DOCUMENT RESUME

ED 089 842 PS 007 036

AUTHOR Rosenfeld, Howard M.
TITLE Time Series Analysis of Mother-Infant Interaction.
PUB DATE 1 Apr 73
NOTE 24p.; Paper presented at the biennial meeting of the Society for Research in Child Development (Philadelphia, Pennsylvania, April 1, 1973)

EDRS PRICE MF-$0.75 HC-$1.50 PLUS POSTAGE
DESCRIPTORS Behavioral Science Research; Developmental Psychology; *Infants; *Measurement; *Observation; *Parent Child Relationship; Reinforcement; *Research Methodology; Socialization; Video Tape Recordings
IDENTIFIERS *Attachment Behavior

ABSTRACT

A method of studying attachment behavior in infants was devised using time series and time sequence analyses. Time series analysis refers to relationships between events coded over adjacent fixed-time units. Time sequence analysis refers to the distribution of exact times at which particular events happen. Using these techniques, multivariate configurations of mother and infant behavior associated within the across time intervals were identified. Mother-infant interactions were videotaped and the behavior coded. The purpose of the development of these methodologies was to predict behavior changes in the context of attachment behavior. (SBT)

TIME SERIES ANALYSIS OF MOTHER-INFANT INTERACTION

Howard M. Rosenfeld*

Symposium on The Analysis of Mother-Infant
Interaction Sequences
Society for Research in Child Development
Philadelphia, Pennsylvania
April 1, 1973

*Mailing Address:
Professor Howard M. Rosenfeld
Department of Psychology
(or Department of Human Development)
University of Kansas
Lawrence, Kansas 66044

TIME SERIES ANALYSIS OF MOTHER-INFANT INTERACTION

Howard M. Rosenfeld

From the perspective of social learning theory, social behavior develops in the context of early interpersonal experiences. A critical feature of such social learning experiences is the repeated occurrence of sequential dependencies between the behavior of the child and the behavior of other persons in his environment. The presumed prototypical outcome of such a process is the normative emergence of attachments between infants and their mothers around the infant's first half year of life.

The primary source of evidence for the social learning explanation has been the experimental demonstration that the rate or probability of a given infant response category can be strengthened by means of the regular occurrence of certain reactions of caretakers--the classic and familiar demonstration of the social reinforcement process. Such evidence is vital to the social learning approach by proving unequivocally that such social reinforcement mechanisms <u>could</u> account for the development of behavior in the natural environment. The limitation of this evidence is its inability to prove that such social contingencies and their consequences are actually characteristic of natural situations.

Thus, naturalistic evidence is necessary to complement the experimental evidence. Unfortunately most naturalistic studies of early social interactions have not been carried out at a sufficiently specific level of analysis to permit convincing assessment of social learning processes. Typically such studies tend to summarize rates of particular child and parent responses over a large block of time, and then to correlate these summary measures across subjects.

For a proper assessment of social learning processes it is necessary to analyze naturalistic data in a way that is more analogous to the procedures of the operant conditioning experiment. Specifically, it is necessary to show that particular responses of the child are selectively reacted to by his caretakers, and that these contingent caretaker reactions are predictive of the subsequent strength of the child's responses. Inasmuch as the caretaker in the natural situation is susceptible to influence by the child,it is also relevant to consider the contingent reactions of the child to the caretaker and subsequent modification of caretaker responses. (Jacob Gewirtz properly would interpret such evidence as "presumptive" social learning, in that in the absence of experimental manipulation of the social contingencies one can not absolutely rule out possible confounding processes in the natural environment. However with the addition of the naturalistic evidence to experimental analysis, the social learning approach could be considerably strengthened as a model of natural acquisition processes).

To assess contingencies of reaction between child and caretaker it is necessary to code and analyze the subjects' responses in terms of their temporal patterns of occurrence over a relatively extended period of time. The most precise form of data that could be collected for such purposes is multivariate time series over elementary time units. That is, a comprehensive system of potentially-social responses should be assessed for child and caretaker, with each response coded for its time of onset and termination. Only in this way can one determine what configurations of social reaction, with what interpersonal timing, are predictive of the elicitation, strengthening and weakening of behavior.

While mother-infant interaction has been recorded by many investigators, we have noted that few, if any, such studies have included comprehensive, multivariate analysis of temporal contingencies of response. Informal information we have received from other researchers indicates that the main reason for the dirth of such studies has been the frustration faced by investigators over how to code and analyze multivariate, time-series data in an efficient, meaningful way. Apparently substantial bodies of films and videotapes of children's interactions have been filed away prior to data analysis due to this deficiency. Consequently, we felt that a critical requisite for both the performance of our own research and, more generally, the encouragement of such research by a wider body of investigators, was to develop procedures for efficiently collecting, coding and particularly for analyzing large quantities of multivariate, time-series data.

