Winnicott, D.W. (1951), Transitional objects and transitional phenomena. In: *Collected Papers: Through Paediatrics to Psycho-Analysis.* New York: Basic Books, 1960, pp. 229–242.

——— (1965), *The Maturational Processes and the Facilitating Environment.* New York: International Universities Press.

Wolff, P.H., (1959), Observations on newborn infants. *Psychosom. Med.,* 21:110–118.

——— (1960), The developmental psychologies of Jean Piaget and psychoanalysis. *Psychological Issues,* Monograph 5. New York: International Universities Press.

——— (1963), The early development of smiling. In: *Determinants of Infant Behavior: Vol. 2,* ed. B.M. Foss. New York: Wiley, pp. 113–134.

——— (1965), The development of attention in young infants. In: *New Issues in Infant Development: Annals of the New York Academy of Science,* 118:815–830.

——— (1966), The causes, controls, and organization of behavior in the neonate. *Psychological Issues,* Monograph 17. New York: International Universities Press.

——— (1971), 'Object permanence' and 'Object relations': Observations on the infant's response to animate and inanimate objects. Presented to the Boston Psychoanalytic Society, May 26. (Reported by L. Vachon in *Bull. Phila. Assn. for Psychoanal.,* 22:235–238, 1972).

——— & White, B.L. (1965), Visual pursuit and attention in young infants. *J. Amer. Acad. Child Psychiat.,* 4:473–484.

Yazmajian, R. (1967), Biological aspects of infantile sexuality and the latency period. *Psychoanal. Quart.,* 36:203–229.

In: The Course of Life. Vol. 1. Infancy. Greenspan & Pollock; Eds.

10

Investigation of the Infant and Its Caregiving Environment as a Biological System

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The Research Problem

The purpose of this chapter is to illustrate a research program designed and carried out as a way to study the infant and its caregiving environment together as a living biological system. There are at least three reasons that this account has relevance to this volume. The first is that psychoanalysis, in its current concern with the argument that a "self-psychology within psychoanalysis" (Kohut, 1977) is needed, is turning once again, as it has from its very outset, to both biology and early develop-

The projects reported in this chapter were carried out while the author was Professor of Psychiatry in the Division of Psychiatry at Boston University Medical Center. Project support was provided by funds from U.S.P.H.S. Project #NICHD 01766 (1965–1969). L. Sander, Principal Investigator, G. Stechler, Co-Principal Investigator in collaboration with P. Burns and H. Julia. Funds from the Grant Foundation, New York, supported work from 1972 to 1974 which was carried out in collaboration with W. Condon (Co-Principal Investigator), P. Chappell, P. Snyder, and J. Gould. Supplemental funds were provided by the University Hospital General Research Support Funds, and Dr. Sander was recipient of NIMH Research Scientist Awards, #K5-MH20-505, between the years 1968–1973, 1973–1978. In addition, Dr. Stechler was recipient of NIMH Career Development Award Level II, #5-K2-MH-18. Reports of the data included in the chapter were presented at the International Society for the Study of Behavioral Development Biennial Conference, July 1975, Surrey, England, and at the annual meeting of the American Academy of Child Psychiatry, October 1975, St. Louis, Missouri. G. Van Melle was responsible for analyzing a major portion of the infant crying data for this report.

ment for light on the matter of the ontogeny of behavioral and psychological organization (e.g., Basch, 1977). Psychoanalysis needs the conceptual and empirical perspective which recent advances in biological systems research are opening up.

The second is that research in the area of early development is currently experiencing a transition in emphasis from the classical experimental approach, which aims at isolating variables, reducing sources of variability, and pursuing a linear concept of causality, toward the study of concurrent and interactive effects of multiple variables, mechanisms of integration, and the formulation of nonlinear concepts of causality. Developmental research itself, then, is looking toward biological models and methods of investigating living processes from the holistic, evolutionary, and systems perspectives of biology.

The third is that intense pressure is being exerted upon clinical facilities to intervene actively now at the earliest pre- and postnatal levels in order to accomplish aims of "primary prevention" of developmental deviations when either the infant or the caregiving environment is considered at risk for them. The pressure is for the predictable manipulation of the developmental process. We have but a meager empirical base of prospective data from which the conceptualization of process can be constructed, or the lawfulness of change, plasticity, or the integration of complex determinants in producing a predictable outcome can be well enough understood to guide "prevention."

It is not clear to many what the differences are between traditional research designs and the study of a living system; this includes the kind of questions that can and cannot be addressed by each, or the relationships between variables which are relevant to either. In what follows, then, certain perspectives drawn from the domain of biology will be introduced, an example of mechanisms of regulation in biological systems given, and an account presented of the design, methodology, and findings of a project aimed at operationalizing some of the implications of a biological systems viewpoint (Sander, 1977).

The first of these perspectives drawn from the biologist's observation of the living system is that time and the temporal organization of events constitute a domain of order that cannot be in any way neglected, avoided, minimized, or bypassed. It remains a central reality around which the significance of other phenomena become assembled. Its importance does not come into view unless one is considering the system, the living organism within its environment of life support.

To begin with, then, and at the most general level, the ecological niche of the newborn is one which must provide at least the essential conditions for the proper negotiation of a profound revision after birth in the temporal organization of the infant's various functions (Sander, Chappell, Gould, and Snyder, 1975). Those who have had the joy of caring for a new baby know what can happen in the wee small hours of the morning. Often, at first, more happens then than during the rest of the 24 hours of the day, until, that is, the baby's rhythms of activity and quiescence tune in to, or synchronize with, the day and night differences within his new environment. At first, in addition to being awake when the rest of the world is asleep, the newborn may be falling asleep himself when he is in the midst of eating or crying and hungry when he should be sleeping. He may swallow when he is in the midst of breathing or bite down on a nipple closing it off, when sucking would allow delivery of milk.

On the basis of present investigations of newborn physiology, it is conceivable now to regard the new baby as a composite of semiindependent physiological subsystems, each with its own rhythm, such as those controlling heart rate, respiration, brain waves, and body movement (Luce, 1970). Infants arrive with varying degrees of coherence or phase-synchrony between these component subsystems. Since they affect such activities as waking, sleeping, and feeding, and, under certain conditions, each has the ability to run on its own time track, they must become harmonized and coordinated within the new baby, and in turn, tuned-up with the regular periodicities of the world and of the people who make up the baby's world.

There are many time levels involved. The rhythms involved may be circadian, that is, arranged in relation to an approximately 24-hour cycle of variation; or ultradian, higher frequency rhythms in relation to timespans less than 24 hours; or infradian, lower frequency rhythms over 24 hours (Sollberger, 1965). Periodic behaviors involved in the interaction between infant and caretaker can be explored at the level of seconds and even microseconds (Stern, 1971; Condon and Sander, 1974; Brazelton, Tronick, Adamson, Als, and Weise, 1975). The orchestration of such a complexity is one of the major accomplishments of the postnatal caretaking task. Its aim is to bring the infant to function as a unified organism in coordinated harmony with an ecology based on a 24-hour cycle, arranged in day-night organization, with the day arranged in subunits such as morning, afternoon, and evening. On the background of harmony at this more macroscopic level, caretaker and infant are engaging in exchanges, cycling at a much higher frequency, in seconds or microseconds, etc. But how does one approach the problem of investigating such complex organization and the mechanisms depending on location of events in time?

We started out trying to conceptualize the lawfulness governing longitudinal changes in the transactions between infant and surround postnatally, in terms of the biological concepts of adaptation and the adaptive process (Sander, 1962). The biologist, however, begins at an even more basic level, namely, with the problem of regulation—the regulation of exchange between the organism and its environment of life support. It is at this most basic point that time plays the fundamental role. I am referring here, again, to the matter of biorhythmicity, a subject which represents one whole discipline of biology, which for more than fifty years has been investigating the adaptive process in terms of mechanisms of temporal organization regulating exchanges in different ecological systems.

The Biological System

An illustration can be given by the way time in the biological system provides the basic organizational structure for a life-support framework by providing for the phase synchronization, or for the co-occurrence of essential periodic encounters between the organism and its niche, such encounters being

sparsely distributed, but at precisely the right time (see Figure 1).

