CONTINUOUS TRACKING OF BEHAVIORAL DEVELOPMENT IN INFANTS

Mark Roberts, Andrew Bondy, Mary Mira, and George Cairns
University of Kansas Medical Center

Author to whom correspondence
should be addressed:

Mary Maria, Ph.D.
Children's Rehabilitation Unit/UAF
University of Kansas Medical Center
39th and Rainbow Blvd.
Kansas City, Kansas 66103

Summary

Traditional scales of infant development provide a one time measure of the number of tasks on the scale an infant performs and his standing relative to his age group. Repeated assessment over time on these scales indicates how many more tasks the infant can now perform and whether his relative status has altered. This strategy fails to measure actual changes in the same emerging behaviors as development progresses. This paper discusses the importance of continuously measuring amounts of the same behavior over time as an alternative strategy. The types of developmental information that can be obtained are demonstrated by the behavioral records of two infants observed over a 25 week period. The data are the changes in frequency and duration of three motor responses in the prone position: chin lifting, chest lifting, and a hands & knees position. The implications of the methodology for research and clinical application are presented.

A. Introduction

The traditional research methodology used to generate infant developmental scales is based upon the presence or absence of specified behaviors within a subject's repertoire. For example, in 1927 Gesell (6) observed 107 infants in a variety of settings during their first 56 weeks of life. The basic data extracted from written protocals and films were the percent of the sample population emitting specific responses at a given age. Several classic studies (1, 5, 15) as well as more recent projects (2) have extended Gesell's data base but have not deviated from the fundamental methodology. A child's development is still assessed by his performance of a set of behaviors typically seen in a similarly-aged population. If it can be assumed that the observation of one occurrence of a response is just as informative as repeated sampling of frequency and duration of that response, then the current data base is satisfactory for developmental assessment. It is our position that this assumption is an unfortunate heritage of the mental testing movement and is not adequate for assessing emerging motor skills of infants.

The prominent early mental tests (e.g. the Stanford-Binet) emphasized verbal responses. No matter how frequently the answer to a question is repeated or how long its duration, it is still scored as a correct or incorrect answer. Frequency and duration measures of the verbal response have little value. By adapting Binet's basic measurement strategy to non-cognitive development Gesell and his followers have assumed that frequency and duration measures of emerging infant behaviors had limited value in this realm also.

Overheads

Infant scales based on the presence/absence strategy yield information about the average age of onset of a behavior and the relative developmental status of an individual infant within his age group. However, with the possible exception of the ordinal scales introduced by Uzgiris and Hunt (16), the presence/absence strategy does not yield complete sequential information about the development of particular response classes (4). Infant scales, no matter how frequently administered, cannot provide any information about how a single emerging behavior is changing. They also fail to allow the study of the differential rates of development of different behaviors and their interactions.

The alternative strategy of continuously measuring the frequency of the same behavior over time is as opposed to presence/absence better suited to the quantification of changing behaviors. All behaviors, across ages and topographies, can be measured in terms of frequency; use of frequency as the basic datum permits the study of many features of behavioral development not possible with the mental test approach. It allows the study of a single individual without comparison to a group; it also allows precise measurement of the interactions among several emerging behaviors. Furthermore, continuous measurement of changing behavior frequencies over time provides a quantification of the rate of change or <u>celeration</u> of emerging behaviors (9, 12). Behaviors which systematically change over time either accelerate or decelerate; the celeration can be expressed by the number of movements per unit time per unit time.

A few investigators using approximations of this strategy for examining the development of infant behavior demonstrated the utility of continuously measuring the amount of the same behavior over time. Halverson (8) and Seth (13) studied prehension by repeatedly filming infant responding to standardized stimuli. Others have measured changes in the rate of consecutive steps (14) and babbles and words (6).

