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Mother–infant interactions and infant intake during breastfeeding versus bottle-feeding expressed breast milk

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Abstract

Bottle-fed infants are at higher risk for rapid weight gain compared with breastfed infants. Few studies have attempted to disentangle effects of feeding mode, milk composition and relevant covariates on feeding interactions and outcomes. The objective of the present study was to compare effects of breastfeeding directly at the breast versus bottle-feeding expressed breast milk on feeding interactions. Mothers with <6-month-old infants (n = 47) participated in two counterbalanced, feeding observations. Mothers breastfed their infants directly from the breast during one visit (*breast* condition) and bottle-fed their infants expressed breast milk during the other (*bottle* condition). Masked raters later coded videos using the Nursing Child Assessment Parent–Child Interaction Feeding Scale. Infant intake was assessed. Mothers self-reported sociodemographic characteristics, infant feeding patterns (i.e. percentage of daily feedings from bottles) and level of pressuring feeding style. Mother and infant behaviours were similar during *breast* and *bottle* conditions. Percent bottle-feeding moderated effects of condition on intake (P = 0.032): greater percent bottle-feeding predicted greater intake during the *bottle* compared with *breast* condition. Effects of feeding mode were not moderated by parity or pressuring feeding style, but, regardless of condition, multiparous mothers fed their infants more than primiparous mothers (P = 0.028), and pressuring feeding style was positively associated with infant intake (P = 0.045). Findings from the present study do not support the hypothesis that feeding mode directly impacts dyadic interaction for predominantly breastfeeding mothers and infants, but rather suggest between-subject differences in feeding experiences and styles predict feeding outcomes for this population.

KEYWORDS
bottle-feeding, breastfeeding, expressed breast milk, infant feeding practices, mother–infant interactions, pressuring feeding style, rapid infant weight gain, responsive feeding style, within-subject

1 | INTRODUCTION

Breastfeeding is the gold standard for infant feeding, as it is associated with numerous benefits for both mothers and infants (Horta et al., 2015; Koletzko et al., 2019). In particular, breastfed infants exhibit healthier weight gain trajectories than their formula-fed peers (Dewey, 1998; Dewey et al., 1993) and are less likely to exhibit rapid weight gain during infancy (Goetz et al., 2018; Li et al., 2012; Mihrshahi et al., 2011; Ventura, 2017b). Rapid weight gain during infancy is one of the earliest postnatal risk factors for the development of later obesity and metabolic dysfunction (Dennison et al., 2006; Ekelund et al., 2006; Sacco et al., 2013; Stettler et al., 2003), implicating infant feeding as an important focus for primary prevention.

Previous research examining mechanisms underlying associations between breastfeeding and healthier weight gain trajectories has typically compared breastfed infants with formula-fed or bottle-fed (regardless of whether formula or expressed breast milk is in the bottle) infants. This research illustrates breastfeeding mothers report using more infant-led or responsive feeding practices and styles (Brown & Lee, 2013; Rametta et al., 2015) and exhibit greater sensitivity to infant cues and less controlling feeding practices compared with formula-feeding mothers (Bernal & Richards, 1970; Crow, 1977; Crow et al., 1980; Dunn & Richards, 1977; Singleterry & Horodynski, 2012), all of which is associated with healthier weight gain trajectories for infants (Hurley et al., 2011; Savage et al., 2016; Spill et al., 2019). Studies of infant intake patterns illustrate that breastfed infants have lower intakes during each feeding and over the course of a day (Heinig et al., 1993). In addition, longer breastfeeding durations are associated with greater infant satiety responsiveness at age 2 years (Brown & Lee, 2012), and infants who were predominantly fed directly from the breast (as compared with predominantly bottle-fed expressed breast milk) were more likely to have high satiety responsiveness at 3–6 years of age (Disantis et al., 2011). Taken together, this evidence suggests that breastfeeding directly from the breast, as compared with bottle-feeding expressed breast milk or formula, may promote responsive feeding interactions that foster infant self-regulation of intake and healthy weight gain trajectories.

However, a fundamental limitation of previous research is the tendency of the vast majority of studies to compare feeding practices of *groups* of breastfeeding versus formula-/bottle-feeding mothers; herein, four key limitations of this approach are highlighted. First, milk type (formula vs. breast milk) is typically confounded with feeding mode (bottle vs. directly from the breast), making it unclear whether intervention efforts should attempt to change what is fed, how it is fed or both. Second, for the majority of mothers and infants, feeding patterns are complex and involve varied combinations of human milk and formula, as well as breast- and bottle-feeding (Ventura, 2017b). Only ∼8% of US infants are exclusively breastfed from the breast (i.e. never receive formula or bottles) (Labiner-Wolfe et al., 2008), whereas ∼16% of infants are exclusively formula-/bottle-fed from birth (Centers for Disease Control and Prevention & National Center for Chronic Disease Prevention and Health Promotion, 2020). Thus, the dichotomy of mothers into breastfeeding versus formula-/bottle-feeding groups oversimplifies most early feeding experiences. Third, not all mothers overfeed during bottle-feeding and bottle-feeding mothers who exhibit lower sensitivity to their infants' satiety cues during feeding interactions may be at higher risk for overfeeding (Ventura & Golen, 2015; Ventura & Mennella, 2017). Given these findings, studies that assume bottle-feeding mothers are a homogenous group likely average-over important variability in maternal feeding practices and styles; better quantification of this variability would allow for better identification of dyads at higher versus lower risk for overfeeding. Fourth, previous research highlights a number of psychosocial and sociodemographic differences (e.g. feeding attitudes and education levels) between mothers who exclusively breastfeed and those who formula-/bottle-feed (Brown & Lee, 2013; McKinney et al., 2016); these differences likely confound associations between feeding mode and feeding outcomes.