We felt that the most promising place to look for the appearance of early social learning processes would be in the interaction between infants and their mothers throughout the earliest normative period of emergence of general social attachments--approximately the second quarter of the infant's first year. (During this period infants typically first exhibit preferences for humans over other sources of stimulation in their natural environment). We decided to limit our initial investigation to the intensive study of individual mother-infant pairs (dyads) throughout this period, and not to be concerned at this time with the degree to which the behaviors and mechanisms involved could be generalized to larger populations.

Another major consideration was how many behaviors to assess and at what level of molarity. For a truly comprehensive assessment of interpersonal contingencies virtually any behavioral category that is potentially discriminable by the other participant should be assessed. On the other hand, at some level of molecularity the amount of data generated can become unwieldy. Our decision was to seek a reasonably comprehensive categorization of the behavior emitted in individual dyads, whether idosyncratic or normative, but not to record minute actions that educated observers agreed e unlikely to be potentially meaningful to the subjects.

To categorize and precisely time the occurrences of events in a large multivariate, interpersonal system obviously requires repeated observations of audio-visual records of the mother-infant interaction process. For this purpose we decided to videotape the subjects at frequent intervals in a standardized naturalistic setting in which the subjects could regularly be kept in range of an unobtrusive camera. Thus a laboratory with a one-way window for videotaping was furnished to resemble a living-room and nursery combination.

Our progress toward the development of efficient procedures for data analysis will be described in the context of the study of our first mother-infant pair (Dyad A). The infant (a second-born son) and mother (who appeared to fall within the normal range of upper-middle class Americans) were videotaped in 14 sessions, typically lasting about 45 minutes each, between the infant's ages of 12 and 34 weeks. Five of the sessions, in which we controlled the availability of toys and mother's attention to the infant, are not directly applicable to our present purposes. Thus we will limit our attention to the other nine nonexperimental or baseline sessions. We told the mother that we wished to periodically videotape infants as they developed, and that to permit a reasonably characteristic sample of her infant's behavior we wanted the environment to be as natural as possible. Thus she was told that she was free to behave as she would in similar settings with which she was familiar. (Please note again that our immediate interest was in detecting interpersonal influence processes within dyads, and not in determining the generality of substantive findings over characteristics of social groups, persons, settings, or ages).

For relatively inexpensive and efficient time-coding of the videotapes, they were duplicated with the aid of a processing apparatus we constructed that allowed us to insert on the duplicate tape the image of a running digital counter that could be set at any rate. We placed this picture of the digital clock on a portion of the duplicate tape in which no codable data was present. (By practicing coding with various speeds of the clock on the same portions of videotape, we found that a rate of one-half second was minimally sufficient to order interpersonal events by time.)

Observers who viewed the tapes listed all categories of behavior of mother or infant that appeared potentially meaningful. The hierarchical, expandable, computer-compatible, coding system that emerged was classified in terms of major categories of visual, kinesic (physical movement), and vocal behavior of mother and infant, and subclassified by more specified activities and by objects of orientation. This resulted in the coding of a huge number of unique events ranging in rates of occurrence. The levels of classification and occurrence are illustrated in the portion of a computer-generated "tree structure" in Table 1. For more expensive computer analyses we collapsed the data into 28 subcategories (Table 2), 14 each for mother and infant, which covered the vast majority of their activities.

TABLES 1 AND 2 HERE

Our coded data were entered into a Honeywell 635 computer for further analysis. Our computer programs developed in cooperation with Charles J. Bangert at the University of Kansas Computation Center, were intended to perform two major functions, which I will refer to as "utility" and "relational" analyses. The utility programs performed such tasks as ordering coded events by their time of occurrence, detecting a variety of errors in coding and sequencing, making preliminary corrections of the errors, and listing and summarizing the data in a variety of ways. (The above tree structure is one example.)

FIGURE 1 HERE

As the complexity of the computer-generated plotting of a few behaviors over about 15 minutes in Figure 1 indicates, computer analysis is important to make sense of the temporal relationships among such variables. Our relational programs included procedures for both time-series and time-sequence analysis. Time-series analysis, of which Markov chains is one familiar example, refers to relationships between events coded over adjacent fixed-time units, whereas time-sequence (or point-process) analysis refers to the distribution of exact times at which particular events happen. Time-series has the advantage of providing a more elementary analysis of temporal data and particularly of being the better-developed analytic tool. While it is not a sufficient tool for our purposes, it provides a reasonable first approximation.

In our limited use of time-series we have sought to identify the multivariate configurations of mother and infant behavior that are associated within and across relatively brief time intervals. In our programs we arbitrarily set two parameters--the size of the time unit, and the number of adjacent time-units to be considered. In practicing with various-sized time units we found that very short intervals (e.g. 1/2 second) tended to generate too many patterns to be reasonably interpretable by a human data analyist, whereas large units (e.g. 16 seconds) tended to reveal only small numbers of rather obvious patterns. Thus, in neither case did the computer efficiently serve us. For our first comprehensive time-series analysis we settled on a four-second time unit, which tended to result in around 50 unique multivariate behavior patterns from our shortened list of 28 variables, in a typical 45-minute session. Table 3 shows part of a computer printout of multivariate behavior occurring over all sets of four adjacent, ~~four~~ one-second states in one session. (The cluster at the left, which occurred "11 times" late in the session, includes infant grunting and looking at the mother, and the mother looking at the infant while speaking in an animated voice and handling him "roughly".)