We ~~propose to~~ apply ed this strategy to the measurement of infant development in the prone position. There are four elements to this strategy. First, a set of mutually exclusive behaviors is defined. In our demonstration project we examined infant motor development in the prone position. Following McGraw's lead (11) we investigated three responses: chin lifting, chest lifting, and a creeping response. McGraw demonstrated that there is considerable change in these behaviors during the infant period. The simultaneous observing and recording of all three responses allows comparisons among behaviors. Second, the selected set of behaviors are repeatedly sampled from the time of initial emergence to the time of decay. Continuous measurement permits the evaluation of rates of change in the specific topographies. Third, stimulus conditions present in the observation setting are held constant throughout the study. This element restricts the range of settings in which the behaviors are observed. Fourth, frequency and duration measures of each response are concurrently monitored, generating two independent types of information that can be analyzed in several ways. The combination of the four elements comprising our strategy makes possible the assessment of interactions among the selected set of behaviors.

The purpose of this report is to present the methodology and the types of information it yields. It is not our purpose to describe completely the changing nature of the developing behaviors which we studied.

B. Method

Two female infants from the Infant Language Research Laboratory at KUMC served as subjects. We observed Sarah from the age of nine to 34 weeks and Cathy from the age of 12 to 32 weeks. Both girls are healthy and are developing normally as indicated by the Denver Developmental Screening Test.

All observations occurred in the play area of the Infant Language Research Center between the hours of two and four p.m. This infant care facility provides the daily routine outlined by LeLaurin and Risley (10). Necessary apparatus for the study includes a playpen mattress, two brightly colored cloth blocks, a stopwatch, and an eight-channel event recorder. The event recorder has two keyboards; each keyboard operates four channels on the event recorder. This arrangement permits two observers to independently record four different behaviors.

At the beginning of each session we removed the infant's shirt and placed a piece of tape (8 cm. X 2 cm.) on her chest midway between her nipples. A thin line drawn horizontally on this tape served as a recording cue to the observers. The child was then placed on the playpen mattress in the prone position. There she faced two observers who were stationed at the narrow end of the mattress, sitting on the playroom rug. The two colored cloth blocks lay between the observers and the child, keeping the child oriented toward the observers and preventing the observers from accidentally viewing the other's keyboard. These stimulus conditions were maintained throughout the study.

Each observation period lasted exactly five minutes. When the infant displayed a target behavior, an observer depressed a pre-assigned key on the keyboard which resulted in a pen-deflection on a revolving tape in the event recorder. The observer continued to press that key until a different response appeared.

The three motor behaviors measured during each five minute session were labeled chin lift, chest lift, and hands & knees position. Each response was defined in terms of its topography. The behaviors were mutually exclusive, but did not include the entire range of behaviors emitted in the observation setting. If the child rested her head on the mat or displayed a non-targeted response (e.g. lay on side), it was not recorded. If the child rolled or crawled off the mat, recording stopped until the infant was returned to the mat and placed in the prone position. Observation sessions were discontinued when the child began creeping off the mat every time she was returned.

Operational definitions of the scored responses are as follows:

1) <u>Chin Lift</u>: The infant's head is raised off the mat; her chest is not raised high enough to reveal the line on the marker tape attached between her nipples.

2) <u>Chest Lift</u>: The infant's chest is raised high enough off the mat to expose the line on the marker tape; both hands contact the mat.

3) <u>Hands & Knees Position</u>: The infant's entire trunk is raised off the mat; her legs are clearly visible from a head-on viewpoint.

Since pen deflections form the basis of the data, two primary types of information can be extracted from the event recorder tapes: the number of times a behavior is initiated and the amount of time the behavior occurs within a session. The frequency measure was expressed as the mean number of responses initiated per minute, and the duration measure was the mean number of seconds the behavior occurred each minute. Each measure was averaged across the two observers and is presented below as the weekly median of these frequency or duration means on semi-logarithmic scales (12). The slope of a straight line fitted to the charted frequencies provides a numerical index of accelerations and decelerations of the frequencies (9). For our purposes a month was a convenient unit of time for expressing change. Therefore, celerations are given as multiples of the number of movements per minute per month. A celeration of x2, for example, indicates that the frequency of a behavior is doubling each month.

C. Results

We observed Sarah a total of 44 times for an average of 1.8 sessions per week for 25 weeks. Cathy participated in 31 sessions for an average of 1.6 sessions per week for 20 weeks.

