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# Social Influences on Formula Intake via Suckling in 7 to 14-Week-Old-Infants

**ABSTRACT:** To investigate social influences on human suckling behavior, 25 healthy, full term, 7 to 14-week-old infants were each bottle-fed their own formula twice by their mother and once in each of four experimental conditions: (a) held, provided social interaction; (b) held, without interaction; (c) not held, provided interaction; (d) not held, without interaction. Volume intake (VI), Total Sucks, infant gaze direction, and time elapsed since the last feeding were determined. There were three major findings: (1) social interaction increased VI; (2) VI was linearly related to the time since the last feeding in held infants; (3) Total Sucks and VI were both highly correlated with privation length when infants did not look at the feeder and when fed by the mother. Thus, social influences exert strong immediate impacts on suckling. Accordingly, suckling functions to obtain both nutrition from and social information about the feeder. © 2007 Wiley Periodicals, Inc. *Dev Psychobiol* 49: 351–361, 2007.

**Keywords:** infant; sucking; feeding; social behavior

## INTRODUCTION

Human feeding can be induced or terminated by physiological signals that reflect energy deficits and surfeits, respectively. It is most strongly influenced however, by events that are independent of energy need. These include characteristics of the feeding setting such as food temperature, flavor and texture (Wansink, 2004), and

social influences in the eating environment, including eating with strangers or with friends and family (deCastro, 1994; Goldman, Herman, & Polivy, 1991).

Unlike adult ingestion, which can occur in isolation, human infant feeding by definition is always embedded in a social context (Kennell, Trause, & Klaus, 1975; Klaus, Trause, & Kennell, 1975). During feeding, held infants receive nutrients, physical support, the calming of touch (Gray, Watt, & Blass, 2000) as well as energy-conservation derived from change in surface to mass ratio. Other social exchanges are also integral to the feeding situation. These include mutual gaze, smiling, and audible interactions; cooing and babbling on the infant's part and inflected speech patterns by the feeder (Papousek & Papousek, 1996). Although these exchanges have been documented and their significance has received considerable thought within the context of mother–infant affectional development (Goldberg, 1977; Stern, 1977), the proximal influences of social interaction on infants' ingestive behavior have not been assessed.

Addressing this is important from a number of perspectives. First, differential contributions of the various aspects of stimulation during feeding are of

Received 1 July 2005; Accepted 5 September 2006

Abbreviations used: TE, time elapsed since the last feeding; VI, volume intake (milliliters per kilogram body weight); SL, number of sucks occurring during a meal while looking at the feeder's face; SNL, number of sucks occurring during a meal while not looking at the feeder's face

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Contract grant sponsor: General Clinical Research Center

Contract grant number: M01 RR00533

Contract grant sponsor: American Heart Association

Contract grant number: 0275040N

Contract grant sponsor: NIMH

Contract grant number: MH 05175-08

Published online in Wiley InterScience

(www.interscience.wiley.com). DOI 10.1002/dev.20221

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interest in their own right. These data will improve our understanding of feeding control and may prove helpful in treating disordered nursing–feeding relationships. Second, appreciating whether and how social factors influence intake may deepen our understanding of how preferences for particular adults develop (Blass & Camp, 2001; Bushnell, Sai, & Mullin, 1983; Pascalis, deSchonen, Morton, Deruelle, & Fabre-Grenet, 1995). Third, identifying how social factors affect feeding during infancy would better inform us of the developmental trajectory of these influences on feeding throughout childhood. Although the influence of flavors experienced through formula or breast milk in early infancy on later flavor preferences is well-established (Mennella & Beauchamp, 2002), the contribution of social factors during feeding in infancy on immediate and future feeding has not been assessed.

Accordingly, we have studied the social determinants of volume intake (VI) from a bottle by evaluating infant–feeder interactions in 25 7 to 14-week-old infants who ingested their own formula from their own bottle and nipple. To evaluate the influence of holding, infants were either held by a nurse-experimenter or fed while sitting in a familiar infant seat. To evaluate the effects of social interaction, infants were fed while the nurse was looking at and speaking to the infant or during silent meals in which the feeder’s eyes were focused on the infant’s chest. The four feedings by nursing staff were bracketed by feedings by the mother, for a total of six feedings. This allowed comparison of infant behavior and VI under the different experimental conditions with that during the infant’s natural meals. The role of direction of infant gaze in determining intake was also established through the videotapes.

A number of alternative hypotheses regarding the relationship between time elapsed since the previous meal and VI were evaluated. If amount ingested was governed by physiological controls only then intake would be related to time elapsed since the last meal. If social conditions impacted VI, however, then the physiologic determinants would be compromised. Our findings demonstrate two independent determinants of suckling in human infants. One reflects physiological/energetic consequences of suckling abstinence. The other is engaged when infants look at the feeder.

