



Breastfeeding, Early Self-Regulation, and Academic Achievement in Kindergarten Among Disadvantaged Children

Jasmine Tua Karing¹ · Alexis Tracy¹ · Christopher R. Gonzales² · Alexandra F. Nancarrow¹ · Emily J. Tomayko³ · Shauna Tominey¹ · Hannah Escobar¹ · Megan M. McClelland¹

Accepted: 9 June 2021 / Published online: 23 August 2021

© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2021

Abstract

Objectives The importance of breastfeeding exposure and children’s development of self-regulation, independently, are well established. Each of these domains also has been linked to better cognitive development and academic achievement in children. However, little is known about how breastfeeding affects development of early self-regulation skills or whether self-regulation mediates the relationship between breastfeeding and academic achievement, particularly for disadvantaged children. This study examined breastfeeding exposure, self-regulation, and academic achievement in kindergarten among a population of children who previously attended Head Start.

Methods Children were recruited from Head Start classrooms in the Pacific Northwest. Breastfeeding exposure was assessed via parent report. Children’s self-regulation (Day Night Stroop, Dimensional Change Card Sort, Head-Knees-Toes-Shoulders-Revised) and academic achievement [Letter-Word Identification and Applied Problems subtests of Woodcock Johnson Tests of Achievement (English) or the Bateria III Woodcock-Muñoz (Spanish)] were directly assessed in fall and spring of kindergarten. Regressions were performed using Stata v14.1 and included breastfeeding exposure as the primary independent variable, controlling for child age, sex, and language spoken.

Results Of the 246 children, 56% were reported as White, 34% Latino/a, 4% African American, and 6% other; 83% were ever exposed to breastfeeding. Breastfeeding exposure was predictive of both fall kindergarten academic achievement (emergent math/literacy scores) and self-regulation ($p < 0.05$) and related to higher math performance in the spring of kindergarten, which was associated with stronger self-regulation in the fall ($p = 0.04$).

Conclusions These findings extend our understanding of the positive effects of breastfeeding exposure on children’s development and support breastfeeding promotion, particularly for children at risk of academic difficulty.

Keywords Breastfeeding · Self-regulation · Academic achievement · Cognitive development

Significance

Self-regulation has a positive influence on the development of early academic skills, and breastfeeding is known to promote cognitive development. This study extends

previous findings by contributing to our understanding of how breastfeeding exposure is associated with early self-regulation skills and academic achievement in kindergarten, which was previously unknown. Although the physical health benefits of breastfeeding are well understood, these findings highlight the importance of breastfeeding to support self-regulation and academic achievement in young children, particularly those at higher risk of academic difficulty.

✉ Jasmine Tua Karing
jasmine.karing@oregonstate.edu

¹ Human Development & Family Sciences, 245 Hallie E. Ford Center for Healthy Children & Families, Oregon State University, Corvallis, OR 97331, USA

² Center for Mind and Brain, University of California, Davis, Sacramento, CA 95618, USA

³ Center for American Indian and Rural Health Equity, Montana State University, Bozeman, MT 59718, USA

Introduction

Self-regulation, defined as the ability to control emotions, behaviors, and cognitions (McClelland & Cameron, 2012), rapidly develops in early childhood and is a malleable skill

that can be strengthened with support over time (Diamond et al., 2007). Although definitions differ, there is consensus that self-regulation includes aspects of inhibitory control (e.g., demonstrating self-control), cognitive flexibility (e.g., switching between tasks or rules), and working memory (e.g., remembering instructions) (McClelland & Cameron, 2012). Strong self-regulation skills predict academic achievement in early childhood, including math and literacy skills, which are important indicators of early school readiness and success (McClelland & Cameron, 2011, 2012). Socio-demographic risk factors, such as low family income, are negatively related to children's self-regulation and academic achievement (Sektnan et al., 2010). Conversely, secure relationships with caregivers established early in life have been shown to support children's self-regulation development and academic achievement, even in the presence of sociodemographic risk (Brody, 1994). For many children, one of the first ways secure relationships are supported is within the breastfeeding relationship, and thus, this relationship may be foundational to the development of self-regulation.

Breastfeeding exposure (i.e., breastfed at least once) has been linked to better outcomes in children (Angelsen et al., 2001; Belfort et al., 2013; Horwood & Fergusson, 1998). For example, research has found higher scores on measures of academic achievement for children who were ever breastfed compared to non-breastfed children. In a study by Huang et al. (2014), children were measured at three different time points over a 10-year period to evaluate the relationship between breastfeeding exposure and the growth of cognitive ability. Even after controlling for an extensive set of covariates, including child characteristics (e.g., race, preterm birth, low birth weight, physical/mental limitations), parental characteristics (e.g., education, employment, parental warmth, emotional support to child), and household characteristics (e.g., household size, household income, number of children, and financial assistance status), an initial benefit for ever-breastfed children was observed that remained significant over time despite similar trajectories for both ever-breastfed and non-breastfed groups of children. Additionally, McCrory and Layte (2011) identified a significant increase in reading and math standardized test scores between 9-year-olds who were ever breastfed compared to those who were not. This finding suggests any exposure to breastfeeding, regardless of duration, exclusivity, and intensity, may positively influence academic achievement, and this benefit may persist over time.