One possible way to address these limitations is to employ a within-subject approach to observe mothers during both breastfeeding and bottle-feeding (Whitfield & Ventura, 2019); this approach would allow for a more direct comparison of how feeding mode affects dyadic interactions, feeding practices and feeding outcomes. A recent pilot study (n = 9) that employed a within-subject design to assess effects breast versus bottle-feeding expressed breast milk on feeding interactions reported that mothers exhibited greater sensitivity to infant cues during breastfeeding compared with bottle-feeding expressed breast milk, but relative consistency in other aspects of the feeding interaction (Whitfield & Ventura, 2019). Further research with larger samples is needed to verify and expand these findings.

To this end, the purpose of the current study was to conduct a within-subject experimental study of mother–infant dyads wherein we observed dyads while breastfeeding directly from the breast and while bottle-feeding expressed breast milk. Our hypotheses were threefold. First, we hypothesized that mothers would show significantly greater sensitivity and responsiveness to infant cues when breastfeeding directly from the breast compared with bottle-feeding

Key messages

- Previous research links breastfeeding to responsive feeding and healthy infant weight trajectories.
- This within-subject study aimed to better understand impacts of breastfeeding versus bottle-feeding expressed breast milk in a sample of predominately breastfeeding mother–infant dyads.
- Findings did not support the hypothesis that feeding mode directly impacts dyadic interaction for this population.
- Rather, between-subject differences in feeding experiences and styles predicted feeding outcomes.

expressed breast milk but that other aspects of mother–infant interaction (e.g. maternal socioemotional and cognitive growth fostering, infant clarity of cues and responsiveness to the mother) would not differ. Second, we hypothesized that infant intake and rate of feeding would be lower, and feeding duration would be longer during breastfeeding directly from the breast compared with bottle-feeding expressed breast milk. Third, we hypothesized that effects of feeding mode on infant intake would be moderated by aspects of the dyad's feeding history, including the percentage of feedings that the infant typically receives from a bottle and the mothers' parity and feeding style. A strength of this within-subject design is the ability to compare mother–infant dyadic interaction, infant feeding behaviours and maternal feeding practices during both breastfeeding and bottle-feeding while also controlling for milk type and maternal and infant characteristics that are strong predictors of feeding decisions and practices.

2 | METHODS

2.1 | Participants

Mothers of infants under 6 months of age (n = 47) were recruited through advertisements on social media platforms (e.g. Facebook and Instagram); advertisements in local Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) clinics; announcements in birthing, breastfeeding and parenting classes; and flyers displayed at local businesses (Figure S1). A priori power analysis based on pilot testing with 12 dyads indicated that a sample size of at least 40 dyads would provide 80% power to detect significant within-subjects (condition, i.e., breastfeeding directly from the breast vs. bottle-feeding expressed breast milk) by between-subject (moderator, e.g., percent bottle-feeding) interaction effects at an $\alpha = 0.05$ Type I error level. Based on our previous experience, we anticipated that ∼15% of mother–infant dyads would either drop out or provide problematic data (e.g. the infant would refuse the feeding); thus, 47 mother–infant dyads were recruited in an attempt to obtain complete data from at least 40 dyads.

Inclusion criteria for infants included (1) born full term (gestational age ≥37 weeks), (2) current weight-for-length ≥5th percentile, (3) currently breastfeeding (either exclusively or in combination with formula-feeding) with occasional or frequent bottle use and (4) had not yet been introduced to solid foods. Inclusion criteria for mothers included (1) between 18 and 40 years old, (2) expressed comfort with bottle-feeding expressed breast milk and (3) predominantly responsible for infant feeding. To protect infants with feeding complications or risk for underfeeding or inadequate growth, exclusion criteria for infants included known risk factors: (1) preterm birth (gestational age <37 weeks), (2) low birth weight (<2500 g), (3) maternal smoking during pregnancy, (4) current or past medical conditions that interfere with oral feeding, (5) history of slow growth or failure to thrive, (6) weight-for-length <5th percentile and (7) diagnosed developmental delay. In addition, dyads who were exclusively formula-feeding were excluded. Mothers who responded to our advertisements and expressed interest in participating were provided with a brief, scripted description of the research project via an initial telephone call. Mothers who remained interested in participating after learning more about the study were immediately screened over the telephone by the research assistant via a screening script.

All data were collected between September 2018 and January 2020. All study procedures followed were in accordance with the ethical standards of the University Institutional Review Board. All participating mothers gave oral and written consent for their own and their infants' participation. Participants were compensated a total of $50 for participation ($25 for each completed study visit).