To establish inter-rater reliability correlation coefficients were calculated by comparing the measurements of each observer for each session. In addition we analyzed rater agreement during one minute observation periods. This procedure increases the probability that the correlation coefficients represent actual observer agreements (3). The mean reliability coefficients (Pearson r) for the frequency measurements by session were .98 for chin lift, .95 for chest lift, and .97 for the hands & knees response. The duration measure yielded correlations of .99 for all three responses. The more conservative analysis of one minute observation periods showed a slight, but not significant decrease in the coefficients. The mean correlation across both children and behaviors was .93.

Insert Figure 1 about here

---

1 The methodology is sensitive to the differential changes in the three behaviors. Figure 1 presents the median weekly frequencies of the behaviors for both children. Chin lifting is tracked through a period of declining significance in the infants' repertoire. Chest lifting and the hands & knees response are developing during the same period. The changing

characteristics of the three responses were highly similar for both infants. From 12 to 32 weeks for Cathy and from nine to 34 weeks for Sarah chin lifting was initiated with diminishing frequency. The deceleration for the records of both infants is ÷2, indicating that in each successive month the frequency was half that of the preceeding month. During this same period the frequency of lifting to chest was accelerating. Cathy emitted the behavior almost twice as often each month as the previous period (x1.9), whereas Sarah's celeration was not as rapid (x1.3). The hands & knees position was not observed until the eleventh week of observation for Cathy and the sixteenth for Sarah (ages 23 and 25 weeks respectively). This behavior developed more rapidly, accelerating from the point of onset fivefold each month for Sarah and sixfold for Cathy. Neither child assumed the hands & knees position until chest lifts were occurring more frequently than chin lifts.

Insert Figure 2 about here

The methodology also allows comparisons of changes in the frequency with which a behavior occurs with changes in the amount of time that the infant engages in that behavior. As an example, Figure 2 presents the changing frequency and duration measures of the three target behaviors for one of the infants. During the developmental period covered by the study Sarah not only initiated chin lifting less often (÷2), she maintained the position for briefer periods of time (÷4); the deceleration was twice as great for duration as for frequency. While the frequency measure of chest lifting was developing gradually (x1.3), the duration measure shows a different pattern. This difference was characterized by a rapid acceleration in the amount of time she held the position during the first eight weeks (x5), followed by a gradual deceleration (÷1.3). There was an inverse relationship between frequency and duration during the last six weeks. The most dramatic celeration for Sarah was the increasing amount of time she maintained the hands & knees position as the behavior was emerging. While she initiated the position with a fivefold increase each month, the amount of time she held the position celerated x30 each month. The second infant's data replicate the relationships between frequency and duration measures shown in Figure 2.

The recording methodology allows the generation of other indices of the three behaviors from the event recorder tapes. It is possible to chart a maximum duration measure which is defined as the longest length of time a particular response lasts within each session. Also, we can combine the frequency and duration data to derive a duration per occurrence measure. Neither measure provided additional useful information about the two subjects. However, these measures may be useful in other populations by being differentially sensitive to certain systematic changes.

D. Discussion

This project was designed to demonstrate the types of developmental information that can be generated by a measurement strategy based on continuous measurement of changing behavior frequencies over time. It was not designed to completely describe infant development in the prone position. To do so would require following a larger number of children from birth until the mastery of all behaviors leading to forward progression. For example, one cannot conclude that chest lifting must occur at a higher frequency than chin lifting for a minimum period of six weeks before a child will make a hands & knees response. However, the search for the parameters predicting the emergence of new motor behaviors is possible. The proposed research strategy permits the study of likely parameters, such as: related behaviors, the amounts of those behaviors (e.g. frequency and duration), the time since onset of the related behaviors, and the interactions of these measurable phenomena. A research strategy that measures only the presence or absence of a response can not study the parameters likely to predict the emergence of behavior.

Two general statements are sufficiently supported by the current data to warrant continued investigation. First, specific forms of motor behavior change at different rates and in different directions within a given period of time. In this project the frequency of chin lifting decelerated while the frequency of the hands & knees position accelerated rapidly.

Second, rates of change in specific responses appear to be similar for different children. This phenomenon is evident from the similar celerations of the slopes in Figure 1.

