Mothers' Jiggling and the Burst–Pause Pattern in Neonatal Feeding*

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Mothers tend to jiggle their newborn infants at the breast, or jiggle the bottle, during pauses in the newborn's sucking. What is the precise effect of jiggling on the infant's resumption of sucking, and how does this in turn affect subsequent jiggling?

The authors observed 52 mothers feeding their infants at ages 2 days and 2 weeks. All feeding was natural and unconstrained. The effect of maternal jiggling was measured by the conditional probability of a burst of sucks as a function of time: (a) after a pause; (b) after the onset of jiggling; or (c) after the offset of jiggling.

The cessation of jiggling proved to be a better elicitor of a resumption of sucking than the jiggling itself. An experiment in which bottles were jiggled according to a predetermined, controlled schedule showed that this phenomenon is due to a contingent response on the part of the infant rather than mothers' anticipation of the burst. Thus the feeding can appear to be an exchange of turns, in which the infant's pause is answered by the mother's jiggling and the end of jiggling is answered by the next burst. Mothers shorten their jiggling over the first 2 weeks. Infants' pauses also grow shorter, though their median pause length (jointly determined by mother and infant) is a somewhat reliable characteristic distinguishing dyads from one another.

The newborn human infant sucks in bursts consisting of about four to ten sucks at a rate slightly slower than 1/sec. The bursts are separated by pauses of roughly the same order of magnitude, 4–15 sec, with the nipple remaining in the infant's mouth. Some 40 mammalian species have had their sucking recorded, and the clustering of sucks into bursts separated by pauses is apparently unique to humans (Wolff, 1968b; Brown, 1973).

The function of the pauses has long been a mystery (Süsswein, 1905). It

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can be shown that infants are quite capable of sucking without pause: When milk flows very rapidly, as from a full breast or an artificial nipple whose hole is so large that the milk drips or squirts, the pauses may disappear entirely and one sees bursts as long as a minute or two.[1] On the other hand, when a hungry infant sucks on a nipple which is not yielding milk (or on a pacifier), the bursts are quite short. Very short bursts in feeding are used by some mothers as a clue that something is occluding the nipple (Kaye, 1972).

From the point of view of the baby's physiology, the pauses serve no obvious function. Swallowing and breathing occur concurrently with sucking. Fatigue seems to be ruled out because the infant pauses no longer on the second breast than on the first, nor do we typically see any increase in the pause durations over the course of a session. As to satiation, bursts do become shorter over the course of each session (from about 10 to about 5 sec as 30–60 gm of milk are consumed; Kaye & Brazelton, 1971), but pauses neither shorten nor lengthen. Also arguing against either fatigue or satiation is the fact that there is no correlation between the duration of pauses and that of the bursts, either preceding or following them (Kaye, 1977b). It is possible that the pauses evolved to allow the flow of milk into the lactiferous sinuses and thus that they are merely vestigial behavior in bottle-feeding and non-nutritive sucking. However, this fails to explain the uniqueness of the burst-pause pattern to human infants. Besides, the pauses are longer than required by the physiology of the mother's breast (Ardran et al., 1958).

Pauses in sucking do have one consistent effect: Mothers (and other feeders) tend to jiggle the baby or bottle, often expressing a belief that this "wakes the baby up" or elicits a resumption of sucking. Kaye (1977b) found one or more jiggles in 28 percent of the pauses in breast- and bottle-feeding, about twice the number found in bursts of equivalent duration. Could this effect provide part of the explanation for the burst-pause pattern unique to our species?

Campbell (1973) noted that among the many types of stimulation whose effects upon sucking had been tested, the principal stimulus mothers use in feeding—jiggling—had been neglected. This is understandable because the vast majority of studies have involved artificial feeding or non-nutritive sucking under laboratory conditions. With few exceptions, they have really been studies of visual, auditory, or taste preference; memory; or perception. The parameters of sucking have served more as indices of other processes than as processes to be investigated in themselves. Such studies have been well reviewed by Marquis (1931), H. Kaye (1967), Kessen et al. (1970), Sameroff (1972), Millar (1974), and Lipsitt (1977). The phenomenon of concern to us, however, is neonatal feeding in its social context as an interaction between mothers and infants. It was therefore essential to observe feedings that were as natural as possible (Dubignon & Campbell, 1968; Kaye, 1972; Campbell, 1973).

[1]In fact, Wolff (1968a) after Peiper (1963) and Süsswein (1905), regarded continual sucking as the normal mode during feeding and the burst-pause pattern as a "non-nutritive" mode into which the infant subsided toward the end of a feed. Kaye (1972) showed that this was not true, earlier findings probably being due to the fact that laboratory apparatus delivered milk at a very rapid flow.

