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Exploring Correlates of Infant Clarity of Cues During Early Feeding Interactions

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ABSTRACT

Background Recommendations aimed at reducing infants' risk for rapid weight gain primarily focus on promoting caregivers' use of responsive feeding practices and styles. These recommendations are grounded in the belief that infants will effectively signal hunger and satiation to their caregivers. To date, few studies have explored how variability in infants' communication of hunger and satiation may contribute to feeding interactions.

Objective Our aim was to explore variability in, and correlates of, infant clarity of cues during feeding interactions.

Design This was a cross-sectional study.

Participants/setting Mother–infant dyads (n=86) were video-recorded during a typical feeding interaction within laboratory-based settings in Philadelphia, PA and San Luis Obispo, CA between June 2013 and June 2017.

Main outcome measures Trained raters later coded videos using the Nursing Child Assessment Parent–Child Interaction Feeding Scale's Infant Clarity of Cues and Maternal Sensitivity to Cues subscales. Infant weight was assessed and standardized to sex- and age-specific *z* scores. Mothers completed questionnaires related to family demographics, infant feeding history, feeding styles, and infant temperament and eating behaviors.

Statistical analyses performed Linear models were used to test for associations between clarity of cues and breastfeeding vs formula-feeding, maternal sensitivity and responsiveness, and feeding and weight outcomes.

Results Infants were approximately 15.5 weeks of age and 53% were female. Clarity of cues was not associated with infant sex, age, temperament, or eating behaviors. Breastfed and formula-fed infants exhibited similar clarity of cues (P=0.0636). Greater clarity of cues for infants was associated with greater maternal sensitivity to cues (P=0.0011) and responsive feeding style (P=0.0464) for mothers. Lower clarity of cues was associated with greater weight-for-age *z* score change for formula-fed infants, but not breastfed infants.

Conclusions Efforts to promote responsive feeding may need to also consider infant clarity of cues. Further research is needed to understand the implications of associations between infant communication and responsive feeding.

RAPID WEIGHT GAIN DURING INFANCY IS ASSOCIated with later obesity risk.[1-5] Particular importance has been placed on the first 6 months postpartum because overfeeding during this early window places infants at significantly higher risk for rapid weight gain compared to overfeeding during later infancy.[6] Understanding behavioral mechanisms underlying infants' risk for rapid weight gain is central for identifying effective targets for prevention efforts.

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Public health recommendations primarily focus on promoting responsive feeding, defined as a caregiver's ability to recognize and respond appropriately to an infant's hunger and satiation cues during feeding interactions.[7-11] These recommendations are based, in part, on previous research suggesting infants have the capacity to self-regulate intake in response to caloric needs[12-15] and that infants' self-regulatory abilities are best fostered by feeding practices that are infant-led and responsive to infant cues.[16-18] Because young infants are dependent on caregivers for what, when, and at times how much they are fed, the purported benefit of responsive feeding is based on the assumption that infants will effectively signal hunger and satiation to communicate their needs and that caregivers' use of feeding practices that are responsive to these cues will decrease risk for overfeeding and rapid weight gain.[19]

Although plausible, a surprising paucity of research has empirically tested the assumption that infants effectively signal hunger and satiation during early milk feeding. Indeed, the few studies that have been conducted suggest significant between-infant variation exists in the extent to which infants communicate during feeding and that this variation relates to feeding mode and mothers' use of responsive feeding practices.[19-22] Given the limited number of studies available, additional research is needed to further understand whether and how infant communication during feeding relates to caregivers' sensitivity to infant cues and use of responsive feeding practices and styles, as well as to feeding and weight gain outcomes. To this end, the aims of the present study were to explore variability in, and correlates of, infant clarity of cues (defined as the extent to which an infant clearly and effectively uses cues to communicate with his or her caregiver during feeding).[23] Potential correlates explored included infant characteristics (ie, sex, age, temperament, and eating behaviors), typical milk type/feeding mode (ie, breastfeeding vs formula-feeding), mothers' observed sensitivity to cues and self-reported responsive feeding style, feeding outcomes during an observed feeding (ie, infant intake and meal duration), and weight-for-age *z* score (WAZ) change during early infancy.

METHODS

Participants and Recruitment

The present study was a secondary analysis of combined data from previous infant feeding studies (Ventura and colleagues, unpublished data, 2015-2017).[24,25] Studies took place across two sites (Philadelphia, PA and San Luis Obispo, CA) between June 2013 and June 2017; additional information about these studies can be found elsewhere (Ventura and colleagues, unpublished data, 2015-2017).[24,25] For all studies, mothers and their infants of either sex were recruited (n=86). Inclusion criteria for infants were: born full-term (>37 weeks gestation) and 32 weeks of age or younger (and, thus, still predominantly fed breast milk or formula[26]). Both breastfeeding and bottle-feeding dyads were recruited. Dyads were excluded if infants were preterm or had medical conditions that interfered with feeding or growth. A variety of methods were used to recruit mothers, including ads in local newspapers; Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) offices; fliers in local stores, coffee shops, or pediatric offices; local parent support groups; and online sites (eg, Facebook). All study procedures were approved by the California Polytechnic State University Institutional Review Board. All participants gave oral and written informed consent for participation.

