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The Breathing Bear: Effects on Respiration in Premature Infants

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INGERSOLL, E. W. AND E. B. THOMAN. *The breathing bear: Effects on respiration in premature infants.* PHYSIOL BEHAV **56**(5) 855–859, 1994.—The sleep states and the regularity of quiet sleep (QS) respiration were investigated in premature infants who were provided a "breathing" teddy bear. The bear (BrBr) is a source of optional rhythmic stimulation that reflects the breathing rate of the individual infant it is with. At 33 weeks CA, 19 premature infants were given a BrBr and 17 were given a nonbreathing bear (N-BrBr). At 35 weeks CA, and again at 45 weeks CA, a 1–2-h interfeed motility recording was obtained. These analog signals were scored for active sleep, QS, and wakefulness; and each 10-s epoch of QS was judged for regularity of respiration using a four-point rating scale. At 35 weeks, the BrBr babies showed slower and more regular respiration during QS. At 45 weeks, the BrBr babies showed more QS and less active sleep. At both ages, only the BrBr babies showed a correlation between respiration regularity and the amount of QS. The findings suggest facilitation of neurobehavioral development as well as entrainment from optional stimulation, which reflects one of the infant's own biological rhythms.

Sleep states, prematures   Breathing bear   Respiration regularity, prematures   Respiration, entrainment
Quiet sleep respiration   Premature, stimulation   Prematures, breathing bear   Prematures, intervention

AN important goal in the nonmedical care of premature infants is to provide an environment that will facilitate the development of their irregular biological rhythms. Toward that goal, various forms of supplemental stimulation have been devised including extra auditory, tactile, and vestibular stimulation for premature infants (3,9,10,13,14,21). The challenge for any intervention program for prematures is to provide conditions that are appropriate for each individual infant. This is especially important because of the possibility of overstimulation, which can have negative physiological consequences (6). We have developed the breathing bear (18) as an intervention that addresses this challenge by offering stimulation that is optional for the infant, is very gentle, and reflects one of the baby's own biological rhythms.

The "breathing" bear is placed in the isolette so that the baby can touch, cuddle with, or even move away from it. The possibility of overstimulation is minimized by the availability of the bear as a potential, but escapable, source of reinforcement and entrainment. It is made to breathe quietly by means of a specially designed pump that remains outside the isolette. The bear's breathing is sinusoidal like the respiratory pattern of a healthy infant, and the rate of breathing is set to reflect each baby's own respiration rate in quiet sleep (QS).

Respiration during QS, one of the infant's most regular biological rhythms, is disrupted by premature birth. For this study, we hypothesized that the bear's regular breathing would serve to entrain the infant's more irregular breathing patterns and, thus, facilitate the infant's development of central regulatory controls for sleep and breathing.

The concept of entrainment holds that in a system of oscillators, an irregular rhythm will gradually match the phase of, or entrain to, a more regular rhythm, or zeitgeber (11). Anders (2) proposed that entrainment involves "higher order central nervous system activity" (p. 410) and should therefore not be a reasonable model for younger, sicker, premature infants. However, the theoretical notions of entrainment originally proposed by biologists and physicists support the feasibility of entrainment as a functional model even in these immature infants (1,5,22).

Indirect support for the entrainment hypothesis was determined in our previous studies, in which we found that following a 2-week intervention period, premature infants given a breathing bear spent more time in contact with their bears than infants given a non-breathing bear (17–19), and that this experience of self-regulation of stimulation led to greater amounts of QS during the preterm period in one study (17) and during the postterm period in another (19). Increased QS means more time spent when the infant is breathing with his or her most regular respiratory pattern. Thus, the results suggested the possibility of entrainment from the bear's very regular breathing.

A more direct test of the entrainment hypothesis was made by investigating the regularity of preterm infants' respiration patterns as a function of exposure to the breathing bear for a 2-week period.

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TABLE 1

DEMOGRAPHIC CHARACTERISTICS

	BrBr	N-BrBr
Males	14	11
Females	13	18
Birth weight (g)	1156.4 (270.5)	1165.8 (234.6)
Gestational age (weeks)	28.9 (2.3)	29.0 (2.0)
Obstetric complications*	10.7 (3.7)	11.0 (2.7)
Neonatal complications†	3.9 (1.7)	3.9 (2.2)
Maternal age (years)	27.7 (5.1)	28.3 (4.9)

Values are mean with SE in parentheses.

