MOTHER AND INFANT CARDIAC RESPONSES DURING BREAST AND BOTTLE FEEDING

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ABSTRACT

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The present study was designed to test the following hypotheses: (a) that breast feeding mothers would show cardiac DRs of lower amplitude than bottle feeding mothers, during feeding; (b) that breast-fed infants would exhibit cardiac DRs of lower amplitude than bottle-fed infants, during feeding; and (c) that breast feeding mothers would show different cardiac responses to sucking than bottle feeding mothers.

Four groups of five mother-infant pairs each, participated in the study. Ten infants were females, ten males, half of each sex being breast-fed and half bottle-fed.

Cardiac activity of both infant and mother was recorded simultaneously during a feeding session. During the session a 95dB horn was sounded three times to elicit the cardiac accelerative component of the DR. Results failed to support hypothesis (a), but did support hypothesis (c). Hypothesis (b) was supported for male infants but not for females. Breast feeding attenuated maternal DRs, and the DRs of infants, except for males early in the feeding session. Bottle feeding mothers did not exhibit the cardiac component of the DR. Breast feeding mothers showed greater cardiac deceleration on sucking onset than did bottle feeding mothers. Additional research is required to determine whether the deceleration represents attention or activation.

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INTRODUCTION

Late in the nineteenth century, artificial feeding of human infants began to gain acceptance as a safe alternative to breast feeding. Prior to that time, survival of the infant hinged heavily on the ability of the mother to breast feed. Even the use of wetnurses was fraught with danger, since some suffered from chronic diseases. Nursing human infants from the udders of goats, cows, or asses was attempted, but with rare success (Fomon, 1967). The advent of pasteurization, the increasing availability of refrigeration, and the technology of modifying curd tension of bovine milk, all three contributed to the trend toward bottle feeding. The resulting popularization of artificial feeding and the mass production of artificial feeding devices were joined, in the years since 1925, by efforts to chemically mimic human mother's milk (McGeorge, 1960).

Today there is renewed interest in the relative merits of breast and bottle feeding. The physiological literature clearly demonstrates the superiority of human breast milk compared to chemical preparations. Breast feeding has been promoted as psychologically superior by psychiatrists (Bartemeier, 1947)

and pediatricians (Aldrich, 1947). However, claims of the psychological superiority of breast feeding are made without substantive empirical verification. Nevertheless, the consistency and fervor with which theoreticians promote breast feeding as psychologically superior to artificial feeding suggests the possibility of an underlying process worthy of empirical investigation. For example, ethological theory suggests that breast feeding, being more biologically natural, should provide greater benefits to the young infant than less natural feeding methods.

Several authors have noted the maternal benefits of breast feeding. Not only is it more convenient and less tedious to breast feed (Thompson, 1971), but several physiological advantages also accrue (Newton, 1971). In addition, breast feeding may be psychologically advantageous to mother in that it enhances her self-perceived adequacy as a mother (Bartemeier, 1947).

Historically, pediatric research on the question of feeding mode antedated psychological research. Thus, in reviewing the literature, pediatric research is considered first.

PEDIATRIC RESEARCH

Pediatric research has employed a wide range of dependent variables in efforts to specify the relative merits of breast and bottle feeding. Consequently, studies in this section of the literature review are considered in categories determined by the major dependent variable(s) of each study.

Mortality, morbidity, weight gain: Much of pediatric opinion, even in recent years, reflects the influence of Woodbury (1925), who concluded that bottle feeding is extremely hazardous to the human infant. He found bottle-fed infants to have higher infection rates, higher death rates, lower body weights, and flesh of reduced density and turgor, compared with breast-fed infants. However, Woodbury's work was conducted before pasteurization and adequate refrigeration for milk storage were available, thus confounding the method of feeding with the quality of the milk.

Controlling for the quality of bottle feeding has not, however, diminished the apparent superiority of breast milk. Two groups of 42 babies each were compared at the Stanford University Medical School Well Baby Clinic (Faber & Sutton, 1930). In this area, milk may be safely stored without artificial refrigeration. One group of babies was fed at breast for less than six weeks, the other group for at least 37 weeks. Growth records for the two groups indicated that: (a) during the first quarter year of life,

breast-fed infants showed a higher mean weight gain rate; but (b) after the first quarter year, bottle-fed infants showed a higher mean rate of gain, a superiority which persisted to the time of weaning. The authors concluded that weaning after the third month is not to be feared, provided that high quality artificial milk is used.

In a sample of over 20,000 infants, breast-fed infants had lower rates of morbidity and mortality than bottle-fed infants (Grulee, Sanford & Herron, 1934).

Resistance to infection: Among 26,061 babies under the care of the Infant Welfare Society of Chicago, the incidence of infections of all types in the breast-fed group was 37.4% as compared to 63.6% in the bottle-fed group (Grulee, Sanford & Herron, 1934). Of the breast-fed group, 28% suffered from a respiratory infection as compared to 37% of the artificially-fed babies. Of the breast-fed group, 5.2% had various gastrointestinal disorders, compared to 16% of the artificially-fed infants. Breast feeding apparently provided a much greater immunity to infection than did artificial feeding.

Of 1500 consecutive admissions of babies under twelve months of age admitted to the Hospital for Sick Children in Toronto for various infections, only 15.1% were wholly breast-fed, 29.1% had been breast-fed for at least six weeks, and 55.7% were artificially fed from birth (Ebbs & Mulligan, 1942). The low incidence of breast feeding among these hospitalized infants was

less than half the incidence of breast feeding in the well baby clinics of the same city.

In a sample of 263 infants, of whom 95 were breast-fed for three months or longer, bottle-fed infants suffered a higher incidence of respiratory infections than did breast-fed infants, during the second half year of life (Stevenson, 1947).

Rashes, gastrointestinal disturbances, diarrhea: In a study primarily designed to specify the differential effects of irradiated versus non-irradiated milk diets for infants, breast-fed infants had the lowest incidence of both diarrhea and rashes (Robinson, 1939). Bottle-fed infants have also been found to have higher rates of gastrointestinal disorders, respiratory infections, and otitis media (Robinson, 1951). Among these bottle-fed infants, infections tended to be of longer duration, and mortality was more frequent. No differences were found as a function of social class, as defined by the father's occupation.

Breast-feeding has been associated with low incidence of infant gastrointestinal disturbances (Ebbs & Mulligan, 1942), although some investigators have found no differences between breast-fed and bottle-fed infants in susceptibility to diarrhea (Rice et al., 1942). It should be noted, however, that hospitals which give supplementary feedings by bottle, confound breast-bottle comparisons since infections might be traced to improperly sterilized rubber nipples.

In one sample of diarrhretic infants less than nine months of age, 41% had been breast fed for a month or more. The mortality rate in this group was 25.9%, whereas in a comparison bottle-fed group the death rate was 76.6% (Smellie, 1939).

In an epidemic of diarrhea in a newborn nursery, eighteen of twenty-five babies being formula-fed died, while six babies receiving both formula and breast milk and eight other babies who received breast milk after having been formula-fed for three or four days either did not contract the diarrhea or recovered health (Cron, Shutter, and Lahmann, 1940). Similarly, in another epidemic, 6 out of 51 sick infants breast-fed died, while 10 of 30 infants given cow's milk with or without breast milk also died (Ormiston, 1941). Of 18 newborns in a nursery who contracted gastroenteritis, 15 died. The gastroenteritis was confined to bottle-fed infants (Sakula, 1943).

Breast-fed infants suffered fewer bouts of fever than artificially-fed infants from birth to nine months of age (Sydow and Faxen, 1954). In a more extensive study, breast-fed infants ranging from 3 months to one year of age had lower rates of acute infections, otitis media, febrile upper respiratory infections, and acute diarrhea (Melander, Vahlquist & Mellbin, 1959).

Possible mechanisms for the protection of breast-fed infants from gastrointestinal and infectious disorders have not been clearly defined. Although the capacity of breast milk to transmit antibodies

has not been demonstrated (Stone and Bakwin, 1948), mice have been passively immunized against Herpes virus through the mammary route (Berry & Slavin, 1943). The immunity against infection vanished when breast feeding was interrupted.

Colostrum and breast milk of humans have demonstrated an immunologenic function, particularly for gastrointestinal infections (Mata & Wyatt, 1971). Within this context, Gyorgy (1971) has reviewed the biochemical uniqueness of human breast milk.

Eczema: Breast feeding has been associated with protection against infantile eczema (Grulee & Sanford, 1936). Partially breast-fed infants had twice the frequency of eczema as wholly breast-fed infants, and infants entirely artificially fed had seven times the eczema as breast-fed infants.

Reviews and summary: Several reviews of the pediatric literature on breast and bottle feeding (Stone & Bakwin, 1948; Morrison, 1950; Newton & Newton, 1951), have suggested that breast feeding is superior for early weight gain and health, particularly for protection against infections. The extent to which these biological advantages promote or enhance psychological development has yet to be determined, but it is likely that an infant relatively protected from biological risk should more readily and more healthily develop psychologically than the infant who is ill.

Specific research using dependent variables of psychological nature is considered next.

PSYCHOLOGICAL RESEARCH

Psychological investigations of early infancy and parent-infant relationships have focused on many variables, only one of which is feeding method. Thus, the outcomes of studies in which feeding method is the major independent variable must be interpreted in light of other pertinent variables, e.g. attitudes, expectations, and emotional health of the parents, temperament of both infants and parents, family size, etc., which in some cases interact with feeding method (Heinstein, 1963).

Much of the very early psychological research on the effects of feeding method on the infant was prompted by the theoretical contribution of Freud (1920), who asserted that the infant develops at breast the prototype of all future love relationships, and that frustration of the infant's oral needs would result in neurotic development, marked by any of a number of behavior disorders, including thumbsucking.

Orality: In her search for the antecedents of orality, Goldman (1948, 1950) investigated the relationship between breast feeding and character formation. In her first study (1948), she administered to 115 adults, rating scales designed to measure optimism, pessimism, passivity, and the desire for the unattainable, and questionnaires designed to reveal autonomy, ambition, aggression, change, dependence, deliberation, endocathexis, guilt,

nurturance, aloofness, conservation, sociability, impulsion, and displaced oral aggression. Factor analysis of the data suggested a bipolar factor which clearly separated the group into "oral optimists" and "oral pessimists." Oral optimists were characterized by optimism, exocathexis, nurturance, and sociability, while oral pessimists were characterized by oral aggression of a verbal nature, endocathexis, and autonomy. Goldman (1950) then combined this data with the length of time each subject had been breast fed in infancy, as determined by maternal report. Goldman concluded that those who were weaned from the breast before the fifth month of life showed primarily oral pessimistic traits, while those weaned later showed oral optimistic traits. This study clearly confounded feeding method with length of nursing available to the infant, since those infants artificially-fed from birth were placed in the same category as those weaned from the breast at less than five months of age. Moreover, Goldman's research suffers from reliance on retrospective reporting to determine age of weaning.