Study Protocol

Dyads visited the laboratory for a 2-hour period to participate in a feeding observation; mothers also completed questionnaires during this visit. Each mother selected when her visit occurred (eg, morning vs afternoon) based on her availability and her infants' typical feeding and sleeping schedule. When scheduling the visit, the research assistant encouraged the mother to select a window of time when her infant would be alert and ready to feed. During the 3 days before the laboratory visit, mothers were asked to keep a feeding diary, wherein they recorded the timing, amount, and typical feeding type/mode (eg, breast milk from the breast, expressed milk from a bottle, formula from a bottle) for each feeding; these data were used to determine mothers' typical feeding type/mode (exclusive breastfeeding, exclusive formula feeding, combination of breast and formula feeding), as well as to calculate the percent of daily milk feedings from a bottle ([number of daily feedings that were expressed breast milk or formula/total number of daily feedings] 100) and the percent of daily feedings that were breast milk ([number of daily feedings that were breast milk/total number of daily feedings] 100).

RESEARCH SNAPSHOT

Research Question: How does infant clarity of cues during feeding relate to infant characteristics, maternal sensitivity to infant cues and adherence to responsive feeding style, and feeding history and outcomes?

Key Findings: In this cross-sectional study, clarity of cues was not associated with infant sex, age, temperament, or eating behaviors. Greater clarity of cues for infants was associated with greater observed sensitivity to cues and self-reported responsive feeding style for mothers. Clarity of cues was similar for breastfed and formula-fed infants; however, poorer clarity of cues was associated with greater weight-for-age *z* score change during early infancy for formula-fed infants only.

Feeding Observations. Mothers were instructed to breastfeed or bottle-feed their infants as they typically would at home. Forty-eight (55.8%) mothers were exclusively breastfeeding and reported they fed their infants both directly from the breast and from a bottle (20.4% 27.1% of daily milk feedings were from a bottle). Thirteen (15.1%) mothers were both breastfeeding and formula feeding (63.9% 37.8% of daily milk feedings were from a bottle; 51.1% 37.4% of daily milk feedings were breast milk) and 25 (29.1%) mothers were exclusively formula feeding. Whether mothers breastfed or bottle-fed during the feeding observation was partially determined by the design of each study: some mothers were allowed to choose whether to breastfeed or bottle-feed (Ventura and colleagues, unpublished data, 2015-2017), whereas other mothers were asked to bottle-feed for the feeding observation.[24,25] However, mothers who were asked to bottle-feed for the feeding observation had experience with bottle-feeding and bottle-fed their babies on a regular basis. Thus, during the feeding observation, 12.8% (n=11) of mothers breastfed, 48.8% (n=42) of mothers fed expressed breast milk from a bottle, and 38.4% (n=33) of mothers fed formula from a bottle.

When mothers indicated they were ready to feed their infants, the interactions were video-recorded (Canon VIXIA HF M41 full HD camcorder; Canon). The camera was placed approximately 10 to 12 feet from the dyad and the research assistant remained concealed behind a partition. Infant intake was assessed by weighing the bottle (for bottle-feeding observations) or infant (for breastfeeding observations) before and after the feeding using a top-loading balance (Ohaus SP601 Scout Pro Portable Balance; Ohaus) or infant scale (model 374; Seca), respectively. To ensure breastfeeding infants' intake assessments were not affected by changes in clothing or diaper weight, research assistants ensured infants were weighed in the exact same clothes and diaper during the pre- and post-feeding weighing. Intake (g) was then converted to volume (mL), assuming a milk/formula density of 1.03 g/mL.[27-29]