METHOD

Subjects

A total of 52 mothers were observed either bottle-feeding or nursing their infants in their hospital rooms at age 2 days and in their homes at 2 weeks. They had been recruited for a longitudinal study of infant development through the first 6 months, and were told that sucking was of interest as an example of a fairly complex skill present at birth. Although 45 of the subjects were observed both in the hospital and 2 weeks later, some data had to be discarded due to equipment malfunctions for either of the two observers (coding was done "live" as described below). This left a total of 75 sessions, including 23 subjects observed at both ages, 19 additional subjects from whom we had data only at 2 days, and 10 from whom we had data only at 2 weeks.[2]

All were healthy full-term infants; two had been delivered by Caesarean section. The mothers included 24 primiparae and 28 multiparae, 22 breast- and 30 bottle-feeders. All were Caucasian, American-born women delivering in a community hospital, which serves a widely varying economic and ethnic constituency. There were 22 girls and 31 boys, including a pair of male fraternal twins (not included in the subsample of 23).

Procedure

All feedings took place in a natural manner at the regular time and place, with the accustomed breast milk or formula, without any apparatus being connected to either subject. Session 1 took place between 5:00 and 5:30 p.m., 36 to 60 hours after delivery. The mothers had just eaten dinner and were sitting up in bed; they were asked to ignore the presence of the observers, to feel free to talk to them but not to expect a reply because the observers would both be concentrating on the baby. In only a few cases, fathers were present in addition to the two observers.

Session 2 took place in the subjects' homes at age 12-18 days. There were some morning, some afternoon, and a few evening feedings at this age. Some fathers, siblings, neighbors, and other relatives were present.

Coding

The most important control in our procedure was that the behavior of mother and infant were coded independently by two observers, and the codings synchronized later by computer. Each observer held a digital keyboard attached to a portable cassette recorder (Datamyte). Depressing any combination of the numerical keys caused those digits to be recorded, and depression of the "Time" key caused the elapsed time to be recorded to a precision of 0.2 sec. The observers' clocks were

[2]Kaye (1977b) reported an exploratory analysis of several aspects of feeding, using data from about half of this sample. The present paper includes the whole sample as well as data from a confirming experiment: It is more a final report than a replication.

synchronized by their simultaneous coding of special signals at the beginning and end of each session.[3]

Event categories coded by observers of the mothers were: ON—Places nipple in infant's mouth; OFF—Removes bottle or removes infant from breast; JIGGLE—Any movement of bottle, breast, or baby which moves nipple in relation to mouth or any touching of baby's lips or facial parts near lips (regarded as continuing until STOP or STROKE); STROKE—Any touching of baby's body or garments that does not meet the definition of JIGGLE (regarded as continuing until STOP or JIGGLE); STOP—End of JIGGLE or STROKE; AWAY—Looks away from baby's face; and LOOK—Looks back to baby's face.

Observers of the infant coded only three categories: ON—Takes nipple; OFF—Nipple out of mouth; and SUCK—Mouth closes down on nipple, visible by muscle movements under the chin and/or jaw movements below ears. The SUCKs were coded at the point of maximum closure (expression), which is easily distinguishable from swallowing, but which provides no information about suction. Although other investigators have been concerned to measure sucking as distinct from expression (Sameroff, 1968), the visible mouth movements that we coded corresponded to the component of sucking most salient to a feeder. It was impossible to include in this coding scheme whether the infant's eyes were open or closed, which might be salient to mothers; this would have required a third observer.

Data Preparation

The two codings for each session were read into the computer, appropriately labeled and synchronized. The next step was to define bursts and pauses. An analysis of SUCK–to–SUCK intervals in many different sessions revealed a bimodal distribution. Most SUCKs were 1.0 to 1.2 sec apart, with the rest of the intervals ranging from 2.5 to 15 or 20 sec (Kaye, 1977b). Intervals greater than 2.0 sec were regarded as pauses. Furthermore, we required at least three SUCKs—i.e., two consecutive intervals of 2.0 sec or less—as criterion for a burst. Others have arrived at these same criteria (Sameroff, 1967; H. Kaye, 1967).[4] Henceforth we shall use the upper-case event label BURST to refer to the

[3]A 1.2-sec adjustment corrected for the difference in response latency of observers coding the sucking (who lagged only 5 ± 1 frames behind the sucks on a 24 frame/sec film) and those coding the maternal behavior (who lagged 35 ± 10 frames behind the behavior).

[4]Occasionally, in a PAUSE-to-BURST interval, a pause might contain one or more isolated SUCKs. In our longest (15-min) session, 11 of the 82 pauses contained isolated SUCKs. These SUCKs were ignored. A rigid criterion such as 2.0 sec inevitably omitted some very short pauses, and introduced some which might not have been perceived by the mother as pauses. What we counted as two bursts of 6.0 and 5.0 sec, separated by a 2.0 sec pause, might "really" have been a 13-sec burst. Such errors, however, along with other unsystematic sources of error like the variability in observer response time, would work against any significant findings.

beginning of bursts (time of the first SUCK) and PAUSE to refer to the end of bursts (time of the last SUCK). Similarly, JIGGLE and STOP refer to the discrete onset and cessation of jiggling. All recoding, transcripting, data analysis, and graphing were done with a software system called CRESCAT developed for investigations of this general kind, where one's data consist of events at particular times or in sequence (Kaye, 1978a).

Reliability

Two kinds of reliability were required: estimations of our accuracy of coding the occurrence of events (interobserver agreement) as well as precision (variations in observer lag-time).