The data indicate that developing behaviors change differently along the dimensions of frequency and duration. Thus, it is not possible to conclude which is the most useful data. These two aspects of each motor position change in the same direction for chin lifting and the hands & knees response. In contrast, the celeration and the relationship between frequency and duration were markedly different for chest lifting. The duration of chest lifting accelerated rapidly and then declined, while the frequency accelerated gradually throughout the study. Therefore, an inverse relationship between the duration and frequency of chest lifting appeared following an initial period of positive covariation. Although the differences between the two measures of chest lifting can not be explained at this time, it is clear that continued use of both frequency and duration measures is justified by the data.

The significant practical applications of this strategy derive from its sensitivity to behavior change in infancy and its ability to detect changes in the course of development at the time that these changes are occurring. Diminishing celerations of emerging behaviors may forecast developmental disabilities or may allow rapid detection of damaging environmental influences. Measures of behavioral celerations appear promising as the base against which to assess the impact of programs designed to intervene in early developmental disorders. It provides the only strategy available for precisely assessing the effects of changes in the course of development in one behavior upon future development in another.

References

1. Bayley, N. Mental growth during the first three years: A developmental study of sixty-one children by repeated tests. Genetic Psychology Monographs, 1933, 14, 1-92. (b)

2. Bayley, N. Bayley Scales of Infant Development. New York: The Psychological Corporation, 1969.

3. Bijou, S.W., Peterson, R.F., Harris, F.R., Allen, K.E. and Johnston, M.S. Methodology for experimental studies of young children in natural settings. Psychology Record, 1969, 19, 177-210.

4. Cairns, G.F. and Karchmer, M.A. Macroquantitative strategies for assessing infant development. Paper presented as part of a symposium titled: Behavior development-measurement issues in the education of young multihandicapped children at the National Association of School Psychologists Annual Meeting, Kansas City, Missouri, March 25, 1976.

5. Cattell, P. The Measurement of Intelligence of Infants and Young Children. New York: The Psychological Corporation, 1940.

6. Edwards, J.S. and Edwards, D.DeA. Rate of behavior development: Direct and continuous measurement. Journal of Perceptual and Motor Skills, 1970, 31, 633-634.

7. Gesell, A.L., Thompson, H. and Amatruda, C.S. Infant Behavior: Its Genesis and Growth. New York: McGraw-Hill, 1934.

8. Halverson, H.M. The acquisition of skill in infancy. Journal of Genetic Psychology, 1933, 43, 3-48.

9. Koenig, C.H. Charting the Future Course of Behavior. Kansas City, Kansas: Precision Media, 1972.

10. LeLaurin, K. and Risley, T.R. The organization of daycare environments: "Zone" versus "man-to-man" staff assignments. Journal of Applied Behavioral Analysis, 1972, 5, 225-232.

11. McGraw, M.B. Development of neuromuscular mechanisms as reflected in the crawling and creeping behavior in the human infant. Journal of Genetic Psychology, 1941, 58, 83-111.

12. Pennypacker, H.S., Koenig, C.H. and Lindsley, O.R. Handbook of the Standard Behavior Chart. Kansas City, Kansas: Precision Media, 1972.

13. Seth, G. Eye-hand coordination and handedness?: A developmental study of visuo-motor behavior in infancy. British Journal of Educational Psychology, 1973, 43(1), 35-49.

14. Shapiro, H. The development of walking in a child. _Journal of Genetic Psychology_, 1962, _100_, 221-226.

15. Shirley, M.M. The First Two Years. A Study of Twenty-Five Babies. Volume I. Minneapolis: University of Minnesota Press, 1931.

16. Užgiris, I.Č. and Hunt, J.McV. Assessment in Infancy: Ordinal Scales of Psychological Development. Urbana: University of Illinois Press, 1975.