Analysis of Video-Recordings. Trained raters (n=6) blinded to study objectives later coded all videos using the Nursing Child Assessment Parent–Child Interaction Feeding Scale (NCAFS).[23] The NCAFS is a reliable, valid, and widely used means of observing and rating mother–child interactions during a feeding session.[23] The NCAFS is validated for use with mothers and their infants aged up to 1 year, can be applied to breastfeeding or bottle-feeding episodes, and has been used during both laboratory- and home-based feeding observations. It contains 76 observable behaviors that are organized into six subscales, four of which describe maternal attributes and two of which describe infant attributes.[23] The present analyses focused on the 15-item Infant Clarity of Cues subscale, which represents the extent to which the infant uses effective cues to clearly communicate his or her needs to the caregiver during the feeding interaction (example item: "Child demonstrates satiation at end of feeding"; possible score range=0 to 15, with higher scores indicating greater clarity of cues), and the 16-item Maternal Sensitivity to Cues subscale, which represents the extent to which the caregiver demonstrates sensitive and contingent responses to the infant's needs and cues (example item: "Caregiver terminates the feeding when the child shows satiation cues or after other methods have proved unsuccessful"; possible score range=0 to 16, with higher scores indicating greater sensitivity to infant cues). The sensitivity to cues subscale contains 6 "contingency items" that specifically indicate whether infant cues are followed by an appropriate response by the mother; the remaining 10 items are not necessarily dependent on infant cues.[28] Thus, both a total score (all 16 items) and a contingency item score (6 contingency items) for sensitivity to cues was calculated. The clarity of cues subscale does not contain any contingency items; thus, just a total score was calculated. Before coding, raters were trained by a certified NCAFS trainer and trained to 85% reliability using the NCAFS training standards.[23] Coding of study videos did not commence until all trainers received their NCAFS certificate.[23] Additional inter-rater reliability assessments were then determined by common coding of 10 study videos and intra-rater reliability was determined by double-coding of 10 study videos. Inter- and intra-rater reliability were established using Pearson's correlation coefficients; both were $r<0.85$.

Additional Measures. Before the beginning of the feeding observation, mothers completed a demographics questionnaire and reported infant birth weight and length. Mothers also reported whether or not their infant had been introduced to complementary foods and beverages and, if so, the age at which they had been introduced. Mothers were also asked to complete several questionnaires. The Rothbart Infant Behavior Questionnaire-Revised Very Short Form[30,31] is a widely used scale that has been validated in diverse samples[30-32]; this questionnaire assesses infant temperament along the dimensions of *surgency/extraversion* (defined as the extent to which the infant shows impulsivity, high activity levels, pleasure seeking, and low shyness; example item: "How often during the week did your baby move quickly toward new objects?"), *orienting/regulation capacity* (defined as the extent to which the infant exhibits that ability to self-regulate his or her behaviors and emotions and maintain attentional focus; example item: "When singing or talking to your baby, how often did s/he soothe immediately?"), and *negative affect* (defined as the extent to which the infant exhibits sadness, discomfort, frustration, fear, and difficulty in soothing; example item: "How often during the last week did the baby protest being placed in a confining place [infant seat, play pen, car seat, etc]?"). The Baby Eating Behavior Questionnaire is a validated measure of mothers' perceptions of infant eating behaviors,[33] conceptualized by the dimensions of infant enjoyment of food (example item: "My baby enjoys feeding time"), food responsiveness (example item: "Even when my baby has just eaten well, s/he is happy to be feed again if offered"), satiety responsiveness (example item: "My baby gets filled up easily"), and slowness in eating (example item: "My baby takes more than 30 minutes to finish feeding"). The Infant Feeding Style Questionnaire,[34] a measure that has been validated in diverse samples,[34] was used to assess maternal behaviors (eg, control) and beliefs (eg, concern about feeding) related to infant feeding to determine the mother's self-reported feeding style; the present analyses focused on the responsive feeding style subscale (example item: "I pay attention when my child seems to be telling me that s/he is full or hungry").

A trained research assistant measured weight and length/height in triplicate for infants and mothers using an infant scale/infantometer (models 374 and 233; Seca) and adult scale/stadiometer (model 736; Seca), respectively. Infant anthropometric data were normalized to sex- and age-specific *z* scores (WAZ) using World Health Organization Anthro software, version 3.2.2.[35] Maternal body mass index was calculated as weight (kg)/height(m)^2.

Statistical Analysis

All analyses were conducted using SAS software, version 9.4.[36] Data were thoroughly cleaned and assessed for normality. Although the distribution for clarity of cues scores was slightly negatively skewed (skewness= −1.42), further inspection of other normality indicators (eg, histogram, Q–Q plot) did not indicate that transformation was needed. One mother did not complete the Infant Feeding Styles Questionnaire and another mother did not complete the Baby Eating Behavior Questionnaire. Descriptive statistics were calculated for sample characteristics and clarity of cues scores. The coefficient of variation for clarity of cues scores (coefficient of variation=[standard deviation/mean] 100) was calculated to describe the extent of between-infant variability in clarity of cues scores within this sample; higher coefficient of variation scores indicate greater variability in clarity of cues.