TABLE 3 HERE

One obvious revelation of the time-series analysis was that successive time intervals, even as large as 4 seconds each, predominantly consisted of the same combination of variables as the events that proceeded them. This points out a major limitation of elementary time-series procedures, which has been documented by prior investigators, namely, that in social interaction data most patterns reflect the structure of <u>intra</u>-individual behavior.

Time-<u>sequence</u> procedures are more likely to reveal the <u>inter</u>personal structure of time-coded behavior. However, we did not find adequate time-sequence methods to be available for our purpose of detecting precise contingencies between interpersonal behaviors in the natural flow of social interaction. (Note that some researchers have contructed more molar units from time-series patterns, then arbitrarily treated the derived units as fixed-time units in the determination of sequential dependencies. While such processes are potentially useful, they are essentially pseudo time-series and not time-sequence, as they ignore the real timing of events.)

We have been developing several kinds of time-sequence programs for our purposes. In this brief presentation I would like to focus on one such program and limit illustrations to some dominant contingencies between pairs of mother and infant behaviors from our 28-variable list. I will further limit the illustrations to pairs of variables that were additionally found to be significantly related in a rough time-series analysis. (The output of this latter program consistes of 2x2 Chi Squares, where legitimate, which indicate whether a given pair of mother and infant behaviors occur in the same time interval greater than or less than chance. Expected values are based upon the presumably stationary distribution of each variable over all 4-second intervals for the entire session. Note that unlike the more familiar Markovian approach, we are here ignoring transitional probabilities between successive units.)

For mother and infant variables that significantly co-occurred in four-second intervals, we used time-sequence analysis to determine the <u>temporal relationship</u> between the variables. Here is where our most promising approach was initiated: a program that will be referred here to as the "relational histogram". (Note that it can be applied to <u>intra</u>personal as well as interpersonal relationships and need not correspond to the results of time-series analysis.) It involves two major steps, the first of which is a program for translating time-series into time-sequence. Three properties of each variable are attended to by the program. These features are numbered 1, 2, and 3 in the illustration in Figure 2. For events that have durations of occurrence lasting beyond one elementary time unit we distinquish two properties: (1) the time of onset and (2) the time of termination. The third property, (3) consists of momentary occurrences of the variables (in which starting and stopping times may be viewed as simultaneous).

FIGURE 2 HERE

To be eligible for inclusion in our subsequent program for detecting temporal contingencies between pairs of such properties on the part of mothers and infants, the distribution of each derived time-sequence had to fulfill additional criteria. The events in each sequence had to occur sufficiently often to permit reliably replicable observations, but its repeated occurrences had to be sufficiently spaced in time to reasonably permit other kinds of events to precede and follow it. In the illustrations to be presented, we arbitrarily set the minimal interval between repeated occurrences of the same kind of event at 3 seconds.

Events that met the above criteria were entered into the relational histogram program. The essence of the program is that one variable (e.g. a behavior of Mother) is tested for its typical location between successive occurrences of a second variable (e.g. a behavior of Infant). For this purpose, the intervals between all successive occurrences of the infant variable were standardized in length (see bottom of Figure 2). All occurrences of the maternal variable were then plotted within the single standardized time interval representing successive occurrences of the infant behavior. Depending upon the distribution of the mother's behavior within the infant's; a variety of plausible inferences can be drawn about the temporal relationship between the two variables. For example, if the mother's behavior typically occurs immediately after the infant's behavior, the implication is that the infant may have caused her response. These and several other possibilities are illustrated by the idealized patterns in Figure 3. The illustrations should be considered as suggestive at this point rather than necessarily coordinated to any fixed formula. However, our computer program at this time does test for the degree to which the data fit four such patterns. We will limit our illustrations of Dyad A to the top two kinds of histogram in Figure 3, indicating that mother's behavior and infant's behavior are causally related.

FIGURE 3 HERE

(Let me add parenthetically that my original intention was to predict the rate of occurrence of particular responses over sessions by means of the social contingencies that were applied to them. It turns out that in our relatively naturalistic study the rates at which many mother and infant responses occurred often was quite low--especially in contrast to the typical operant experiment in which the experimenter zaps the subject with a reinforcer at high rates over short time intervals. To get similar quantities of data in natural situations apparently requires substantially more data collection per dyad than the hour or so per week of the present study. Thus I feel that the best way to illustrate some of the contributions or our programs at this time is to emphasize the detection of interpersonal contingencies by combining computer outputs over sessions, rather than to attempt to predict behavior changes within or over sessions from weaker trends.)