In this figure, Enright (1960) illustrates the activity of three batches of synchelidium (amphipods or "sand fleas") collected from three different beaches in Southern California, some 319 in one, 2,100 in another, and 600 in a third. Because of coastal configurations, the time and character of tidal ebb and flood on different beaches vary from one beach to another. The time and configuration of tidal peaks and troughs characteristic for the three beaches from which the samples of amphipods were collected are illustrated in the top line of each of the three sections of Figure 1. It is to be noted that the time between tidal peaks is 14.4 and 11.2 hours for one beach, 16.0 and 9.0 another, etc. The ecology of the amphipod is such that the time for its greatest activity on the beach occurs at the onset of the ebbing tide, estimated for the three populations by the arrow. The meaning of "fitting together," or adaptation, in respect to the organization of the ecological system, is dramatically portrayed by the lower line of the graph for each of the three sections. This represents a count of the numbers of actively swimming amphipods in each sample at a sequence of time points; this line shows peaks of swimming activity in the creatures which correspond to the estimated time of expected peak activity on their respective beaches. However, when being counted, the amphipods now are *not* at the beach at all, but in the laboratory, each group isolated under the same controlled and constant conditions. Regulation of the timing of the recurrent activities essential for its survival from *endogenous* sources within the amphipod adjust it to, or synchronize it with, resources provided by essential recurrent events in its environment being regulated by a separate independent and *exogenous* source of periodicity. The meaning of phase synchrony for the organism as a whole is that of establishing a general *state of readiness* for the encounter. If properly timed, evidently the key exchanges between the interacting components of the system need only be episodic, not continuous.

Much has been learned of the various mechanisms governing phase-control of biorhythms (Aschoff, 1969). Investigators of the role of biological rhythms in different ecological

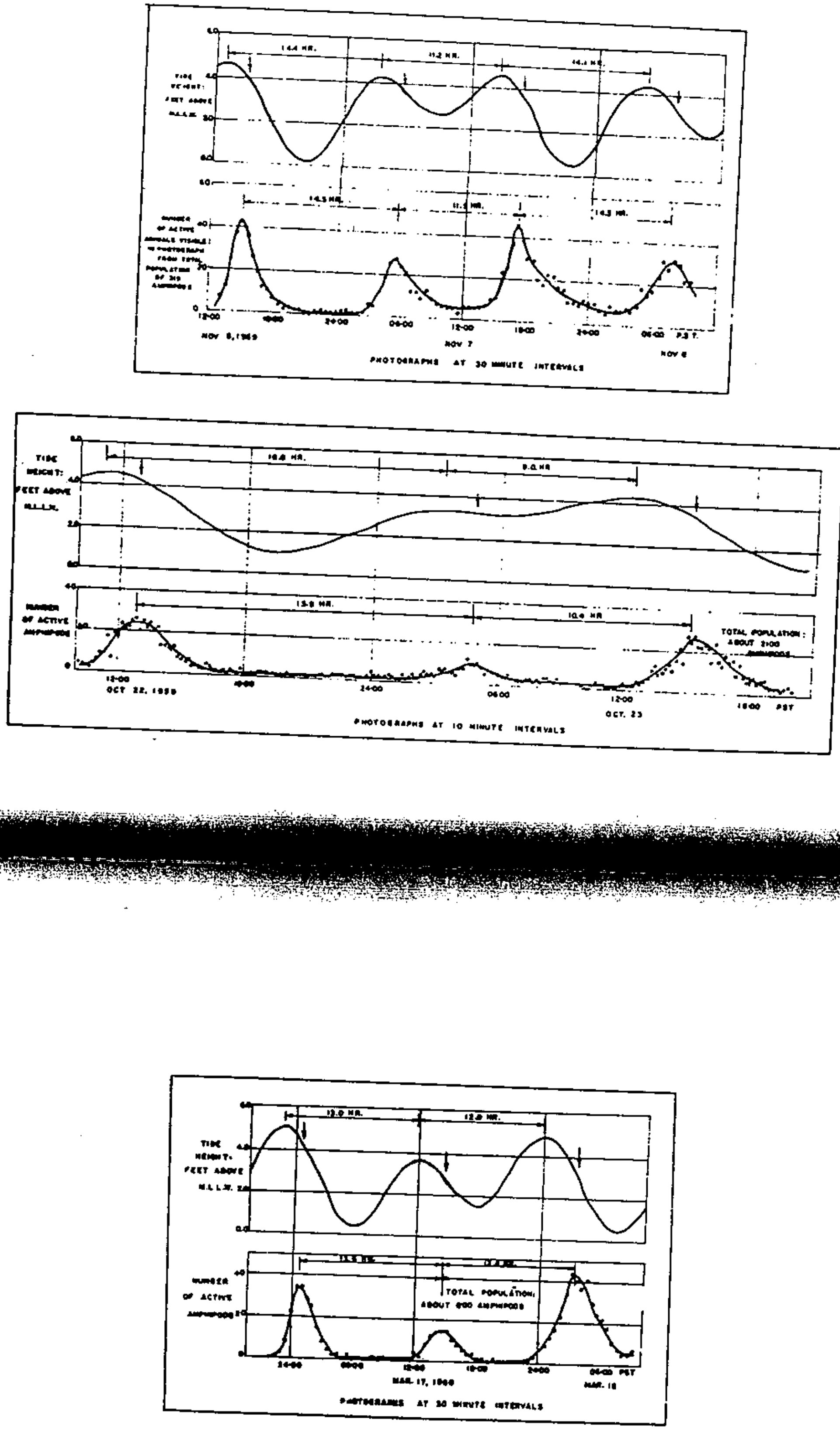

FIGURE 1. Activity rhythms in *Synchelidium* n.sp. isolated in laboratory, compared with tidal movements (U.S.G.S predictions) on beach from which they were collected. Vertical arrows on tide graph indicate position of estimated maximal activity of amphipods. Note that the time scales differ. (Reprinted from Enright, 1960. Copyright 1960, Waverly Press.)

systems suggest that both the processes of adaptation without and of integration within the organism can be resolved as matters of phase-synchronization of interacting components (Halberg, 1960; Pittendrigh, 1961; Aschoff, 1969).

Each infant arrives with a unique set of regulatory characteristics, and each meets a caretaking environment with its own unique regulatory features, two disparately organized entities at the outset, to say the least. The way they finally adjust themselves to exist together around the clock in some reasonable harmony consequently involves exchanges which must also be uniquely configured. But unique configurations become manageable as with the three different beach configurations of Figure 1, at least conceptually, when one focuses on the timing of recurrence of certain specific variables relevant to each of the interacting partners and on the temporal pattern which the timing of such recurrence establishes.

The Infant and Caregiving Environment as a System

The initial strategy of our investigation, then, was to make the unit of observation not the infant alone, or the caretaker as a separate entity, but the two in concurrent action together around the clock. Systems constituted differently in terms of the particular characteristics of infant or of caretaker provide experiments in nature. The strategy of comparing the 24-hour course of events over time in different systems provides clues to mechanisms of regulation. The second step, then, was to devise methods by which we could chart day by day, the values of multiple variables related to the different functions or subsystems mediating between the participants. Variables would be selected which could be given quantitative values and could be continuously recorded or frequently sampled. The third step, finally, was to compare across the infant-caregiving systems at some outcome point the progress in the development of the functions and the sensorimotor subsystems on which the measurements of variables had been recorded. The effect that having a role in the regulation of essential exchanges has on the developmental process of infant functions provides further

clues as to *mechanism* and *process*, especially if such infant functions can be assessed in terms of the specific way they contribute to regulation of the system. This can be carried out, for example, by perturbing the system and charting the course of recovery of variables related to particular subsystems (Cassel and Sander, 1975).

A combination of methods therefore is necessary in order to study the organization of events in the infant-caretaker system and the changes in this organization over the first days and weeks of postnatal life. The scope of the chapter does not permit more than the briefest description of the methods we have used and the three major categories of variables which have been combined to describe the temporal organization of events in the postnatal infant-caregiver system over the first weeks of life.