Associations between infants' clarity of cues and characteristics were assessed using *t* test and correlation analyses. General linear models (four total) were used to test associations

Table 1. Characteristics of mothers and infants (<32 weeks of age) who participated in infant feeding studies (n=86 dyads)

Characteristics	Data
Infant characteristics	
Female, n (%)	46 (53.5)
Age, wk, mean SD[a]	15.5 7.6
Weight-for-age *z* score at birth, mean SD	0.22 0.92
Weight-for-age *z* score during study, mean SD	0.02 0.82
Weight-for-age change, mean SD	−0.21 1.04
Maternal/familial characteristics:	
Age, y, mean SD	29.8 5.6
BMI,[b] mean SD	27.7 7.1
Primiparous, n (%)	46 (54.1)
Married, n (%)	57 (67.1)
Participation in federal assistance (eg, WIC[c]), n (%)	35 (40.7)
Family income level, n (%)	
<$15,000/y	17 (19.8)
$15,000 to <35,000/y	15 (17.4)
$35,000 to <75,000/y	11 (12.8)
>$75,000/y	35 (40.7)
Not reported	8 (9.3)
Level of education, n (%)	
Did not complete high school or high school degree	21 (24.4)
Some college or college degree	65 (75.6)
Racial/ethnic category, n (%)	
Non-Hispanic white	48 (55.8)
Non-Hispanic black	21 (24.4)
Hispanic	12 (14.0)
Other	5 (5.8)
Infant feeding history	
Current feeding type, n (%)	
Exclusive breastfeeding	48 (55.8)
Exclusive formula-feeding	25 (29.1)
Mix of breastfeeding and formula-feeding	13 (15.1)
Introduced complementary foods and beverages, n (%)	14 (16.3)
Age at introduction,[d] wk, mean SD	19.7 3.3
NCAFS[e] Scores, mean SD	
Infant clarity of cues[f]	12.0 1.9
Maternal sensitivity to cues[g]	13.1 2.1

(*continued*)

Table 1. Characteristics of mothers and infants (<32 weeks of age) who participated in infant feeding studies (n=86 dyads) (*continued*)

[a]SD=standard deviation.
[b]BMI=body mass index; calculated as kg/m[2].
[c]WIC=Special Supplemental Nutrition Program for Women, Infants, and Children.
[d]Only includes infants who had been introduced to complementary foods and beverages (n=14).
[e]NCAFS=Nursing Child Assessment Parent—Child Interaction Feeding Scale.
[f]Possible score range=0 to 15.
[g]Possible score range=0 to 16.

between clarity of cues (modeled as the dependent variable) and: (1) typical feeding type/mode (collapsed into two groups: any breastfeeding (exclusive or in combination with formula-feeding) vs exclusive formula-feeding); (2) observed feeding mode (breastfed vs bottle-fed), (3) mothers' observed sensitivity to cues; and (4) mothers' self-reported responsive feeding style. General linear models (two total) were also used to examine whether clarity of cues (modeled as the independent variable) predicted outcomes of the observed feeding, including: (1) infant intake and (2) duration of feeding. Associations between clarity of cues and WAZ change between birth and study entry were assessed using a linear mixed model with repeated measures. Given previous research suggesting different weight-gain outcomes for breastfeeding vs formula-/bottle-feeding infants,[37-39] potential moderating effects of typical feeding type/mode (any breastfeeding vs exclusive formula-feeding) or observed feeding mode (breastfed vs bottle-fed) on associations between clarity of cues and WAZ change were also examined. A P value <0.05 was used as a criterion for statistical significance of main and interaction effects.

To consider potential sociodemographic covariates while also considering potential collinearity among sociodemographic variables and the need for parsimonious models due to the small sample size, preliminary analyses were conducted to assess associations among sociodemographic variables, as well as test the potential significance of covariates within linear models (data not shown). Potential covariates tested included: infant sex and age, typical feeding type/mode (any breastfeeding vs exclusive formula-feeding; only considered within models where typical feeding type/mode was not the independent variable), maternal age, body mass index, parity, marital status, WIC participation, family income, education, and race/ethnicity. In general, covariates were highly correlated ($P<0.001$) and typical feeding type/mode (any breastfeeding vs exclusive formula-feeding) was the covariate most consistently statistically ($P<0.05$) significant within each model. Thus, in the interest of maintaining parsimony and minimizing effects of collinearity, typical feeding type/mode was the only sociodemographic covariate included in all relevant linear models. In addition, within analysis of associations between clarity of cues and feeding outcomes (intake, duration of feeding), the amount of time elapsed between the infant's previous feeding and the feeding observation was also included as a covariate to control for possible effects of variation in infant hunger.

RESULTS

Sample characteristics are presented in Table 1. Mean infant age was 15.5 weeks (range=1.6 to 31.0 weeks). Mean age of mothers was 29.8 years and mean body mass index was 27.7. Approximately one-fifth of mothers reported a family income <$15,000 per year and 44% reporting being of minority racial/ethnic groups. Mean clarity of cues score was 12.0 1.9 (range=4 to 15). The coefficient of variation was 15.9%.