Videotapes of pilot subjects breast- and bottle-feeding their infants and a 16mm color film of one of our 2-week sessions were used to estimate our reliability of coding. Interobserver agreement, coding vs. failing to code an event, was defined as the number of events in a particular category on whose occurrence both coders agreed within 2.0 sec, divided by the average number of occurrences seen by the two coders. When we compared a coding of the filmed mother with the codings we had done live while the session was being filmed, we found agreement of 85 percent. Comparison of two codings made from the film or videotapes by different observers on different occasions yielded coefficients of agreement greater than 90 percent for the event categories BURST, PAUSE, JIGGLE, and STOP.

A second type of reliability involved the variability in times at which particular events were coded. Although 2.0 sec was the *maximum* deviation between two coders which we accepted as "agreement," the vast majority of agreements were closer. For those events on which two coders agreed, their mean deviation was 0.9 sec for both BURST and PAUSE and 1.4 sec for both JIGGLE and STOP. This provides a confidence interval; it means that in this study any interevent latency A–B of less than about 1 sec could actually represent a simultaneous occurrence of A and B, or a sequence B–A. The errors are assumed to have been distributed randomly.

Validity of JIGGLE

The event category STROKE was included because we were unsure that the definition of JIGGLE, movement of the nipple with respect to the infant's mouth or vice versa, would capture the phenomenon of concern to us. Movements assigned to the category STROKE, such as stroking the infant's leg or adjusting his shirt, might be equivalent to jiggling from the point of view of the mother's active involvement with the infant, and could presumably be felt by the infant. Therefore, after the data had been thoroughly analyzed in relation to the category JIGGLE, we repeated the analysis described below using STROKE instead of JIGGLE (each of these mutually exclusive categories constituted a STOP for the other). Neither STROKE nor STROKE–STOP affected the probability of a BURST. Finally, we repeated the analysis treating STROKE and JIGGLE as equivalent, effectively transforming all STROKEs into JIGGLEs; this produced a considerable diminution in the effects reported. In general, the effects could still be seen, but were less consistently significant. Accordingly, the results reported use the original definitions of JIGGLEs: STROKEs are ignored.

Experiment

In a second study, one of the authors (A.W.) bottle-fed a sample of 12 newborns in the hospital nursery. This sample was racially heterogeneous, had received a variety of systemic drugs during labor, and included four Caesarean sections (a representative proportion for the hospital). All were healthy fullterm babies whose mothers elected bottle-feeding. Each served as his or her own control, across five different jiggling conditions administered according to a predetermined, randomized schedule. Four of the conditions resulted from a 2 × 2 crossing of short (1-2 sec) vs. long (3-4 sec) jiggles with early (2 sec after the last SUCK) vs. late (4 sec after the SUCK) onset times. The definitions of "early," "late," "short," and "long" were based on the distributions of PAUSE–to–JIGGLE and JIGGLE–to–STOP durations when infants are fed by their mothers (Kaye, 1977b). The fifth condition consisted of pauses in which the bottle was not jiggled.

All infants were tested twice in the first night (9 p.m. and 1 a.m. feedings) when they were 18 to 24 hours old; 10 of the 12 were tested on two or three successive nights, for a total of 40 sessions (899 pauses). Although some infants contributed more data than others, the proportions contributed by the different infants were the same across all conditions.

Close-up videotapes of the infant's faces with the bottles allowed more precise coding, and the two independent modes (sucking and jiggling) were coded twice and averaged for every session, yielding a reliability coefficient of 95 percent and a confidence interval better than 0.5 sec.

RESULTS

We begin with the study of mothers and infants. As Kaye and Brazelton (1971) found, the pauses in which mothers jiggled were longer, not shorter than those in which they did not. In the present study, the 1306 pauses without jiggles averaged 6.6 ± 3.7 sec whereas the 508 pauses in which mothers jiggled averaged 9.8 ± 4.6; however, from these data alone we cannot say whether the mothers' jiggling lengthened the pauses or tended to occur in pauses which were already long or which would have been even longer had the mothers not jiggled.

The proper way to answer such a question is in terms of conditional probabilities, the method used to compute mortality rates: Of all those pauses that have lasted at least x sec, what proportion will end in the next 1-sec interval, and is this likelihood affected by whether the mother has jiggled? After $x + 1$ sec, a smaller number of pauses remain for consideration: How does the likelihood that they will end depend on whether the mother has jiggled? For any 1-sec interval we were concerned with three conditions, as shown in Figure 1 (a): pauses in which the mother had not yet jiggled and the infant had not yet resumed sucking; those in which she had started to jiggle and continued to jiggle; and those in which she had started and stopped jiggling. Each point represents BURSTs-per-opportunity-to-BURST at that point in time.