Methods

It was while working with a stabilimeter to measure the motor activity of the newborn, which we first had constructed in 1958, that the idea emerged of using the infant's bassinet itself to monitor, continuously, automatically, and around the clock, the timing of events in the infant and the way they matched the clock time of occurrence of activities and interventions of the caretaker. It was important that this bassinet be exactly like any infant's ordinary bassinet, both for the mother and for the infant, so that their developing interaction would not be disturbed—no wires on the baby, no special maneuvers by the mother.[1] The present model, almost indistinguishable from an ordinary nursery bassinet, provides unattended a continuous record on a real-time basis, around the clock and day

[1] Over the years the ideas and efforts of a number of engineers and researchers have contributed to the present monitoring bassinet model, especially those of Dr. Don Jackson of Williamson Developmental Co.; Dr. Gerald Stechler, now chairman of the Department of Child Psychiatry, Boston University School of Medicine; Mr. Richard Burwen of Burwen Labs; Dr. Herbert Teager, Director of Biomedical Engineering at Boston University Medical Center; Dr. Jeffrey Gould, Director of the Department of Newborn Medicine at Boston City Hospital; and Mr. Paul Miller of the Department of Neuropsychology, Boston University School of Medicine.

after day, of seven different states[2] of sleep or wakefulness in the infant, its crying, its respirations, its activity, the time when it is removed from and when it is returned to its bassinet, and the presence of its caretaker at the side of the bassinet.

This first set of variables provided by the monitor record was combined for analysis with sets of infant, caretaker, and interactional behavioral variables that had been obtained by event-recorded observations[3] during a feeding or over the entire course of an awake period from transition to awake until the onset of the first subsequent non-REM substage of sleep. These measures were chiefly those of frequency, duration, and sequence, with a rough intensity scale for certain of the variables. In one project, event-recorded observations of feeding interaction were carried out daily for the first month of life and twice weekly over the second month.

A third category of variables was measured by a third set of methods to obtain repeated assessments of specific sensorimotor functions of the infant. These involved: infant behaviors upon presentation of visual stimuli, especially that of the human face (Stechler, Sander, Burns, and Julia, 1973); the use of specific perturbations to the ecological system by altering important visual configurations, such as by masking the mother's face during a feeding (Cassel and Sander, 1975); sucking behavior (Burns, Sander, Stechler, and Julia, 1972); crying behavior (Van Melle, Sander, Stechler, Julia, and Burns, 1973). In more recent independent research by Boston University investigators, substitution of a strange feeder (Chappell and Sander, 1978) and

[2] The research team has accomplished the computer interfacing of the monitor output, giving high agreement between sleep-state distributions obtained by the analysis of monitoring data using computer-state recognition programs and the scoring of concurrent 5-parameter sleep polygraphy (Sander, Gould, Snyder, Lee, Teager, and Burmen, 1976).

[3] Event recording methods were begun by the Boston University group in 1965 by Padraic Burns, M.D., using a Rustrak 4-key event recorder (Burns et al., 1972). The present method has been developed by Dr. Patricia Chappell from her original infant-mother interactional variables and her recording method using a 15-second epoch (Boismier, Chappell, and Meier, 1970). Dr. Chappell's present method utilizes a 60-key computer interfaced keyboard recorder based on the White Recording and Transcription System (White, 1970) as modified by Mr. Paul Miller at Boston University, now of Sunrise Systems, Inc. (Chappell and Sander, 1978).

acoustic stimulation, especially that of the human voice (Condon and Sander, 1974) have been used to further examine avenues of adaptive exchange. It should be self-evident that continuous monitoring entails the generation of huge amounts of data. Upon the heels of the problem of developing relatively nonintrusive methods to obtain such data came the problem of developing procedures and programs to reduce and analyze them, while hard upon the heels of that problem came the problem of display and communication of the data.

Thus far in the chapter certain points have been made: (1) about regarding infant and caretaking environment, taken together, as an interactive regulative ecological system; (2) about the charting of changes over time in the organization of events within the system; (3) about individual uniqueness of the interacting partners who constitute different infant-environment systems (the unique organization of the individual requires unique exchange patterns by which the partners can achieve adapted coordination and maintain mutual regulation); (4) about the specificity of events and exchanges that bond the partners so regulated; (5) about a connection between the role of specific infant functions in the early regulation of exchanges with the caregiver, their course of development, and their adaptive employment at later points in development.

The following examples illustrate the way these points have been operationalized in study of the infant-caregiver system and are not intended as a comprehensive review of the project findings.

Research Findings

Figure 2 provides an illustration of the relationships that come to light as simple variables from infant and caregiver are recorded continuously, around the clock in real time, and are charted for visual display (Sander, 1969). The infant variables were occurrence of crying and of movement; the caregiver variable was removal and return of infant to bassinet. Such simple variables, continuously and automatically recorded, provide an observational window on a two-partner system, illustrating the

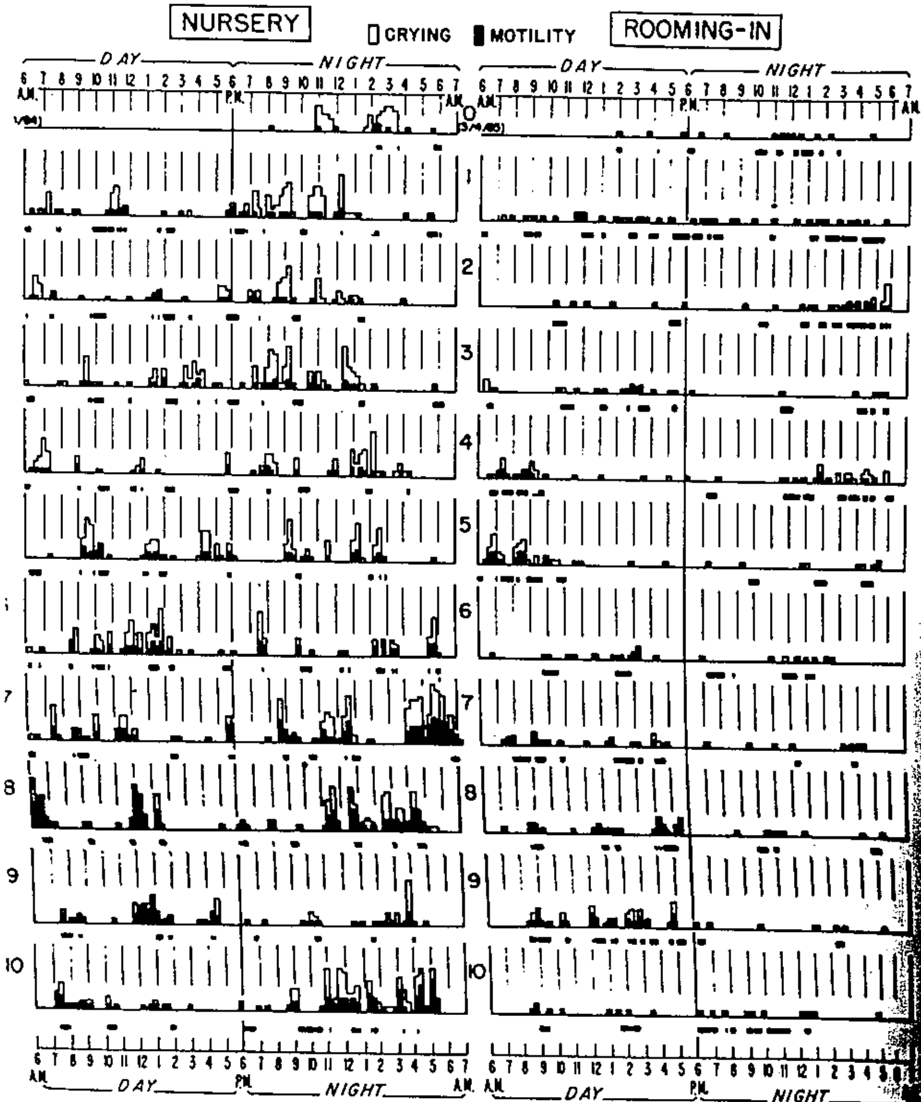

FIGURE 2. Relative frequency, duration, and distribution of motility, crying, and caretaking blips as measured by bassinet monitor for a nursery and a rooming-in baby over the first 10 days of life. Caretaker interventions for each baby and for each day of life are represented by black marks directly below solid lines indicating days of life. (Reprinted from Sander and Julia, 1966. Copyright 1966, American Psychosomatic Society.)

way change over days can be displayed and indicating those features of the adaptive process which distinguish differently constituted systems.