## METHODS

Mothers were first contacted either during their birthing stay at the Boston Medical Center, Boston University School of Medicine (a hospital serving an urban, multiethnic, low-income population) or at area Women, Infants, and Children (WIC) offices (a government-sponsored program providing nutritional advice and resources to low-income women and children). At the

time of initial contact, the purpose of the study was presented in general terms and permission was obtained to call the mothers for scheduling purposes. Mothers were contacted by phone when their infants were 6–11 weeks of age; the study was explained in detail and the mothers were invited to participate. Written informed consent was obtained on arrival to the study center. The study was conducted at the General Clinical Research Center (GCRC) at Boston University School of Medicine. Each mother was compensated with \$40 per day and transportation expenses, and meals were provided during her time at the GCRC. This study was approved by the Institutional Review Board of the Boston University School of Medicine.

Twenty-five 7 to 14-week-old infants participated in the study. This sample size provided about 80% power to detect a .6 SD difference in intake between conditions. All infants were full-term with birth weights appropriate for gestational age. Table 1 presents the demographics of the participants. Infants were growing well, had no known pre- or postnatal medical problems, and had not been exposed to illicit drugs. The sample was from an inner city area. Most of the infants were African-American (72%) and 64% percent were male. All six feedings (first and last by the mother, 2nd–5th by nursing staff) took place within a 12-day time span. Examining feedings by the mother first and last provided baseline information on infants’ interactive behavior and intake as well as drift during the course of the study. Only bottle-feeding infants were studied. This enabled precise control of formula availability, allowed the infant to ingest his or her fill, and provided accurate measurement of volume ingested and ingestion pattern, all of which breastfeeding would have precluded. Furthermore, bottle-feeding allowed us to vary whether infants were held or not held during feeding.

Mothers recorded when the infant’s last feeding ended to the nearest 15 min prior to departing from home. Infants were weighed ( $\pm 10$  g) on a hospital-grade scale wearing only a dry diaper. Feedings occurred in a dimly lit, quiet room. Mothers were not instructed to feed in any particular manner. For all feedings 240 mL ( $\pm 1$  mL) of the infant’s brand of commercial formula were prepared by the infant’s mother in the usual manner and offered to the infant through his or her bottle and nipple. In the experimental conditions, the volume of formula was concealed from the nurses by wrapping the bottle. In feedings with the mothers, the volume of formula was not concealed, in order to allow the mothers to continue to feed their infants in their usual, natural manner, which by observation frequently involved the mother’s visual assessment of the remaining contents of the bottle.

**Table 1. Subject Demographics ( $n = 25$ )**

Characteristic	Mean (SD)
Gestational age (weeks)	39.2 (1.2)
Birth weight (kg)	3.19 (.46)
Current weight (kg)	5.68 (.83)
Average rate of weight gain since birth (g/day)	78.8 (13.3)
Chronological age at study (weeks)	10.5 (1.9)
Maternal age (years)	24.9 (7.9)

Each infant participated in four different experimental feeding conditions, with no more than two feedings per day. The order of the four feeding conditions was randomly assigned to each infant. Research nurses served as the feeders in the experimental conditions, thereby providing greater control over feeder behavior than would have been achieved by the mothers. The nurses were trained in the specific feeder behaviors necessary for each of the paradigms described below. Each nurse was given specific written instructions prior to beginning the assigned paradigm. Each nurse participated in at least one "practice" feeding with an infant subject not included in the data for analysis, during which her adherence to the prescribed feeding behavior was evaluated and critiqued. In addition, during the experimental procedure, the research team monitored adherence to the prescribed behavior for the assigned feeding paradigm to ensure consistency and accuracy. Assignment of one of seven research nurses was randomized with the restriction that an infant be fed only once by a given nurse. Nurses were uninformed as to the study's hypotheses. Mothers either left the study room to observe through a window or remained in a distant corner of the room, well outside the infant's view.

The four feeding conditions were the product of a  $2 \times 2$  design in which social interaction with the feeder and holding during feedings were crossed:

- (1) A research nurse *held* the infant and *provided social interaction* through voice, touch, facial expression, and looking at the infant's face and eyes.
- (2) A nurse fed the infant while the infant was seated in a reclining infant *seat* (i.e., *not held*), and *provided social interaction* as in (1).
- (3) A nurse *held* the infant but directed her gaze to the infant's chest, thereby *denying social interaction*. She did not speak to the infant, look at the infant's face or eyes, or touch the infant with her free hand.
- (4) The infant was fed in the infant seat, (*not held*) as in (2) with *social interaction denied* as in (3).

Feeding was started promptly after the mother declared that the infant was hungry (a minimum of 1 hr from the last feeding). The nurse paused the feeding at her discretion to burp the infant. The feeding was declared complete when the infant ceased sucking and rejected additional attempts to elicit sucking by inserting the nipple into his or her mouth. The infant was then burped, and a single additional attempt to elicit sucking was made by inserting the nipple into the mouth and gently moving it from side to side. This effort lasted no more than 1 min. When no sucking ensued, the feeding was declared complete. Employing this method to determine meal completion led to full agreement among the mother, researcher, and nurse that eating had finished. Volume remaining in the bottle was measured and VI was expressed in mL/Kg body weight.