Let us consider only two categories of infant vocal behavior which typically receive certain notorious and consensual interpretations--the coo and the fuss. Given my personal interest in the development of conversational behavior, I was particularly interested in the typical relationships of the coo and fuss in Dyad A to categories of mother's vocal behavior. Four mother variables were found to reliably enter into such relationships--neutral voice, soothing voice, animated voice, and unusual voice--the last consisting in oddities such as whistling and clicking. Table 4 shows that the mother's and infant's vocal categories were differentially related to each other by time-series analysis (the arrows indicate probable direction of influence from time-sequence analysis). The infant's fusses were associated with mother's neutral and soothing voices, while coos were associated with the mother's animated (arousing) and unusual voices.

TABLE 4 HERE

Figure 4 presents one set of histograms relevant to the interpretation of the temporal association between infant fussing and mother soothing. The interval in the top histogram indicates the standardized distance in deciles between the infant's terminations of fusses. Within it are plotted the relative occurrences of mother's initiation of soothing responses. The shape of the histogram indicates that mother's soothing was responsible for the termination of the infant's fussing. (The bottom histogram plots the infant's terminations of fussing within the mother's soothing, and reveals a similar relationship to the top histogram. Other histograms, not shown, further indicate that the start of infant fussing evoked soothing by the mother).

FIGURE 4 HERE

Table 5 shows some of the kinesic activities of mother that were related to infant fussing and cooing. Figure 5 presents one relevant histogram from the final session, relating the infant's completion of cooing to the mother's termination of gentle stimulation. The implication is that the completion of cooing provided the occasion for the mother to terminate gentle stimulation.

TABLE 5 AND FIGURE 5 HERE

At this point, one might reasonably inquire if the absolute duration of the interval between coos might affect the temporal location of the mother's behaviors? Indeed it could, and the process could be obscured within a standardized interval. Thus our histogram program also lists histograms separately for different sizes of interval, as shown on the bottom of Figure 5. The four intervals shown constitute the entire standardized histogram. In each case the mother followed the infant in the first decile, with a lag of not greater than three seconds.

In conclusion, the technology now appears to be available for testing the implications of social learning therory for the timing of natural social behavior--at a reasonably comprehensive and detailed level of analysis. This technology includes relatively inexpensive and rapid means for coding of data in computer-compatible form, computer programs for arranging and checking data, and, in particular, programs for detecting temporal relationships among multivariate events. Initial substantive results obtained by application of these procedures generate confidence in the value of their further development and more general usage. We would be most interested in communicating with others who have collected data or developed procedures relevant to multivariate temporal analysis.

Table 1

Rosenfeld

MBT07? - TREE STRUCTURE OF SYMBOLS

ROSENFELD M/I SET K6 06/15/72

TIME UNITS ARE SECONDS

LEVELS 1 2 3 4 5 6 7 8 9 10 11 12	STARTS	TOTAL TIME ON	MEAN TIME ON	MEAN TIME OCCUR
I	311	2649	8.5	1674.3
. I1	53	458	8.6	886.7
. . I1.	53	458	8.6	886.7
. . . I1.B	25	286	11.4	915.0
. . . I1.C	6	29	4.8	996.2
. . . I1.D	18	81	4.5	323.7
. . . I1.E	2	18	8.8	1347.3
. . . I1.G	2	45	22.4	1473.7
. I2	4	83	20.7	780.2
. . I2B	1	81	81.0	774.1
. . I2F	3	2	0.6	1071.6
. I3	84	1186	14.1	1715.1
. . I3A.D	20	92	4.6	346.1
. . I3B	44	832	18.9	1810.8
. . . I3B.	44	832	18.9	1810.8
. . . . I3B,D	37	793	21.4	1833.4
. . . . I3B,E	2	6	3.1	471.2
. . . . I3B,G	5	33	6.6	1517.4
. . I3C.E	17	235	13.8	1870.2
. . I3D.E	3	27	8.9	2105.3
. I4	157	325	2.1	1599.6
. . I4A	17	40	2.3	1258.2
. . I4B	38	62	1.6	1457.6
. . I4E	88	65	0.7	1120.7
. . I4F	11	154	14.0	1966.5
. . I4H	3	3	1.1	735.8
. I5	4	2	0.6	659.5
. . I5A	2	1	0.6	112.2
. . I5B	1	1	0.6	1922.2
. . I5C	1	1	0.6	491.3
. I6	5	593	118.6	2374.1
. I7A	4	2	0.6	769.7
	203	1930	9.5	988.3