The data were obtained over the first 10 days of life from two ecological systems: an infant boarded in a general hospital newborn nursery, on 4-hourly scheduled feedings given by many different nurse caretakers on frequently changing duty hours; and an infant roomed in on the maternity floor with its own experienced (multiparous) mother providing complete care and breast feeding on an infant-demand regimen. The legend identifies the data displayed. The display shows (a) the gross asynchrony in the nursery in timing between the recurrent caretaking interventions and the recurrent episodes of activity in the infant; (b) the persistence in the nursery of a high degree of activity and crying over the entire 10 days, with the greatest portion of activity and crying produced per 24 hours remaining in the 12 night hours; and (c) in contrast, the baby rooming in with single caretaker showing far less total activity and crying. There is an evenly distributed amount of activity all through Day 2, with a great many frequently repeated responses by the mother. By Day 3, for the rooming-in pair, there is already synchrony emerging between episodes of activity in the infant and episodes of caretaking events, between which there are long periods of no exchange. Not only is there coordination of caretaker with infant at the onset of an infant activity span, but a correspondence of activity of the mother over the total duration of the infant's activity span. Then, between Days 4 and 6, for this pair the 24-hour distribution shifts so that the greatest amount of the activity and crying of the infant begins to settle in the 12 day hours, with long sleep periods and only rare exchange at night.

The essential points presented in Figure 2 have been confirmed in larger samples of normal infants reared in the neonatal nursery and in samples of normal infants roomed in with a single caretaker, receiving a demand feeding regimen (Sander, Julia, Stechler, and Burns, 1972; Sander and Julia, 1966). In the latter group, those receiving infant-demand feeding, predictable organization of the 24-hour day begins during the first 10 days of life. The shift of the major occurrence of motility and crying from night to day hours occurs for the sample between the fourth and sixth day. By 10 days of life the major part of the longest sleep period each day has settled within the 12 night hours.

By contrast, for samples of normal infants boarded in the newborn nursery for 10 days, circadian rhythmicity does not begin at all during the first 10-day period. Activity and crying remain greatest during the 12 night hours, as in Figure 2. On Day 11 we have transferred the infants of such a sample, one by one, to the individual care of a single foster caretaker who roomed in with them around the clock as sole caretaker. The caregiving response shifts at this point from a clock-scheduled timetable to interventions contingent to the infant's change of state, i.e., the individual caregiver provides a demand feeding regimen.

Within 24 hours the motility and crying output of the infants dramatically reverse their day/night distribution and assume the normal pattern. Persistent effects of these very stressful first 10 days in the 4-hourly scheduled nursery on circadian rhythmicity are seen when such infants are kept with the single rooming-in foster surrogate mother over the next 2 weeks while being monitored. During this subsequent 2-week period, a precocious advance in day/night differentiation takes place, which during the same days of life significantly exceeds that of the infant rooming in with single caretaker from birth. Furthermore, there are clear differences between male and female infants in this effect, the female infants responding to the stress with a significantly more advanced degree of day/night difference. Infant effects, caretaking effects, and age-in-days-of-life effects thus interact in producing the different courses which differently constituted systems reveal when we can chart them day by day.

Figure 3 illustrates the day-by-day distribution over the first month of life of the total duration per 24 hours of awake-active states, plotted here in terms of 3-day means for 30 infants. What we see is a daily duration of awake-active states over the first 3 days of life which is not reached again until the end of the first month. This effect is independent of caretaking regimen. The same curve is obtained whether the infants are

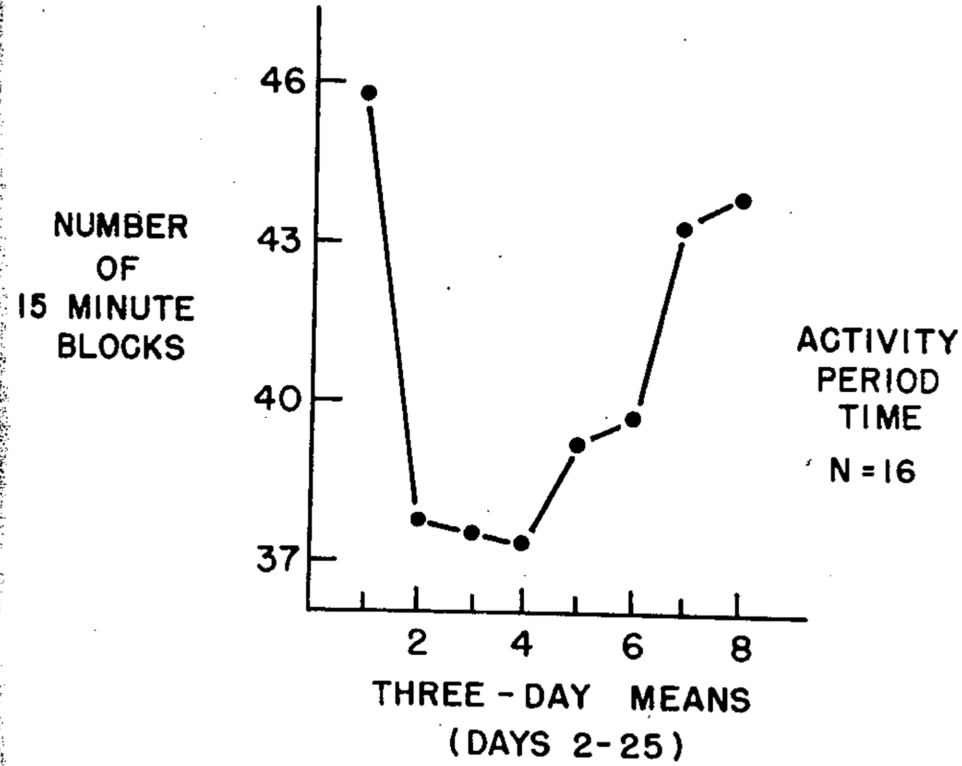

FIGURE 3. Awake-active states per 24 hours. Each point represents a mean for 3 days of number of 15-minute segments of the 24-hour record, which are characterized by activity increase above sleep level or crying or removal from bassinet by caretaker. N = 16 babies, 8 cared for in nursery, and 8 in rooming-in condition. Quadratic F = 27.85; df = 1/84; Cubic F = 7.37; df = 1/84; Linear F = 1.464; df = 1/84. (Reprinted from Sander et al., 1972).

boarded in the nursery or cared for by a single caretaker in the rooming-in situation. This phenomenon of increased duration of awake states in the first 3 days of life we have interpreted to be a result of disruption of the temporal organization of infant physiology which, up until the time of birth, had depended on the 24-hour fluctuations of maternal factors responsible for maintaining the fetal temporal framework. The longer duration of states of relative arousal over the first 3 days serves nevertheless to provide necessary conditions for increased frequency and duration of exchange with the caregiver and an increased frequency of trials through which the two can achieve adapted coordinations. Through these exchanges, new entraining cues that recur in the interaction at specific points in the caregiving sequence can reestablish a new postnatal temporal organization of the 24-hour day (as we saw for Day 2 in the rooming-in baby illustrated in Figure 2). When one couples the finding of greater 24-hour arousal over the first 3 days of life with the evidence that in the rooming-in, demand-fed infant appropriate day/night distributions of sleep and awake states begin between Days 4 and 6, one is faced with the possibility that something essential is jelling during those first 3 days regarding the organization of circadian rhythmicity. Further evidence that these first 3 days of heightened arousal may have a different significance than the ensuing days is provided by the crying record of the nursery-reared group. Although in the nursery there is no change in caregiving regimen, the high level of total 24-hour crying of the first 3 days falls strikingly in this group after the third day. By the end of the first week of life, the clock-scheduled, nursery-reared infant appears to conserve energy. Instead of crying until something happens—an effort early in the week that may go on uninterrupted for 1–2 hours if there is no caregiving response—by the end of the week there is a burst of crying, then a pause during which a drowsy appearance may be present, then another arousal and outburst of vigorous crying and a subsequent pause. We have seen this go on over and over, then, for as long as 2 hours or until the nurse intervenes. Such behavior often can be observed in the night hours, when the nursing staff is reduced and long de-

in response to crying are unavoidable, as was pointed out by Aldrich, Sung, and Knop (1945).