* Scored on Prechtl (1968) scale. Possible number of nonoptimal events ranges from 0–42.

† Scored on postnatal complications scale (Littman and Parmalee, 1978). Possible number of nonoptimal events ranges from 0–10.

METHOD

Subjects

The subjects were 56 very low-birth weight premature infants, enrolled at an average age of 33 weeks conceptional age (CA) at three hospitals with level III nurseries. Subjects were included only if they were without genetic anomalies, major physical problems such as congenital heart malformation, or known central nervous system abnormality. At each hospital, the infants were randomly assigned to a breathing bear (BrBr) or non-breathing bear (N-BrBr) group. Demographic information for the subjects in the two groups is presented in Table 1. There were no differences in demographic characteristics as a function of experimental condition or hospital.

General Procedures

At 33 weeks CA, the infants in the BrBr group were provided with a breathing teddy bear placed in the isolette. The baby could regulate the amount of rhythmic stimulation received by making or breaking contact with the bear.

The bear was made to breathe by means of a pump that was outside the isolette, connected to a bladder within the bear's torso via a plastic hose. An important characteristic of the bear is that it was designed to breathe quietly to avoid imposing a constant and unavoidable sound.

Every 5 days, a researcher would observe the baby through a QS episode and determine the mean QS respiration rate. The bear's rate of breathing was then set at one-half of that infant's respiration rate (19). The one-half rate was selected because premature babies have relatively fast respiration rates (in the range of 60 breaths per minute in QS), and their actual rates were judged by parents and staff to be too fast for gentle stimulation. However, evidence suggests that the one-half rate actually used for the bears should be almost as effective for entrainment as the basic frequency (1). The infants in the N-BrBr group received an identical bear, but it did not breathe.

At 35 weeks CA, a 1–2-h interfeed motility (respiration and body movements) recording was obtained. A thin pressure-sensitive transducer pad (8″ × 2″ × $^3/_{16}$″) was placed under the infant, and this was connected to a chart paper recorder. A single channel of analog signals from the infant's respiration and body movements was recorded on 2-in. chart paper.

The recordings were scheduled to begin immediately following a feeding, and when interruptions were expected to be minimal, so they could last for 2 h of the interfeeding period. However, some recordings were interrupted by parental and/or medical interventions. Accordingly, the mean duration of these recordings was 91.1 min (SD = 23.0; range = 41.7–120.0). Because rate and quality of respiration in QS was the major focus of this study, at least 10 min of QS was required for a recording to be included in the data analysis. All infants were discharged from the hospital before 40 weeks CA.

At 5 weeks postterm (45 weeks CA) another interfeed respiration/motility recording was obtained in the home, using the same procedures. The mean duration of the recordings at 45 weeks was 84.0 min (SD = 41.1; range = 28.5–161.2).

Sleep and Respiration Measures

The signals from the motility recordings were scored, in 10-s epochs, for QS, active sleep (AS), and wakefulness (WA). This state scoring procedure has been shown to be reliable and valid (16). The amount of time in each state was measured as a percent of observation time.

Each epoch of QS was assessed visually for regularity of respiration (QSR) (4,15,20), using a four-point rating scale, with the rating categories defined as follows:

QS-A: very regular respiration. Extremely consistent lateral and vertical spacing of respiratory waveforms throughout 10-s epoch; no body movements.

QS-B: regular respiration. Fair to good consistency of lateral and vertical spacing of respiratory waveforms; no body movements.

QS-C: irregular respiration. More irregular than QS-B. Poor consistency in respiratory waveforms; slight to moderate body movements.

QS-D: very irregular respiration. Includes large movements and startles, apneas, and periodic respiration.

Examples of each of these rating categories are presented in Fig. 1. It can be seen in this figure that regularity of the breathing pattern in an epoch is distinctive from the breathing rate (the number of breaths) in an epoch.