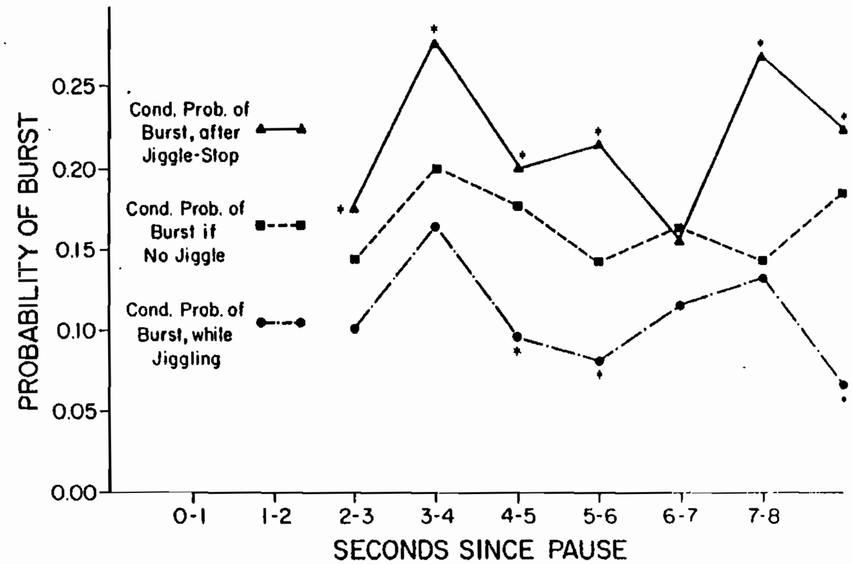

Figure 1(a). Conditional probability of infant's resumption of sucking, as a function of time since pause, depending on whether mother has done nothing (middle function, or baseline); is jiggling infant (lower function); or has jiggled and stopped (upper function). Points marked with * are $p < .05$ by chi-square test, in comparison with baseline.

Figure 1(a) shows that the baseline probability of a BURST, as long as the mother did not jiggle, was about .15 for every 1-sec interval after a pause. Thus, although the distribution of pause duration shows that long pauses are less likely than short pauses, still the conditional probability of a pause that had already lasted 10 sec lasting at least 11 sec is about the same as the probability of one that had lasted 3 sec lasting at least 4 sec.

All three functions were measured from the same starting point, the PAUSE. For any 1-sec interval, the three conditions were mutually exclusive: either the mother had not yet jiggled, or she was jiggling, or she had jiggled and stopped. Thus either the PAUSE–JIGGLE condition or the PAUSE–JIGGLE–

STOP condition could be compared to the baseline (PAUSE, no JIGGLE) by chi-square with one degree of freedom.[5]

The points plotted by circles in Figure 1(a) indicate that mothers' jiggling *per se* did not increase the conditional probability of a BURST. If anything, it suppressed it. The effect was small, and not consistently significant throughout the whole time range following a PAUSE.

If the behavior of mother and infant are to be thought of as turn-taking, then we should not consider JIGGLE as the mother's turn. It is only the start of her turn, which has a duration JIGGLE-to-STOP comparable to BURST-to-PAUSE. The top curve in Figure 1(a) shows that after the sequence of events PAUSE–JIGGLE–STOP, there was a sharp and significant rise in the probability of a BURST. So it is not jiggling which hastens the BURST, but JIGGLE-and-STOP.

The effect of the cessation of jiggling, the STOP, can be compared with the JIGGLE itself in Figure 1(b) where both conditional probabilities are plotted as a function of the time since the JIGGLE. Figure 1(c) shows the effect after a PAUSE–JIGGLE–STOP, in relation to the time elapsed after the STOP: by the third second, the probability of a BURST was back to the baseline level, or about

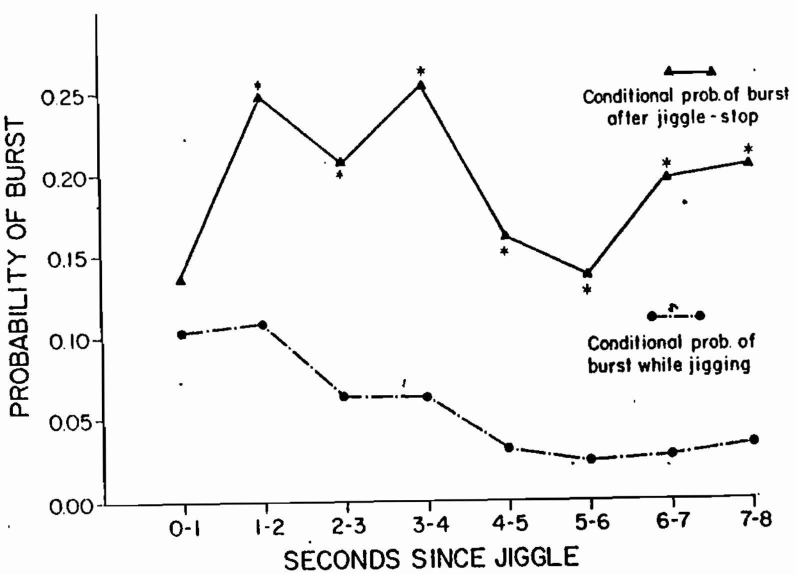

Figure 1(b). Conditional probability of infant's resumption of sucking, as a function of time since onset of jiggling, depending on whether mother continues jiggling or has stopped (* $p < .05$ by chi-square).