Wide differences between nursery and rooming-in groups in motility and/or crying output were shown by infants under these different postnatal caretaking circumstances, as demonstrated by the 24-hour monitoring method (Figure 4).

On the other hand, wide individual infant differences were demonstrated between infants under the same caregiving regimen. Figure 5 shows the length of each sleep period over the first month of life plotted in sequence as it occurred for two infants receiving the same caregiving regimen over the first month of life, namely individual fostering in the rooming-in (demand-fed) situation.

The gradual postnatal appearance of circadian rhythmicity is illustrated for one infant in Figure 6. Here the data were cast in terms of minutes of sleep per hour. One-hour, lagged, autocorrelations were performed for a 210-hour span (second to tenth day) and a consecutive 240-hour (eleventh to twentieth day). The ultradian rhythm which appears clearly in the first 210-hour analysis is replaced by a major 24-hour rhythm in the subsequent 240-hour analysis. It has not been generally recognized that 24-hour sleep-awake organization begins to occur between Days 4 and 6 under optimal circumstances, nor that circadian rhythmicity can be established in the second week of life.

Continuous sleep state data also reveal individual differences related to the rate of achieving circadian rhythmicity. In Figure 7 are shown the autocorrelations obtained over Days 11–20 of life for two infants, both having had the nursery experience of care over the first 10 days, and both having had the same caretaking regimen of individual surrogate mother rooming in over the second 10 days. The first subject is a male and the second a female. The individual difference seen here are consistent with the differences between males and females which we found in comparing males and females for extent of day/night difference in sleep occurrence during the second 2 weeks of life. The effect of the stressful initial 10-day, nursery experience seems to *advance* precociously the rate of organization of the 24 hours for females so they sleep significantly

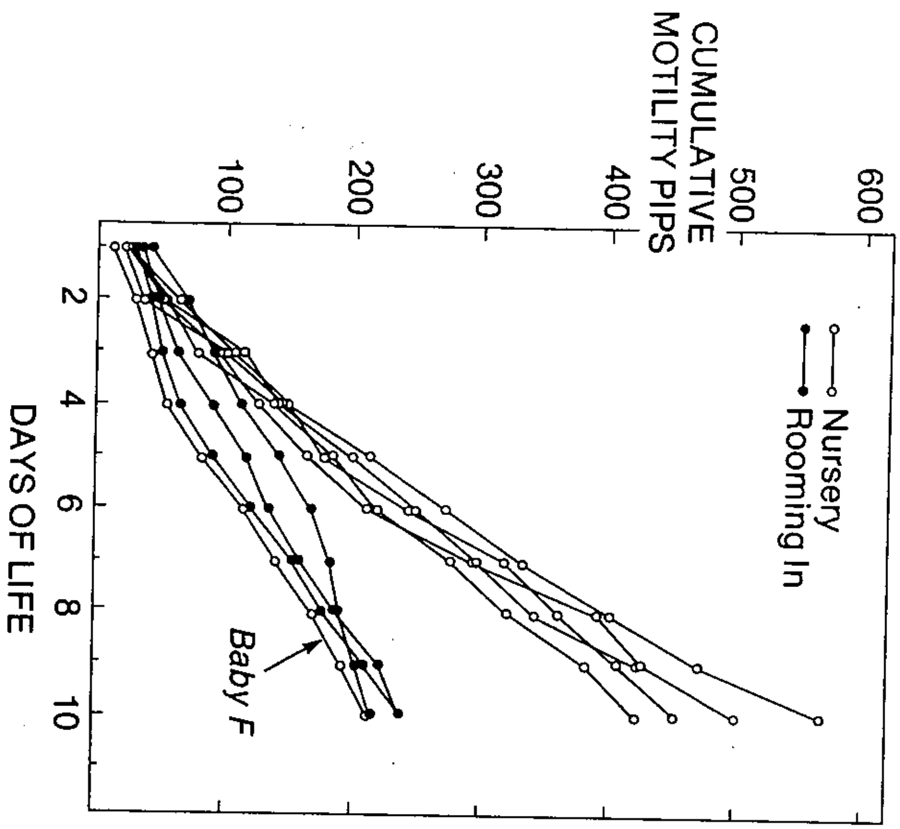

FIGURE 4: Cumulative graph of motility blips (24-hour totals) recorded by monitoring bassinet for 6 nursery and 3 rooming-in infants over the first 10 days of life. By Day 4, the two populations have diverged in activity generated, except for Baby F, who belonged to the sample boarded in the neonatal nursery. (Reprinted from Sander and Julia, 1966. Copyright 1966, American Psychosomatic Society.)

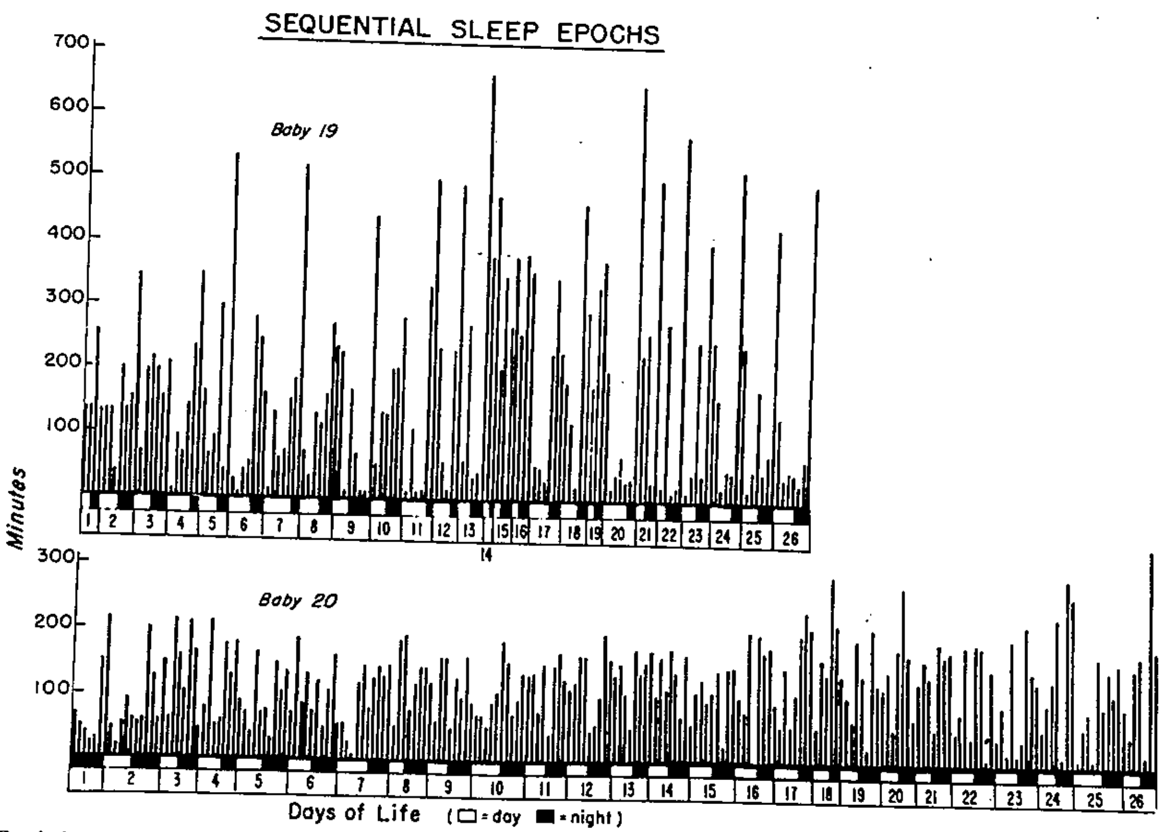

FIGURE 5. Real-time durations of all sleep periods plotted in actual sequence over the first 29 days of life for two infants. Black sections represent hours between 6 p.m. and 6 a.m. each day. (Reprinted from Sander, 1975. Copyright 1975, Plenum Publishing Corp.)