The present study examines how breastfeeding exposure is related to children's self-regulation and academic achievement as they make the transition into kindergarten. Self-regulation is an important predictor of academic achievement that stems, in part, from having a secure attachment relationship and thus is a potential mediator to explore. For example,

it is within the early breastfeeding relationship that many children first develop the foundation for a secure attachment (Gibbs et al., 2018). Through shared eye contact, physical closeness, and vocalizing, mothers who are breastfeeding their children have the potential to use these moments to foster a secure and positive relationship, providing a secure base for further self-regulation development. This may be related to better self-regulation in children and to stronger academic achievement as they enter formal schooling.

Purpose

The importance of both breastfeeding exposure and self-regulation on early academic achievement is well established. However, little is known about the relationship between breastfeeding and the development of self-regulation skills in early childhood or whether self-regulation mediates the relationship between breastfeeding exposure and academic achievement. It may be especially beneficial to understand the relationship between having ever been breastfed and self-regulation skills during the transition to formal schooling as children enter kindergarten, particularly among children in families from disadvantaged backgrounds who are at greater risk of falling behind academically than their peers (Reardon, 2013).

In the early years of children's development, self-regulation is primarily an external process, when children's first means of regulating their emotions and behaviors include crying and cooing (Posner & Rothbart, 2000). Infants rely on their caregivers to provide the regulation required to meet their needs. It should be noted that many of these behaviors can be engaged in while bottle-feeding, but evidence suggests stronger connections between and greater frequency of these behaviors and breastfeeding. In one study, children who were breastfed were more likely to use their caregiver for comfort and as a secure base when exploring (Gibbs et al., 2018). Moreover, studies suggest that many of the behaviors associated with having a secure attachment (e.g., maternal sensitivity, autonomy support) are those also essential to the development of self-regulation (Bernier et al., 2010).

In the present study, we examined if breastfeeding exposure predicted self-regulation skills and academic achievement at age five during the transition to formal schooling for children who attended Head Start, a preschool program developed to serve low-income families. We hypothesized breastfeeding exposure would have significant positive associations with children's self-regulation skills and academic achievement in the fall of kindergarten based on previous research that found breastfeeding exposure predictive of children's academic achievement (Huang et al., 2014; McCrory & Layte, 2011).

We also examined if self-regulation in the fall of kindergarten served as a mediator between breastfeeding exposure and academic achievement in the spring of kindergarten. We expected to find indirect pathways from breastfeeding exposure through self-regulation to academic achievement in the spring of kindergarten. Specifically, we anticipated that children exposed to breastfeeding would be more likely to have stronger self-regulation skills at the fall of kindergarten, which would be related to stronger academic achievement in the spring of kindergarten.

Methods

Participants

Participants were recruited from Head Start classrooms in the Pacific Northwest region of the United States ($N=246$ children). For children to participate in the study, parents signed a written informed consent statement approved by the (Blinded) University Institutional Review Board, which also approved all study protocols. Direct assessments were conducted in the fall and spring of kindergarten. At each of these two time points, children were directly assessed in two to three sessions lasting no longer than 15 min. Families received a \$20 gift card for participation at each time point (fall and spring), for a total of \$40 during the kindergarten year.

Measures

Language Screener

The Simon Says and Art Show subtests of the Pre-Language Assessment System (preLAS) were used to determine whether a child should receive the direct self-regulation and academic assessments in English or Spanish (Duncan & De, 1998). Simon Says measures receptive language proficiency, and Art Show measures expressive language. These two subtests of the preLAS have strong reliability and validity in Spanish-speaking preschool age children (Rainelli & López, 2017). Out of 20 possible points, children were considered to pass the preLAS if they received a score of 15 or more and assessments were given in English.

Direct Measures of Self-Regulation

To best measure the complex construct of self-regulation, we used multiple measures assessing inhibitory control, cognitive flexibility, and overall self-regulation. The Day-Night Stroop task (Gerstadt et al., 1994) is a measure of children's inhibitory control, one aspect of self-regulation. The task presents children with a series of 16 cards with pictures of

a sun or moon. Children are asked to say the opposite of what they see, saying “day” for a moon and “night” for a sun. For each trial, children receive 0 points if they said the same word for the picture on the card, 1 point if they self-corrected themselves starting with the same word and then saying the opposite word, and two points if they said the correct word without any correction. Children receive a sum score of the cards that they respond to correctly ranging from 0 to 32. The Day-Night Stroop task has been shown to be a reliable and valid assessment in prekindergarten- and kindergarten-age children (Rhoades et al., 2009). In the current sample, the internal reliability or Cronbach's alpha was 0.86.

The Dimensional Change Card Sort (DCCS) is a measure of cognitive flexibility, which is another part of self-regulation. Children are asked to sort cards first by color (pre-switch phase), then by shape (post-switch phase) (Zelazo, 2006). If children receive a score of 5 or more, out of 6, they pass the post-switch phase and move on to the border section. In this section, children are asked to sort cards based on the presence of a border around some cards. Overall score is the total number of cards sorted correctly, ranging from 0 to 24. In the current sample, the internal reliability or Cronbach's alpha was 0.72.