Security: Plotting the security scores of college students as a function of the number of months the student had been breast-fed in infancy produced a U-shaped function, with the highest security scores for those students who had been entirely bottle-fed or breast-fed for more than one year (Maslow & Szilagyi-Kessler, 1946). However, the confounding of feeding method with weaning age is

clear: infants breast-fed until nine or twelve months of age are usually weaned directly to cup, while those breast-fed for shorter periods are typically weaned to cup via bottle. Those infants entirely bottle-fed would typically be given more total sucking opportunity than those infants breast-fed for nine to twelve months and then weaned directly to cup.

Behavior problems: In a seven-year follow-up study of 109 infants, 62 breast-fed and 47 artificially-fed, the artificially-fed infants later showed a higher frequency of feeding and sleeping problems, bed-wetting, fear, and nervousness, than did those children breast-fed as infants (Childers & Hamil, 1932).

Forty-seven girls and 47 boys who had remained in the Berkeley Growth Study from infancy through age 18 were observed to determine the effects of both feeding method and duration of nutritive sucking on several dependent variables, including the incidence of mild behavior problems during the preschool period and again in adolescence, and a number of personality measures based on projective techniques administered during adolescence (Heinstein, 1963). Single variable analysis revealed no clear advantage for either boys or girls as a function of breast or bottle feeding, but a total longer duration of nutritive sucking was associated with more problem behavior in boys, but not in girls, particularly in middle childhood years. Girls with warm mothers fared better with breast feeding, while those girls with relatively

cold mothers showed fewer disturbances if formula fed.

A survey of 24 kindergarten children suggested that partial or total breast feeding on a flexible schedule are associated with good psychological adjustment (Newton, 1951). Although interviews were used to gain data on early feeding, medical records were consulted where possible to validate the interview data. Adjustment was measured by observational methods and teacher ratings of school behavior.

Breast feeding was not found to be a significant factor in the incidence of thumb and/or finger sucking (Traisman & Traisman, 1958). This study confirmed the observation that breast-fed infants do indeed suck their thumbs, even when fed on demand (Simsarian, 1947). Newton (1971) has suggested that this finding may reflect a difference in manner of breast feeding from the traditional method of unrestricted access to the breast. Recent trends in America have progressed to the point that access to breast is restricted to the satisfaction of hunger, whereas formerly breast contact was also a common source of comfort and pacification. Unrestricted access is currently the practice in some portions of the world. The implication of Newton's hypothesis is distinctly psychoanalytic: the reduction in breast availability frustrates the oral drive and results in displacements and possible long-term fixations, manifested as thumbsucking and behavior problems, respectively.

Hypertension: Feeding method may have a direct bearing on the development of hypertension, in that hypertension may be a function of high sodium content in the diet (Guthrie, 1968). The sodium content of commercially prepared infant foods is higher than is necessary for adequate growth and to compensate for obligatory losses through skin and kidneys. In contrast, the sodium content of mother's breast milk is presumably optimal for the infant (Georgy, 1971).

Organization of behavior: As empirical knowledge expanded beyond the explanatory scope of psychoanalytic theory, investigators have increasingly utilized the concept of the organization of behavior to integrate their findings. This concept assumes the presence of inborn reflexes, which are structurally relegated to noncortical areas of CNS. As life proceeds, the infant develops the capacity to inhibit certain of these reflexes, while simultaneously synthesizing others into what appear as intentional movements and actions. Cerebration is a process which is believed responsible for the apparently increasingly organized behavior of the infant. Cerebration refers to the process of increasing cortical control over motor behaviors.

Examination of the sucking and breathing behaviors of infants revealed that breast-fed infants fed more easily and with less disorganization of sucking, swallowing, and breathing (Halverson, 1944). Breast-fed infants were able to maintain and reestablish

coordination of these three activities under conditions in which bottle-fed infants typically failed. Given a dry nipple on the third day of life, breast-fed infants suck more slowly than bottle-fed infants (Dubignon & Campbell, 1968a, 1968b). While sucking rate increases during each of the first four days of life for all infants, the daily rate increase is less for the breast-fed infant. Thus, breast-fed infants sucked more slowly than their bottle-fed agemates by the fourth day of life, suggesting that the human infant, even in the first few days of life, is making adjustments to his environment (Campbell, 1968).

Differences between breast-fed and bottle-fed infants extend to topography of the sucking response (Applebaum, 1970). The breast-feeding infant sucks with compression of lips, gums, and cheek muscles, using the tongue in a front-back motion to bring the nipple and areola into the posterior oral cavity. The bottle-feeding infant, on the other hand, must use a tugging motion on the rubber nipple, simultaneously flanging his lips into a circular pattern and relaxing the cheek muscles. The rubber nipple also tends to interfere with the movement of tongue, and thus interferes with muscular control at the upper esophageal orifice.

Research has also focused on the strength of the sucking response. Ribble (1943) pointed out that at least 40% of the 600 infants she observed had difficulty sucking, to the point they were unable to nourish themselves, unless repeatedly prompted and

assisted. Ribble did not separate her infants on the basis of feeding method. Norval (1946), although reporting a lower percentage of infants with sucking deficit, concurred with Ribble in urging mothers not to be too easily discouraged from breast feeding. Other findings suggest in fact that infants with sucking deficit should be maintained at breast. By the fourth day of life, breast-fed infants seemed more interested in sucking, and produced significantly longer sucking responses while cup- and bottle-fed infants developed a weaker sucking reflex (Davis et al., 1948).

Feeding method apparently has no effect on the total duration of sleep per day, the duration of the longest sleep period, or the number of feedings, of both term and permaturely delivered infants (Parmalee, Schulz, & Disbrow, 1961).

Bell (1966) found breast-fed newborns at higher levels of arousal than bottle-fed agemates. He measured arousal level by eliciting the prone head reaction immediately after an anthropometric examination, which preceeded feeding by about one-half hour. Bell accounted for the difference in arousal level by referring to differences in the amount of milk retained between feedings, pointing out that since breast milk is digested more readily, the breast-fed infant is more likely to feel hungry, and thus be at a higher activity level. Bell's findings are in basic agreement with those of Davis et al. (1948), who found significantly higher general activity rates in breast-fed infants after the sixth day of life.

This higher level of arousal and greater activity level may eventuate in increased interaction with environmental stimuli and as a result, increased, enhanced, and earlier motor performance and intellectual growth. This seems the case. Breast-fed infants walked alone almost two months before their bottle-fed agemates (Hoefer and Hardy, 1929). In addition, duration of breast feeding is correlated with age of learning to walk (Douglas, 1950). This correlation did not disappear when babies of working mothers, overweight and underweight babies were excluded, and when different groups of babies were considered separately.

A sample of 382 schoolchildren, of whom 39.9% were exclusively breast-fed for one year or longer, and only 18% were breast-fed less than one month, were administered the Stanford achievement test, the Pintner Patterson performance scale, and the Binet-Simon intelligence scale (Hoefer & Hardy, 1929). The groups with the highest scores in relation to their age on all these tests were those exclusively breast-fed 4 to 9 months. Of all the breast-fed, 4.9% had IQs of 130 or higher, while none of the artificially-fed children attained scores this high. Those fed exclusively breast milk after the ninth month showed a decline in all test performances, and often scored lower than the artificially-fed group. Children fed only breast milk in the latter part of the first year of life also had higher death rates (Woodbury, 1925).

Learning ability, brain development, and nutrition are clearly

biochemically interrelated (Coursin, 1972; Winick, 1969). Besides the essential role of fats, brain development in early months requires the availability of cystine, which is high in mother's milk and low in bovine milk (Sturman et al., 1970; Gyorgy, 1971). Thus, one might speculate that early breast feeding enhances brain development, thus permitting earlier cerebration, and in turn allowing the infant greater advantage from environmental stimulation.

Reviews and summary: Reviews of the psychological literature on breast and bottle feeding have generally concluded that the evidence at this point is too incomplete to formulate conclusions about relative merits of either feeding method (Caldwell, 1964; Davis & Ruiz, 1965). The studies reviewed above, however, suggest that breast feeding, particularly for the first nine months, facilitates development, assists in the organization of early reflexes, leads to earlier walking and higher scores on some developmental tests, and may assist in the prevention of behavior disorders.

Single variable analysis of data representing periods of years, particularly where joined by retrospective designs, has not provided clear results. More specific results, examining contiguous parameters of the feeding situation, are required. Newton (1951) has attempted to increase specificity by subdividing the breast-feeding group into subgroups based on experiential factors: never, abortive, supplemented, and successful breast feeding experiences constituted the subdivisions. More clarity is likely to result from

more precise measurement of infant behaviors as well. For example, both motion pictures and psychophysiologic recordings have been used to quantify maternal and infant behaviors (Kulka et al., 1966).

ETHOLOGICAL CONTRIBUTIONS

Ethologists have contributed to the controversy over the relative merits of breast and bottle feeding by pointing out the reflexive abilities of the human newborn to search for and grasp the breast (Prechtl, 1958; Eibl-Eibesfeldt, 1970), and the naturalness of breast feeding for both infant and mother. Some authors of pamphlets promoting breast feeding have suggested that breast feeding represents the attainment of full motherhood, that is, breast feeding is required for complete development of maternal characteristics (Phelps, 1962). No empirical evidence supports this contention. Other writers have stressed the importance of breast feeding to the infant, in helping him to form emotional bonds to his mother. This assertion likewise awaits clear empirical validation.

Bowlby (1951) urged that in cases of infant adoption the original mother be encouraged to breast feed the infant and adoption be postponed until weaning. Bowlby felt that the later stress of separation would be less than the increased risks and emotional costs of artificial feeding.

Other writers have stressed the warmth and closeness of the breast feeding situation. In a speculative review of the literature, Montague (1971) contended that one of the greatest benefits of breast feeding to both infant and mother is the increased amount of skin contact which they enjoy, and which the bottle-fed infant does not

receive. Although the evidence on this point for human infants is less than clear, Harlow (1958) has shown that monkeys deprived of skin contact failed to develop normally, and particularly did not exhibit normal social behaviors.

However, it has not been demonstrated that bottle-fed and breast-fed infants differ in the overall amount of handling or "skin contact" received from caregivers.

EFFECTS ON MOTHER

Although some research attention has been paid to personality factors associated with the decision to breast feed an infant (Newton, 1971), very little attention has been paid to effects of feeding method on the mother. However, some physiological effects are known.