2.2 | Study design

This study was a within-subject experimental study; the within-subject factor was feeding mode: (1) at the breast versus (2) from a bottle. Dyads visited our laboratory on two separate days for approximately 2 h each visit. During each visit, mothers were observed while feeding their infants under one of two counterbalanced experimental conditions: During one visit, the mother breastfed her infant directly from the breast (*breast* condition), and during the other visit, the mother bottle-fed expressed breast milk to her infant (*bottle* condition). The order of conditions was randomized using a computer-generated randomization scheme. This randomization resulted in an even distribution of order of conditions (51% [n = 24] *breast*, *bottle*, 49% [n = 23] *bottle*, *breast*). The two visits were separated at minimum by 1 day of washout and at maximum by 1 week to reduce effects of infant maturation on feeding behaviours; average length between visits was 3.4 ± 1.8 days. Each visit occurred at the same time of day to control for the infant's circadian rhythms and variations in intake (Matheny et al., 1990).

2.3 | Protocol and measures

During the 3 days prior to the first visit and throughout the study period, mothers were asked to refrain from introducing new foods or liquids to their infant. At the beginning of each visit, mothers were interviewed about when the infant last fed and slept and whether any disruptive events occurred during the previous 24 h. The visit was rescheduled if the research assistant was informed that the infant was experiencing temporary changes in his or her feeding behaviour (e.g. due to illness or vaccinations). In addition, the research assistant verified that the mother was still breastfeeding with occasional or frequent bottle use and that the infant had not yet been introduced to solid foods. No dyads changed their feeding mode or introduced solids between the initial telephone screening and study visits. After a brief acclimation period, wireless electrocardiogram (ECG) leads were placed on both the mother and infant to assess physiological responses (i.e. heart rate variability) to the feeding. The mother and infant were then allowed to acclimate further before the feeding observation. These ECG data were not included in the present study and are described elsewhere; for more details, see Ventura et al. (n.d.).

2.3.1 | Feeding observation

When the mother indicated that her infant was ready to feed and her infant exhibited hunger cues (e.g. rooting and sucking on hands), the research assistant helped the mother and infant prepare for the feeding. Immediately prior to the start of the feeding, the research assistant used a smart remote (GoPro Smart Remote, GoPro, California, USA) to synchronously start three digital cameras (GoPro HERO5 Black, GoPro, California, USA). Cameras were placed in three inconspicuous locations: (1) ∼4 ft. in front of the dyad, (2) behind the mother's left shoulder and (3) behind the mother's right shoulder. This three-point set-up ensured effective camera views of both the mother's and infant's faces, allowing for high precision during behavioural coding. The research assistant instructed the mother to breastfeed or bottle-feed expressed breast milk her infant as she normally would at home. The research assistant then moved to an adjacent room to minimize potential influence on the feeding but observed the feeding through a one-way mirror.

The research assistant returned to the testing room when the mother indicated that the feeding was over. The research assistant then asked the mother to use a Likert scale to rate how similar the feeding was compared with other feedings at home (1 = *not at all similar*, 10 = *very similar*) and how much milk her infant consumed compared with other feedings at home (1 = *much less*, 5 = *about the same*, 9 = *much more*). Infant breast milk intake was objectively measured by weighing the infant on an infant scale before the feeding began and after the feeding ended using an infant scale (model 374; Seca, Hamburg, Germany) (Haase et al., 2009). The research assistant ensured that the infant wore the same clothes and diaper for the pre- and post-feeding weight measurements. Intake (g) was converted to volume (mL), assuming a breast milk density of 1.03 g/mL (Riordan, 2005). Duration of feeding was measured in minutes and defined as the time between the first instance that the infant latched onto the breast or bottle and the mothers' verbal indication that the feeding was over. Additionally, rate of feeding (mL/min) was calculated by dividing intake (mL) by duration of feeding (min), and intake per kg body weight was calculated by dividing intake by measured body weight (mL/kg).

2.3.2 | Video analysis

Video recordings from each feeding observation were later coded using the Nursing Child Assessment Parent–Child Interaction Feeding Scale (NCAFS) (Oxford & Findlay, 2015). This scale has been widely used to observe and quantitatively measure parent–infant interactions during a feeding session. This scale contains six subscales: four subscales that measure maternal behaviours and two subscales that measure infant behaviours. With respect to the subscales that focus on maternal behaviours, (1) the Sensitivity to Infant Cues subscale contains 16 items that measure the mother's ability to accurately read and respond to her infant's cues during the feeding interaction (example item: "Caregiver comments verbally on child's satiation cues before terminating the feeding"), with higher scores representing greater sensitivity to the infant's cues; (2) the Response to Child Distress subscale contains 11 items that reflect whether and how the mother responds to infant potent disengagement cues (e.g. crying; example item: "The caregiver stops or starts the feeding"), with higher scores representing greater responsiveness to child distress; (3) the Socioemotional Growth Fostering Subscale contains 14 items that assess the extent to which the mother fosters the infant's socioemotional growth during the feeding interaction (example item: "Caregiver engages in social forms of interaction (plays games with the child) at least once during the feeding"), with higher scores indicating that the mother engaged her infant in more socioemotional growth fostering during the feeding; and (4) the Cognitive Growth Fostering Subscale contains nine items that assess the extent to which the mother fosters the infant's cognitive growth during the feeding interaction (example item: "Caregiver talks to the child about things other than food, eating, or things related to feeding"), with higher scores indicating that the mother engaged her infant in more cognitive growth fostering during the feeding. With respect to the subscales that focus on infant behaviours, (1) the Clarity of Cues subscale contains 15 items that measure the infant's ability to clearly signal his or her needs during the feeding interaction (example item: "Child demonstrates satiation at the end of feeding"), with higher scores representing greater clarity of cues, and (2) the Responsiveness to Caregiver subscale contains 11 items that assess the infant's attentional responsiveness to the mother and mothers' attempts at engagement (example item: "Child responds to feeding attempts by caregiver most of the time"), with higher scores representing greater responsiveness to the caregiver. The NCAFS has been validated for infants aged up to 1 year, for both breast- and bottle-feeding observations and for home- and lab-based observations and reported that Cronbach's alphas for subscales range between $\alpha = 0.60$ and 0.85 (Oxford & Findlay, 2015).