There was no association between clarity of cues and infant sex (F[1, 85]=0.04, P=0.8340) or infant age (r[86]=0.07, P=0.5468). There was also no association between clarity of cues and negative affect (r[86]=0.05, P=0.6325), surgency/extraversion (r[86]=0.06, P=0.5658), or orienting/regulation capacity (r[86]= −0.01, P=0.9072). There was no association between clarity of cues and mothers' perceptions of infant enjoyment of food (r[85]=0.18, P=0.1060), infant food responsiveness (r[85]= −0.01, P=0.9651), infant slowness in eating (r[85]=0.07, P=0.5188), or infant satiety responsiveness (r[85]=0.05, P=0.6535).

The association between typical feeding type/mode (any breastfeeding vs exclusive formula-feeding) and clarity of cues was not significant (F[1, 85]=3.53, P=0.0637; Table 2). Average clarity of cues scores were 12.2 1.7 for breastfeeding infants vs 11.4 2.3 for formula-feeding infants. In addition, infants who were breastfed during the feeding observation exhibited similar clarity of cues compared to infants who were bottle-fed (F[1, 85]=0.11, P=0.7465; Table 2).

There was a significant positive association between clarity of cues and the observed maternal sensitivity to cues total score (F[1,85]=11.52, P=0.0011; Table 2), indicating greater clarity of cues was associated with greater sensitivity to cues. This association remained when considering the sensitivity to cues contingency item score (F[1,85]=8.96, P=0.0036; data

Table 2. Results from general linear models predicting infant clarity of cues[ab] from feeding type/mode,[c] and maternal sensitivity to infant cues[ad] and responsive feeding style[e] for infants (<32 weeks of age) who participated in infant feeding studies (n=86)

Variable	Estimate	Standard error	*t*	*P* value
Model 1: Association between infant clarity of cues and typical feeding type/mode				
Intercept	11.36	0.38	30.29	<0.0001
Any breastfeeding (referent=exclusive formula-feeding)	0.84	0.45	1.88	0.0637
Model 2: Association between infant clarity of cues and observed feeding mode				
Intercept	11.67	1.01	11.50	<0.0001
Any breastfeeding (referent=exclusive formula-feeding)	0.80	0.46	1.73	0.0869
Breastfed during observed feeding (referent=bottle-fed)	−0.21	0.63	−0.32	0.7465
Model 3: Association between infant clarity of cues and observed maternal sensitivity				
Intercept	7.19	1.28	5.60	<0.0001
Any breastfeeding (referent=exclusive formula-feeding)	−0.06	0.50	−0.13	0.8997
Sensitivity to infant cues	0.37	0.11	3.39	0.0011
Model 4: Association between infant clarity of cues and maternal-reported responsive feeding style				
Intercept	780	1.80	4.33	<0.0001
Any breastfeeding (referent=exclusive formula-feeding)	0.76	0.44	1.72	0.0883
Responsive feeding style	0.86	0.43	2.02	0.0464

[a]Assessed using the Nursing Child Assessment Parent-Child Interaction Feeding Scale.

[b]Possible score range=0 to 15.

[c]Although a number of potential covariates were tested for inclusion in the linear models (ie, infant sex and age; typical feeding type/mode; maternal age; body mass index; parity; marital status; Special Supplemental Nutrition Program for Women, Infants, and Children participation; family income; education; and race/ethnicity), covariates were highly correlated and typical feeding type/mode (any breastfeeding vs exclusive formula-feeding) was the covariate most consistently marginally (P<0.10) or statistically (P<0.05) significant within each model. Thus, in the interest of maintaining parsimony and minimizing effects of collinearity, typical feeding type/mode was the only sociodemographic covariate included in linear models that did not include typical feeding type/mode as the independent variable.

[d]Possible score range=0 to 16.

[e]Assessed using the Infant Feeding Style Questionnaire[34]; possible score range=1 to 5.

Table 3. Results from general linear models predicting infant intake and feeding duration from infant clarity of cues[a] during an observed feeding for infants (<32 weeks of age) who participated in infant feeding studies (n=86)

Variable	Estimate	Standard error	*t*	*P* value
Model 1: association between infant intake (mL) and infant clarity of cues				
Intercept	41.79	35.86	1.20	0.2341
Time since last feeding (min)[b]	0.19	0.07	2.50	0.0144
Any breastfeeding (referent=exclusive formula-feeding)[c]	−33.08	12.13	−2.73	0.0078
Infant clarity of cues	4.63	2.83	1.63	0.1059
Model 2: association between duration of feeding (min) and infant clarity of cues				
Intercept	2.03	4.65	0.44	0.6636
Time since last feeding (min)	0.01	0.01	0.28	0.7789
Any breastfeeding (referent=exclusive formula-feeding)	−2.34	1.62	−1.45	0.1516
Infant clarity of cues	1.05	0.38	2.79	0.0066

[a]Assessed using the Nursing Child Assessment Parent—Child Interaction Feeding Scale; possible score range=0 to 15.