A subset of 10 infants was videotaped during their feedings with two digital camcorders (Sony Electronics, Tokyo, Japan). One camera was at middle distance to capture Infant Gaze Direction in relation to the feeder's face. The second camera provided a close-up view of the infant's face to record the Total Sucks that occurred during the meal. Behaviors were coded from the videotapes using a computer-compatible event recording system (Observer 3.0, Noldus Information Technology, Lees-

burg, VA). Infant Gaze Direction (to feeder's face or averted) was coded as a continuous behavior. We did not separately score eye-to-eye contact because of the difficulty in confidently assessing eye contact from the videotapes. Sucks were coded as discrete events (enabling the precise calculation of Total Sucks during specified time frames) and identified in a separate coding session independent of Infant Gaze Direction. Twenty-five percent of the tapes were coded for reliability by an independent rater who was unaware of study hypotheses. Agreement for Infant Gaze Direction and timing of changes in Infant Gaze Direction exceeded 90%, as did identifying Total Sucks occurring over time (accuracy level of one half second). Total Sucks and Infant Gaze Direction data were integrated using the event-recording software to allow quantification of Total Sucks when the infant was either looking (termed "sucking while looking" (SL)) or not looking at the feeder's face ("sucking while not looking" (SNL)).

A variable called "Suckling-Looking Index" was created to represent the absolute number of sucks by which SNL exceeded SL in a given meal. We trichotomized the Suckling-Looking Index into three groups of equal size based on the relationship between SNL and SL. The resulting three Infant Gaze Direction categories therefore were: (1) meals in which  $SNL > SL$  (SNL exceeded SL by between 290 and 1022 sucks); (2) meals in which  $SNL < SL$  (SL exceeded SNL by between 46 and 400 sucks); (3) meals in which  $SNL \approx SL$  (meals in which the difference between SL and SNL was between the two ranges outlined in (1) and (2)).

### Statistical Analysis

The PROC MIXED procedure in SAS v8.0 (Cary, NC) was used to perform many of the statistical analyses. PROC MIXED is a more flexible statistical procedure than analysis of variance because it allows for occasional missing data. For clarity of presentation, however, the more familiar terminology of analysis of variance is used to describe the present findings.

## RESULTS

Mean interval between feedings was  $2.7 \pm 1.0$  hr. Mean VI during nurse-feedings was  $18.9 \text{ mL/kg} \pm 11.3$ . Mean VI during both mother-feedings was  $22.8 \text{ mL/kg} \pm 9.1$ . VI during the first feeding by the mother did not differ substantially from VI during her second feeding ( $22.1 \text{ mL/kg} \pm 2.1$  vs.  $24.6 \text{ mL/kg} \pm 3.2$ ), ( $F(1,8) = .62$ ,  $p = .46$ ). VI was positively correlated with time since the last meal for all four nurse-fed conditions in all 25 infants ( $r = .51$ ,  $p < .0001$ ) (Fig. 1), and in the subset of 10 infants with videotaped feeding behaviors ( $r = .41$ ,  $p = .01$ ). The influence of TE was therefore statistically controlled in selected analyses, as described below.

### Effect of Holding and Social Interaction on Feeding

**Main and Interactive Effects of Social Interaction and Holding on Volume Intake.** A  $2 \times 2$  (social interaction [social interaction or no social interaction]  $\times$  holding

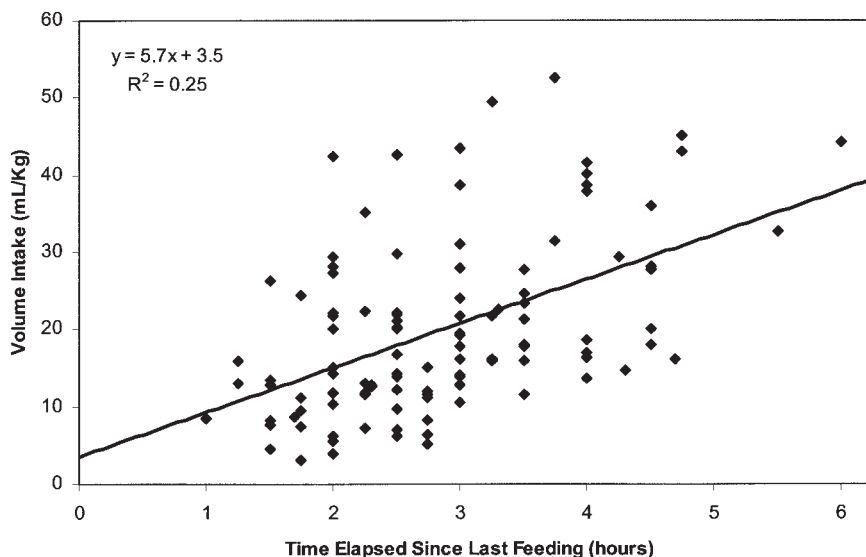


FIGURE 1 Volume intake by the time elapsed since last feeding, all conditions ( $n = 25$  subjects).

[held or not held]) repeated measures analysis of covariance (controlling for TE) assessed the contributions of holding and social interaction, and their statistical interaction, on VI in the sample of 25 infants. Social interaction substantially impacted VI ( $F(1,49) = 9.81, p = .003$ ), while holding did not ( $F(1,49) = .15, p = .70$ ) (Tab. 2). The interaction of holding  $\times$  social interaction only approached statistical significance ( $F(1,47) = 3.16, p = .08$ ).