After data collection was complete, video coding was completed over a 3-month period by trained raters ($n = 2$) who were masked to the study purpose and hypotheses. Raters were trained by a certified NCAFS trainer and were required to demonstrate >90% inter-rater reliability based on NCAFS training videos prior to video coding. Inter-rater reliability was further established by common coding of 10% of study videos; video coders demonstrated high inter-rater reliability (percent agreement = 95%). Inter-rater reliability was checked monthly by common coding of 5% of study videos to prevent coder drift.

2.3.3 | Anthropometrics

Infants' weight and length measurements were assessed in triplicate using an infant body weight scale and infantometer (models 374 and 233; Seca, Hamburg, Germany), respectively. Triplicate measures were averaged. Infants' weight and length values were normalized to sex- and age-specific weight-for-length *z*-scores (WLZ) using the World Health Organization Growth Standards (WHO Multicenter Growth Reference Study Group, 2006).

2.3.4 | Questionnaires

In between the first and second visits, mothers completed a family demographic questionnaire, which assessed infant sex, birth weight and length; maternal education level, race/ethnicity, marital status and parity; and annual family income level. Mothers were also asked to report whether their infants received breast milk only or a combination of breast milk and formula, as well as the percentage of daily milk feedings that came from bottles (vs. directly from the breast; referred to from hereon as percent bottle-feeding). Mothers also completed the Infant Feeding Styles Questionnaire (IFSQ) (Thompson et al., 2009). This measure assesses maternal behaviours (e.g. control) and beliefs (e.g. concern about feeding) related to infant feeding. Questionnaire items are used to calculate five feeding style scores, but the present study focused on the Pressuring Feeding Style subscale (example item: "I believe it is important for my infant to finish all of the milk in his/her bottle"). This scale has been validated in diverse samples and demonstrated acceptable internal reliability (H coefficient = 0.79) (Thompson et al., 2009).

All study data were collected and managed using REDCap (Research Electronic Data Capture) tools (Harris et al., 2009; Harris et al., 2019). REDCap is a secure, web-based software platform designed to support data capture for research studies. The data that support the findings of this study are available from the corresponding author upon reasonable request.

2.4 | Statistical analyses

All analyses were conducted using SAS v.9.4. All data were assessed for normality prior to analysis. Primary dependent variables were (1) NCAFS subscales (Maternal Sensitivity to Infant Cues, Response to Infant Distress, Socioemotional Growth Fostering and Cognitive Growth Fostering; Infant Clarity of Cues and Responsiveness to Caregiver); (2) intake (mL); (3) intake corrected for infant body weight (mL/kg); (4) duration of feeding (min); and (5) rate of feeding (mL/min). Four dyads only had data for one condition because the dyad dropped out of the study after the first visit (n = 2) or the infant refused the bottle during the *bottle* condition (n = 2). In addition, two infants had an unexplained weight loss during the *breast* condition and two during the *bottle* condition and thus did not have data on intake, intake per kg body weight or feeding rate. Videos were lost for one dyad due to a camera malfunction; this dyad did not have NCAFS data for either condition.

Linear mixed models (SAS PROC MIXED) were used to adjust for the repeated measures (conditions) and treat differences between participants as random. A strength of this approach is that it allows for estimation of models with missing data using maximum likelihood estimation under a missing at random (MAR) assumption (Singer & Willett, 2003). Preliminary analyses explored whether visit number (first vs. second) or order of conditions (*breast*, *bottle* vs. *bottle*, *breast*) impacted any of the dependent variables, as well as whether condition affected mothers' reports of how similar the feeding was compared with other feedings at home and how much milk her infant consumed compared with other feedings at home. Based on these preliminary analyses, models testing effects of condition (*breast* vs. *bottle*) on dependent variables were adjusted for infant age, time since last feeding (calculated as the duration of time elapsed between the infants' last pre-visit feeding and the start of the observed feeding) and visit number.

Backward stepwise regression was used to explore whether additional variables moderated effects of feeding mode on infant intake. Backward stepwise elimination was applied to both main effects and interactions with feeding mode. The following variables were included in the initial model: visit number, order of conditions, infant age, time since last feeding, infant WLZ, percent bottle-feeding, maternal-reported pressuring feeding style, observed maternal sensitivity to infant cues and parity, as well as the interactions between these variables and feeding mode. For both main and interaction effects, an alpha-to-remove cut-off of 0.25 was used to eliminate terms from the model, but terms were only considered significant predictors if the *P*-value for main or interaction effects was <0.05. Identified covariates (infant age, time since last feeding, and visit number) were not removed from the model.