[b]The amount of time elapsed between the infant's previous feeding and the feeding observation was determined from feeding records kept by mothers before the laboratory visit; this variable was included as a covariate to control for possible effects of variation in infant hunger.

[c]Although a number of potential covariates were tested for inclusion in the linear models (ie, infant sex and age; typical feeding type/mode; maternal age; body mass index; parity; marital status; Special Supplemental Nutrition Program for Women, Infants, and Children participation; family income; education; and race/ethnicity), covariates were highly correlated and typical feeding type/mode (any breastfeeding vs exclusive formula-feeding) was the covariate most consistently marginally ($P<0.10$) or statistically ($P<0.05$) significant within each model. Thus, in the interest of maintaining parsimony and minimizing effects of collinearity, typical feeding type/mode was the only sociodemographic covariate included in linear models.

not shown). Greater clarity of cues for infants was also associated with greater levels of self-reported responsive feeding style for mothers ($F[1,84]=2.02$, $P=0.0464$; Table 2).

As illustrated in Table 3, the association between infant intake during the observed feeding and clarity of cues was not significant ($F[1,85]=2.67$, $P=0.1059$). However, greater clarity of cues was a significant predictor of longer feeding duration ($F[1,85]=7.78$, $P=0.0066$).

There was no association between clarity of cues and WAZ at birth ($F[1, 85]=1.40$, $P=0.2401$) or at study entry ($F[1,85]=0.00$, $P=0.9528$; data not shown). Clarity of cues was not directly related to change in WAZ from birth to study entry ($F[1,84]=0.13$, $P=0.7154$), but a significant interaction between typical feeding type/mode (any breastfeeding vs formula-feeding) and clarity of cues was noted ($F[1, 85]=5.32$, $P=0.0236$; Table 4). The Figure presents predicted WAZ change estimates for breastfeeding vs formula-feeding infants; to ease interpretation of the interaction between clarity of cues and typical feeding type/mode, clarity of cues was modeled as lower (−1 standard deviation below the

Table 4. Results from mixed linear model with repeated measures predicting infant weight-for-age *z* score change from birth to study entry from infant clarity of cues[a] for infants (<32 weeks of age) who participated in infant feeding studies (n=86)

Variable	Estimate	Standard error	*t*	*P* value
Intercept	0.18	0.09	1.96	0.0528
Time (infant age in weeks)	0.15	0.07	2.24	0.0278
Any breastfeeding (referent=exclusive formula-feeding)[b]	−0.22	0.09	−2.56	0.0123
Infant clarity of cues	−0.01	0.01	−2.09	0.0400
Infant clarity of cues any breastfeeding (referent=exclusive formula-feeding)[c]	0.02	0.01	2.31	0.0236

[a]Assessed using the Nursing Child Assessment Parent-Child Interaction Feeding Scale; possible score range=0 to 15.

[b]Although a number of potential covariates were tested for inclusion in the linear models (ie, infant sex and age, typical feeding type/mode, maternal age, body mass index, parity, marital status, Special Supplemental Nutrition Program for Women, Infants, and Children participation, family income, education, and race/ethnicity), covariates were highly correlated and typical feeding type/mode (any breastfeeding vs exclusive formula-feeding) was the covariate most consistently marginally ($P<0.10$) or statistically ($P<0.05$) significant within each model. Thus, in the interest of maintaining parsimony and minimizing effects of collinearity, typical feeding type/mode was the only sociodemographic covariate included in linear models.

[c]Interaction term for the interaction between infant clarity of cues and any breastfeeding.