Table 2

Twenty-eight variables selected
for time-series analysis

1)	I1.E (look at mother)	15)	M1 (look at infant
2)	I1.D, .X (look at self)	15)	M3A, B (activate stimulus)
3)	I1.B (look at mobile)	17)	M3C-E, H; M7A, B (stimulus closer)
4)	I1.A, .C, .L, .N, .T, .V (look at toys)	18)	M3F, G; M7C, D (stimulus farther)
5)	I1.Y, .Z (look at untouchables)	19)	M4A (voice arousing)
6)	I1.F-K, .M, .O, .S, .U, .W (look at other objects)	20)	M4B (voice soothing)
7)	I2A (lean-reach)	21)	M4D (voice neutral)
8)	I2B-F (relocate)	22)	M4E (voice questioning)
9)	I3A (handle objects)	23)	M4F-J (voice strange)
10)	I3B (mouth objects)	24)	M5 (relocate infant)
11)	I3D, I5, I7 (misc. problems)	25)	M6B, C, G, H, I (rough stimulation)
12)	I4A, H (voice positive)	26)	M6A, D, E, K, M, P (gentle stimulation)
13)	I4B, E (voice ambiguous)	27)	M6F, J, L, N, O, Q, T (caretaking)
14)	I4F, G (voice negative)	28)	M3I; M4C; M6S; M6U (interference)

Figure 1

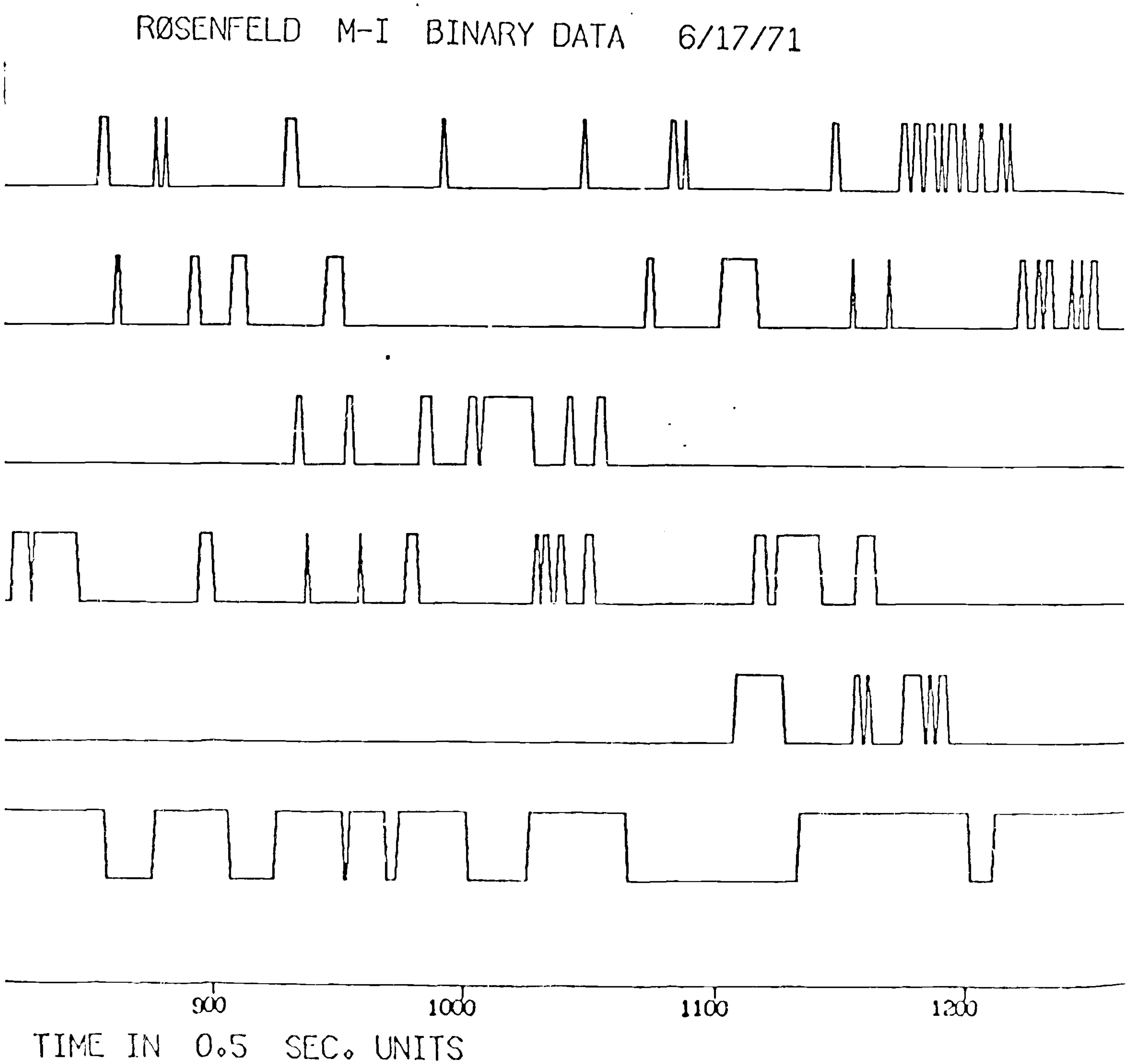
RØSENFELD M-I BINARY DATA 6/17/71
900
1000
1100
1200
TIME IN 0.5 SEC. UNITS

Table 3

MULTIVARIATE MARKOV ANALYSIS
LIST OF 'ON' VARIABLES FOR 4-WAY TRANSITION STATES ON 23 VARIABLES

ROSENFELD M/I SET C8 COLLAPSING TO 1 SEC. 09/30/72

ROWS ARE THE TIMES, ENTRIES IN THE ROWS ARE THE 'ON' VARIABLES, TIME

NO.	13	COUNT	11	NO.	14	COUNT	11
MTIME	3099.9	VMT	0.976	MTIME	1500.4	VMT	0.376
FIRST	3074.5	LAST	3111.5	FIRST	620.5	LAST	1901.5
COX'S U	5.448			COX'S U	-1.422		