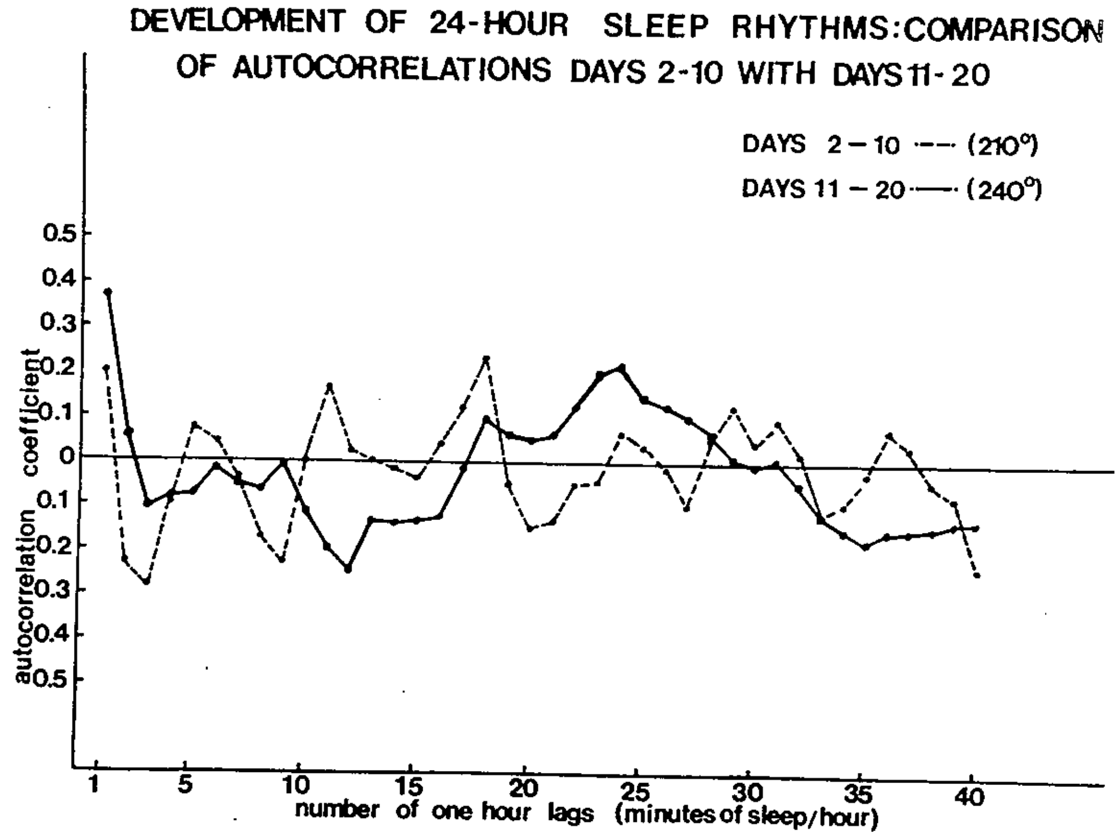

FIGURE 6. One-hour, lagged, autocorrelations of minutes of sleep per hour for sleep, Days 2–10 (210 hours) and Days 10–20 (240 hours) for infant rooming in with single surrogate foster mother.

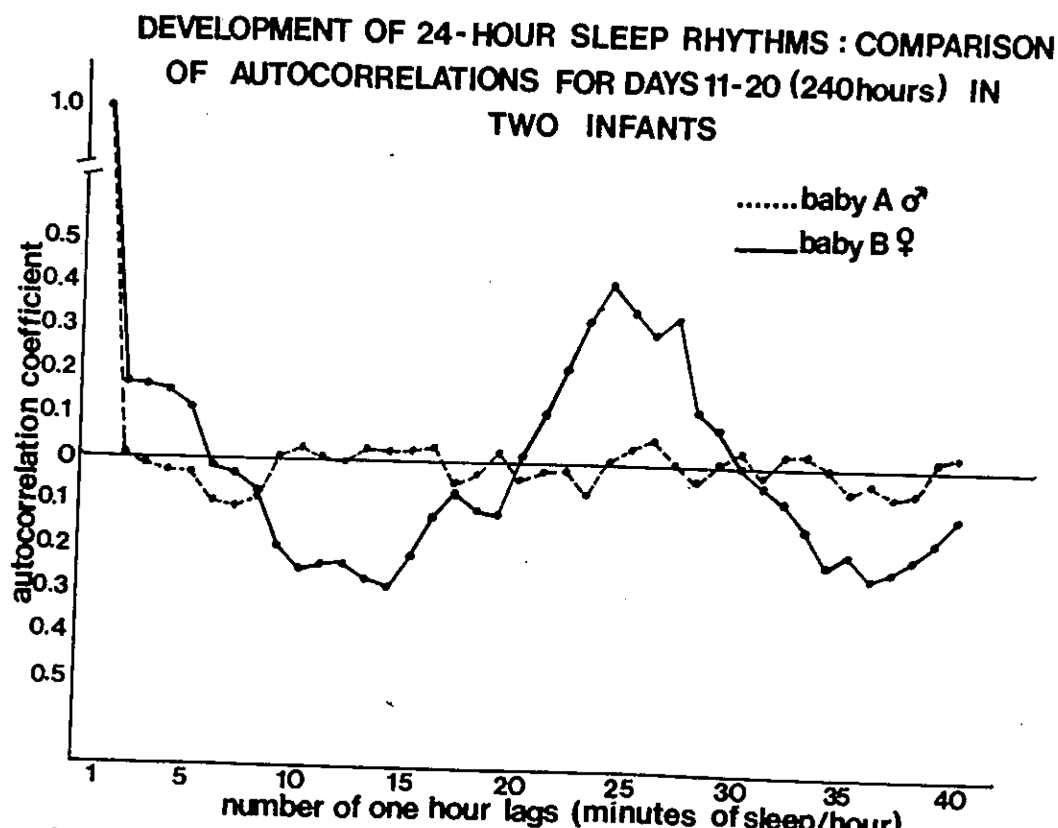

FIGURE 7. One-hour, lagged, autocorrelations of minutes of sleep per hour, over Days 10–20 (240 hours) on two babies, (a) male

more at night and less in the day. The same 10-day nursery experience appears to *retard* the rate of day/night organization during the second 2 weeks of life for the males, who are also receiving the same caregiving regimen as the females during the second 2 weeks, i.e., an individual surrogate mother rooming in (Sander, et al., 1972).

Comparison by Julia (Sander, Stechler, Julia, and Burns, 1970) of autocorrelations calculated over 240 hours during the second 10 days of life, obtained from infants individually fostered in the first 10 days (n = 8) with those boarded in the newborn nursery in the first 10 days (n = 8), indicates that while the former show their circadian peak of sleep occurrence at precisely 24 hours, the latter group shows a wider range of deviations from a 24-hour peak in a significant number of the sample, i.e., peaks at 23 to 25 or 26 hours.