The Head-Toes-Knees-Shoulders-Revised (HTKS-R) task was used to assess children's overall self-regulation and taps inhibitory control, cognitive flexibility, and working memory in children ages 3–8 years (McClelland et al., 2014). In the first section, children are asked to say *head* if the assessor says *toes* and *toes* if the assessor says *head*. In the next section, children are told to touch their head (or toes) when asked to touch their toes (or head). Then, in the following section, both rules are included (head/toes opposite and knees/shoulders opposite). In the last section, the rules are switched, with head and knees paired and shoulders and toes paired. The overall score for this measure ranges from 0 to 118. The HTKS-R measure has demonstrated strong reliability and validity in diverse samples (McClelland et al., 2014; Wanless et al., 2011). In the current sample, the HTKS-R demonstrated strong internal reliability with a Cronbach's alpha of 0.90.

Direct Measures of Academic Achievement: Emergent Literacy and Math Skills

The Letter-Word Identification and Applied Problems subtests of the Woodcock Johnson Tests of Achievement (Woodcock et al., 2001) were used to assess children's emergent literacy and math in English or Spanish (Muñoz-Sandoval et al., 2009). Previous research has demonstrated high reliability and validity ($\alpha > 0.80$) for all subtests (Woodcock et al., 2001): reliabilities range between 0.98 and 0.99 for English speaking preschool children and 0.84–0.98 for

Spanish-speaking children. Early literacy and math skills have been shown to be strongly related to self-regulation development and early school success (McClelland & Cameron, 2011, 2012). In the present study, *W* scores were used in the analyses, which are standardized based on the average performance of a child at a given age.

The Letter-Word Identification subtest assesses letter skills and developing word-decoding skills. The Applied Problems subtest of the Woodcock Johnson Tests of Achievement measures children's early math operations needed to solve practical problems in English or Spanish. Reliabilities are 0.92–0.94 for English-speaking preschool children and 0.93–0.95 for Spanish-speaking preschool children.

Demographics and Breastfeeding

In addition to direct child assessments, a demographic questionnaire was mailed to all participating families. Following each of the two in-person direct measurement sessions (fall and spring of kindergarten), efforts were made to increase response rates by mailing additional copies of the questionnaires and following up with phone calls to families that had not yet responded.

Parents reported breastfeeding exposure by responding to the question, “Did you ever breastfeed or pump breast milk to feed your child?” as part of a larger demographic questionnaire.

Responses were as follows: 0 = no, 1 = yes. Breastfeeding duration also was included in the questionnaire using the following question: “If yes- for how long?” The response option for this question was open-ended to allow respondents to write the value for duration measured in months.

Analytic Strategy and Missing Data

Data analyses were conducted using Stata 14.1 (StataCorp, 2015). During the transition from preschool to kindergarten, children in Head Start attended elementary schools within their respective school districts. Because of this, participating children were rarely clustered within the same kindergarten classrooms (average cluster = 2); therefore, models did not account for nesting. Missing data on breastfeeding exposure occurred on account of families not returning their demographic survey ($n = 127$, 51%). All families who returned their questionnaire responded to the breastfeeding question. Additionally, no differences were found between families who were missing complete data on breastfeeding exposure and outcome variables. The missing data on fall self-regulation (Day/Night; $n = 1$, 1%, DCCS; $n = 3$, 1%), and spring academic achievement measures (emergent literacy; $n = 12$, 5%, math; $n = 12$, 5%) resulted from a lack of response from the participating child as well as attrition and

other extraneous circumstances for direct assessments (e.g., child was absent on the scheduled data collection day). Data were assumed to be missing at random. We used multiple imputation to generate 50 datasets in Stata; these datasets were used in all primary analyses ($N = 246$). Results from imputed datasets were combined into a single imputed result. No significant differences were found between imputed and non-imputed results.

To determine if breastfeeding exposure (yes/no) predicts self-regulation skills and academic achievement (emergent literacy and math) in the fall of kindergarten, a series of linear regressions was performed. Each regression included breastfeeding exposure as the primary independent variable, controlling for child age in months, child sex, and child language during the kindergarten assessment. To investigate the nature of the relationship between breastfeeding exposure and academic achievement in the spring of kindergarten, a mediation analysis was performed. Two models were used to explore the relationship between the independent variable, breastfeeding exposure, and the two dependent variables of spring academic achievement (literacy and math), using a measure of self-regulation in the fall of kindergarten as the mediating variable.

Results

Fifty-three percent of the sample were female, and 47% were male. The average age in the fall of kindergarten was 67.3 ± 3.7 months, and parents reported their child's race as White (56%), Latino/a (34%), African American (4%), and more than one race (6%). Of this sample, 94% were proficient in English at the beginning of kindergarten; the remaining children (6%) were given assessments in Spanish.