1,	I1.E	,I4B,E	,M1	,M4A	1,	I4B,E	,M1	,M4E
	M6RUGH							
2,	I1.E	,I4B,E	,M1	,M4A	2,	I4B,E	,M1	,M4E
	M6RUGH							
3,	I1.E	,I4B,E	,M1	,M4A	3,	I4B,E	,M1	,M4E
	M6RUGH							
4,	I1.E	,I4B,E	,M1	,M4A	4,	I4B,E	,M1	,M4E
	M6RUGH							

Figure 2

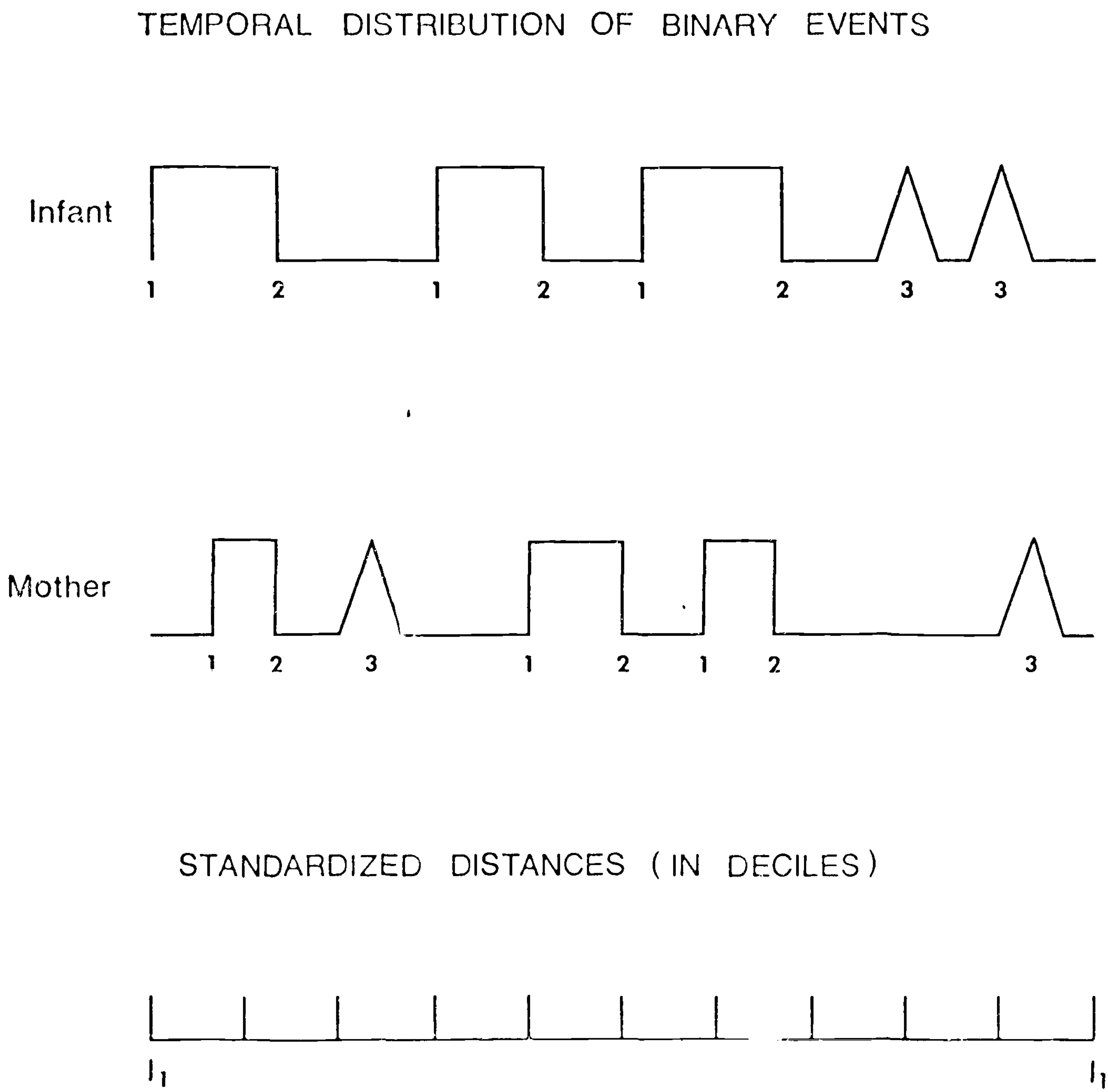
TEMPORAL DISTRIBUTION OF BINARY EVENTS
Infant
1 2 1 2 1 2 3 3
Mother
1 2 3 1 2 1 2 3
STANDARDIZED DISTANCES (IN DECILES)
I_1
I_1