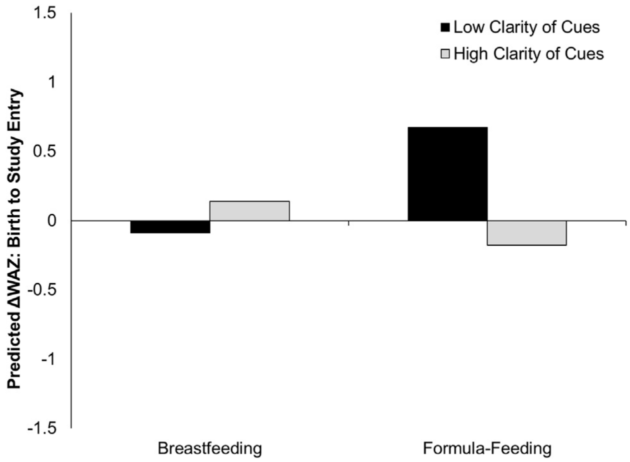

Figure. Association between infant clarity of cues[a] and predicted infant weight-for-age *z* score[b] change from birth to study entry[c] for breastfeeding vs formula-feeding mothers. Bars represent predicted infant weight-for-age *z* score change (ΔWAZ) from birth to study entry for breastfed vs formula-fed infants. To represent the significant interaction between clarity of cues and typical feeding type/mode, clarity of cues was modeled as lower (−1 standard deviation [SD] below the mean; black bars) vs higher (+1 SD above the mean; gray bars) values to create predicted WAZ change estimates. [a]Infant clarity of cues was assessed using the Nursing Child Assessment Parent−Child Interaction Feeding Scale; possible score range=0 to 15, with higher scores indicating the greater clarity of cues during an observed maternal-infant feeding interaction. [b]Mothers reported infant birth weight and infant weight was measured in triplicate at study entry; weight data were normalized to sex- and age-specific *z* scores (WAZ) using World Health Organization Anthro software, version 3.2.2. [c]Mean infant age at study entry was 15.5 7.6 weeks.

mean) vs higher (+1 standard deviation above the mean) values to create predicted WAZ change estimates (Figure). For breastfed infants, those with higher clarity of cues had a slightly positive WAZ change, whereas those with lower clarity of cues had a slightly negative WAZ change. In contrast, formula-fed infants with higher clarity of cues exhibited a slightly negative WAZ change, whereas formula-fed infants with lower clarity of cues showed a larger, positive WAZ change. The association between clarity of cues and change in WAZ from birth to study entry was not moderated by observed feeding mode (F[1, 84]=1.59, P=0.2105; data not shown).

DISCUSSION

The present study was a secondary analysis of combined data from infant feeding studies, wherein infant clarity of cues and maternal sensitivity to infant cues during a typical milk-feeding interaction were objectively assessed via a validated and widely used behavioral coding scheme.[23] A key finding of this study was that strong, positive associations exist between infants' clarity of cues and mothers' observed sensitivity to infant cues and self-reported responsive feeding styles. However, within this sample of young infants, variability in clarity of cues was noted, with some infants showing relatively lower clarity of cues (meaning the infant displayed fewer or less effective cues to communicate his or her needs to the caregiver during the feeding interaction) with others showing relatively higher clarity of cues (meaning the infant exhibited a greater number and clearer cues to communicate during the feeding). Potential implications of poorer clarity of cues are suggested by the finding that typical feeding type/mode modified the association between clarity of cues and change in WAZ scores from birth to study entry, with lower clarity of cues predicting a larger, positive WAZ change for formula-feeding, but not breastfeeding, infants.

These descriptive findings from the present study are consistent with the few previous studies that have also described infant communication during feeding. Mean clarity of cues scores noted in the present study were comparable to clinically relevant reference data provided in the NCAFS training materials (ie, mean clarity of cues score was 12.77 1.95 for a reference sample of 1,638 mother−infant dyads).[23] Previous studies suggest that although, on average, infants are consistent in the number and types of cues exhibited across observed feedings,[22] significant between-infant variation exists for the overall number of cues and specific profile of cues different infants used to communicate satiation.[21,22,40] In addition, greater consistency in the number and types of cues exhibited across observed feedings was significantly associated with mothers' greater levels of self-reported responsive feeding style.[22] One possible interpretation of these findings is that low clarity of cues is a learned response that infants develop in response to mothers' low sensitivity to cues and less responsive feeding styles.[41] Another possible interpretation is that infants who are less consistent and exhibit less clarity of cues during caregiver−child interactions are more difficult to feed responsively because there is less information upon which to base feeding decisions. Taken together, these descriptive analyses suggest that not all infants are effective communicators during infant feeding interactions, which highlights the possibility that responsive feeding may be more difficult for some caregivers than others. Further research using longitudinal designs is needed to better understand bidirectional influences between infant communication and caregiver sensitivity and responsiveness during feeding interactions.

Clarity of cues was not associated with infant sex or age, or mothers' ratings of infant temperament or eating behaviors. The present study was a secondary data analysis and may have lacked adequate power to assess these associations. Previous research supports associations between infant age and communication during feeding,[20,40,42] and longitudinal studies examining changes in infant communication during feeding illustrate that older infants exhibit a broader repertoire of behaviors,[20,40,42] likely due to maturation in their motor and social skills. In addition, studies examining other aspects of infant eating behaviors (eg, food and satiety responsiveness[33] and acceptance of novel foods[43]) have found associations between eating behaviors and infant sex[33] and temperament,[43] suggesting that infant characteristics could provide some predictive discrimination between infants with better vs poorer communication during feeding. However, further research with larger, more diverse samples and longitudinal designs is needed to more fully understand these associations.