The total response rate for the demographic questionnaire was 48% ($N = 119$). Similar response rates for demographic questionnaires have been observed among this population in previous studies (e.g., McClelland et al., 2019). All parents who returned the demographic questionnaire responded to questions regarding breastfeeding. In total, 83% of children were reported as having been exposed to breastfeeding. Duration responses ranged 0 to 42 months ($M = 8.1$ months, $SD = 8.9$). Means and standard deviations for all study variables can be found in Tables 1 and 2. Correlations between study variables using the original dataset (without imputed data) are presented in Table 3.

Results of regression analyses indicated that breastfeeding exposure significantly predicted self-regulation skills and emergent literacy and math outcomes in the fall of kindergarten after controlling for child age in months, child sex, and child language (Table 4). Similar results were found with listwise deletion: breastfeeding exposure significantly predicted self-regulation (Day-Night R^2 total = 0.06, $\beta = 0.17$,

Table 1 Descriptive statistics for non-imputed study variables in the fall and spring of kindergarten

Continuous variable	<i>N</i>	<i>M</i>	<i>SD</i>	Range
Child age (months)	246	67.3	3.7	59.6–73.9
Fall self-regulation				
HTKS-R	246	71.9	32.2	0–118
Day/night	245	26.2	6.8	0–32
DCCS	243	15.3	5.2	5–24
Fall math	246	420.3	22.4	301–462
Fall emergent literacy	246	343.7	28.3	264–486
Spring emergent literacy	234	382.8	31.7	264–514
Spring math	234	433.8	20.4	318–467
Breastfeeding duration (0 = none)	114	8.1	8.9	0–42
Categorical variables			Yes (%)	No (%)
Breastfeeding exposure (yes/no)	119		83	17
English language learner	246		6	94
Child sex	246		47 (male)	53 (female)

HTKS-R Head Toes Knees Shoulders-Revised, *DCCS* Dimensional Change Card Sort, *Day/Night* Day-Night Stroop task

Table 2 Descriptive statistics for imputed major study variables in the fall and spring of kindergarten (*N* = 246)

Continuous variables	<i>M</i>	<i>SD</i>	Range
Child age (months)	67.3	3.7	59.6–73.9
Fall self-regulation			
HTKS-R	71.9	32.2	0–118
Day/night	26.2	6.8	0–32.9
DCCS	15.3	5.3	4.6–24.2
Fall math	420.3	22.4	301–462
Fall emergent literacy	343.7	28.3	264–486
Spring emergent literacy	383.8	32.4	264–514.6
Spring math	433.8	20.5	318–475.4

HTKS-R Head Toes Knees Shoulders-Revised, *DCCS* Dimensional Change Card Sort, *Day/Night* Day-Night Stroop task

$p < 0.05$), emergent literacy (R^2 total = 0.10, $\beta = 0.23$, $p < 0.05$), and math (R^2 total = 0.19, $\beta = 0.20$, $p < 0.05$). Breastfeeding duration, however, was not significantly related to outcome measures in the fall and spring of kindergarten after controlling for child age, child sex, and child language.

To determine if self-regulation in the fall of kindergarten significantly mediated the relationship between breastfeeding exposure and academic achievement in the spring of kindergarten, mediation models were analyzed with emergent literacy and math as outcomes (Figs. 1, 2). A significant indirect effect was found between breastfeeding exposure and math ($\beta = 0.18$, $SE = 0.08$, $p = 0.04$) through children's fall self-regulation scores on the Day-Night Stroop task. Specifically, breastfeeding exposure was related to stronger self-regulation in the fall of kindergarten, which was then

related to higher math scores in the spring of kindergarten. No significant indirect effects were found between breastfeeding exposure and emergent literacy through children's fall self-regulation scores on the Day-Night Stroop task.

Discussion

This study investigated if breastfeeding exposure predicted self-regulation skills and academic achievement in the fall of kindergarten for a sample of children from families with low-income. Additionally, we examined if self-regulation skills in the fall of kindergarten mediated the relationship between breastfeeding exposure and academic achievement in the spring of kindergarten. Results indicated that breastfeeding exposure was predictive of fall kindergarten self-regulation and literacy and math scores. A significant indirect effect also was found where fall self-regulation significantly mediated the relationship between breastfeeding exposure and math scores in the spring of kindergarten. However, no significant indirect effect was found between breastfeeding exposure and literacy in the spring of kindergarten.

When examining the relationship between breastfeeding exposure predicting self-regulation and academic achievement (e.g., emergent literacy and math skills) in the fall of kindergarten, our findings suggest that children who were ever breastfed entered kindergarten with stronger self-regulation skills and emergent literacy and math skills than those who were never breastfed. This finding supports previous research finding higher academic achievement among breastfed children compared to non-breastfed children at 3 and 6 years of age (Huang et al., 2014; McCrory & Layte, 2011),

Table 3 Correlations between study variables using non-imputed data (N = 246)