In the differentiation of a longest sleep period per 24 hours, individual differences in 24-hour organization between infants receiving the *same* caregiving regimen can be demonstrated, as well as the group differences in 24-hour organization between *groups* of infants receiving *different* caregiving regimens. In Figure 5, the first baby, Baby 19, shows the presence of an excellent differentiation almost from the outset. There is a clear longest-sleep period per day with a number of clearly shorter periods. After Day 3 the occurrence of the longest-sleep period per 24 hours becomes consistently located in the night segment. This was a responsive, well-organized baby, easy to care for. The second infant, Baby 20, by contrast, though also meeting our rather stringent criteria for normality, and cared for under the same individual demand feeding caregiving, produced a record which showed many more sleep periods of briefer duration, and little differentiation of sleep-period length. It was difficult to identify one clear longest-sleep period per 24 hours. Period-length differentiation appeared only toward the end of the first month, and the stable occurrence of the longest-sleep period per 24 hours within the 12 night hours was only getting under way on the tenth day of life. This infant was reported by both the foster mothers to be the most difficult to care for of all the infants of the sample.

We found, for the babies, n = 27, of this project (three

samples differently constituted as to caretaking system, of 9 infants each) that there was a significant positive correlation between length of longest-sleep period per 24 hours and length of longest-awake period per 24 hours, a "period-length" factor, if you will (as Figure 5 suggests).

There was also an interaction of length of longest-sleep and longest-awake period per 24 hours with the effect of the individual caretaker. Over Days 11–25 of this study, with each nurse fostering 8 babies, we found evidence that one of the two foster nurses produced infants with significantly longer longest-sleep and longest-awake periods per 24 hours than did the other. For any given infant-caretaker ecological system, interactions between infant determinants and caretaking determinants set the stage for individual uniqueness of their exchange patterns.

As one looks more closely at infant differences in sleep and awake behavior, it is evident that the way babies wake up and go to sleep is quite different. For some, crying begins during the last REM period and increases steadily to imperative levels; the last thing to occur in the awakening sequence for such infants may be the opening of the eyes. In other instances, the infant, with but very little increase of movement over that of his last REM period, may open his eyes and lie relatively quiet for 10-15 minutes, until finally the first whimper will be produced.

In addition to the many obvious, as well as subtle, differences between our two principal foster nurses, with which we became familiar in detail, there were striking differences in style of caretaking by our natural mothers also (Group C). Each of these had had experience with at least one previous baby of her own and had developed a measure of confidence in her own way of doing things. For example, one such mother's dictum, apparently handed down from her mother, was that she would not pick up her baby until the infant had cried for five minutes. Our records showed a crying curve for this pair which was just an order of magnitude above that of the other natural mother pairs. However, everything otherwise went well. Another mother, who tended to keep the bassinet with her in the room in which she was working, would respond at the very first sign of arousal, scarcely ever allowing her infant more than a whimper before she responded. We were hard put to locate the few scattered single crying blips that were accumulated on that record.

Time does not permit a review of the data from which we have studied the matter of *specificity* of the synchronization or bonding between the individual infant and the individual caretaker. We have done this by rearing infants with one experienced foster mother rooming with the infant 24 hours a day from birth and then on the eleventh day changing to another experienced foster mother. The change is marked by significant increases in the occurrence of distress events during feeding and in 24-hour crying over hours and days subsequent to the change (Van Melle et al., 1973). Another way of studying specificity by event-recorded interactional observations is to change caretakers for a single feed on Day 7, when only one individual has done all the feeding up to that point; still another is to mask the familiar caretaker during a feeding on Day 7, comparing infant behaviors and state distributions during the awake period, including latency to first non-REM sleep period, with values obtained on Day 6 and before (Cassel and Sander, 1975).

Finally, the repeated assessment of the developmental course of key sensorimotor functions that are involved in transacting the regulatory exchanges between the partners in differently constituted infant caregiving systems indicates important relationships to be understood. We have carried out repeated assessments twice weekly over the first 2 months of life of a variety of infant behaviors related to the visual system, when the infant is presented with the human or drawn face under systematically different stimulus conditions of presentation. These have included "looking" and "looking away" time, peripheral gaze, motility, crying, etc. (Stechler et al., 1973). The course is quite strikingly different in the three different caregiving systems over the first 2 months of life, significant differences appearing, for example, in total looking time and crying during stimulus presentation (Stechler et al., 1973; Sander, Stechler, Burns, and Lee, 1979). It is our conviction that in spite of the more careful individual fostering after the tenth day of life, the effects of those first 10 stressful days of

being boarded in the newborn nursery persist over the rest of the first 2 months of life and influence the integration of sensorimotor functions in state and interactional regulation.

Summary

In summary, then, the study of infant and caregiver as an interactive regulative system by continuous monitoring and methods of repeated measurement on infant and caregiver variables centers our attention on the temporal organization of events. We have indicated the following.

1. Birth is a point of profound rupture in mechanisms of temporal organization in the fetal-maternal system.

2. The ecological niche of the newborn must provide for a reestablishment of this temporal organization postnatally in terms of a framework of new exchanges between neonate and environment which constitute the initial processes of regulation and adaptation and represent interactions of infant, caretaker, and age-in-days-of-life determinants.

3. The first 3 days may be a crucial span of time in which the interaction of events responsible for optimal 24-hour temporal organization is established. Events such as the recurrence of maternal entraining cues in consistent relation to state changes in the infant provide the necessary conditions for the array of biorhythms that characterize both the infant and its caregiving environment to gain the organization that will ensure their role in the regulation of the system.

4. Individual infant differences in periodicities and rates of change over the first days of life, interacting with individual differences in caretaking configurations, eventuate in specific patterns of 24-hour exchange between the two. Mechanisms of bonding are based on the way specificity of regulation is established and maintained in the system. Much of this specificity depends on time and the timing relationships between events in critical recurring caregiving situations.

5. This specificity of regulatory fittedness between a particular infant and a particular caregiver can reach an appreciable degree by the tenth day of life.

6. The later adaptive employment of sensorimotor functions upon which the establishment of regulatory coordination in the system has depended is influenced by this earlier role which they have played in establishing that regulation.

Discussion

The material that has been presented of an investigation of the infant and its caregiving environment together as a biological system illustrates the perspective that such an approach provides, directing attention to mechanisms and processes of change in the organization of events in the system, as one goes from fetal to postnatal life. Fundamental to this perspective is the role of time and the central place of temporal organization as a first level in the construction of the behavioral framework of interaction between the participants making up the system. The central role of biorhythmicity in the achievement and maintenance of coherence in the living system cannot be underestimated. Biorhythmicity requires a consideration of 24-hour, around-the-clock time as well as the time structure of events in briefer durations. Events between infant and caregiver assume importance in terms of the exactness of their synchrony, of the temporal characteristics of their phase relationships, and of their characteristics of asynchrony. There is a *background* in the low frequency rhythms (e.g., states of sleep and awake or activity and quiescence) that is necessary for the analysis of characteristics of interaction between the higher frequency rhythms that make up the *foreground* of the interaction (e.g., sucking, linguistic-kinesic, gaze and gaze-aversion rhythms, etc.) Time requires a holistic perspective of different levels in the system as well as providing the framework for studying the precise individual specificity of the process of "fitting together" by which adapted interaction in a given *moment* of time is achieved. The process of fitting together effects connection or bonding between the unique dispositions and behavioral configurations of partners that have behavioral organizations that are highly disparate, i.e., the newborn infant and its caregiver.

The methodological and analytic requirements for the investigation of change in the organization of living systems during the lifespan differ from the more traditional experimental paradigm; the questions one asks are different; the route of discovery is different. For example, from the visual display of continuous and repeated measures, points of change come into focus or the relationships between interacting variables change, differences in rates of change appear, or the "history dependence" of the system becomes evident.

In other publications (Sander et al., 1979) based on the same biological systems perspective, data have been presented as illustration of the way particular sensorimotor systems of the infant (e.g., the visual system) become integrated over the first 2 months of life in relation to their role in the achievement and maintenance of initial regulation. Visual behavior plays an important role in the regulation of the initial feeding interaction, and the feeding interaction is in turn directly related to the regulation of states in the sleep/wake continuum. In other words, the infant's employment of specific sensorimotor systems becomes shaped by the contribution such systems make to more basic state regulation as an around-the-clock adaptive requirement for infant and caregiver. This viewpoint suggests that the "ordering function" proposed by Basch (1975), as being a function central to the ontogeny of self, is itself determined by an interactional ontogeny integrating basic biological processes in a specific adaptive context. The infant's active organization of his world involves the inseparable nature of the endogenously active biological processes which underly our conceptual domains of regulation, adaptation, integration, and organization.