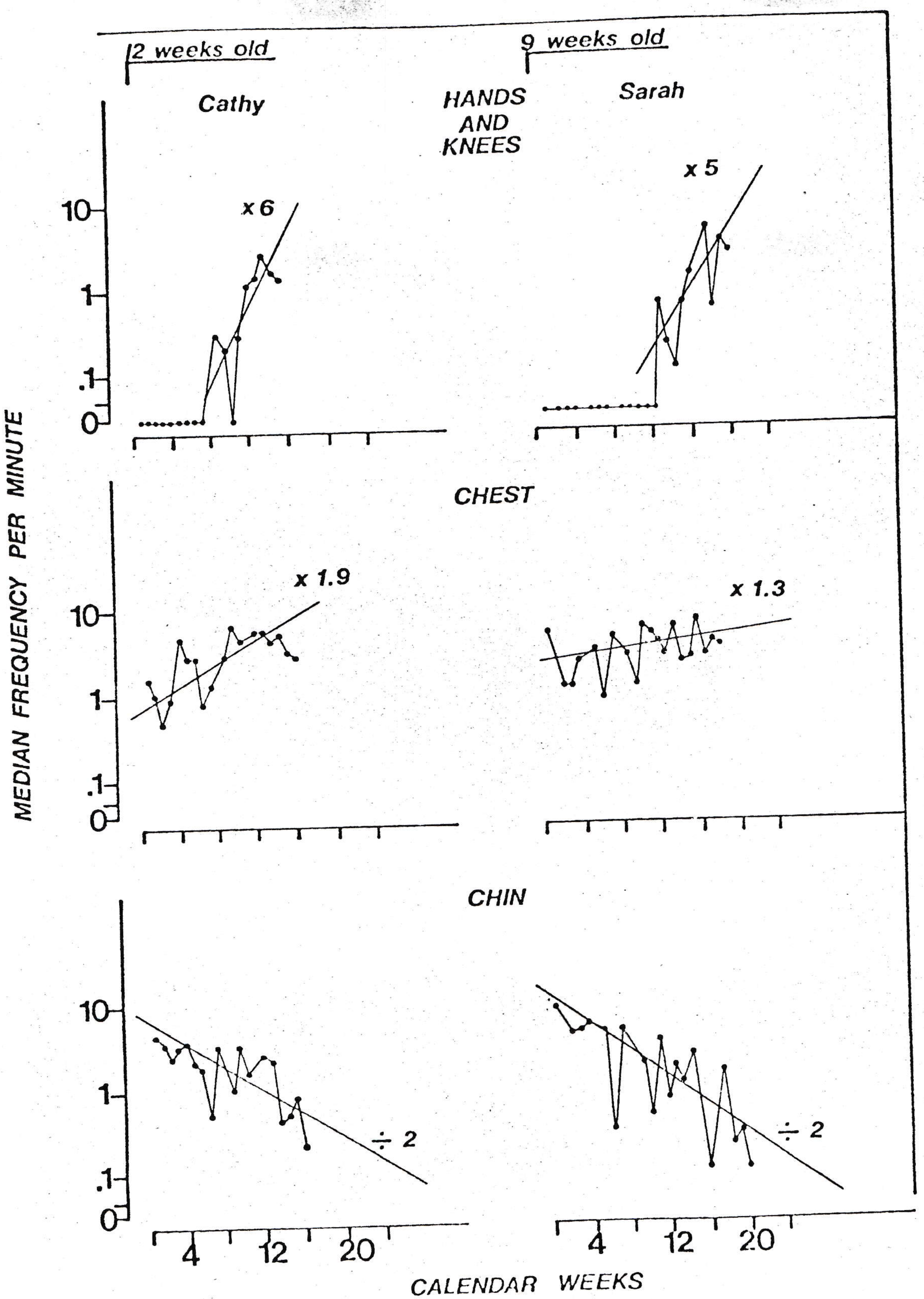
Footnotes

[1]The preparation of this paper and the data collection reported in it were supported by Maternal and Child Health Grant Number 7250 and United States Public Health Service Grant HD - 04756.

Figure Caption

Figure 1. Frequency changes in three prone behaviors.