	1	2	3	4	5	6	7	8	9	10	11	12
1) Child age (months)	-											
2) Child sex	-0.03	-										
3) English language learner	0.04	-0.02	-									
4) Breastfeeding exposure	0.08	0.10	0.02	-								
5) Breastfeeding duration	0.01	-0.02	0.06	0.42***	-							
6) Fall self-regulation (Day/Night)	0.20**	-0.02	-0.05	0.20*	0.12	-						
7) Fall self-regulation (HTKS-R)	0.28***	-0.03	-0.20**	0.18***	0.03	0.48***	-					
8) Fall self-regulation (DCCS)	0.14*	-0.05	-0.21***	-0.10	-0.20*	0.27***	0.37***	-				
9) Fall literacy	0.21**	-0.04	-0.11	0.24**	-0.02	0.26***	0.41***	0.31***	-			
10) Fall math	0.15*	-0.02	-0.37***	0.24**	0.08	0.42***	0.63***	0.45***	0.55***	-		
11) Spring literacy	0.29***	-0.05	-0.09	0.27**	-0.02	0.25***	0.40***	0.30***	0.70***	0.52***	-	
12) Spring math	0.22**	-0.09	-0.21***	0.22*	0.06	0.32***	0.49***	0.40***	0.47***	0.71***	0.52***	-

* $p < 0.05$
 ** $p < 0.01$
 *** $p < 0.001$
 **** $p < 0.06$

while extending evidence of these relationships to a low-income sample. Moreover, results suggests that connections between breastfeeding and self-regulation may be a promising area to explore in future studies.

These findings also indicate that positive relationships between breastfeeding exposure and self-regulation exist among children who share similar demographic risk factors. Ample research suggests that children from disadvantaged backgrounds often experience cumulative risk factors that contribute to a growing achievement gap between these children and their more advantaged peers [e.g., (Barnett & Lamy, 2013; Haskins, 2005)]. Studies have demonstrated that children from disadvantaged backgrounds who are experiencing multiple risk factors may be less able than their peers to regulate their attention in goal-directed tasks (Evans & Rosenbaum, 2008). Findings from the current study suggest that breastfeeding exposure is related to stronger self-regulation among disadvantaged children, which is especially important as children enter formal schooling and are met with increased social and cognitive demands (Rimm-Kaufman et al., 2009).

Children who enter kindergarten with strong self-regulation skills are more likely to draw upon these skills during the transition to formal schooling (Cameron et al., 2020). Results of the current study suggest that ever-breastfed children entering kindergarten may be more equipped to successfully navigate the transition to formal schooling compared to their non-breastfed peers. Our findings suggest that exposure to breastfeeding supports developmental influences that positively shape a child’s early self-regulation skills and academic achievement, and the process through which this happens warrants further investigation.

Furthermore, prior breastfeeding studies with more diverse samples that control for income differences are limited in addressing the confounding effects of positive environmental factors outside of economic status. Several studies have demonstrated that breastfeeding duration and exclusivity are associated with better self-regulation yet fail to control for potential confounding variables, such as home environment, child care, and maternal education (Belfort et al., 2013). Thus, the benefits of breastfeeding may be further elucidated if examined in a sample with resource homogeneity. Additionally, how long a mother breastfeeds her baby is influenced by many complex factors. Measuring length of time does not capture the frequency and intensity of the breastfeeding relationship. Although measuring breastfeeding exposure alone does not depict the many aspects of this complex relationship, it can capture a mother’s intent. This was supported in the present study by mothers who initiated breastfeeding indicating that they did so for an average of 8.1 months, which aligned with current state duration rates in the Pacific Northwest (CDC).

Table 4 Breastfeeding exposure predicting academic achievement in fall of kindergarten (*N* = 246)

	HTKS-R	D-N	DCCS	Literacy	Math
Child age (months)	0.28***	0.19**	0.16*	0.19**	0.14*
Child sex	-0.03	-0.03	-0.04	-0.05	-0.04
Child language	-0.22***	-0.07	-0.21**	-0.13*	-0.38***
Breastfeeding Exposure	0.13	0.17*	-0.07	0.23*	0.20*
Adj R ² total	0.13	0.06	0.06	0.10	0.19

Values represent standardized regression coefficients (β) over 50 imputations

HTKS-R Head Toes Knees Shoulders-Revised, D-N Day-Night, DCCS Dimensional Change Card Sort

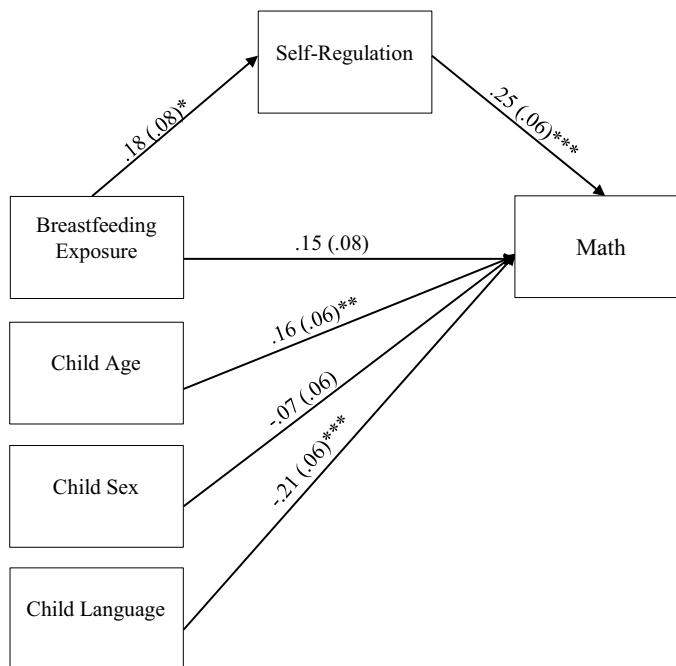
* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