**Effects of Holding and Social Interaction on the Relationship between Volume Intake and Time Elapsed Since the Last Feeding.** We also determined whether the relationship between VI and TE was influenced by either social interaction or holding. First, repeated measures ANCOVA assessed whether *social interaction*, TE, and their interaction influenced VI. The interaction (social interaction  $\times$  TE) was not statistically reliable ( $F(1,48) = 1.78, p = .19$ ). The analysis was repeated,

assessing holding, TE, and their interaction. The interaction, in fact, was statistically reliable ( $F(1,48) = 5.18, p = .03$ ). This interaction is depicted in Figure 2, demonstrating that TE and VI were closely linked in held infants, but not when these same infants were not held.

**Effect of Infant Gaze Direction on Feeding**

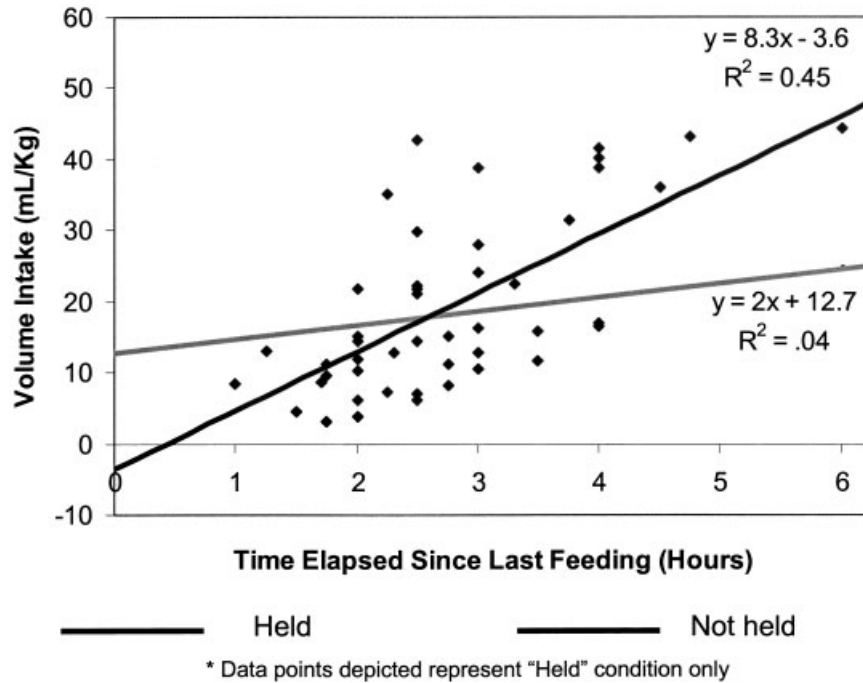
The influence of Infant Gaze Direction was evaluated in the subset of 10 infants who were videotaped during feedings. Because VI was positively correlated with Total Sucks (Pearson  $r = .52, p < .001$ ), Total Sucks during a given feeding interval served as a first approximation of VI during that interval.

**Meal Characteristics by Experimental Condition in 10 infants with Data on Observed Sucking and Looking Behavior.** Table 2 presents meal parameters by experimental condition in the 10 infants for whom sucking and

Table 2. Meal Characteristics by Feeding Condition (Mean, SE)

Condition	Volume Intake (mL/kg) <sup>a</sup>	Meal Duration (Minutes)	% Time Looking at Feeder's Face	Time Spent Crying (Minutes)	Total Number of Sucks
Sample size	25	10	10	10	10
Held and provided social interaction	20.7(1.9)	12.0 (1.9)	35.9 (9.0)	.22 (.67)	498 (111)
Not held, provided social interaction	25.4 (2.8)	12.4 (1.9)	32.0 (9.0)	1.06 (.67)	524 (111)
Held, denied social interaction	17.1 (2.0)	12.3 (1.9)	21.8 (9.5)	2.32 (.71)	310 (116)
Not held, denied social interaction	15.1 (1.9)	8.5 (2.0)	18.5 (9.0)	.82 (.67)	488 (111)
First feeding by mother	20.1 (1.9)	10.6 (1.9)	22.9 (8.6)	.63 (.67)	504 (111)
Second feeding by mother	25.4 (2.9)	9.9 (2.0)	16.0 (9.1)	1.58 (.71)	547 (116)

<sup>a</sup>Volume intake is adjusted for time elapsed since last feeding.



**FIGURE 2** VI versus TE in held versus not held conditions ( $n = 25$  subjects). Data points depicted represent "Held" condition only.

looking behaviors were recorded. One-way repeated measures ANOVA did not reveal any statistically reliable differences among the six conditions in this study (four nurse-feeding and two mother-feedings) in either meal duration ( $F(5,43) = .93, p = .47$ ); percent time when gaze was directed at the feeder's face ( $F(5,43) = .82, p = .54$ ); amount of time spent crying ( $F(5,43) = 1.17, p = .34$ ); or total number of sucks ( $F(5,43) = .74, p = .60$ ).