Figure 1

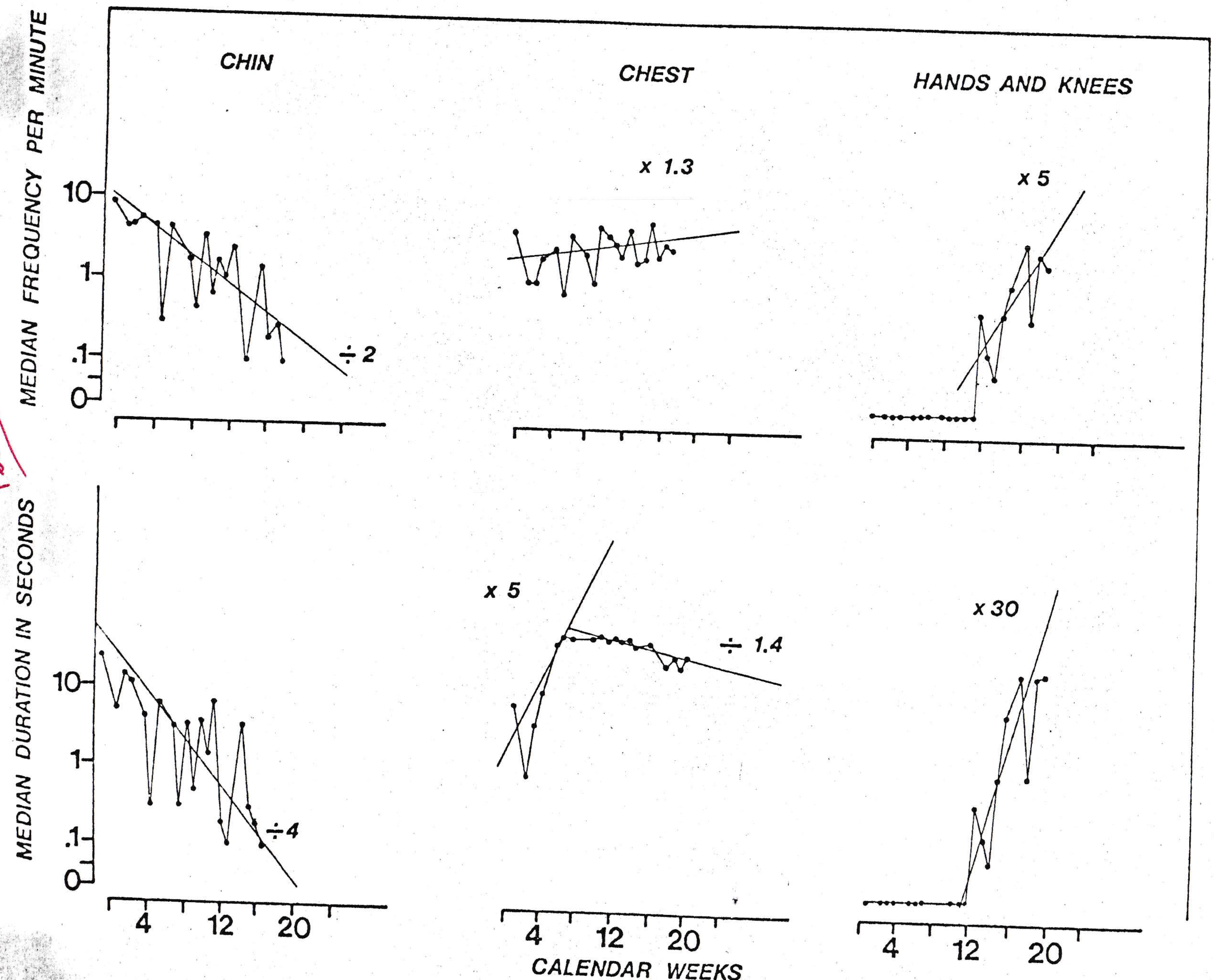


12 weeks old
9 weeks old
Cathy
HANDS AND KNEES
Sarah
x 6
x 5
10
1
.1
0
CHEST
x 1.9
x 1.3
CHIN
÷ 2
÷ 2
MEDIAN FREQUENCY PER MINUTE
4
12
20
CALENDAR WEEKS

Figure Caption

Figure 2. Frequency and duration measures of the development of three behaviors in a single infant.

Figure 2



MEDIAN FREQUENCY PER MINUTE
MEDIAN DURATION IN SECONDS
Per min
CHIN
CHEST
HANDS AND KNEES
10
1
.1
0
x 1.3
x 5
÷ 2
x 5
x 30
÷ 1.4
÷4
4
12
20
CALENDAR WEEKS