Expression of milk from the nipple is a hormonal reflex involving oxytocic secretions of the posterior pituitary gland as a response to rhythmic stimulation of the areola (Newton and Newton, 1951). Systemic infusion of the oxytocic principle results in expansion of contractile cells lining the alveoli, thus expressing their contents. This principle of oxytocic secretion is also responsible for the concomitant shortening of the period of lochia and the earlier resumption of normal uterine size by the breast-feeding mother.

Psychological effects of breast feeding on the mother may in part be predicted from knowledge of hormonal components of the feeding method (Newton, 1971). Since intensive lactation suppresses the normal pituitary cycle associated with menstrual regularity, in favor of prolactin and oxytocin, hormonally-mediated mood changes might not appear. Feelings of motherliness may result from the frequent reminder of a full breast. Moreover, since the breast-feeding mother is likely to relegate feeding responsibilities to others

less often than her bottlefeeding counterpart, she is more involved in maternal tasks, and feels more involved with her infant.

Some women are sexually stimulated and aroused by the rhythmic stimulation of the breast by the infant's mouth (Newton, 1971). During lactation the mammary skin temperature is elevated (Abolins, 1954), and the uterine contractions which result from the activity of the posterior pituitary during milk expression have been measured (Moir, 1934).

Lactating female rats are very resistant to disruption of temperature regulation by chemical means, suggesting that lactation helps stabilize some autonomic systems (Thoman et al., 1968, 1970).

Relationships between breastfeeding and sexual attitudes and behaviors are as likely correlational as causal; ethical considerations do not permit experimental manipulation. The amount of milk spontaneously ejected by lactating mothers during periods of sexual arousal was related to the woman's subjective level of sexual arousal (Campbell and Petersen, 1953). Breastfeeding mothers as a group were interested in as rapid a return to active intercourse with their husbands as possible (Masters & Johnson, 1966). Mothers who breast fed were more tolerant of masturbation and social sex play in their children (Sears, Maccoby, and Levin, 1957). Future research designs should include measurement of attitudes and behaviors prior to and after the breastfeeding experience, to try to separate at least some aspects of causation from the morass of correlations.

GENERAL CONCLUSIONS

From this review of the literature, it is possible to draw some tentative conclusions, from which specific hypotheses can be generated.

1. Breast feeding is advantageous to the infant in that:
    a. Breast feeding provides superior nutrition for an important early weight gain, and protection from infection of many types.
    b. Breast feeding provides cystine, which is important to early brain development. Cystine is found in very low quantity in bovine milk.
    c. Breast feeding promotes a strong sucking reflex, and provides for the early coordination of complex breathing, swallowing, and sucking activities. In this context, breast feeding appears to facilitate the organization of behavior, and may stimulate the process of cerebration and the voluntary inhibition of otherwise reflexive responses.
2. Breast feeding may be considered advantageous to the mother in that:
    a. Breast feeding assists in uterine involution, reducing the time of lochia and the possibility of hemorrhage.

b. Breast feeding may accentuate the maternal role and reinforce mothers' feelings of being needed by the infant.

c. Breast feeding may provide stability of autonomic functions, perhaps reducing the range of moods.

d. Breast feeding may be emotionally arousing for the mother, contributing to her feeling of involvement with and bonding to her infant.

3. Breast feeding may facilitate parent-infant relationships in that:

a. Breast feeding may provide increased opportunity for skin contact, the development of parent-infant bond, and enhanced social development.

b. Breast feeding may reduce the probability of later behavior problems.

PRESENT STUDY

Variables defined: Researchers gathering data from the behavior of infants have long been plagued with the issue of specifying relevent behaviors. One area of recent interest in resolving this difficulty, and one which lent itself readily to the hypotheses to be tested in this study, has been the use of psychophysiological measures. Among these measures, heart rate (HR) offers the advantage of early stability and reliability in the ontogenesis of behaviors, without suffering loss of sensitivity to a variety of stimuli (Steinschneider, 1967; Eichorn, 1970). This same measure, HR, can be used to gather information on both the stability or disruptibility of an ongoing behavior, and the state or level of arousal of the subject.

During a period marked by consistent, organized behavior, the HR is stable. Two measures of disruption are available: the elicitation of the orienting reflex (OR) and the elicitation of the defensive reflex (DR), called the startle reflex by some researchers (Pavlov, 1927; Sokolov, 1963). HR deceleration is one of the most reliable indices of the OR, while the DR is evidenced by HR acceleration (Graham & Jackson, 1970). The OR is consistently elicited by a novel stimulus of moderate intensity, while a very intense stimulus characteristically produces the DR. The present study planned the elicitation of the DR in both infants and mothers by

a loud auditory stimulus (horn).

Although a few studies have produced conflicting findings, most researchers report the cardiac component of the DR to be a stable response, especially after the newborn period. The cardiac accelerative DR has also been found to be reliable in newborns (Lipton, Steinschneider, and Richmond, 1961), and has been shown to habituate very little if any, even after 40 trials (Bartoshuk, 1962).

Interpretation of human cardiac behavior has followed two basic themes: attention, and arousal or activation.

Interpretation of HR data in terms of attention is based on the directional HR response (Lacey et al., 1963). According to this interpretation HR deceleration is assumed to reflect physiologically the organism's psychological preparation to attend to biologically significant features of environmental stimulation. According to Graham & Jackson (1970) HR deceleration is one component of the orienting reaction and can be observed at all age levels with the possible exception of the newborn period. Indeed, cardiac deceleration has been demonstrated in adults (Lacey et al., 1963), children (Kagan & Rossman, 1964), and infants (Lewis et al., 1966) during tasks that evaluate attention to visual and/or auditory stimulation. Note that if HR deceleration is a component of the orienting reaction it follows from Sokolov's theory (1963) that cortical "neural" models are involved in information processing

and attention. Activation theory, on the other hand, does not assume direct cortical involvement.

Interpretation of HR data in terms of activation theory is tied directly to function of the sympathetic and parasympathetic divisions of the autonomic nervous system (Cannon, 1928; Duffy, 1972). Accordingly, HR acceleration is related to sympathetic arousal while cardiac deceleration is related to parasympathetic function. To the extent that the activation interpretation of HR reactivity is unilinear and does not assume inferred models of cortical activity, it is a more parsimonious explanation of HR activity than the attention or Sokolovian "neural model" interpretation. On the other hand, the activation interpretation suffers in that (a) much of the critical work supporting the theory has been conducted with non-human organisms (McDonald, Stern & Hahn, 1963; DuCharme, 1966) and (b) much of the cognitive component remains poorly understood (Lacey, 1967; Campos & Johnson, 1966, 1967).

Specific Hypotheses: From the general conclusions cited above, the following hypotheses were generated.

1. In a breast and bottle feeding comparison, breast-fed infants would have cardiac DRs of less magnitude, reflecting greater autonomic stability, than bottle-fed infants.

2. In a breast and bottle feeding comparison, breast feeding mothers would have cardiac DRs of less magnitude than bottle feeding mothers.

3. In a breast and bottle feeding comparison, breast feeding mothers would be differentiated from bottle feeding mothers in the cardiac response to sucking onset.

METHOD

Subjects: Twenty infant-mother pairs were recruited through the offices of pediatricians and by direct letter on publication of the birth announcement. Ten of the infants were breast-fed, ten bottle-fed. Within each feeding group, half were males, half females. No infant born at less than 37 weeks gestation, or by other than vaginal delivery with occipital vertex presentation, or who received an Apgar score of less than 7 at 5 minutes post partum, or who showed evidence of observable anomoly or illness, was included in the sample. Infants whose mothers delivered under general anesthesia were not included. All mothers were caucasian multiparas, between 18 and 30 years of age at delivery. All infants were between 6 and 8 weeks of age when tested. Each mother was financially reimbursed for participating in the study. (No differences in dependent measures were found as a function of maternal parity or age).

Equipment: Cardiac activity of both mother and infant was simultaneously and continuously recorded on a two-channel Beckman type RS Dynograph, equipped with electrocardiographic transducers. A Sound Shield white noise generator provided a continuous masking noise of 25dB. A 6VDC horn, vibrating at 335 Hz and mounted 50 cm directly above the head of the mother seated feeding her infant, produced an additional auditory signal of 70dB, $\pm$ 5dB, at mother's ear.

Procedure: Each participating mother was invited to feed her infant in the experimental setting the day prior to the scheduled participation appointment. No mother accepted.

Experimental sessions for all infant-mother pairs were identical. As mother and infant arrived and were greeted, mother was seated behind a partition which separated her from the polygraph. Electrodes were then attached to the infant, while mother observed. E then held the infant to demonstrate the appropriate manner of burping, so as not to disturb the electrode placements. E then continued holding the infant, out of view of mother, while a female assistant attached the maternal electrodes. The infant was then handed to the mother by the assistant.

Electrode placement was as follows: For the infant, the active electrode was placed over the sternum, the referent along the spine at a point directly dorsal to the sternum, approximately the ninth thoracic vertebra, and the ground over the first lumbar vertebra. For the mother, the active electrode was placed over the sternum, the referent one half the distance from the right clavicle to the right pinna, three cm posterior to the sternocleidomastoid muscle, and the ground electrode on the posterior aspect of the left ear lobe.

After electrode attachment, mother was instructed as to the experimental procedure. She was asked not to speak to her infant or to E during the feeding session, except to notify E when the infant was being burped. One full minute of recording was then

accomplished, with mother sitting quietly, holding her infant. Active feeding was then initiated. During the feeding session, the assistant observed mother and infant through a one-way viewing mirror, and provided information on sucking onset and offset directly to the polygraphic record by means of a remote controlled event recorder.

The horn was sounded three times: at one minute after initial sucking onset, one minute after the onset of sucking following the mid-feeding burping pause, and thirty seconds following the termination of sucking. Pilot data indicated that this timing arrangement for the presentation of stimuli would permit observation of cardiac response to sucking onset and horn presentation without confounding. Each horn blast was of three seconds duration.

During the experimental session, infants wore only diaper, plastic pants, and T-shirt. Mothers were requested to wear blouses which opened in front, to facilitate electrode attachment.

Room temperature was held constant at 24°C, and relative humidity was maintained at 40%. All experimental sessions were scheduled between 9:00 and 11:00 o'clock in the morning.

The experimental session is illustrated in Figure 1.