[5]There is reason to assume the test is unaffected by the fact that data are pooled over subjects, because the number of observations is large relative to the number of subjects and the subjects all had equal opportunity to contribute to each of the cells.

one chance in six that a BURST would come in any 1-sec interval, as we saw in Figure 1(a). In other words, if the BURST did *not* occur immediately following a STOP, its likelihood of occurrence declined back to the baseline probability of a BURST had the mother not jiggled. The actual numbers of BURSTs and opportunities-to-BURST are shown below each point in Figure 1(c). The other functions are based on large numbers; for example at 2-3 sec in Figure 1(a), the total N is 1814.[6] The total number of pauses in which mothers jiggled (1b) was 508; and of these, 350 ended before the BURST as shown in Figure 1(c).

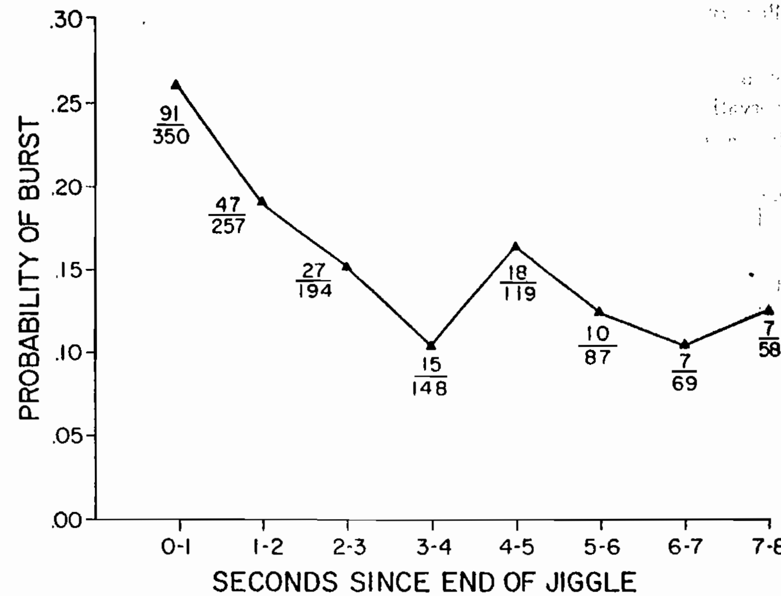

Figure 1(c). Conditional probability of infant's resumption of sucking, as a function of time since mother's cessation of jiggling. Actual numbers of BURSTs over opportunities-to-BURST (total pauses still open) are shown under each point.

Experimental Confirmation

Analysis of the effect of a mother's jiggling and stopping upon the length of pauses under natural conditions is complicated by the variability in the time of onset (latency from PAUSE to JIGGLE) and the duration of jiggling. These variables might have been confounded by the mother's observation of her infant's behavior, or by the variability she experienced in the duration of pauses when she did nothing. It was not clear whether the jiggling actually affected the burst-pause cycle or whether mothers somehow fitted their jiggling to characteristics of the cycle which they were able to anticipate.

[6]In all these functions, if the mother jiggled a second time, we included that pause in the analysis only up to the point in time where the second JIGGLE occurred: So we have analyzed the effect of first JIGGLEs and STOPs only.

To answer this question we turned to the experimental data, where we had bottle-fed another group of newborns in a controlled manner. Because the jiggling was scheduled in advance and administered strictly in relation to the onset of pauses, there was no possibility of fitting the jiggling to an anticipated burst.

The results confirmed those found in the mother-infant study. When a jiggle ended, an immediate burst was significantly more likely to occur than if the jiggle continued or if there had been no jiggle. However, this was only true after short jiggles (Figure 2). After another second of jiggling, the likelihood of a burst rose significantly above the baseline, then fell back to the baseline probability regardless of whether the feeder stopped or continued to jiggle.

This experiment shows that there is indeed a contingent response on the part of the infant, rather than an adjustment by the mother. In the experiment as in the observational study, the sequence PAUSE–JIGGLE–STOP had a 40 percent likelihood of leading to a BURST within 2 sec.

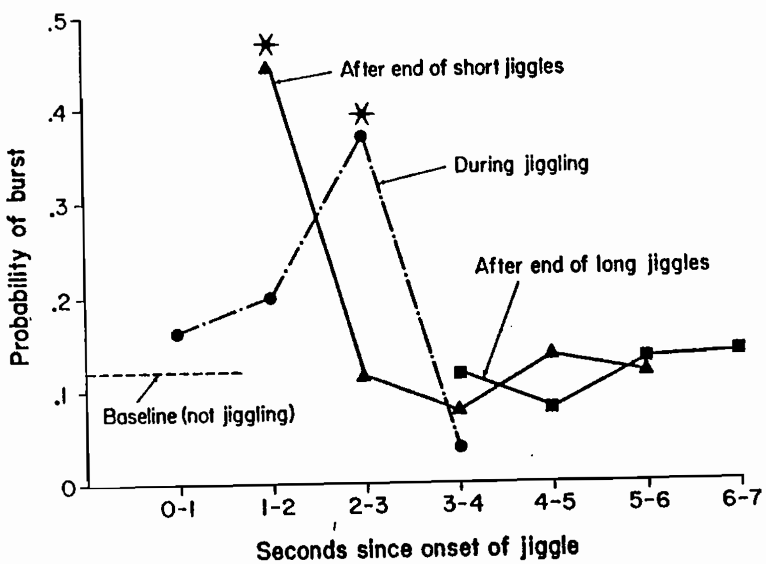

Figure 2. Conditional probability of infant's resumption of sucking as a function of time since the onset of bottle-jiggling by an experimenter. Total N = 899 pauses (* $p < .01$ by chi-square).