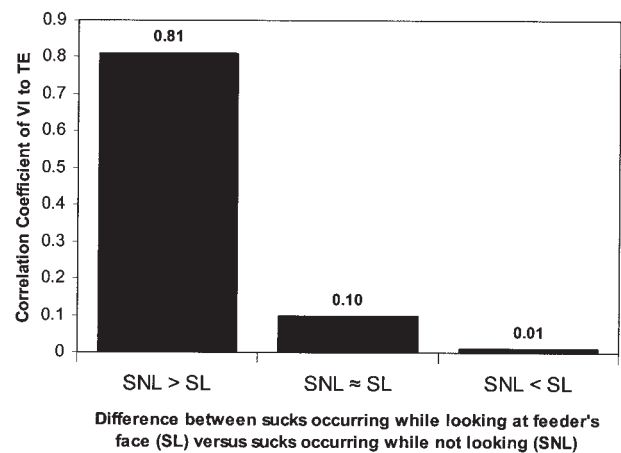
**Relationship between Volume Intake and Time Elapsed Since the Last Feeding Determined by Infant Gaze Direction during Sucking.** Infant Gaze Direction influenced the relationship between TE and VI. Two-way repeated measures ANOVA revealed a statistically reliable TE  $\times$  Infant Gaze Direction interaction ( $F(2,21) = 5.58, p = .01$ ). This is shown in Figure 3, which presents the Pearson correlation coefficients that relate TE and VI for each Infant Gaze Direction category.

**Incidence of Sucking While Looking at the Feeder's Face (SL) and Sucking While Not Looking at the Feeder's Face (SNL) by Feeding Condition**

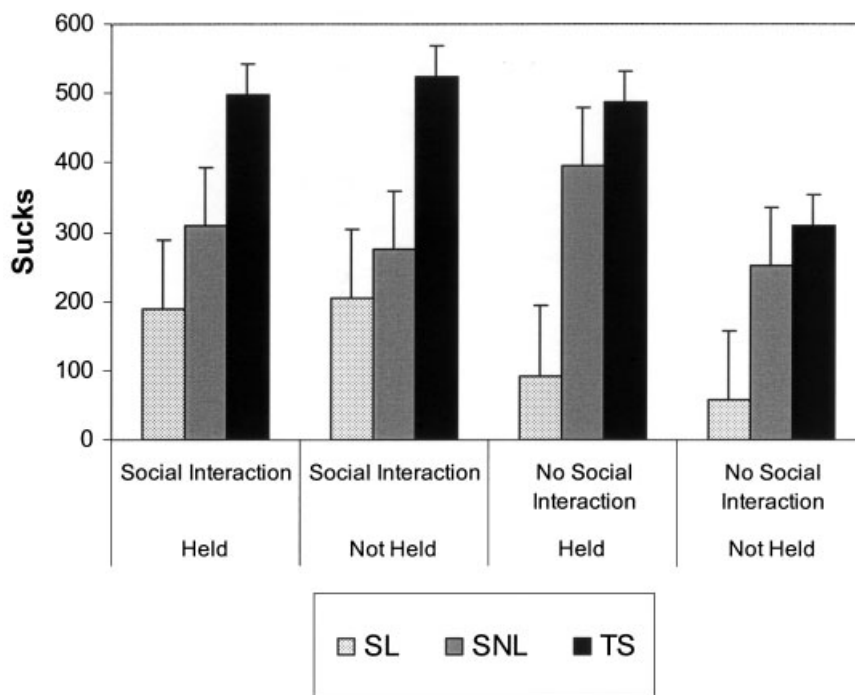
The distributions of sucking that occurred during periods of looking and not looking at the feeder are shown in Figure 4. A two-way repeated measures ANOVA determined if Total Sucks, SNL, and SL differed among

the four nurse-feeding conditions. Neither holding ( $F(1,28) = 28, p = .41$ ) nor social interaction ( $F(1,28) = 1.75, p = .20$ ) determined the Total sucking. Likewise, neither holding ( $F(1,28) = 1.77, p = .19$ ), nor social interaction ( $F(1,28) = .28, p = .60$ ), predicted SNL.

In contrast, social interaction influenced the amount of sucking-while-looking-at-the-feeder ( $F(1,28) = 8.06, p = .008$ ). This influence was also reflected in the proportion of Total Sucks that occurred while the infants were looking at the feeder (SL) ( $F(1,28) = 6.24, p = .02$ ):



**FIGURE 3** Correlation coefficient for VI and TE based on primary infant gaze direction ( $n = 10$  subjects).



**FIGURE 4** Sucks during looking and not looking at feeder, by condition ( $n = 10$  subjects).

SL when feeding without social interaction accounted for  $22.8\% \pm SE 7.5$  of Total Sucks, as opposed to  $46.4\% \pm SE 7.3$  when fed with social interaction. Holding was not significantly linked to SL ( $F(1,28) = .01, p = .91$ ).

### Predicting Volume Intake and Behavior during Mothers' Feedings

To evaluate how the behavior of infants in feedings with mothers was similar or dissimilar to the socially interactive or nonsocially interactive nurse-feedings, we categorized feedings as one of *three types*: (1) with mothers, (2) with nurses and social interaction provided or (3) with nurses and social interaction denied. One-way repeated measures ANOVA demonstrated that feeding category influenced the Suckling-Looking Index ( $F(2,46) = 4.08, p = .02$ ) (Fig. 5). According to Tukey's posthoc analysis the significant difference was between mother feedings and those by socially interactive nurses ( $p = .02$ ).