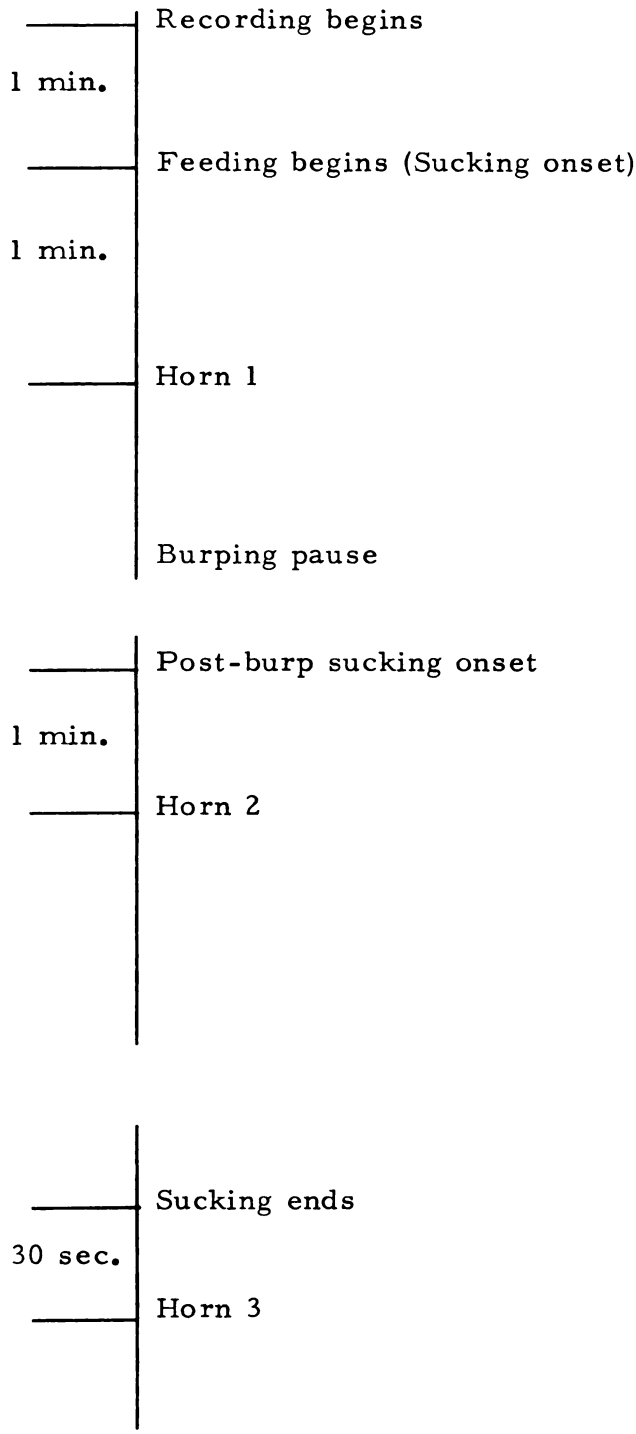

Figure 1. Graphic representation of experimental session.

DATA REDUCTION

The EKG records were scored manually. Beginning at a point 15 seconds prior to the onset of sucking, 39 successive 5-second intervals were demarcated. Beginning at a point 15 seconds prior to the onset of sucking following the mid-feeding burping pause, 27 additional 5-second intervals were defined. Beginning at a point 15 seconds after the termination of sucking, 6 additional successive 5-second intervals were defined. For each interval, the number of R waves was counted. This sum became the interval score. R waves located on a line dividing two intervals were included in the earlier interval.

Response definitions: For each mother and infant, three response analyses were planned: cardiac response to sucking, cardiac response to the horn, and overall HR variability. For purposes of statistical tests, the responses were defined as follows:

1. Cardiac response to sucking (CRS): The criterion was the difference in interval scores between that interval in the first 30 seconds following sucking onset, which reflected a change in HR from the three immediate pre-sucking intervals, and whichever of the three pre-sucking interval scores would yield the least difference, and thus the most conservative measure. The first shift in HR following sucking onset determined the direction of response, which was reflected by algebraic sign. In order to

take into account the Law of Initial Values (LIV), and since the groups were independent but not random, analysis of covariance was performed (see below). The covariate for each criterion was the immediate pre-sucking-onset interval score. CRS scores were developed from both sucking onset points for each subject.

2. Cardiac response to the horn (CRH): Like CRS, this response was defined as the difference in interval scores between that interval in the first 20 seconds following stimulus (horn) presentation which differed most from pre-stimulus levels, and the pre-stimulus interval from which it differed least. For analysis of covariance, the immediate pre-stimulus interval score was used as the covariate. Three criteria or dependent scores and three covariates were developed for each subject.

3. HR variability: For the 36 intervals following initial sucking onset and the 24 intervals following the post-burping sucking onset, interval scores were recorded for each subject. The mean interval score for each minute was computed, for each subject. These means served as the raw data, and were treated by analysis of variance.

For all analyses of variance and covariance, the following factors were used: sex of infant, feeding method, time during the session (repeated measures), and all possible interactions.

Computer program: Computer analysis of the data was accomplished using the program BMDX69, Multivariate analysis of

variance and covariance, version of July 15, 1968. This program, developed by the Health Sciences Computing Facility, UCLA, and modified by the statistical research laboratory, University of Michigan, was selected primarily because it adjusts the sums of squares on the basis of regression coefficients between criterion and covariate, and thus satisfies the LIV. This program is available through Michigan Time Sharing (MTS), the University of Michigan, Ann Arbor, Michigan.

RESULTS

Cardiac response to sucking (CRS): Maternal response to sucking onset was cardiac deceleration, depicted in Figure 2. Analysis of covariance revealed that sex of infant had a significant effect ($F=7.25$, $df=1/16$, $p<.05$), as did the interaction of infant sex and feeding method ($F=4.82$, $df=1/16$, $p<.05$). (Tables summarizing all analyses of variance and covariance are found in the appendix.) Mothers who bottle fed sons showed the least deceleration, while mothers who breast fed sons showed the greatest deceleration. Feeding method did not clearly differentiate the decelerative responses of mothers of daughters.

The infants' CRS is shown in Figure 3. Analysis of covariance disclosed four significant effects: sex of infant ($F=35.87$, $df=1/16$, $p<.01$), feeding method ($F=5.79$, $df=1/16$, $p<.05$), and the interactions of each of these variables with time during the session, sex x time ($F=4.83$, $df=1/15$, $p<.05$) and feeding method x time ($F=4.83$, $df=1/15$, $p<.05$). Breast-fed males showed deceleration on both sucking onsets, while bottle-fed males exhibited a very slight deceleration on initial sucking onset, and a more marked decelerative response on the second sucking onset. Females of both feeding groups showed initial deceleration, but exhibited cardiac acceleration on the second sucking onset. In both cases, breast-fed females showed greater magnitude of response than

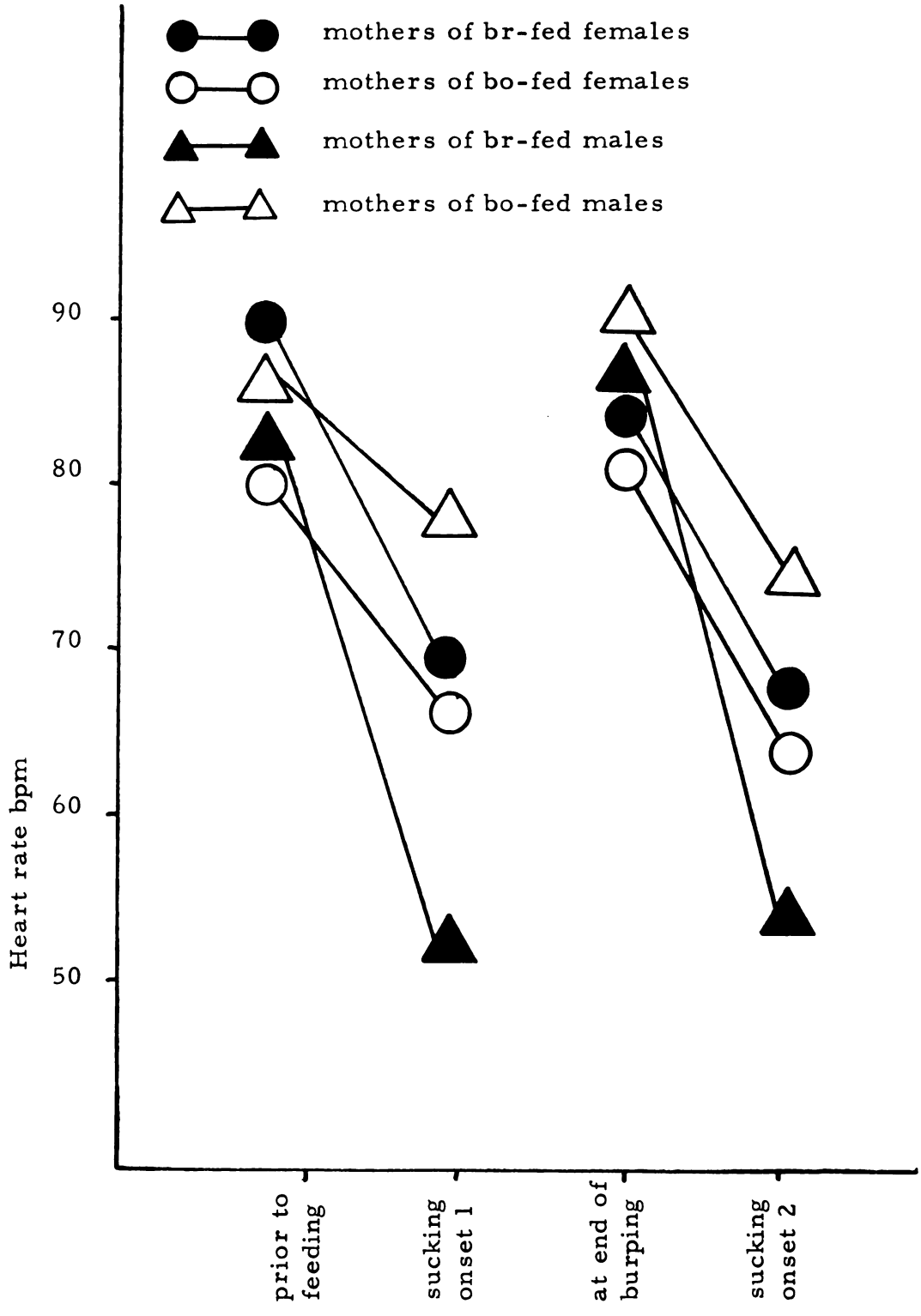

Figure 2. Mothers' cardiac response to sucking (CRS)