Figure 3

RELATIONAL HISTOGRAMS

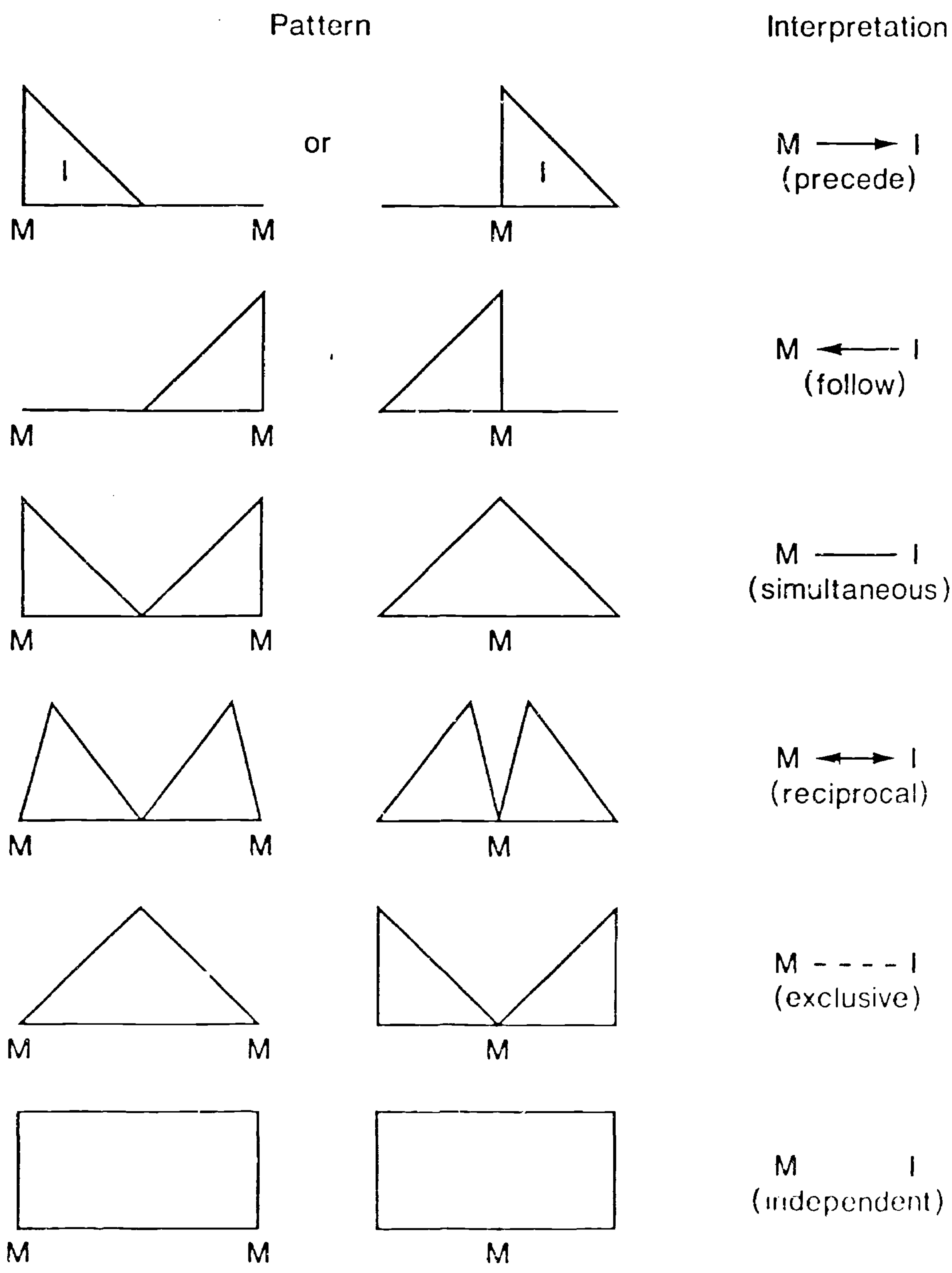

Table 4

SIGNIFICANT TEMPORAL RELATIONSHIPS
BETWEEN MOTHER AND INFANT VOCALIZATIONS
(DYAD A)