3 | RESULTS

3.1 | Sample characteristics

Table 1 summarizes sample characteristics. Approximately half of infants were female (n = 20). Average infant age was 3.1 ± 1.4 months old. Average WLZ at birth was −0.77 ± 1.52 and at study participation was 0.07 ± 0.86. The majority of infants (76.6%) were exclusively fed breast milk; the remaining 23.4% were receiving breast milk and formula. Average typical percentage of daily milk feedings from a bottle (percent bottle-feeding) was 24.3% of daily milk feedings. Approximately half of dyads (51.1%, n = 24) reported low percent bottle-feeding (<20% of feedings), 44.7% (n = 21) reported medium percent bottle-feeding (20–80% of feedings), and only two reported high percent bottle-feeding (>80% of feedings). Average mother age was 32.3 ± 4.2 years. Slightly over half of mothers were primiparous (55.3%), and the majority (87.2%) were married. The majority of mothers reported a family income of >$100,000/year (59.6%), held a bachelors or graduate degree (78.7%) and were non-Hispanic White (66.0%). Average pressuring feeding style score was 1.9 ± 0.5.

TABLE 1 Sample characteristics (n = 47)

	% (n) or mean (SD)	Range
Infant characteristics		
Sex, % (n) female	42.6 (20)	
Age, months	3.2 (1.4)	0.8–5.7
Birth WLZ	−0.77 (1.52)	−4.42–3.53
WLZ at study entry	0.07 (0.86)	−1.34–2.65
Maternal/familial characteristics		
Age, years	32.4 (4.2)	20.5–39.5
Parity, % primiparous	55.3 (26)	
Marital status, % married	87.2 (41)	
Federal assistance (e.g. WIC), % participating	8.5 (4)	
Family income level		
<$50,000/year	14.9 (7)	
$50,000 to <$75,000/year	19.2 (9)	
$75,000 to <$100,000/year	6.4 (3)	
>$100,000/year	59.6 (28)	
Level of education		
Did not complete high school	2.3 (1)	
High school degree	6.4 (3)	
Some college/vocational degree	12.8 (6)	
Bachelors or graduate degree	78.7 (37)	
Racial/ethnic category		
Non-Hispanic white	66.0 (31)	
Hispanic white	25.5 (12)	
Asian	8.5 (4)	
Pressuring feeding style score[a]	1.9 (0.5)	1.2–3.2
Infant feeding		
Current milk type		
Breast milk only	76.6 (36)	
Breast milk and formula	23.4 (11)	
Percentage of daily milk[b] feedings from a bottle	24.5 (22.7)	(0.0–95.0)

Abbreviations: WIC, Special Supplemental Nutrition Program for Women, Infants, and Children; WLZ, weight-for-length z-score.
[a]From the Infant Feeding Styles Questionnaire; possible score range = 1–5.
[b]Defined as expressed breast milk or infant formula; all infants had not yet been introduced to complementary foods and beverages.

3.2 | Within-subject effects of feeding mode on dyadic interactions and feeding outcomes

Within preliminary analyses, we explored whether visit number (first vs. second) or order of conditions (*breast*, *bottle* vs. *bottle*, *breast*) impacted any of the dependent variables of interest, as well as whether condition affected mothers' reports of how similar the feeding was compared with other feedings at home and how much milk her infant consumed compared with other feedings at home. These preliminary analyses illustrated that there was no effect of visit number on mothers' sensitivity to infant cues (F[1,44] = 0.01, P = 0.922), socioemotional growth fostering (F[1,44] = 0.03, P = 0.869) or cognitive growth fostering (F[1,44] = 0.59, P = 0.448) or on infant clarity of cues (F[1,44] = 0.00, P = 0.980), responsiveness to caregiver (F[1,44] = 0.65, P = 0.426), intake (F[1,45] = 0.68, P = 0.415), intake per kg body weight (F[1,45] = 0.44, P = 0.511), duration of feeding (F[1,45] = 0.10, P = 0.752) or rate of feeding (F[1,45] = 0.15, P = 0.696). Mothers exhibited significantly greater responsiveness to child distress during the first visit compared with the second (10.4 ± 0.1 vs. 9.8 ± 0.2, respectively; F[1,44] = 6.25, P = 0.016). There was no effect of order of conditions (*breast*, *bottle* vs. *bottle*, *breast*) on mothers' sensitivity to infant cues (F[1,40] = 0.99, P = 0.327), responsiveness to child distress (F[1,40] = 2.00, P = 0.165), socioemotional growth fostering (F[1,40] = 0.04, P = 0.840) or cognitive growth fostering (F[1,40] = 0.61, P = 0.438) or on infant clarity of cues (F[1,40] = 0.03, P = 0.865), responsiveness to caregiver (F[1,40] = 0.09, P = 0.765), intake (F[1,38] = 1.94, P = 0.172), intake per kg body weight (F[1,38] = 0.73, P = 0.399), duration of feeding (F[1,42] = 1.43, P = 0.238), or rate of feeding (F[1,38] = 0.11, P = 0.742). There were no significant effects of condition on mothers' reports of how similar the feeding was compared with other feedings at home (F[1,45] = 2.09, P = 0.156) or on how much milk the infant consumed compared with other feedings at home (F[1,45] = 0.01, P = 0.917).