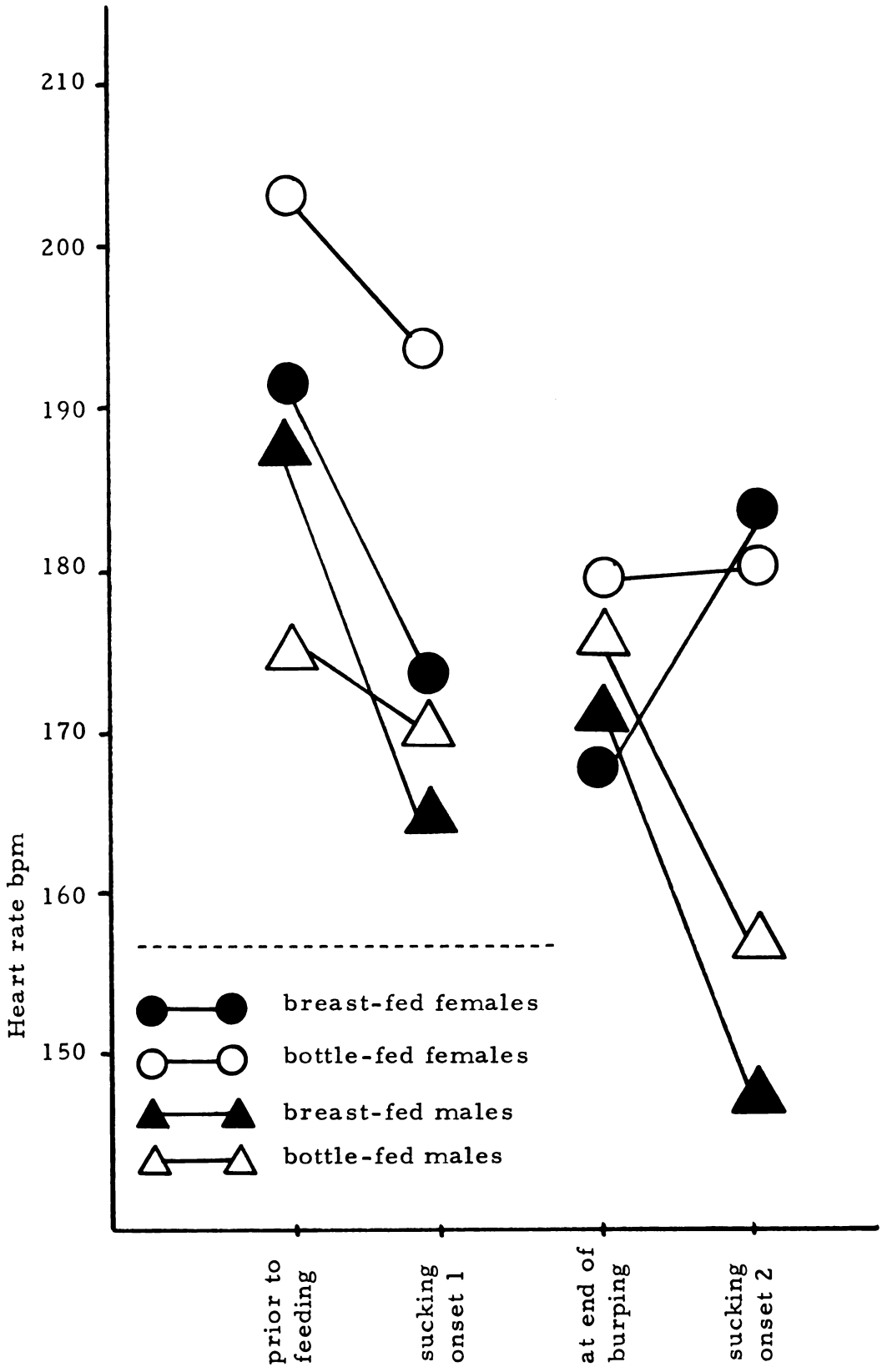

Figure 3. Infants' cardiac response to sucking (CRS).

bottle-fed females.

Cardiac response to the horn (CRH): Contrary to expectation, the horn did not consistently elicit the cardiac accelerative component of the DR. Maternal CRH is shown in Figure 4. Analysis of covariance of these data showed that only feeding method had a significant effect ($F=8.66$, $df=1/16$, $p < .01$). Figure 5 depicts maternal cardiac response to the horn as a function of feeding method only. Bottle-feeding mothers showed consistent cardiac deceleration on all three presentations of the horn, while breast-feeding mothers showed cardiac acceleration on the first two presentations, and cardiac deceleration on the third, which occurred after feeding had terminated.

The response of infants to the horn, depicted in Figure 6, was more complex than that of their mothers. Analysis of covariance revealed three significant effects. Both sex of the infant ($F=6.58$, $df=1/16$, $p < .05$) and feeding method ($F=6.49$, $df-1/16$, $p < .05$) had significant effects, as did the interaction of feeding method with time during the session ($F=7.22$, $df-2/31$, $p < .01$). The effect of feeding method is most easily seen. Breast-fed infants exhibited deceleration on horn 1, and acceleration on horns 2 and 3. The responses of bottle-fed infants are influenced by the infant's sex, with bottle-fed females showing decelerative reactions to horns 1 and 2, and acceleration to horn 3, and their male counterparts

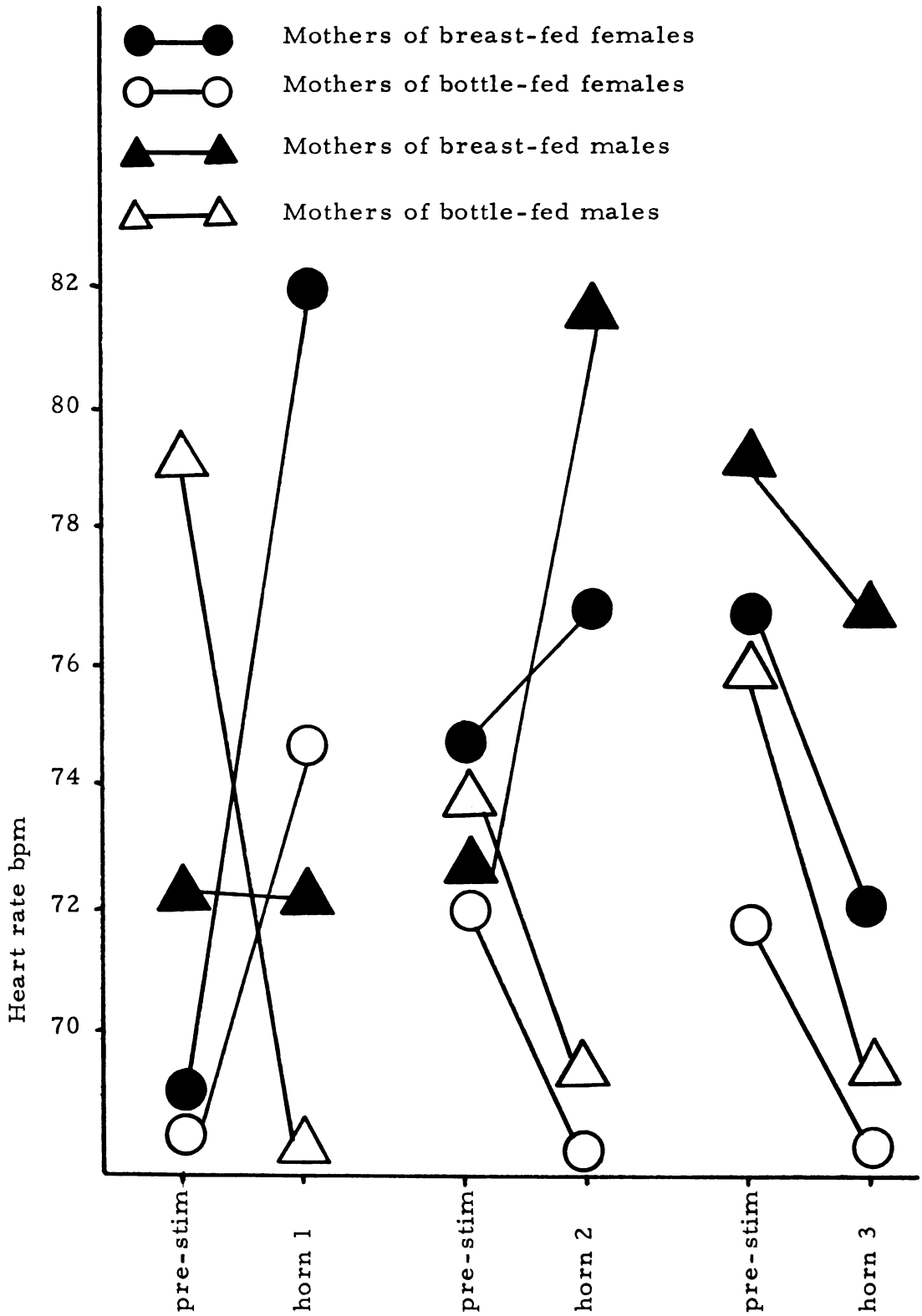

Figure 4. Maternal cardiac response to the horn (CRH).