The percentage of time that infant gaze was directed to the feeder's face was not significantly associated with 3-category feeding type ( $19.7\% \pm SE 6.2$  with mothers,  $34.0 \pm 6.1$  with socially interactive nurses, and  $20.1\% \pm 6.2$  with nonsocially interactive nurses,  $F(2,46) = 1.90, p = .16$ ).

This reliable difference predicts that VI should be sensitive to TE during maternal feedings. Linear regression analysis, accounting for the repeated feedings by

mothers within a subject demonstrated the significant positive association between TE and VI for the two meals in which the mother fed her infant (Fig. 6).

### DISCUSSION

This is the first demonstration that certain aspects of the social milieu differentially influence human infant suckling and VI of 7 to 14-week-old infants when they ingested their familiar formula from their own bottle and nipple when being fed by a stranger. Three powerful influences have been identified.

First, social interaction during feeding increased VI by 43% relative to feedings in the absence of social interactions. This influence was independent of whether infants were held or not. Reduced VI absent social interaction demonstrates that the hypothesized physiological/behavioral promoters of suckling, such as dehydration, energy loss, change in gastrointestinal state, or suckling abstinence, were not sufficient to sustain ingestion, at least during a single meal. Nor could the rewarding aspects of the suckling act per se, of infant calming and of reduced heat transfer, sustain high levels of ingestion in the absence of social interaction. This cannot be attributed to infants being upset when feeding occurred without interaction because infants did not cry or fuss significantly more during noninteractive meals and seemed otherwise calm.

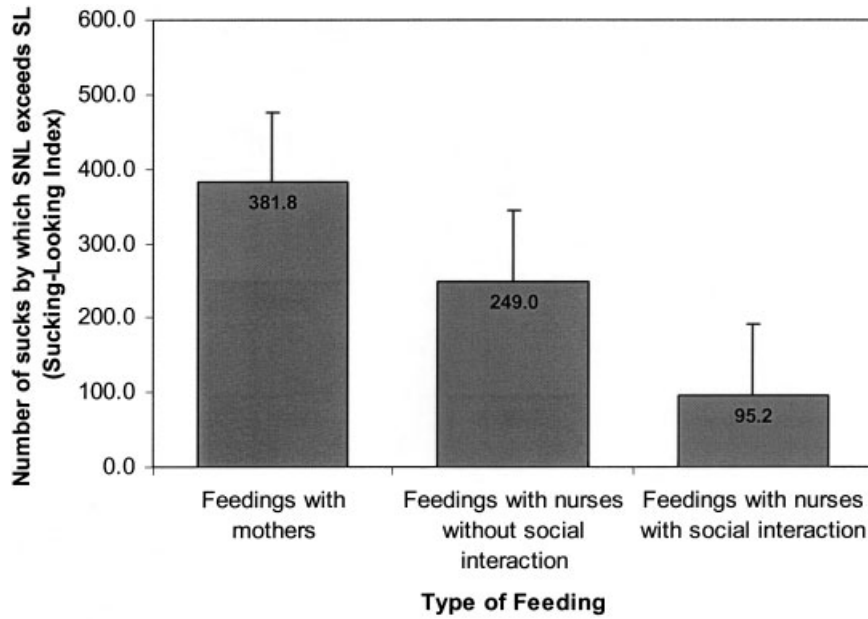


FIGURE 5 Suckling-Looking Index by type of feeding ( $n = 10$  subjects).

Second, the relationship between VI and time elapsed since the last feeding indicates that infants between 7 and 14 weeks of age detect some correlate of privation and adjust their VI accordingly. The correlate has not been identified: it may reflect energy expended since the end of the last meal, changed gastric or gastrointestinal status, or suckling abstinence during the interval.

Third, the positive correlation between VI and time elapsed since the last feeding was driven by two circumstances surrounding feeding; namely, being held

during the meal and *not* looking at the feeder when sucking. Holding infants during feeding was sufficient for VI to be determined by a correlate of abstinence. Linear regression analyses captured the relationship between VI and TE for each holding condition as seen in Figure 2. The intercept for held infants approached zero, as would be expected from a system that is sensitive to the consequences of suckling abstinence. When infants were not held, however, the slope of  $2.0x + 12.7$  did not differ significantly from zero. This uncoupling of suckling from