Our first hypothesis was that mothers would show significantly greater sensitivity and responsiveness to infant cues when breastfeeding directly from the breast compared with bottle-feeding expressed breast milk but that other aspects of mother–infant interaction (e.g. maternal socioemotional and cognitive growth fostering, infant clarity of cues and responsiveness to the mother) would not differ. As illustrated in Table 2, this hypothesis was only partially supported. Mothers showed similar levels of sensitivity to infant cues (F[1,44] = 2.58, P = 0.115), responsiveness to infant distress (F[1,44] = 1.49, P = 0.229), socioemotional growth fostering (F[1,44] = 0.24, P = 0.625) and cognitive growth fostering (F[1,44] = 0.09, P = 0.767) during the *breast* and *bottle* conditions. Infants exhibited similar levels of clarity of cues (F[1,44] = 0.28, P = 0.597) and responsiveness to the mother (F[1,44] = 0.95, P = 0.335) during the *breast* and *bottle* conditions.

Our second hypothesis was that infant intake and rate of feeding would be lower and feeding duration would be longer during breastfeeding directly from the breast compared with bottle-feeding expressed breast milk. As illustrated in Table 2, no significant differences between conditions were seen for infant intake (F[1,45] = 0.23, P = 0.634), intake per kg body weight (F[1,45] = 0.28, P = 0.598) or rate of feeding (F[1,45] = 0.52, P = 0.476). Duration of feeding was significantly longer during the *breast* compared with *bottle* condition (F[1,45] = 4.25, P = 0.045).

TABLE 2 Effects of *breast* versus *bottle* feeding conditions mode on feeding outcomes

	Breast[a]	Bottle[a]	*F*-value	*P*-value
Maternal NCAFS subscales				
Sensitivity to Infant Cues[b]	14.7 (0.2)	14.3 (0.2)	2.58	0.115
Responsiveness to Infant Distress[c]	9.9 (0.2)	10.2 (0.1)	1.49	0.229
Socioemotional Growth Fostering[d]	11.7 (0.2)	11.5 (0.3)	0.24	0.625
Cognitive Growth Fostering[e]	6.4 (0.3)	6.3 (0.3)	0.09	0.767
Infant NCAFS subscales				
Clarity of Cues[f]	13.0 (0.1)	12.8 (0.2)	0.28	0.597
Responsiveness to Caregiver[c]	7.7 (0.2)	7.4 (0.2)	0.95	0.335
Infant intake and feeding behaviours				
Intake (mL)	91.9 (5.0)	87.6 (5.2)	0.23	0.634
Intake per kg body weight (mL/kg)	15.4 (0.8)	14.7 (0.9)	0.28	0.598
Feed duration (min)	19.0 (1.5)	15.7 (1.4)	4.25	0.045
Feed rate (mL/min)	8.1 (1.5)	7.1 (0.6)	0.52	0.476

Notes: Separate linear mixed models were conducted for each outcome. All models adjusted for order of conditions, time since last feeding and infant age.
Abbreviation: NCAFS, Nursing Child Assessment Satellite Training Parent–Child Interaction Feeding Scale.
[a]Column values are mean (*SE*).
[b]Possible score range = 0–16.
[c]Possible score range = 0–11.
[d]Possible score range = 0–14.
[e]Possible score range = 0–9.
[f]Possible score range = 0–15.

3.3 | Moderators of effects of feeding mode on infant intake

We used backward stepwise regression to test our third hypothesis, which was that effects of feeding mode would be moderated by aspects of the dyad's feeding history, including the percentage of feedings that the infant typically receives from a bottle and the mothers' parity and feeding style. Backward stepwise regression examining whether additional variables moderated effects of condition on infant intake revealed no moderating effect of visit number, order of conditions, infant age, time since last feeding, infant WLZ, maternal-reported pressuring feeding style, observed maternal sensitivity to infant cues and parity. Within the final model (Table 3), only percent bottle-feeding moderated the effect of condition of infant intake ($P = 0.032$). Greater percent bottle-feeding predicted greater intake during the *bottle* relative to *breast* condition, with each 5 percentage point increase in percent bottle-feeding associated with a 2.41-mL increase in infant intake during bottle-feeding compared with breastfeeding. Figure 1 illustrates the moderation effect of percent bottle on the relationship between condition and the amount consumed; for illustrative purposes, infant intake during the *breast* and *bottle* conditions was estimated for dyads with the sample average level of percent bottle-feeding, as well as 1 SD below and 1 SD above the mean. As illustrated in Figure 1, infants who were bottle-feeding more than average exhibited greater intake during the *bottle* condition compared with the *breast* condition, whereas infants who were bottle-feeding less than average exhibited greater intake during the *breast* condition compared with *bottle* condition.

Although neither parity nor pressuring feeding style moderated the effect of feed type on infant intake, both were significant predictors of infant intake (Table 3). Multiparous mothers fed their infants an average of 17.1 ± 7.5 mL more than primiparous mothers, regardless of condition ($P = 0.028$). In addition, each additional point increase in pressuring feeding style was associated with an average increased intake of 16.8 ± 8.1 mL, regardless of condition ($P = 0.045$).