The experimental results demonstrated an effect of STOP upon BURST after both "early short" and "late short" jiggles. However, the STOP after longer (3-4 sec) jiggles, including "early long," which ended at the same time in the pause as "late short" jiggles, had no effect. In other words, only brief jiggling elicited a BURST. As with the mothers' jiggling, on those occasions when STOP did not elicit a BURST within a second or two, the likelihood of a BURST returned to the baseline.

Change in Jiggling

If a mother is more likely to elicit a BURST within 2 or 3 sec when she stops jiggling than when she starts jiggling, and if this effect mainly occurs after brief jiggles, we might expect her to learn over the course of many feeding sessions to shorten her jiggling, to STOP sooner. This was indeed the case. The mothers' median JIGGLE–to–STOP durations averaged 3.1 ± 1.9 sec at 2 days and only 1.8 ± 1.0 sec at 2 weeks. The decrease was significant both for the group on whom we had observations at both ages (matched t (21) = 3.28, $p < .001$; binomial sign test $p < .01$) and for the cross-sectional comparison between those analyzed at 2 days only and those at 2 weeks only (t (28) = 1.95, $p < .05$).

Changes in Pauses

The contingency functions shown in Figure 1 were also examined for ages 2 days and 2 weeks separately, and they looked the same: STOP tended to elicit a BURST. If mothers ended their jiggling sooner and the STOP elicited a BURST we would expect pauses themselves to grow shorter over the first two weeks. Not surprisingly, this is what we found. More surprisingly, however, we also found a shortening of those pauses in which mothers did not jiggle. The functions from 2 days and 2 weeks, showing the conditional likelihood of a burst, were compared at each 1-sec interval by chi-square as in Figure 1. The differences were consistently significant ($p < .05$). So not only the pauses in which mothers jiggled, but all pauses tended to be shorter at 2 weeks than at 2 days; whether as a result of the changes in mothers' jiggling, or as a result of some other process such as maturation, we cannot say. There was no difference in burst durations between 2 days and 2 weeks.

Individual Differences

The results discussed so far were obtained by pooling data from a substantial number of subjects. We therefore wished to obtain some indication of the consistency or variability across individual subjects of those phenomena revealed in the sample as a whole. In addition, our claim that mothers decrease the duration of their jiggling because the end of a jiggle elicits a BURST—in other words, that they learn to STOP sooner because stopping has been reinforced by the infant—would be strengthened if individual differences in the infant contingency at 2 days predicted differences in the mothers' jiggling durations at 2 weeks.

The conditional probabilities plotted in Figure 1 represent one partner's behavior as a function of the other's—more precisely, as a function of time since some event occurred, so long as certain other events had not yet occurred. Any one session could not provide enough pauses, jiggles, etc. to compute a conditional probability second by second for each subject. However, we were able to compute three *summary* conditional probabilities for each dyad at each age:

PAUSE→BURST, the proportion of each infant's PAUSEs, which led to a BURST within 5 sec and before the mother jiggled;

PAUSE→JIGGLE, the proportion of all PAUSEs, which led to a JIGGLE within 5 sec and before the next BURST;

STOP→BURST, the proportion of all STOPs, which led to a BURST within 2.5 sec and before the mother jiggled again.

The times used as criterion values, 5 sec for PAUSE→BURST and PAUSE→JIGGLE and 2.5 sec for STOP→BURST, were chosen so as to yield mean values of around 30-50 percent for the sample as a whole (i.e., so as to discriminate among the subjects). The variables were fairly normally distributed. Correlations among them are shown in Table 1. These results suggest that the interaction between mothers and infants at age 2 weeks was different from what it had been at age 2 days. At both ages there was a negative correlation between PAUSE→BURST and PAUSE→JIGGLE (which shared the same denominator, the total number of PAUSEs in each session). At 2 weeks, however, there was a significant correlation between PAUSE→JIGGLE, the mother's quickness to take her turn when the infant stopped sucking, and STOP→BURST, the infant's quickness to take his turn when the mother stopped jiggling. This means that by 2 weeks there were some dyads in which both partners were fairly quick to take their turns when the other partner stopped, and other dyads in which both

TABLE 1
Intercorrelation among variables

	P→B	P→J	
% PAUSE→BURST in 5 sec			
% PAUSE→JIGGLE in 5 sec	−.45**		Age 2 days
% STOP→BURST in 2.5 sec	0	0	(N = 42)
% PAUSE→BURST in 5 sec			
% PAUSE→JIGGLE in 5 sec	−.57***		Age 2 weeks
% STOP→BURST in 2.5 sec	0	.43**	(N = 33)