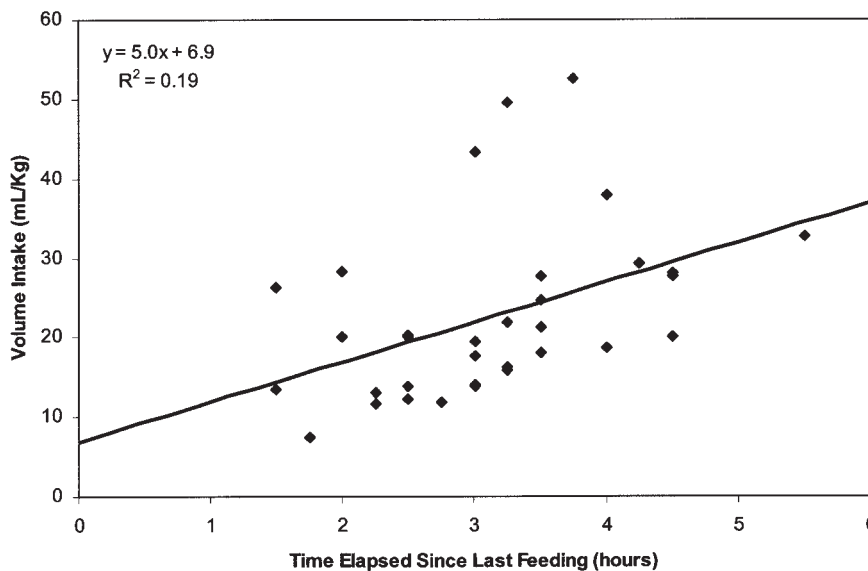


FIGURE 6 VI by TE, feedings by mothers ( $n = 25$  subjects).

physiological control when infants were not held points to both social and physiological determinants of VI during suckling. In summary, VI and TE are coupled or uncoupled depending on whether infants were held or not. Holding, therefore, was a sufficient but not necessary condition for some concomitant of suckling abstinence to be revealed.

Although social interaction, as defined above, did not influence the relationship between VI and TE, this observation is complicated by the fact that infants are not passive recipients of social interaction. This active participation in social interaction was reflected in infants' looking at their feeder, which we designated as infant social behavior. When sucking occurred primarily when *not* looking at the feeder (SNL), the correlation between VI and time elapsed since the last feeding was strong. In contrast, when infants sucked primarily when looking at the feeder's face, there was essentially no correlation between VI and time elapsed since the last feeding. Infants were most likely to suck the most while looking away from the feeder's face when social interaction was denied by the feeder. In contrast, looking at the feeder while sucking occurred more when infants were provided with social interaction by the feeder.

Dissociation of deprivation time from VI during SL implies the presence of two control systems over sucking in infants 7–14 weeks of age. One, sensitive to privation length, is manifest during sucking while not looking at the feeder's face. The other determinant is of a social nature and is expressed when infants suck while looking at the feeder. Sucking while looking at the feeder's face may mask or disengage the physiological control and may serve thereby to obtain information about and form attachment with the mother. This is entirely consistent with differences in VI according to incidence of sucking while looking at the feeder's face during both mother and nurse feedings.

All mothers held their infants during feeding, and although their social behaviors were not coded, no mother denied social interaction when initiated by her infant. One might therefore presume that feedings with mothers would most closely resemble stranger-feedings when infants were held and provided social interaction. Mother-fed infants behaved as they did when fed by noninteractive nurses; significant sucking occurred while not looking at the feeder's face in both instances. This suggests that one function of SL is to learn about, recognize, remember, and be attracted to the feeder's face. Presumably, these infants had already "learned" about their mother's faces, and, therefore, spent relatively less time looking at them during suckling. Direct coding of mothers' behaviors during feeding in relation to infant intake and sucking behavior will be an important focus of future research.

Differential patterns observed in the present studies are likely to be initiated during maternal feedings starting at about 4 weeks of age when infants first start to look at the mother's face and especially her eyes during feeding (Wolff, 1987). Crying 4-week-old infants can be soothed by individuals who provide them sucrose while in eye contact. Sucrose alone does not stop crying, nor does eye contact alone (Zeifman, Delaney & Blass, 1996). Moreover, eye contact in conjunction with sucrose delivery or pacifier sucking, can be sufficient for infants at different ages to develop and express a preference for the person providing these moieties (Blass & Camp, 2003). Thus, the role of feeding may become particularly salient for infant social development around age 4 weeks, through the confluence of ingestive behavior, eye contact, and face recognition, in all likelihood with biological underpinnings. In principle, nursing serves more than a nutritive role alone from when it begins to be functionally intertwined with other critical aspects of human infant development. Although important attachment mechanisms are clearly in place from birth, sucking while looking at the feeder provides an additional pathway through which maternal attachment either occurs, is strengthened, or redefined. On this view, infants should be preferentially attracted to socially interactive feeders, even though total time looking (i.e., SL + SNL) at the feeders did not differ between conditions.

Enhanced VI during social interactions requires comment. First, increased sucking while looking at interactive feeders might reflect attentional and affective systems underlying infant attraction to faces, especially animated ones, as well as attention to the spoken word and its source. Sustained eye contact could arouse infants nonspecifically to be channeled into the prepotent behavior of sucking. Precedence for this interpretation can be found in the animal literature (Valenstein, Cox, & Kakolewski, 1968). Alternatively, social interactions may enhance VI by causing the signals that arise from stomach and GI tract to be ignored either through competing attention or by direct inhibition. This is supported by findings from infant rat studies in which gentle handling caused infant rats to take in a mean of 17% of their body weight in a single meal, an extraordinary amount, with the highest intake of 25% body weight (Cramer & Blass, 1983). Presumably, in human infants gastric signals could also be ignored or inhibited during periods of excitation.