4 | DISCUSSION

Findings from this within-subject experimental study suggest that feeding mode does not significantly alter dyadic interaction during feeding in the short term for predominately breastfeeding dyads. Mothers exhibited similar levels of sensitivity to infant cues, responsiveness to infant distress, socioemotional growth fostering, and cognitive growth fostering, and infants exhibited similar levels of clarity of cues and responsiveness to their mothers during breastfeeding and bottle-feeding expressed breast milk. Assessment of potential moderators revealed significant moderating effects of familiarity with bottle-feeding, as indicated by mothers' reports of percentage of daily milk feedings that came from a bottle; in particular, greater percentage of daily milk feedings from a bottle was associated with greater intakes

TABLE 3 Solution for fixed effects for predicting infant intake during *breast* and *bottle* feeding conditions

	Estimate	SE	*F*-value	*P*-value
Intercept	37.71	22.55		
Infant age (in months)	1.16	2.59	0.20	0.656
Time since last feeding (in minutes)	0.10	0.10	0.90	0.348
Visit number			0.79	0.380
First visit	Ref	–		
Second visit	6.13	6.88		
Feeding condition			4.22	0.046
Breast	Ref	–		
Bottle	−21.19	10.31		
Percentage of daily milk feedings from a bottle	−0.29	0.23	0.19	0.668
Parity			5.20	0.028
Primiparous	Ref	–		
Multiparous	17.08	7.49		
Maternal-reported pressuring feeding style	16.79	8.12	4.27	0.045
Feeding condition × percent bottle-feeding			4.93	0.032
Breast condition × percent bottle-feeding	Ref	–		
Bottle condition × percent bottle-feeding	0.72	0.32		

Ref, reference

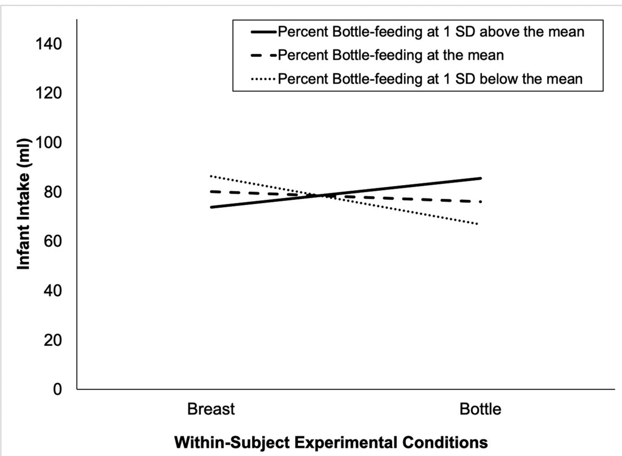

FIGURE 1 Percent bottle-feeding moderated the effect of feeding mode on infant intake (*P* = 0.032). To illustrate the interactive effect of percent bottle-feeding and feeding mode, infant intake during the *breast* and *bottle* conditions was estimated for dyads with the sample average level of percent bottle-feeding (24.3% of daily milk feedings), as well as 1SD below the mean (2.29% of daily milk feedings) and 1 SD above the mean (45.6% of daily milk feedings). Infants who were bottle-feeding less than average (1 SD below the mean) exhibited greater intake during the *breast* condition compared with *bottle* condition. Infants who were bottle-feeding more than average (1 SD above the mean) exhibited greater intake during the *bottle* condition compared with the *breast* condition

during bottle-feeding expressed breast milk relative to breastfeeding directly from the breast, whereas lower percentage of daily milk feedings from a bottle was associated with greater intakes during breastfeeding compared with bottle-feeding. Of note, two between-subject factors, parity and pressuring feeding style, were significant predictors of infant intake, with greater infant intakes across both feeding modes predicted by multiparity and greater levels of pressuring feeding style.

The only within-subject difference noted between breastfeeding and bottle-feeding expressed breast milk was significantly longer feeding duration during breastfeeding compared with bottle-feeding. This finding is consistent with previous studies comparing the microstructure of breastfeeding versus bottle-feeding, which illustrates infants exhibit greater feeding efficiency during bottle-feeding, defined as more sucks per sucking burst, significantly longer sucking burst and less resting time between sucking bursts, resulting in shorter feeding durations for bottle-feeding compared with breastfeeding (Taki et al., 2010). During both breastfeeding and bottle-feeding, infants show maturation-related improvements in feeding efficiency that are specific to their typical feeding mode (Taki et al., 2010), which are likely due, in part, to learning and increased familiarity with the feeding mode. These findings likely explain the moderating effects of percent bottle-feeding on feeding mode seen in the present study given infants exhibited greater intakes during the feeding mode they typically experienced more often.

Previous observational research comparing feeding interactions of breastfeeding versus formula-/bottle-feeding dyads suggests that mothers exhibit greater sensitivity to infant cues and adherence to a responsive feeding style during breastfeeding and use of more controlling feeding practices and pressuring feeding style during bottle-feeding (e.g. Crow et al., 1980; Wright et al., 1980). The findings of the present study suggest that these previous findings may reflect differences in the feeding attitudes, practices and styles of mothers who breastfeed versus formula-/bottle-feed rather than effects of feeding mode on feeding interactions (Brown & Arnott, 2014; Brown & Lee, 2013). Of note, variance in between-subject factors predicted greater intakes across both modes of feeding, including mothers' previous experience with infant feeding and higher levels of pressuring feeding. These findings further suggest that, in the short term, bottle-feeding expressed breast milk does not lead to lower sensitivity to infant cues and greater infant intakes, per se, but rather that mothers' feeding experiences and styles may be important targets for interventions aimed promoting healthy intake patterns during infancy.