**** $p < 0.06$

Fig. 1 Fall Kindergarten Self-Regulation Mediation Model Predicting Math in the Spring of Kindergarten. Values represent standardized coefficients. Values in parentheses represent standard error. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$



Note. Values represent standardized coefficients. Values in parentheses represent standard error. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

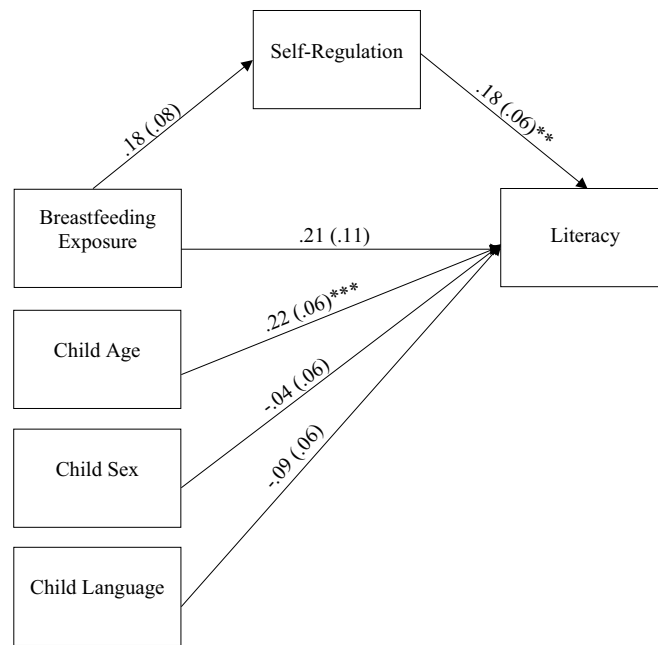
It is possible that breastfeeding exposure contributes uniquely to the bidirectional nature of self-regulation and early academic skills. In a recent study, findings suggested children's self-regulatory and cognitive skills are concurrently developing and that engaging in early cognitive activities is beneficial for self-regulation development and vice versa (Cameron et al., 2019). Thus, the bidirectional nature of self-regulation and emergent math and literacy skills may pose a challenge in detecting this sequential pathway with specificity (Blair & Ursache, 2011; McClelland et al., 2010). Knowing more about the context of each child's breastfeeding exposure (e.g., frequency, duration, quality of the parent-child relationship) as well as reasons why children were

not exposed to breastfeeding (e.g., child or family special needs or health challenges) might strengthen future studies.

Limitations and Future Directions

The present study had a number of strengths, but also some limitations. For example, we were not able to assess characteristics of the parent-child relationship in this study. Observing the parent-child interaction during feeding (breastfeeding or alternate forms of feeding, such as bottle-feeding) could further clarify mechanisms explaining the relationship between breastfeeding, self-regulation, and academic achievement.

Fig. 2 Fall Kindergarten Self-Regulation Mediation Model Predicting Literacy in the Spring of Kindergarten. Values represent standardized coefficients. Values in parentheses represent standard error. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$



Note. Values represent standardized coefficients. Values in parentheses represent standard error. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

We also were limited in examining and accounting for exclusivity, frequency, and intensity of breastfeeding, making it challenging to detect dose-dependent benefits. For example, breastfeeding duration and exclusivity are important predictors of outcomes in children. Length of time spent breastfeeding has been shown to be a protective factor for cognitive development. As shown in studies that measured exclusivity and duration (Quinn & Bor, 2001; Gómez-Sanchiz et al., 2003; Oddy et al., 2011), dose-dependent benefits included higher academic test scores, specifically emerging vocabulary skills, and increased mental development. Although it was beyond the scope of the present study, these are important factors to consider when investigating the relationship between breastfeeding and child outcomes. It also is important to note that there was a considerable amount of missing data on the breastfeeding exposure variable (51%), although this was the same amount of missing data that was found in the overall demographic questionnaire. Of the mothers who completed the demographic questionnaire, most said they breastfed their child (83%). Thus, our results should be interpreted within the context of mothers who are likely to breastfeed their children.

Finally, breastfeeding benefits are derived from both biological and relational aspects. This study was limited because it was not able to take into account the biological benefits or the context of the relational aspects of breastfeeding. Biological factors include biologically active peptides and essential long chain polyunsaturated fatty acids that influence brain growth and support the biological

explanation between breastfeeding and brain development (Mosca & Gianni, 2017). Because of the robust evidence to support this biological link, the inability to differentiate between the contributions of biological and relational benefits is a limitation of this study. It is plausible that these components interact in dynamic ways, adding to the nuance of distinguishing individualized contributions.