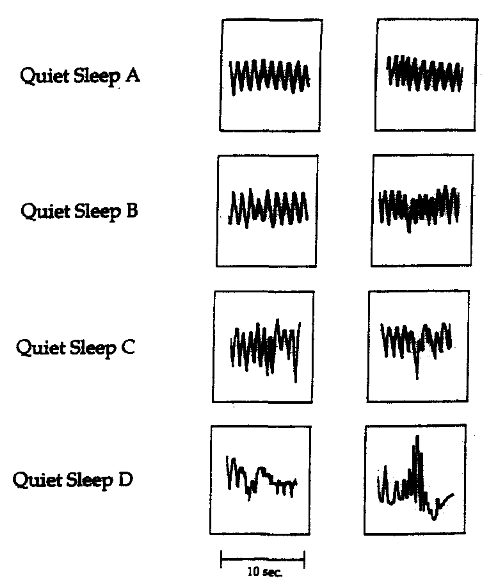

FIG. 1. Examples of the four categories of respiration regularity: QS-A, very regular respiration; QS-B, regular respiration; QS-C, irregular respiration; QS-D, very irregular respiration.

TABLE 2

PERCENT OF TIME SPENT IN EACH STATE DURING THE PRETERM AND POSTTERM RECORDINGS

Group	Preterm (35 weeks CA)				Postterm (45 weeks CA)			
	n	QS	AS	WA	n	QS	AS	WA
Breathing bear	19	32.66 (2.82)	58.99 (3.48)	8.34 (1.76)	15	37.26 (3.93)*	58.41 (4.74)*	4.34 (3.62)
Nonbreathing bear	17	34.34 (3.22)	54.41 (3.05)	11.25 (2.98)	17	27.78 (2.61)	69.89 (2.92)	2.33 (1.55)

Values are mean with SE in parentheses.
* $p < 0.05$ for comparison between Br and N-BrBr groups.

Interrater reliabilities for the state scoring and respiration ratings were above 90%. Validity for the respiration rating procedure has also been demonstrated (4,7).

The frequency of each of these rating categories was measured as a percent of the total number of QS epochs in the observation.

Data Analyses

Because of the constraint on QS time for including subjects' records, occurrences of equipment failures, and interruptions by the nursing and medical staff, there were 36 infants whose data were useable at 35 weeks CA (19 BrBr, 8 males, 11 females; 17 N-BrBr, 7 males, 10 females) and 32 infants who were recorded at 5 weeks postterm (15 BrBr, 7 males, 8 females; 17 N-BrBr, 6 males, 11 females).

Analyses of variance (ANOVAs) followed by simple effects tests were used to assess group differences at each age. Preliminary analyses indicated no sex or hospital effects for any measure, and these variables are not included as factors in the analyses reported. Longitudinal analyses were not carried out because only 12 of the infants (seven BrBr and five N-BrBr) were recorded at both ages.

RESULTS

Effects of the BrBr on the Sleep States

The distributions of the states for the two groups at 35 and 45 weeks CA are indicated in Table 2. There were no group differences at 35 weeks in the allocation of time to any of the states. However, at 45 weeks, there was a significant group × state pattern interaction, $F(2, 60) = 3.47, p < 0.05$, with simple effects analyses showing that the BrBr group had significantly more QS, $F(1,30) = 4.21$, $p < 0.05$, and less AS, $F(1, 30) = 4.48$, $p < 0.05$, than the N-BrBr group.

Effects of the BrBr on Respiration Rates

The mean respiration rates in QS and AS for the two groups at 35 and 45 weeks CA are presented in Table 3. At 35 weeks, the BrBr infants showed a significantly lower mean rate of respiration during QS, $F(1, 34) = 4.37$, $p < 0.05$. Respiration rates during AS did not differ for the two groups.

Effects of the BrBr on QS Respiration Regularity

The mean QSR ratings for the two groups at 35 and 45 weeks CA are presented in Table 4. At 35 weeks, there was a significant pattern difference for the four QSR ratings, $F(3, 102) = 8.12$, $p < 0.01$. Comparisons of the separate QSR categories indicated that the BrBr infants had significantly more QS-A, $F(1, 34) = 16.12$, $p < 0.001$, and less QS-C, $F(1, 34) = 15.99$, $p < 0.001$, than N-BrBr infants. QS-B and QS-D showed no differences as a function of group.

There were no differences between the groups in the distribution of QSR ratings at 45 weeks CA.