However, there are important caveats to these conclusions that should be addressed and explored in future research. This study consisted of mothers who were exclusively or predominantly breastfeeding and who fed expressed breast milk (not formula) when bottle-feeding; slightly over half of our sample reported typically low levels of bottle-feeding. In addition, our sample was predominantly white and affluent and scored relatively high on our measure of sensitivity to infant cues (14.5 out of 16) (Oxford & Findlay, 2015) and relatively low on our measure of presuring feeding style (1.9 out of 5) (Thompson et al., 2009). Thus, it is possible that the lack of differences between breastfeeding and bottle-feeding expressed breast milk seen in this study was attributable to homogeneity in maternal characteristics and mothers' high levels of sensitivity and low levels of pressuring feeding style. It is also possible that percent bottle-feeding moderated effects of feeding mode on infant intake because rates of bottle-feeding were relatively low. Further research is needed to understand whether the present findings generalize to larger, more diverse samples of mothers who are engaged in greater levels of bottle-feeding or who exhibit greater variation in maternal sensitivity to infant cues and pressuring feeding style scores.

Only one breastfeeding and one bottle-feeding interaction were observed and assessed in the present study. Previous longitudinal, observational research illustrates that longer durations of breastfeeding predict more responsive maternal feeding style during later infancy and childhood (Blissett & Farrow, 2007; DiSantis et al., 2013; Fisher et al., 2000; Taveras et al., 2004); thus, it is possible that feeding mode affects mothers' feeding practices and styles and dyadic feeding interactions in ways that are not observable during a single feeding interaction. To date, the majority of longitudinal studies on this topic do not include a baseline measure of responsive feeding during early infancy, making it unclear whether breastfeeding promotes responsive feeding or whether mothers' initial level of responsiveness predicts both likelihood to breastfeed and later feeding styles (Ventura, 2017a). Further longitudinal research is needed to understand whether and how effects of feeding mode may accumulate over time, and it is imperative that this research employs study designs that can disentangle relative effects of feeding mode, milk composition and sociodemographic covariates on the development of feeding interactions and outcomes across infancy.

Based on the within-subject experimental design of the present study, milk type was assumed to be held constant because infants were fed breast milk directly from the breast during one condition and expressed breast milk from a bottle during the other condition. However, it is possible that the milk fed during these conditions was not equivalent due to compositional changes related to the expression, storage, transit and/or preparation of expressed breast milk. It has been well documented that the composition of breast milk varies over the course of a day (Mitoulas et al., 2002), as well as over the course of a feeding (Hall, 1975). This dynamic quality of breast milk is lost when expressed breast milk is delivered via a bottle, but the significance of this loss for infant intake or eating behaviours remains unclear (Drewett, 1982; Nysenbaum & Smart, 1982; Smart, 1978). A recent meta-analysis did not find significant changes in the macronutrient or energy content of human milk that was fresh versus frozen and thawed (Yochpaz et al., 2020), but some aspects of human milk storage and preparation can negatively affect micronutrient profiles and bioactive components that may regulate appetite and growth (Ballard & Morrow, 2013; Fields et al., 2016). Storage conditions (e.g. temperature and duration) can also negatively alter the odour of human milk (Loos et al., 2019). However, there is a paucity of research examining whether these compositional changes affect infant feeding behaviour or intake. In the present study, when the breast milk was expressed, the temperature at which it was stored and how long it was stored were not assessed; thus, possible effects of these factors on milk composition and infant intake could not be considered. These issues would be an important consideration for future research.

In conclusion, findings from the present study did not support the hypothesis that feeding mode (breastfeeding directly from the breast vs. bottle-feeding expressed breast milk) directly impacts dyadic interaction for predominantly breastfeeding mothers and their young infants, but rather suggest between-subject differences in feeding experiences and styles predict feeding outcomes for this population. A recent review of feeding recommendations for infants and young children highlighted the fact that most feeding recommendations focus on *what* to feed; far fewer provide recommendations related to *how* to feed (National Academies of Sciences, Engineering, and Medicine, 2020). However, emerging research and recommendations that do focus on the *how* of infant feeding consistently highlight the benefits of responsive feeding practices and styles and the importance of promoting responsive feeding, regardless of feeding mode, to foster infant self-regulation of intake and healthy weight gain trajectories (Institute of Medicine, 2011; Pérez-Escamilla et al., 2017). Findings from the present study align with this notion, but further research with more diverse samples and longitudinal assessments of the development of feeding interactions across infancy is needed to further understand whether and how feeding mode affects dyadic interactions, infant intake and risk for rapid weight gain.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONTRIBUTIONS

AKV designed research, developed overall research plan and protocols, oversaw study, analysed data, wrote paper and holds primary responsibility for final content; MKH conducted research via hands-on conduct of the experiment and data collection and wrote paper; JL performed statistical analysis and wrote paper.

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SUPPORTING INFORMATION

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