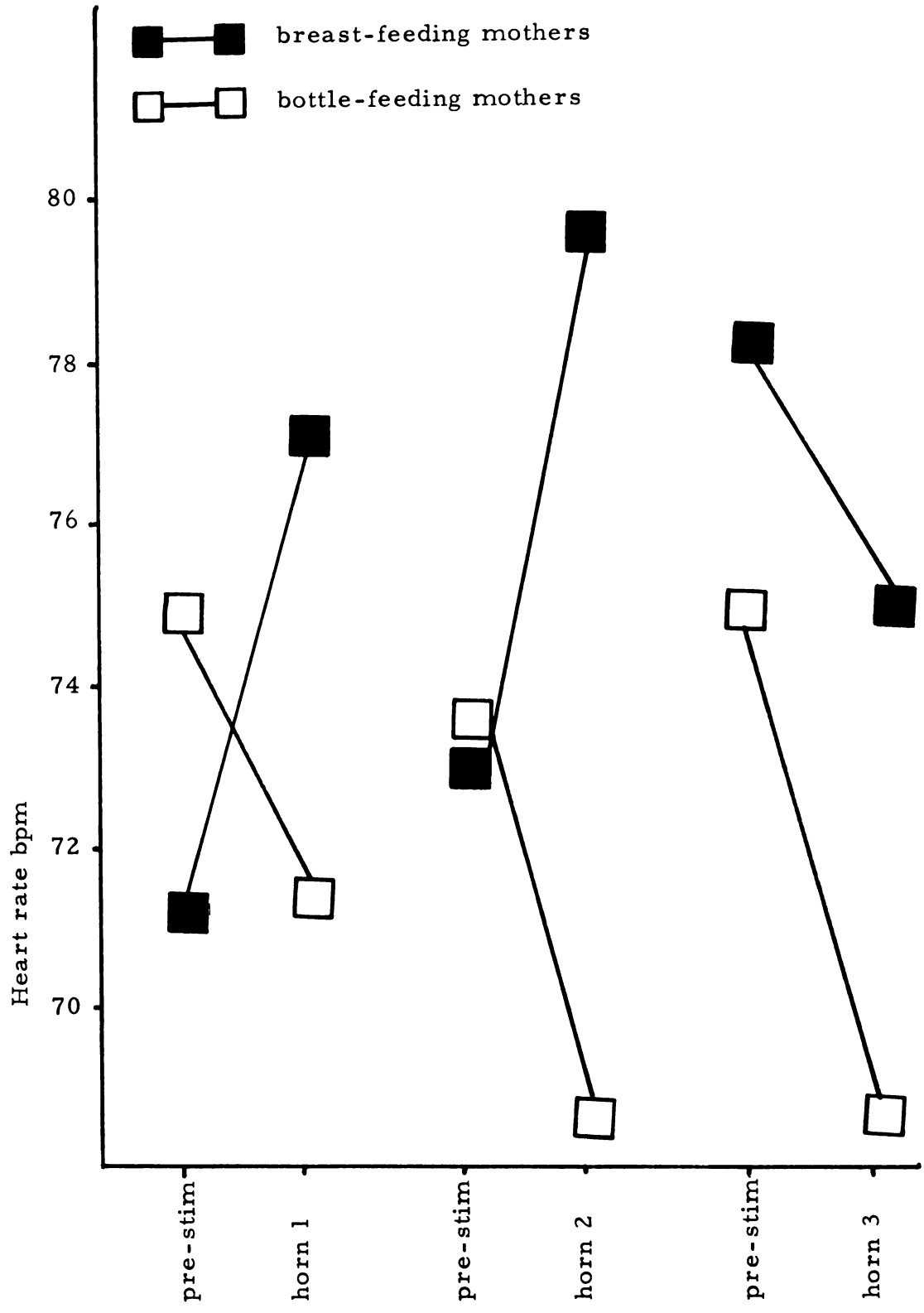

Figure 5. Maternal cardiac response to the horn (CRH) as a function of feeding method.

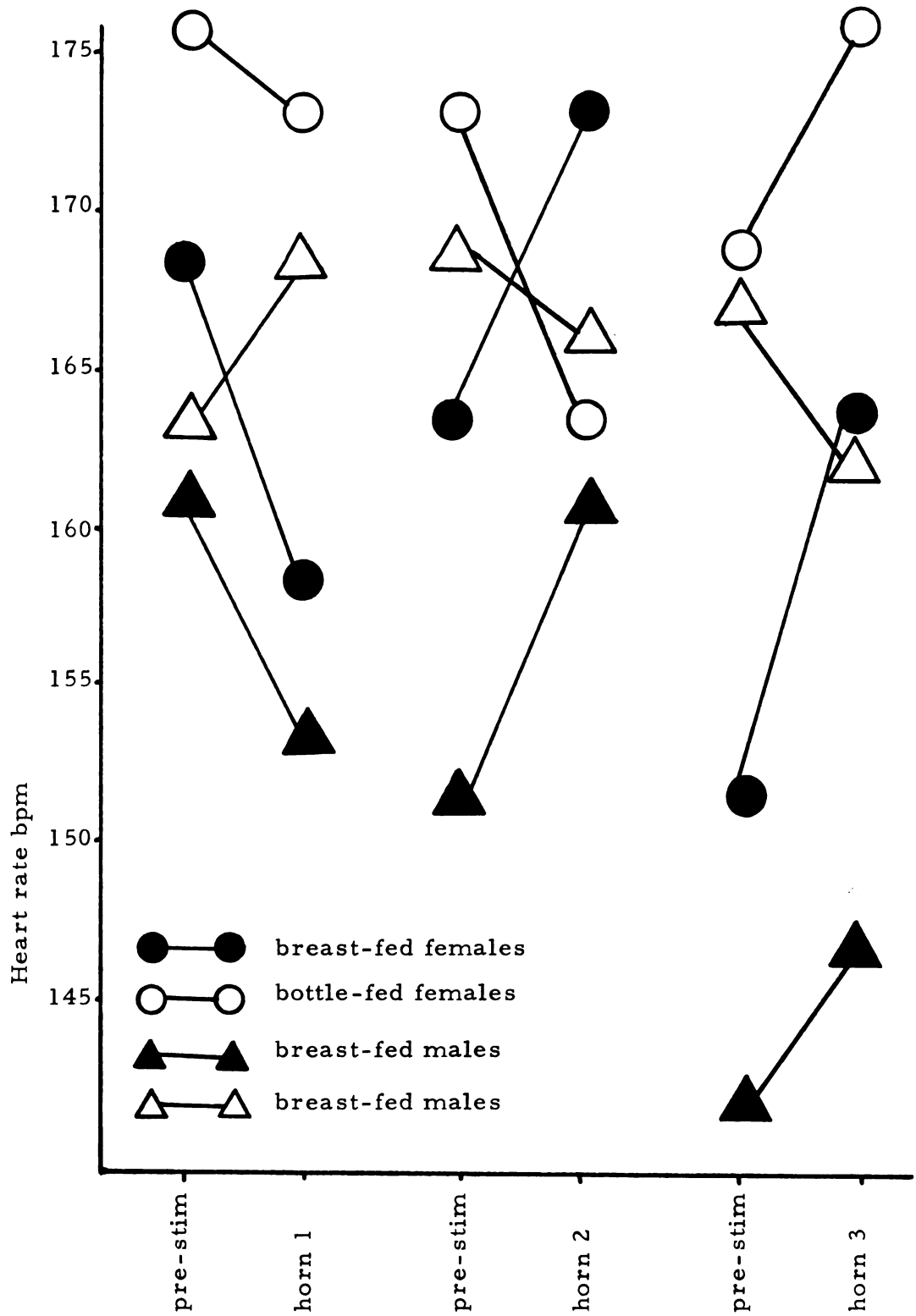

Figure 6. Infants' cardiac response to the horn (CRH).

exhibiting acceleration to horn 1 and deceleration to horns 2 and 3. Overall, the responses of breast-fed infants were of greater magnitude than those of bottle-fed infants.

Heart rate and HR Variability: Maternal group mean HR for each of the five scored minutes is shown in Figure 7. Analysis of variance disclosed three significant factors. Sex of infant had a significant effect ($F=32.79$, $df=1/16$, $p<.01$), as did the interaction of infant sex and feeding method ($F=20.14$, $df=1/16$, $p<.01$). Mothers of sons in general showed higher HR than mothers of daughters. Breast-feeding mothers of sons had lower HRs than their bottle-feeding counterparts, while breast-feeding mothers of daughters had higher HRs than their bottle-feeding counterparts. Time during the session also had a significant effect ($F=5.49$, $df=4/64$, $p<.01$). All mothers showed some deceleration from minute 1 to minute 2, as a result of sucking onset. Similar decelerations were also obtained from minute 4 to minute 5, again as a function of sucking onset.

Maternal HR variability is illustrated in Figure 8. Mothers of bottle-fed females showed the least variability of HR, while those who bottle-fed male infants showed the greatest variability.

Infant HR during the five scored minutes is depicted in Figure 9. As revealed by analysis of variance, significant effects obtained for sex of infant ($F=76.44$, $df=1/16$, $p<.01$), feeding

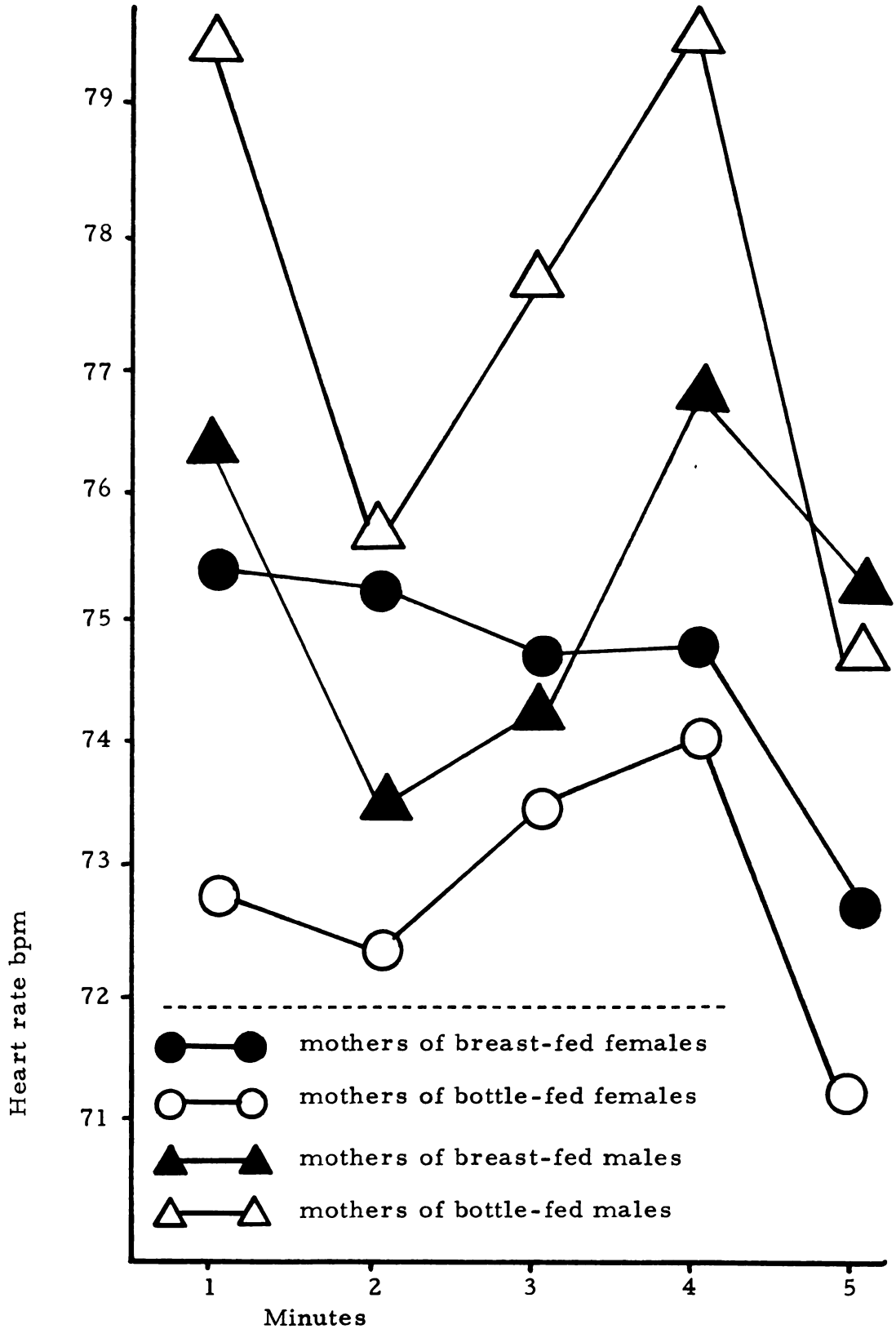

Figure 7. Maternal heart rate during each of 5 scored minutes. Minutes 1 and 4 begin with sucking onset.