Conclusions for Practice

Results of the current study extend our understanding of the positive effects of breastfeeding exposure on children's social and cognitive development. As children and families navigate the increasingly complex school structure, it is important that parents, teachers, administrators, and policy-makers understand the significance of supporting children's early social and cognitive development and how children's previous experiences or home risk factors may support or hinder school success. Additional future directions should include a focus on developing policy and promotion efforts to increase breastfeeding rates throughout the United States as well as to better understand the relational and biological aspects of breastfeeding most closely associated with self-regulation and academic outcomes. For example, understanding how the parent–child relationship develops in the context of breastfeeding (e.g., making eye contact, participating in shared attention, developing a secure relationship) and how these behaviors specifically relate to self-regulation

may help inform intervention programs to strengthen these aspects of the breastfeeding relationship as well as to extend these same behaviors in relationships with children who are not able to be breastfed. These findings also may be used to inform existing programs that aim to promote awareness of the benefits of breastfeeding. The implementation of such programs may be successful in increasing the physical health and later cognitive development of many children throughout the country, particularly children who face sociodemographic disadvantages in early life.

Acknowledgements This work was supported by the United States Department of Education Institute for Education Sciences grant #R305A150192 (PI: MM) to Oregon State University. ET was supported by the National Institute of General Medical Sciences under Award Number P20GM104417. The content is the responsibility of the authors and does not necessarily represent the official views of the Institute of Education Sciences, or the United States Department of Education, or the National Institutes of Health. In addition, we thank all the participating children, families, teachers, and schools in this research study.

References

- Angelsen, N. K., Vik, T., Jacobsen, G., & Bakketeig, L. S. (2001). Breast feeding and cognitive development at age 1 and 5 years. *Archives of Disease in Childhood*, *85*(3), 183–188. <https://doi.org/10.1136/adc.85.3.183>
- Barnett, W. S., & Lamy, C. E. (2013). *Achievement gaps start early. Closing the opportunity gap: What America must do to give every child an even chance*. Oxford University Press.
- Belfort, M. B., Rifas-Shiman, S. L., Kleinman, K. P., Guthrie, L. B., Bellinger, D. C., Taveras, E. M., Gillman, M. W., & Oken, E. (2013). Infant feeding and childhood cognition at ages 3 and 7 years: Effects of breastfeeding duration and exclusivity. *JAMA Pediatrics*, *167*(9), 836–844. <https://doi.org/10.1001/jamapediatrics.2013.455>
- Bernier, A., Carlson, S. M., & Whipple, N. (2010). From external regulation to self-regulation: Early parenting precursors of young children's executive functioning. *Child Development*, *81*(1), 326–339. <https://doi.org/10.1111/j.1467-8624.2009.01397.x>
- Blair, C., & Ursache, A. (2011). *A bidirectional theory of executive functions and self-regulation* (2nd ed.). Guilford Press.
- Brody, G., Stoneman, Z., & McCoy, J. (1994). Contributions of protective and risk factors to literacy and socioemotional competency in former head start children attending kindergarten. *Early Childhood Research Quarterly*, *9*(3–4), 407–425.
- Cameron, C. E., Kim, H., Duncan, R., Becker, D., & McClelland, M. M. (2019). Bidirectional and co-developing associations of cognitive and academic skills during kindergarten. *Journal of Applied Developmental Psychology*, *62*, 135–144.
- Cameron, C. A., Pinto, G., Stella, C., & Hunt, A. K. (2020). A Day in the Life of young children drawing at home and at school. *International Journal of Early Years Education*, *28*(1), 97–113.
- Centers for Disease Control and Prevention. National Center for Chronic Disease Prevention and Health Promotion, Division of Nutrition, Physical Activity, and Obesity. Data, Trend and Maps [online]. Retrieved May 13, 2021, from, <https://www.cdc.gov/nccdphp/dnpao/data-trends-maps/index.html>.
- Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Pre-school program improves cognitive control. *Science*, *318*(5855), 1387–1388. <https://doi.org/10.1126/science.1151148>
- Duncan, S. E., & De, A. E. A. (1998). *PreLAS2000 assessment kit*. CTB/McGraw-Hill.
- Evans, G. W., & Rosenbaum, J. (2008). Self-regulation and the income-achievement gap. *Early Childhood Research Quarterly*, *23*, 504–514.
- Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: Performance of children 3 1/2–7 years old on a Stroop-like day-night test. *Cognition*, *53*(2), 129–153. [https://doi.org/10.1016/0010-0277\(94\)90068-x](https://doi.org/10.1016/0010-0277(94)90068-x)
- Gibbs, B. G., Forste, R., & Lybbert, E. (2018). Breastfeeding, parenting, and infant attachment behaviors. *Maternal and Child Health Journal*, *22*(4), 579–588. <https://doi.org/10.1007/s10995-018-2427-z>
- Gómez-Sánchez, M., Cañete, R., Rodero, I., Baeza, J. E., & Avila, O. (2003). Influence of breast-feeding on mental and psychomotor development. *Clinical Pediatrics (phila)*, *42*(1), 35–42. <https://doi.org/10.1177/000992280304200106>
- Haskins, R., & Rouse, C. (2005). *Closing Achievement Gaps*. Brookings Institution.
- Horwood, L. J., & Fergusson, D. M. (1998). Breastfeeding and later cognitive and academic outcomes. *Pediatrics*, *101*(1), E9. <https://doi.org/10.1542/peds.101.1.e9>
- Huang, J., Peters, K. E., Vaughn, M. G., & Witko, C. (2014). Breast-feeding and trajectories of children's cognitive development. *Developmental Science*, *17*(3), 452–461. <https://doi.org/10.1111/desc.12136>
- McClelland, M. M., & Cameron, C. E. (2011). Self-regulation and academic achievement in elementary school children. *New Directions for Child and Adolescent Development*, *2011*(133), 29–44. <https://doi.org/10.1002/cd.302>
- McClelland, M. M., & Cameron, C. E. (2012). Self-regulation in early childhood: Improving conceptual clarity and developing ecologically valid measures. *Child Development Perspectives*, *6*(2), 136–142.
- McClelland, M. M., Cameron, C. E., Duncan, R., Bowles, R. P., Acock, A. C., Miao, A., & Pratt, M. E. (2014). Predictors of early growth in academic achievement: The head-toes-knees-shoulders task. *Frontiers in Psychology*, *5*, 599. <https://doi.org/10.3389/fpsyg.2014.00599>
- McClelland, M., Ponitz, C., Messersmith, E., & Tominey, S. (2010). *The handbook of life-span development: Cognition, biology, and methods* (Vol. 1). Wiley.
- McClelland, M. M., Tominey, S. L., Schmitt, S. A., et al. (2019). Red light, purple light! results of an intervention to promote school readiness for children from low-income backgrounds. *Frontiers in Psychology*. <https://doi.org/10.3389/fpsyg.2019.02365>
- McCrorry, C., & Layte, R. (2011). The effect of breastfeeding on children's educational test scores at nine years of age: Results of an Irish cohort study. *Social Science and Medicine*, *72*(9), 1515–1521. <https://doi.org/10.1016/j.socscimed.2011.03.002>
- Mosca, F., & Gianni, M. L. (2017). Human milk: Composition and health benefits. *Pediatrica Medica e Chirurgica*, *39*(2), 155. <https://doi.org/10.4081/pmc.2017.155>
- Muñoz-Sandoval, A. F., Woodcock, R. W., McGrew, K. S., Mather, N., & Ardoino, G. (2009). *Batería III Woodcock-Muñoz*, (Vol. 3). Ciencias Psicológicas, pp. 245–246.
- Oddy, W. H., Li, J., Whitehouse, A. J., Zubrick, S. R., & Malacova, E. (2011). Breastfeeding duration and academic achievement at 10 years. *Pediatrics*, *127*(1), e137–145. <https://doi.org/10.1542/peds.2009-3489>
- Posner, M. I., & Rothbart, M. K. (2000). Developing mechanisms of self-regulation. *Development and Psychopathology*, *12*, 427–441.
- Quinn, P. J., O'Callaghan, M., Williams, G. M., Najman, J. M., Andersen, M. J., & Bor, W. (2001). The effect of breastfeeding on child development at 5 years: A cohort study. *Journal of Paediatrics and Child Health*, *37*, 465–469.