*$p < .05$; ** $p < .01$; *** $p < .001$

partners were slower or less likely to take their turns. Because we speculated that the shortening of mothers' jiggling might be a result of the infant's tendency to reinforce the mother's STOPs with BURSTs, we predicted that individual differences in the infants' STOP→BURST scores at 2 days would predict differences in the mothers' median jiggling durations at 2 weeks or in their degree of shortening from 2 days to 2 weeks. This was not supported. Nor did STOP→BURST at 2 days predict any of the variables in Table 2 at 2 weeks, including itself. The phenomenon in which STOP tends significantly to elicit BURST is a robust one, evident in all our subsamples (boys and girls, first-borns

TABLE 2
Correlation over time (N = 23)ª

At 2 days	At 2 weeks P→B	P→J	S→B
% PAUSE→BURST in 5 sec	.31	0	.54*
% PAUSE→JIGGLE in 5 sec	−.54**	.47*	0
% STOP→BURST in 2.5 sec	0	0	0

ª N reduced to 21 for correlations with S→B because 2 subjects lacked jiggles ending within pauses.

and later-borns, bottle- and breast-fed). It does not seem to be a variable on which stable individual differences are seen, at least when assessed in a single feeding at each age. Observation of more feedings might have revealed individual differences, as is the case with other newborn behavioral characteristics (Kaye, 1978b).

Table 2 does show significant stability in PAUSE→JIGGLE, the mother's quickness to jiggle when her infant stopped sucking ($r = .47$, $p < .05$). This characteristic of the mother at 2 days also produced a one-way cross-correlation, predicting PAUSE→BURST (negatively) at 2 weeks. A mother's tendency to jiggle at 2 days may have had some effect upon her infant's BURSTs when she did not jiggle at 2 weeks ($r = -.54$, $p < .01$). It is as though infants whose mothers had been more likely to jiggle tended, by 2 weeks, to wait for their mothers to jiggle. This can be illustrated in a cross-lagged panel correlation (Figure 3). Here we have included only the 23 subjects with data at both ages. As we previously pointed out, PAUSE→BURST and PAUSE→JIGGLE were necessarily negatively correlated at each age: Both were affected by the extent to which the baby began sucking before his mother jiggled, and vice versa. Within 5 sec after the PAUSE, there could be either a BURST or a JIGGLE, or there could be neither. It was more likely by 2 weeks for either a BURST or a JIGGLE to occur within the 5 sec, than for neither to occur. This is why the negative correlation between PAUSE→BURST and PAUSE→JIGGLE was stronger at 2 weeks than at 2 days. The cross-lagged correlation shows that whatever was more likely at 2 weeks, BURST or JIGGLE, was predicted much better by the mothers' jiggling tendencies at 2 days than by the infant's behavior.

As reported, the infants' quickness to BURST increased from 2 days to 2 weeks, whether mothers jiggled or not. There was also, however, significant stability in individual infants' median pause lengths between the two ages ($r = .49$, $p < .01$). Thus we have found a third effect upon duration of pauses: An effect of the mother's JIGGLE-and-STOP, an effect of age, and an individual-difference effect. The latter must not be thought of as stability in the infants, but as jointly produced by individual dyads. By contrast, there was only a .21 correlation (N.S.) between the median lengths of bursts across the two ages.

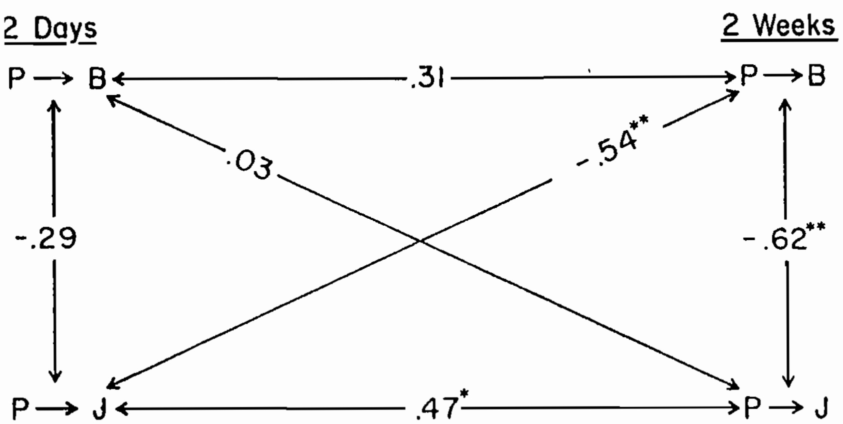

Figure 3. Cross-lagged panel correlations suggest that a mother's likelihood of jiggling within 5 sec of her infant's pauses at 2 days influenced her infant's tendency to wait for her jiggle (i.e., − (P→B)) at 2 weeks.

Group Differences

We analyzed boys and girls separately, 2 days vs. 2 weeks, first- vs. later-born, and breast- vs. bottle-fed infants, always obtaining results substantially the same as those shown in Figure 1. We also performed Sex × Parity × Feeding Method × Age (repeated measure) ANOVAS on our dependent variables. The main effects of age have already been described. Other main effects and interaction effects were not significant.

DISCUSSION

Why did the human species evolve a burst-pause pattern in neonatal sucking? Why do all mothers tend to jiggle the infant, breast, or bottle when the infant pauses? And why do many mothers shift toward shorter jiggling? Although none of these questions can be answered definitively, some answers are more plausible than others.