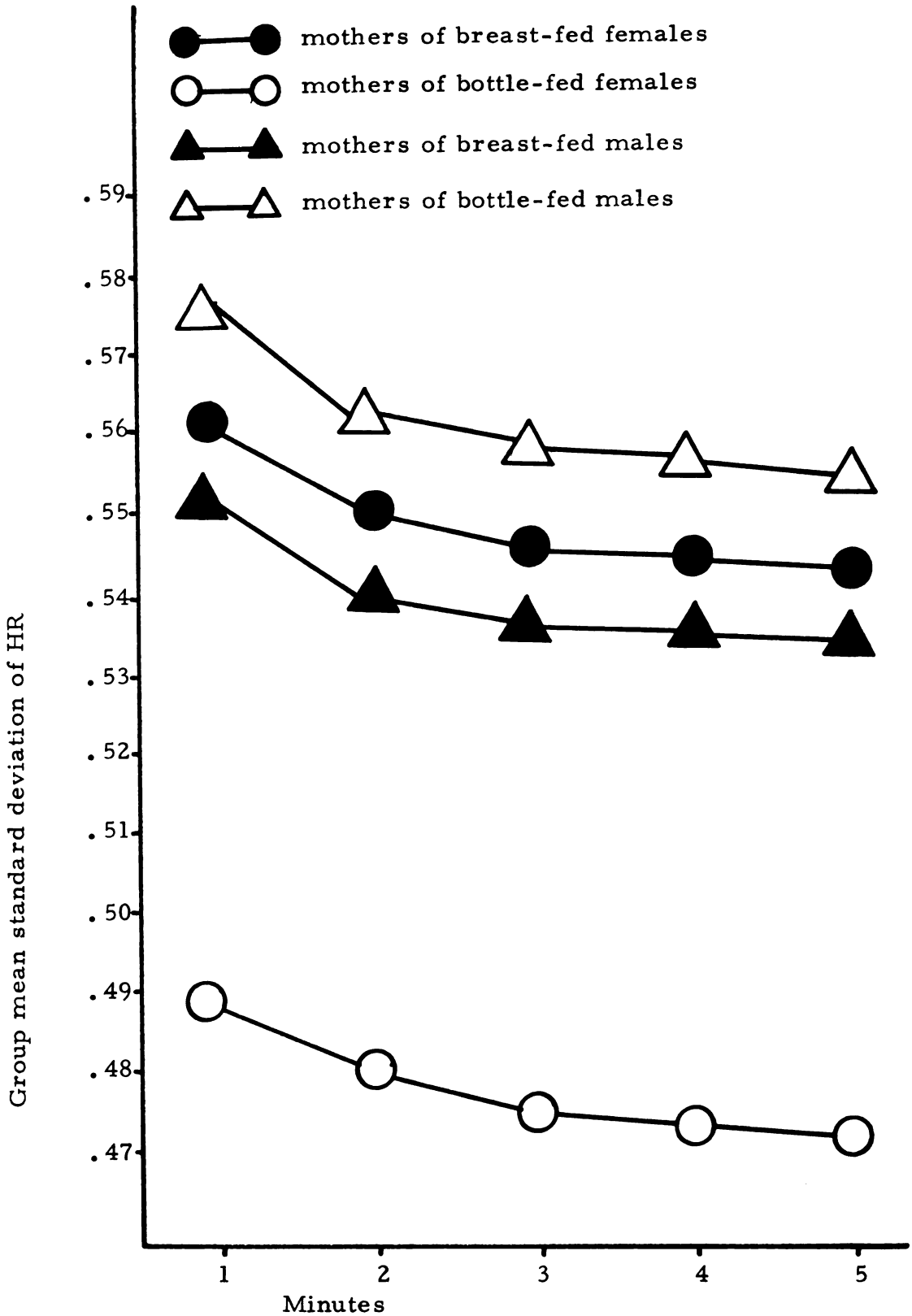

Figure 8. Maternal HR variability during the five scored minutes. Minutes 1 and 4 begin with sucking onset.

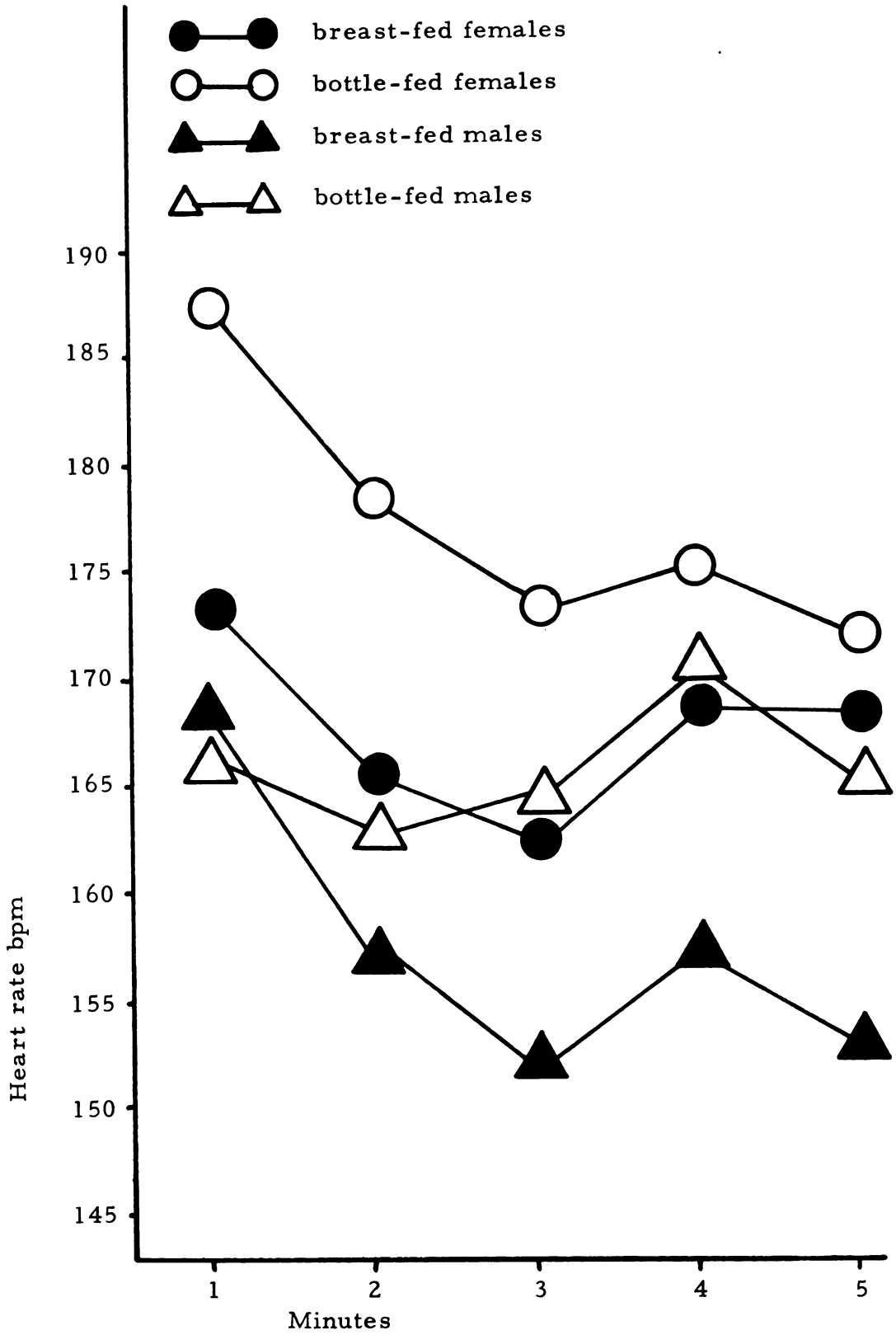

Figure 9. Infants' HR during each of the five scored minutes. Minutes 1 and 4 begin with sucking onset.

method ($F=52.74$, $df=1/16$, $p<.01$), time during the session ($F=9/13$, $df=4/64$, $p<.01$) and the interaction of these three ($F=2.68$, $df=4/64$, $p<.05$). Female infants showed higher HR than males, and bottle-fed infants showed higher HR than breast-fed infants. As in the instance of their mothers, infants showed deceleration from the first to second and fourth to fifth minutes. Infants HR variability is depicted in Figure 10. Minutes 2 and 5 began with presentations of the horn. In the first instance, the horn eventuated a rise in HR variability for the breast-fed females, while all other groups exhibited a decrease in HR variability. Horn 2 produced an increase in variance for breast-fed males, while all other groups showed a decrease in variability. Overall, breast-fed infants showed higher HR variability than bottle-fed infants.