- Rainelli, S., Shearer, R., Fernandez, V. A., Greenfield, D., & López, M. (2017). Validity of the first two subtests of the preschool language assessment scale as a language screener for Spanish-speaking preschool children. *Early Childhood Research Quarterly*, 38, 10–22. <https://doi.org/10.1016/j.ecresq.2016.08.001>
- Reardon, S. F. (2013). The Widening Income Achievement Gap. In (Vol. 70): Educational Leadership, pp. 10–16.
- Rhoades, B. L., Greenberg, M. T., & Domitrovich, C. E. (2009). The contribution of inhibitory control to preschoolers' social-emotional competence. *Journal of Applied Developmental Psychology*, 30(3), 310–320. <https://doi.org/10.1016/j.appdev.2008.12.012>
- Rimm-Kaufman, S. E., Curby, T. W., Grimm, K. J., Nathanson, L., & Brock, L. L. (2009). The contribution of children's self-regulation and classroom quality to children's adaptive behaviors in the kindergarten classroom. *Developmental Psychology*, 45(4), 958–972. <https://doi.org/10.1037/a0015861>
- Sektan, M., McClelland, M. M., Acock, A., & Morrison, F. J. (2010). Relations between early family risk, children's behavioral regulation, and academic achievement. *Early Child Research Quarterly*, 25(4), 464–479. <https://doi.org/10.1016/j.ecresq.2010.02.005>
- Wanless, S. B., McClelland, M. M., Acock, A. C., Ponitz, C. C., Son, S. H., Lan, X., Morrison, F. J., Chen, J.-L., Chen, F.-M., Lee, K., Sung, M., & Li, S. (2011). Measuring behavioral regulation in four societies. *Psychological Assessment*, 23(2), 364–378. <https://doi.org/10.1037/a0021768>
- Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). Woodcock-Johnson III tests of achievement.
- Zelazo, P. D. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols*, 1(1), 297–301. <https://doi.org/10.1038/nprot.2006.46>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.