366
Male	-.116	.139	.404	-.065	.099	.514	.367**	.142	.010
Non-White	-.511*	.214	.017	.033	.154	.832	-.282	.217	.193
Two-parent household	.304	.198	.125	-.010	.141	.942	.269	.198	.176
Maternal age at birth	.044*	.017	.010	-.019	.012	.127	.001	.017	.982
Birth order	-.484***	.085	.001	-.085	.061	.186	-.018	.088	.835
Maternal working hours	-.001	.008	.909	.004	.006	.519	-.001	.008	.881
Public assistance	-.058	.225	.796	.013	.161	.938	.017	.224	.940
Maternal depression	.004	.008	.620	-.011	.006	.073	.004	.009	.630
Planned pregnancy	.191*	.081	.019	.040	.059	.496	.063	.082	.441
Model fit									
Chi-square					526				
Root mean square error of approximation					.064				
Nonnormed fit index					.907				
Comparative fit index					.940				

* $p < .05$. ** $p < .01$. *** $p < .001$ (two-tailed).

moderate in magnitude (assuming there is a genetic correlation between the variables). Although the inclusion of autoregressive measures of intelligence and key covariates is useful, sibling-based designs are ultimately important for parsing out the possibility of genetic confounding in observational research designs.

It is also important to consider what the effect sizes themselves revealed in the current analysis. The advantage that appeared to emerge for performance on measures of crystallized intelligence among breastfed children was statistically significant and robust, however, the size of the effect was in line with prior research (Anderson et al., 1999; Kramer et al., 2008). On one hand, our results suggest only a small to moderate benefit from breastfeeding. However, given that intelligence arises from multiple causative pathways (including genetic factors), we also might not expect for the effects of breastfeeding to comprise much more than a modest part of the etiological picture⁸ (see also Girard et al., 2017). Ritchie (2017, p. 345) recently urged additional, and needed, caution by noting that, "Ultimately, large (quasi-) experimental studies—not meta-analysis of observational research—will be required to resolve this question." Thus, although there might be various reasons to encourage breastfeeding among new mothers, doing so for the sole purpose of raising the intelligence of a child is unlikely to yield a substantively large benefit in the population.

Conversely, if situations preclude children being breastfed, there is little reason to suspect that nonbreastfed children will lag substantially behind their breastfed peers for indicators of intelligence. A final point of caution concerns possible bias in the sample. Among other differences that emerged, mothers who never breast-

fed were more likely to have dropped out of the SECCYD before its completion, or to have missing data. Although the models presented in the article included imputed values for cases missing on the predictor variables, concerns over sample bias cannot be fully dismissed (we discuss this in more detail in the [online supplemental material](#)).

Ultimately, our results provide a useful and timely replication and extension of prior research on the topic of breastfeeding and general intelligence (Kanazawa, 2015; Mortensen et al., 2002). Although some caution is needed when interpreting our results, they nonetheless add to the storehouse of information on a topic that continues to be relevant for both physicians as well as members of the general population globally. The pattern of evidence seems relatively clear at this point. That there is a correlation of small-to-medium magnitude between breastfeeding and intelligence seems apparent (Mortensen et al., 2002). However, the extent to which we can infer causal effects, or determine the possible pathways of such effects, remains decidedly unclear at the present juncture (Ritchie, 2017).

⁸ The editor reminded us of this point, and we agree that it is important to emphasize.

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