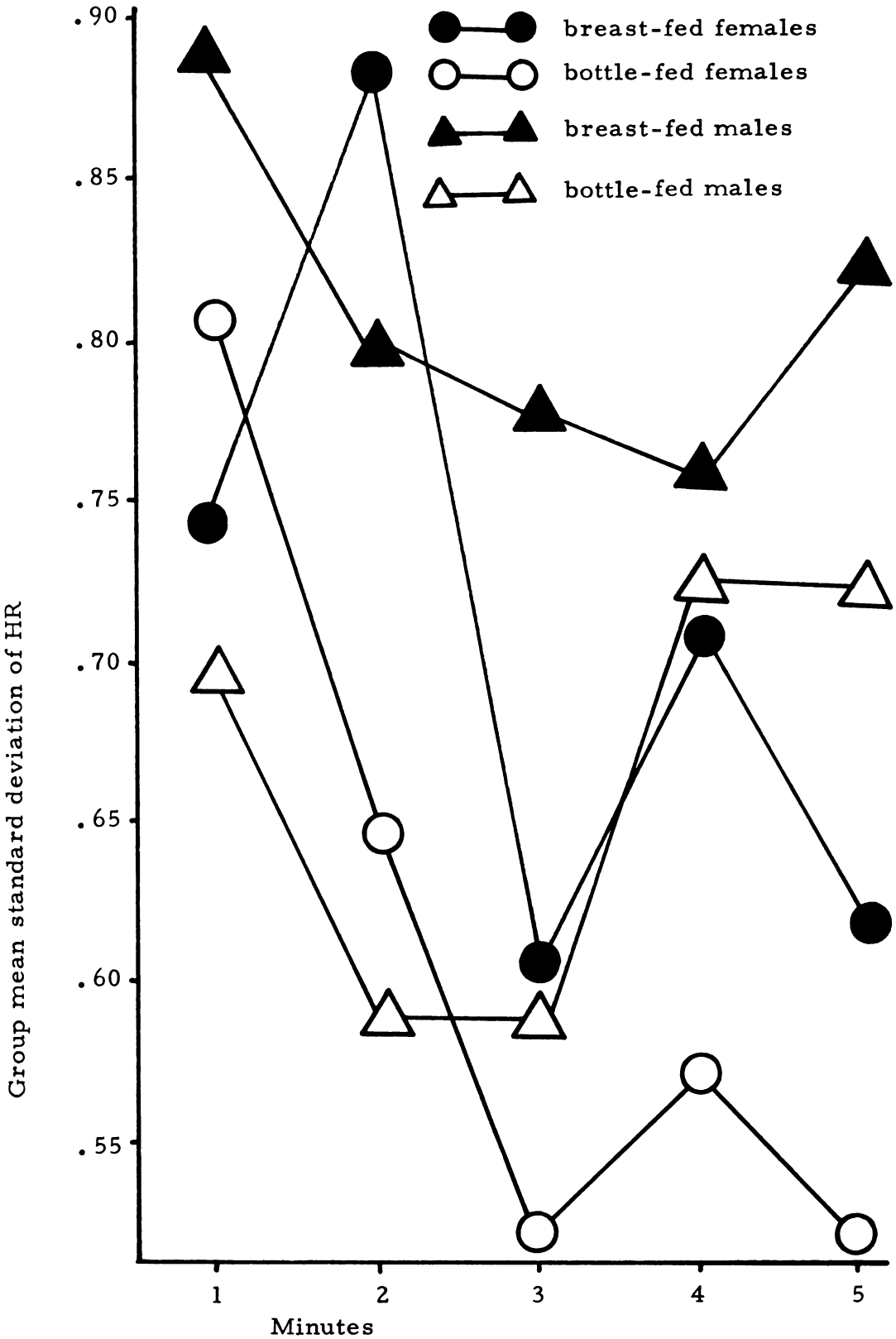

Figure 10. Infants' HR variability during the five scored minutes. Minutes 1 and 4 begin with sucking onset.

DISCUSSION

The purpose of the present study was to investigate various hypotheses concerning the relative advantages and/or disadvantages of breast and bottle feeding for mother and infant. Simultaneous recording of maternal and infant HR in response to sucking onset and to an auditory stimulus revealed the following patterns of HR reactivity:

(a) Mothers of sons exhibited greater HR deceleration to sucking onset than did mothers of daughters,

(b) Mothers of breast fed male infants showed greater HR deceleration to sucking onset, than did mothers of bottle fed male infants,

(c) During feeding, breast feeding mothers showed HR acceleration in response to the auditory stimulus, while bottle-feeding mothers showed HR deceleration,

(d) Non-feeding maternal response to the auditory stimulus was characteristically HR deceleration,

(e) Male infants showed consistent HR deceleration to sucking onset, whereas female infants showed HR deceleration to initial sucking onset but HR acceleration to the post-burp sucking onset,

(f) Breast-fed infants showed more consistent HR deceleration to sucking onset than did bottle-fed infants,

(g) Breast-fed infants showed HR deceleration to the first auditory stimulus presentation, but HR acceleration to the second and third presentations. Bottle-fed female infants, on the other hand, showed HR deceleration to the first and second auditory stimulus presentations and HR acceleration to the third auditory presentation. Bottle-fed male infants accelerated to the first auditory stimulus, and decelerated to the second and third auditory stimulus presentations,

(h) Independent of direction of HR response, breast-fed infants showed greater magnitude HR responses to the auditory stimulus than did bottle-fed infants.

The fact that feeding method did not influence the HR responses to sucking onset of mothers of daughters, but did influence the HR responses of mothers of sons, suggests that the method of feeding may be of greater psychobiological significance for male infants and their mothers, than for female infants and their mothers. Moreover, this conclusion holds forth whether one takes an attention or an activation interpretation of HR responsivity. For example, to the extent that HR deceleration reflects attentional processes it would seem that maternal attention to the feeding situation is optimal when breast feeding a male infant. In addition, breast-fed male infants are protected from environmental

disturbances, while bottle-fed males are not. (Feeding method did not significantly affect the female infants' HR response to the horn.) Although not directly assessed in this study, one possible implication of this effect may be that breast feeding is a more potent determinant of the emerging attachment relationship for mother and son than it is for mother and daughter. From an ethological standpoint, heightened maternal attentiveness when breast feeding male infants, and the protective effect of breast feeding for male infants, would be consistent with the lesser viability of male infants and their presumably greater need for protective caregiving.

The discovery that feeding method is related to maternal cardiac responsivity during feeding but not following feeding is particularly intriguing. One interpretation would be that the specific act of breast feeding is accompanied by lowered perceptual thresholds, such that a stimulus which ordinarily may elicit an OR now elicits a DR. (In psychoanalytic terms, this would be interpreted as perceptual vigilance.) Such a mechanism would have adaptive significance in that the breast feeding mother would be more easily distracted from her feeding task in the event of danger.

The finding that breast-fed infants consistently exhibited decelerative and accelerative HR responses of greater magnitude than bottle-fed infants is compatible with earlier reports that breast-fed infants are at higher levels of arousal (Bell, 1966;

Davis et al., 1948). The apparent discrepancy between present and previous studies in direction of HR response can be clarified by using the term reactivity rather than arousal, thereby more accurately describing differences in response magnitude. Thus, it appears that breast-fed infants have a greater capacity to respond to stimuli than bottle-fed infants. Since interaction with the environment, stimulus recognition, and activity level (but not motor development) are all positively correlated with learning rate and later intelligence, one might hypothesize that breast feeding facilitates intellectual and cognitive development (see Hoefer & Hardy, 1929). Obviously, such an adventurous hypothesis requires much systematic confirmation before it can be accepted with conviction.

APPENDIX

Table 1. Summary of analysis of covariance for mothers' cardiac response to sucking (CRS)

SOURCE	SS	df	MS	F	p
Between subjects					
Sex of infant	2.5539	1	2.5539	7.25	<.05
Feeding method	0.7177	1	0.7177	2.03	NS
Sex X feeding	1.6980	1	1.6980	4.82	<.05
Subjects w. groups	12.0906	16	0.7557		
Within subjects					
Time during session	0.1166	1	0.1166	0.33	NS
Sex X time	0.0059	1	0.0059	0.01	NS
Feeding X time	0.4314	1	0.4314	1.22	NS
Sex X feeding X time	0.1166	1	0.1166	0.33	NS
Error	5.2833	15	0.3532		

Table 2. Summary of analysis of covariance for infants' cardiac response to sucking (CRS).

SOURCE	SS	df	MS	F	p
Between subjects					
Sex of infant	24.9109	1	24.9109	35.87	$<.01$
Feeding method	4.0211	1	4.0211	5.79	$<.05$
Sex X feeding	0.0098	1	0.0098	0.01	NS
Subjects w. groups	49.5457	16	3.0966		
Within subjects					
Time during session	1.4947	1	1.4947	2.15	NS
Sex X time	3.3534	1	3.3534	4.83	$<.05$
Feeding X time	3.3533	1	3.3533	4.83	$<.05$
Sex X feeding X time	1.4257	1	1.4257	2.05	NS
Error	10.4163	15	0.6944		

Table 3. Summary of analysis of covariance for mothers' cardiac response to the horn (CRH).

SOURCE	SS	df	MS	F	p
Between subjects					
Sex of infant	0.0219	1	0.0219	0.02	NS
Feeding method	6.6700	1	6.6700	8.66	<.01
Sex X feeding	0.0172	1	0.0172	0.02	NS
Subjects w. groups	29.9842	16	1.8740		
Within subjects					
Time during session	0.1323	2	0.0661	0.08	NS
Sex X time	3.1908	2	1.5954	2.07	NS
Feeding X time	0.4896	2	0.2448	0.31	NS
Sex X feeding X time	0.2779	2	0.1389	0.18	NS
Error	23.8548	31	0.6695		

Table 4. Summary of analysis of covariance for infants' cardiac response to the horn (CRH).

SOURCE	SS	df	MS	F	p
Between subjects					
Sex of infant	11.0980	1	11.0980	6.58	<.05
Feeding method	10.9394	1	10.9394	6.49	<.05
Sex X feeding	2.6214	1	2.6214	1.55	NS
Subjects w. groups	31.3724	16	1.9608		
Within subjects					
Time during session	4.5556	2	2.2778	1.35	NS
Sex X time	6.6365	2	3.3182	1.96	NS
Feeding X time	24.3545	2	12.1772	7.22	<.01
Sex X feeding X time	0.5440	2	0.2720	0.16	NS
Error	52.2449	31	1.6853		

Table 5. Summary of analysis of variance of mothers' HR.

SOURCE	SS	df	MS	F	p
Between subjects					
Sex of infant	1.2321	1	1.2321	32.79	<.01
Feeding method	0.0049	1	0.0049	0.13	NS
Sex X feeding	0.7569	1	0.7569	20.14	<.01
Subjects w. groups	60.5712	16	3.7857		
Within subjects					
Time during session	0.8266	4	0.2066	5.49	<.01
Sex X time	0.2594	4	0.0648	1.72	NS
Feeding X time	0.1146	4	0.0286	0.76	NS
Sex X feeding X time	0.1186	4	0.0296	0.78	NS
Error	2.4048	64	0.3757		

Table 6. Summary of analysis of variance of infants' HR.

SOURCE	SS	df	MS	F	p
Between subjects					
Sex of infant	19.0969	1	19.0969	76.44	<.01
Feeding method	13.1769	1	13.1769	52.74	<.01
Sex X feeding	0.00009	1	0.00009	0.00	NS
Subjects w. groups	89.6153	16	5.6009		
Within subjects					
Time during session	9.1286	4	2.2821	9.13	<.01
Sex X time	0.3706	4	0.0926	0.37	NS
Feeding X time	0.4426	4	0.1106	0.44	NS
Sex X feeding X time	2.6854	4	0.6713	2.68	<.05
Error	15.9884	64	0.2498		

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