In the present study, breastfed and formula-fed infants exhibited similar clarity of cues. This finding is inconsistent with findings reported by Shloim and colleagues,[21] who noted that breastfed infants showed greater levels of both engagement (eg, hunger) and disengagement (eg, fullness) cues compared to formula-fed infants. Furthermore, an association between feeding mode during the feeding observation (ie, feeding directly from the breast vs from a bottle) and clarity of cues was not found, which may have been due to the fact that some breastfeeding mothers were asked to bottle-feed their infants due to study protocol. These findings should be interpreted with caution due to the correlational nature of this secondary analysis, but one possible implication of these findings is that clarity of cues is not necessarily driven by feeding mode. It is conceivable that clarity of cues would predict which dyads are successful with breastfeeding, given that breastfeeding is an inherently more infant-led interaction because active engagement of the infant is needed to initiate and maintain each feeding.[44] In addition, because the caregiver cannot readily assess how much the infant consumes during breastfeeding, greater attention to infant cues is needed to assess the feeding adequacy; in contrast, the bottle-feeding caregiver has more knowledge about how much milk is available and consumed and may base feeding decisions on these bottle-based cues, especially when infant cues are inconsistent or unclear.[24,25] However, further research exploring associations among feeding type/mode, infant clarity of cues, and maternal responsiveness is warranted.

Breastfeeding vs formula-feeding moderated the association between clarity of cues and early WAZ change: for breastfeeding infants, WAZ change from birth to study entry was similar for infants with lower vs higher clarity of cues, whereas for formula-feeding infants, WAZ change was greater when infants had lower clarity of cues compared to when infants had higher clarity of cues. This finding may suggest that greater clarity of cues is particularly protective for formula-feeding infants, who are at heightened risk for overfeeding and rapid weight gain compared to breastfeeding infants,[37,39,45-48] but further research is needed to verify these interpretations and better understand how clarity of cues may impact, or be impacted by, feeding mode and longer-term feeding outcomes.

Limitations of the present study highlight potential foci for future research. As indicated, the present study was a secondary analysis of combined data from infant feeding studies and positive findings should be considered hypothesis-generating. Although the sample was somewhat diverse in terms of race/ethnicity and socioeconomic status (46% minority, 41% WIC participants), it was not necessarily representative of the US population, and more than half the sample was non-Hispanic white, highly educated, and exclusively breastfeeding, which may limit generalizability of study findings.[49] In addition, features of the observed feeding may have limited the validity of this assessment: the feeding occurred in a laboratory (instead of a familiar home environment), only one feeding was assessed, and some mothers were asked to bottle-feed (instead of being allowed to choose to breastfeed or bottle-feed). Whether these mothers felt uncomfortable feeding in a laboratory-based setting or whether they would have opted to breastfeed vs bottle-feed, given the choice, was not assessed. Thus, it is possible that some mothers' observed sensitivity to infant cues or infants' clarity of cues was impacted by these factors. Overall, these exploratory findings highlighted a number of associations between clarity of cues and feeding outcomes, but further research is needed to more directly test these associations using more diverse, well-powered samples using both cross-sectional and longitudinal approaches. A strength of this study was inclusion of both observed and self-reported data; further research should continue to use both objective and subjective measures of caregivers' and infants' behaviors during feeding to enable a multidimensional understanding of the bidirectional influences of early feeding interactions and outcomes.

CONCLUSIONS

Promotion of responsive feeding is an important focus for further research and prevention efforts, but, to date, most studies aimed at understanding how to promote responsive feeding have taken a mother-centric approach, focusing on the potential impact of mothers' responsiveness to infants' cues. Few studies are available to support the fundamental assumption of responsive feeding: that infants will effectively communicate their needs during feeding interactions. The present study suggests that variability exists in how well infants communicate during feeding and that certain caregivers may need more nuanced support—beyond recommendations to feed responsively to infant cues—to achieve high-quality feeding interactions that support appropriate infant intake and growth trajectories. Thus, an implication of findings from the present study is support for the notion that future efforts aimed at promoting responsive feeding within research or clinical settings needs to understand the potential contributions of both caregivers and infants to feeding interactions, especially among higher-risk populations such as formula-feeding dyads and families from a lower sociodemographic status. Expanding awareness of how infant communication during feeding may either hinder (in the case of lower clarity of cues) or augment (in the case of higher clarity of cues) mothers' abilities to adopt and employ responsive feeding styles is a likely first step toward better informing early, targeted prevention and intervention efforts.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

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AUTHOR CONTRIBUTIONS

A. K. Ventura designed the study, oversaw all aspects of data collection, management, and analysis, and reviewed, revised, and finalized the manuscript. S. Sheeper and J. Levy assisted with reviewing the literature and wrote the first draft of the Introduction, Methods, and Results sections.