In still other publications (Sander, 1962, 1964, 1969, 1975; Sander et al., 1975), the changing organization of events and interactions over the first 3 years of life in the infant-caregiver system has been described as a sequence of levels of fitting together between infant and caregiver. These extend from a beginning level of coordination concerned with biological issues, such as those related to regulation of states of sleep and waking and the basic functions of feeding, motility, etc., to the levels of adaptation concerned with fitting together between toddler and caregiver on the basis of correct inferences of intentions, goals, feelings, words, and expressions. Each new task of "fitting together" is ushered in by new activities or capabilities that the infant can begin to introduce into the interaction with its caregiver. The preservation of an active role for the infant in the adaptive sequence is the basis for the establishing and maintenance of the infant's or toddler's "sense of agency" (Lewis, 1977) in actively organizing his adaptive repertory. Such an active role is essential in the widening achievement of effectance in self-regulation. Self-regulatory capability becomes crucial as the complexity of adaptation increases over the second and third years of life. Such increasing complexity calls into play additional newly emerging mechanisms of integration as a means of maintaining the coherence of the individual in his unique adaptive situation. These integrative mechanisms must involve the development of a language and of symbolic representations that have gained common usefulness both to the individual and his caregivers; they must involve also a certain awareness of one's own state, dispositions, intentions, and thought content.

This epigenetic sequence of issues of adaptive coordination constructs an ontogeny of self-regulation, each issue for the infant relating specific caregiving contexts to his own individual adaptive content, and depends on additional increasingly differentiated and, for the infant, newly employed mechanisms of integration. The negotiation of the sequence of issues provides the basis for proposing that the ontogeny of self-regulation is paralleled by an ontogeny of awareness and self-awareness. The latter are functions which increasingly enter the construction of the repertory of adaptive strategies by which infant and caregiver become coordinated, especially in the second and third years of the child's life. From the adaptive perspective, consciousness (or awareness) is not a generally uniform or unitary state, the same for everyone, but involves an individual organization of state and content of awareness in terms of the moment-by-moment configuration of the ongoing process of that individual's adaptive encounter. Here, the static imagery of structures is not adequate to capture the conceptualization of temporally organized process. The necessary conditions for the ontogenetic progression of self-awareness as a mechanism of self-regulation depends, then, on the

capacity for changing organization of events and processes *in the system* and not only on the potential of the individual infant.

Obviously, the later steps in the establishing of this sequence of adaptive coordinations, which now involve "secondary process" functions such as representations and their recognition, require a partner also capable of specificity of fittedness in these more subtle levels. Prior to this level of adaptation during the *second* 18 months of life in the infant-mother system there has been the foundation of a long history of regulatory achievements that have been gained by the partners over the *first* 18 months. These coordinations now provide a mutually experienced context in which the "meaning" of each other's behavior is already clear for the most part. This context of mutual familiarity provides the necessary condition to set the stage for precision of fitting together on these next, more subtle levels of thought and inner perception that involve the "reading" of intentionality, feeling states, emotional expression, etc. It is the correct reading of intentionality that is critical for the preservation of initial trust during negotiation of the later issues. Correct and specific recognition by the "significant other" during the second 18 months may be a necessary requirement for a consolidation of the experience of self-recognition and for the establishment of the function of self-recognition in further adaptation. Validation of the toddler's perception of his own state and inner content by the partner's act of recognition is essential for the toddler to learn to depend on his own inner perception to guide his continuing active organizing of his widening repertory of adaptive strategies. Conversely, at this chronological point in development, the invalidation of his own inner percepts in the adaptive encounter requires him to turn to alternative "defenses"—inhibition, compliance, etc. A new level of recognition in the second 18 months of life involving the coordination of mutual awareness, then, is a system achievement, an "emergent property" of the whole, setting the stage for an integration greater than the part properties of either of the partners alone. It is a matching or meeting by which the system comes to be regulated at the level of the spirit, so to speak, a regulation that provides "states" in the system necessary for the successful inclusion of subsequent, even more subtle mechanisms such as those of long-term goals, identifications, values, etc.

There are other conditions as well that are provided by the state of organization in the system. These constitute necessary contextual elements for the progression of changes in organization that mark the ontogeny of self-regulation. Here I am referring not only to the maintenance in the system, as a system's characteristic, of the infant's role as "agent" in organizing his world, but the construction of the "intermediate area" as formulated by Winnicott (1951). From the systems perspective, the context for "the intermediate area" is that of the mother "holding the situation in time"—a condition that allows the infant to experience inner and outer percepts at the same moment in time without his option for the initiation of activity in the service of integrating the inner and outer domains being threatened or preempted by demands for regulation. The "intermediate area" can be viewed as an "emergency property" of the system, an "open space" in regulatory exchanges when these are considered in terms of their temporal organization. The formulation of the "open space" in the postnatal infant-caregiver system has been discussed in more detail elsewhere (Sander, 1977). It is mentioned here only to illustrate the alternative conceptualizations, offered by the systems perspective, from which to consider conditions necessary for change in organization during development.

There is a fundamental polarity of events and directions in the biological system (i.e., attachment and detachment, bonding and isolation, synchrony and asynchrony, combination and differentiation, togetherness and separation, complexity and unity, etc.) that provides the context for organizing processes that allow for unique adaptive and integrative solutions to be arrived at in each system. In formulating a "self psychology" from the perspective of the biological system, the necessary conditions for the emergence of a coherent self as a step in the ontogeny of self-regulation will fall into the domain of emergent properties of the system.

There are new vistas currently in biology which elaborate the properties of open systems, especially those that are far from equilibrium. These formulations are concerned with new

concepts such as the difference between information and instruction, that between resilience and stability, the "amplification of adaptation," "order through fluctuation," mechanisms related to "boundary properties," and the role of "attractor surfaces" (Holling, 1976; Prigogine, 1976; Waddington, 1976).

As psychoanalysis now turns again both to biology and to early development to implement the formulation of a self psychology, it is to newer data and newer conceptualizations in both disciplines that we must look for more adequate tools to grapple with the task. Obviously, there is a great distance to go, but what must be done now is to orient our research directions and designs so that the exploration of development in terms of the infant and its environment together as a biological system can begin. Data are needed to provide the empirical base from which to formulate and document the rapid and lawful process of changing organization of the system, as exchanges between its component parts increase in scope and complexity over the first years of life, both within the developing individual and in relation to his larger environment of life support.

References

Aldrich, C., Sung, C., & Knop, C. (1945), The crying of newly born babies: II. The individual phase. *J. Pediatrics*, 27:89–96.

Aschoff, J. (1969), Desynchronization and resynchronization of human circadian rhythms. *Aerospace Med.*, 40:844–849.

Basch, M.F. (1975), Toward a theory that encompasses depression: A revision of existing causal hypotheses in psychoanalysis. In: *Depression and Human Existence*, ed. E. J. Anthony & T. Benedek. Boston: Little, Brown.

——— (1977), Developmental psychology and explanatory theory in psychoanalysis. *Annual of Psychoanalysis*, 5:229–263.

Boismier, J., Chappell, P., & Meier, G. (1970), A behavior inventory for assessing states of arousal in the human newborn. Paper presented at the meeting of the Southeastern Psychological Association, Louisville, Ky.

Brazelton, T.B., Tronick, E., Adamson, L., Als, H., & Wise, S. (1975), Early mother-infant reciprocity. In: *Parent-Infant Interaction*. CIBA Foundation Symposium 33 (new series). Amsterdam: Elsevier, pp. 137–154.

Burns, P., Sander, L., Stechler, G., & Julia, H. (1972), Distress in feeding: Short-term effects of caretaker environment on the first 10 days. *J. Amer. Acad. Child Psychiat.*, 11:427–439.

Cassel, T. Z., & Sander, L. W. (1975), Neonatal recognition processes and attachment: The masking experiment. Paper presented at biennial meeting of the Society for Research in Child Development, Denver, Colo.