The linkage between abstinence and subsequent suckling and intake was unexpected on two grounds. First, this linkage is absent in rat infants, which appear to be opportunistic feeders that maximize intake of all available milk from the mother, independent of privation level (Blass, 1995). Second, the linkage was readily overcome in the present studies when infants sucked while looking at the feeder. Three possible mechanisms could



determine suckling intake as a function of privation length. Intake could be linked to a correlate of energy expended during the abstinence interval. Second, intake could be determined by diminished levels of gastric or GI fill reflecting gastric clearance or changes in the levels of circulating GI hormones during abstinence. Third, intake might reflect the amount of sucking that was missed during the period of abstinence. Support for the last hypothesis was provided by Cramer and Blass (1985) who demonstrated in rats that intake is governed by suckling abstinence and not its nutritive consequences. Suckling during abstinence in human infants in the form of pacifier use has been associated with a reduction in breastfeeding, but the mechanism underlying this effect and a direct link between nonnutritive suckling on a pacifier and subsequent reduction in volume of intake has not been tested in human infants (Howard et al., 2003). In addition, hedonic response to the odor or flavor of the formula declines in the postprandial state (negative alliesthesia), and the reduced hedonic response to the formula may underlie reduced intake with shorter periods of deprivation (Soussignan, Schaal, & Marlier, 1999).

We find it unlikely that the diminution of VI control during meals taken in the infant seat reflects a disruption of behavior. Infants did not present any signs of being upset when fed in the infant seat. All had had experience with such seats in the past and some infants had been fed by their mothers or other caretakers while sitting in the seats. The basis for holding permitting the linkage of suckling and the period of suckling abstinence has not been identified.

A substantial literature documents the robust effect of social cues on human eating behavior. Eating is facilitated by the presence of familiar others (deCastro & Brewer, 1992) and peer models powerfully shape food choices (Birch, 1980; Duncker, 1938; Rosenthal & McSweeney, 1979). Social influences on eating have been documented even in early childhood (Birch, 1980; Birch, Marlin, & Rotter, 1984; Birch, Zimmerman, & Hind, 1980). Parental prompting increases intake in children as young as 12 months (Klesges et al., 1983), but the influence of social cues on feeding behavior in younger infants has received little attention in the scientific literature. Although researchers have frequently employed the feeding setting as a context for studying maternal–infant relationships, to our knowledge, no studies have documented the effect of social cues on infant feeding as early as 7 weeks of age.

In short, these findings cohere with two putative functions of human infant suckling. The most obvious function is for infants to derive sufficient milk from the mother to exceed their energy requirements and track their growth trajectory. This is likely determined by

physiological/behavioral systems that monitor and replenish, (indeed exceed) energy losses that occur between suckling bouts. Enhanced socially linked intake suggests a potential second function of nursing–suckling interactions: acting as a medium for infants to learn about the characteristics of the feeder, normally the mother (Blass, Ganchrow, & Steiner, 1984; Bushnell et al., 1983; Pascalis et al., 1995).

There are several limitations to the study. First, the sample size was relatively small. Although we were able to detect robust behavioral phenomena with this small sample size, confirmation and further investigation of these findings with a larger sample would be useful. Our study also evaluated infants while being fed by a stranger, as opposed to their mothers. Having research nurses conduct the protocol allowed us the very tight experimental control which would have been absent in more naturalistic feedings with mothers. Although clear differences emerged in feedings conducted under the different conditions with the nurses, the feedings by the mothers differed from nurse feedings in a number of ways which we have reported in the Results. Therefore, confirmation in future studies that the differences detected between conditions during the nurse feedings persist when the mother feeds under these conditions would provide additional support for our conclusions. Also, because all infants were, by necessity, bottle-fed in our protocol, it is unknown if our findings extend to breastfeeding. Therefore, extrapolation of the findings to the nursing relationship should be done with caution. Finally, this study found differences in the relationship between VI and time elapsed since the last feeding based on whether sucking occurred while looking versus not looking at the feeder's face while sucking. It is possible that sucking morphology may have changed while looking at the feeder's face, compared to when not looking at the feeder's face, such that VI per suck was greater. This is a testable hypothesis with the appropriate equipment to gauge suck morphology, and is an issue for future research.

To our knowledge, these are the first data to indicate that social cues affect VI and its control even during early infancy. Because feeding control is so elastic, the current findings take on added significance, with potential implications for poor feeding on the one hand, and overeating on the other. The current studies provide an early developmental basis for enhanced feeding under felicitous social settings (deCastro & Brewer, 1992; Herman, Roth, & Polivy, 2000) and for increased VI when visual and auditory attention are also directed externally (Bellisle & Dalix, 2001; Blass et al., 2006). These particular disengagements of physiological controls over intake by external events may provide a developmental vector for contemporary obesity.

## NOTES

This study was supported by grant M01 RR00533 of the General Clinical Research Center, Clinical Research Feasibility Funds, at Boston University School of Medicine to Dr. Lumeng, grant 0275040N American Heart Association Fellow-to-Faculty Transition Award to Dr. Lumeng, and NIMH MH 05175-08 to Dr. Blass.

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