Let us begin by reviewing our results. Only one effect is known for the pauses in sucking: they elicit a response from mothers. However, maternal jiggling does not hasten the next burst: It is the *cessation* of jiggling in a pause that tends to elicit a new burst of sucking. Our experimental evidence shows that this effect is not due to the mothers' anticipation of the next burst, and that it is more prevalent after short jiggles. Mothers seem to be sensitive to this contingency though not precisely aware of it, for over the first two weeks they change their response from "jiggle until he starts sucking again" to "jiggle and stop". By age 2 weeks, both the duration of jiggling and the duration of pauses are shorter.

If we had found a high correlation between the infants' behavior at 2 days and their mothers' behavior at 2 weeks or the mothers' change over that period, it would have made a strong argument that the mothers' change in behavior was caused by their infants' contingent reinforcement of the cessation of jiggling. The lack of such a finding, however, does not negate the argument. The phenomenon in which the cessation of jiggling tended to elicit a burst of sucks was prevalent in our whole sample, as was the shortening of mothers' jiggles. Since STOP→BURST did not yield reliable individual differences, we could hardly expect it to predict the change in behavior of individual mothers. The basic findings were true of both breast- and bottle-fed infants, boys and girls, primiparous and multiparous mothers.

The Mother

In a wide variety of situations in later infancy, one observes maternal responses similar to jiggling the newborn during feeding. Brazelton et al. (1974), Richards (1974), Stern (1974), Papousek and Papousek (1975), Kaye (1977a), Fogel (1977), Newson (1977), Schaffer et al. (1977), and others have examined turn-taking between mothers and infants in a variety of situations . Bruner (1975), Snow (1977), and many others have discussed its possible significance for the early growth of language. The tendency to fill pauses is pervasive in mothers' interactions with their babies, and the present findings merely illustrate the earliest instance.

To some extent our results suggest a degree of symmetry between the behavior of both partners. When her baby pauses, the mother might jiggle, or she might not. When the mother stops jiggling, the infant might suck, or the infant might not. When the infant is in the midst of a burst, she is unlikely to jiggle. When she is in the midst of jiggling, the infant is less likely to resume sucking.

There is also, however, some important asymmetry. The smooth alternation of turns comes about, when it does come about, by the mother's accommodating her turns to the temporal organization imposed by the infant. Her turns get shorter and so (therefore?) do infant pauses. The burst–pause pattern does not really depend upon her intervention. If she does nothing, the infant will organize sucking in essentially the same manner. There is merely a slight tendency to delay the onset of a burst, all other things being equal, until after her jiggling stops; or to hasten the onset of some of the bursts, so they come right after she stops.

We do not suggest that the infant is in any way conscious of the effect his or her behavior may have, or that the infant intends to reinforce the mother. Nonetheless, because jiggling tends to prolong the pauses, and jiggle-stop tends to elicit a resumption of sucking, the potential reinforcement is there. "Tends to elicit" does not mean every time, of course; but partial reinforcement may well shape a tendency on the mother's part to reduce the duration of her jiggles over the course of many feeding sessions.

The Infant

The fact that the end of a jiggle does increase the probability of a burst—or more precisely, that it sometimes has no effect and sometimes is followed by an immediate burst—is not difficult to understand when we consider the nature of neonatal reflexes. This response seems to lie somewhere between a reflex like the Moro, which is externally-stimulated but still depends upon the infant's state and activity, and a primary circular reaction (Baldwin, 1895).

We must assume that a variety of adaptive functions affected the evolution of neonatal sucking rhythms. One set of functions have to do with obtaining food. But the infant's behavior affects the social environment as well, and these effects in turn have had evolutionary consequences. When we think of the infant's differentiation of reflexes into skills as accommodation to an environment, we need also to be aware of how the environment accommodates itself to the infant. The neonate's reflexes and automatisms are appropriate for the nutritive social environment into which he or she is born, an environment that may include sets of "reflexive" built-in responses of its own. However, the organization of the infant's behavior will itself impose and elicit an organization in the environment.

We have said that any semblance of social interaction in this period is due to the mother's social intentions and to the infant's endogenous rhythms and reflexes, rather than to communicative intentions on his or her part. However, the newborn's immaturity at birth may be an important asset—for it guarantees a degree of salient regularity, rhythmicity, and predictability to behavior, which will not again be possible once higher cortical processes take over. The human mother apparently makes use of the fact that she can predict the temporal structure of her infant's behavior. She uses it to build a basic pattern of interaction which will eventually *not* depend upon biological clocks but upon mutual monitoring and feedback. The newborn's rhythms provide a clear structure into which mothers quite unconsciously fit the turn-taking characteristic of human dialogue. As a result, we believe, the infant eventually learns to anticipate the turn-taking and to assume his or her own role in it as an active partner.

It may be that a species which is going to rely so heavily upon communication and co-operation, and in which so much knowledge and basic skill is going to be passed on through interaction and discourse, has evolved mechanisms of behavior in its newborns which serve to guide parents in interacting with them.

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