MOTHER	INFANT	
	COO	FUSS
NEUTRAL		← MI
SOOTHING		↔ MI
ANIMATED	→ MI	
UNUSUAL	→ MI	

Figure 4

INTERPERSONAL HISTOGRAMS

Variables

Mother (M): Start Soothing Voice
Infant (I): Stop Fuss-Cry

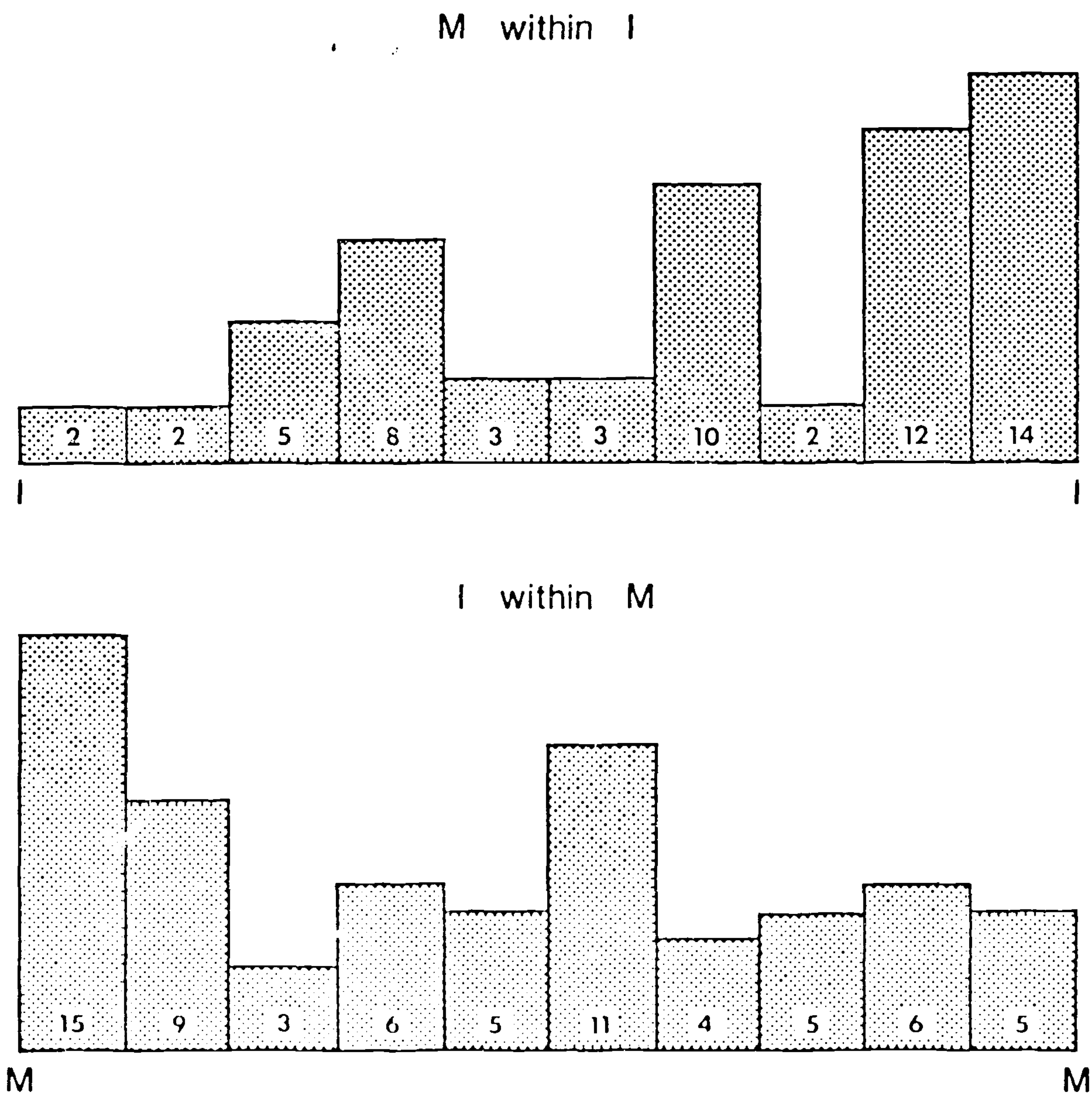

Table 5

SIGNIFICANT TEMPORAL RELATIONSHIPS
BETWEEN MATERNAL STIMULATION
AND INFANT VOCALIZATION
(DYAD A)

MOTHER	INFANT	
	COO	FUSS
ADJUST I'S POSITION		⟷ MI
OBJECT CLOSER -UNREACHABLE		→ MI
GENTLE	← MI	→ MI

Figure 5

HISTOGRAM NO. 19 SEQ 6 (M6GNT?) WITHIN SEQ 3 (I4A,H?)

```
4 ****
0
0
0
0
0
0
1 *
0
0
```

FOR 4 INTERVALS IN SEQUENCE 3, MEAN INT. LENGTH = 25.75 STD. DEV. I
POINTS IN SEQUENCE 6 = 5 POINTS OCCURRING SIMULTANEOUSLY IN BOTH SEQ

A	B	C	D	E	F	G	H	I	J		LENGTH
1	1	1	1							A=	13.8(1)
0	0	0	0							B=	23.4(1)
0	0	0	0							C=	32.2(1)
0	0	0	0							D=	34.4(1)
0	0	0	0							E=	( )
0	0	0	0							F=	( )
0	0	0	0							G=	( )
0	0	1	0							H=	( )
0	0	0	0							I=	( )
0	0	0	0							J=	( )