Relationship Between QSR and QS

At 35 weeks CA, a significant correlation was found between the amount of QS-A and the amount of total QS for the BrBr babies ($r = 0.52$, $n = 20$, $p < 0.05$) but not for the N-BrBr babies ($r = -0.04$, $n = 17$, NS). At 45 weeks CA also, the correlation for the BrBr babies was significant ($r = 0.69$, $n = 16$, $p < 0.01$) but not for the N-BrBr babies ($r = -0.07$, $n = 16$, NS). These relationships are presented in scattergrams for the two groups in Figs. 2 and 3.

DISCUSSION

The present study replicates our previous finding (19) of increased QS at 5 weeks postterm in premature infants who had a BrBr during the preterm period; and it extends these findings by providing evidence for differences in characteristics of the infants' QS breathing during the preterm period. The infants showed not only slower but more regular respiration at 35 weeks CA as a function of having had a BrBr for 2 weeks. The normal developmental course is for QS respiration to become slower, from the preterm period to later ages (8,12). Thus, the results of this study provide further evidence for facilitation of develop-

TABLE 3

RATES OF RESPIRATION DURING QS AND AS DURING THE PRETERM AND POSTTERM RECORDINGS

Group	Preterm (35 weeks CA)			Postterm (45 weeks CA)		
	n	QS	AS	n	QS	AS
Breathing bear	19	48.34 (2.87)*	56.53 (2.56)	15	40.65 (2.19)	47.35 (2.54)
Nonbreathing bear	17	56.16 (2.32)	62.09 (1.36)	17	39.86 (1.71)	46.78 (2.28)

Values are mean with SE in parentheses.
* $p < 0.05$ for comparison between BrBr and N-BrBr groups.

TABLE 4

QUIET SLEEP REGULARITY RATINGS DURING THE PRETERM AND POSTTERM RECORDINGS

Group	Preterm (35 weeks CA)					Postterm (45 weeks CA)				
	n	QS-A	QS-B	QS-C	QS-D	*n*	QS-A	QS-B	QS-C	QS-D
Breathing bear	19	47.40 (3.95)*	34.98 (2.70)	6.84 (1.09)*	10.78 (2.96)	15	29.35 (3.35)	56.39 (3.13)	10.88 (2.40)	3.38 (0.64)
Nonbreathing bear	17	27.55 (2.79)	42.41 (3.41)	14.00 (1.45)	16.04 (3.17)	17	30.07 (4.06)	55.19 (3.88)	11.66 (3.12)	3.08 (0.76)

Values are mean with SE in parentheses.
* $p < 0.001$ for comparison between BrBr and N-BrBr groups.

ment of central regulatory controls for state and respiration by the BrBr intervention.

We did not replicate the finding in our first study of BrBr babies showing increased QS during the preterm age (17). There are possible reasons for this difference in results. The earlier study was conducted several years ago, and the premature population changes continuously as a function of advances in medical technology and nursing strategies; consequently, infants survive after being born at earlier conceptional ages and those born at later ages show lower morbidity. In addition, the earlier study used 24-h time-lapse video recordings, scored in 5-min intervals. This is in contrast to less than 2 h of direct observation, recorded in 10-s epochs, for the present study.

The greater regularity of breathing found in this study supports the notion that preterm infants can be entrained by the bear's rhythmic stimulation. Other studies have used rhythmic stimulation to facilitate the development of premature infants, but the rhythms chosen have either been arbitrary or were chosen to reflect maternal rhythms of breathing or heart rate; or the stimulation was arhythmic. Although we do not have comparison groups of babies with bears that breathed at different rates, the results from this study using baby-based respiration rates suggest that entrainment may be an appropriate concept for guiding the selection of relevant BrBr breathing rates. It should be noted that entrainment can be inferred without a demonstration of synchrony between the breathing of the bear and the baby: "the phases need not be entrained, only the frequencies" [(1), p. 175). Future study can address our proposition that self-reflecting stimulation rates are optimal by comparing the efficacy of varied rhythms of BrBr breathing.

Evidence for validity of the QSR measures is provided by a comparison of the data from this study with those obtained in a different geographical region by another investigator. Holditch–Davis (7) made 4-h direct observations of premature infants at

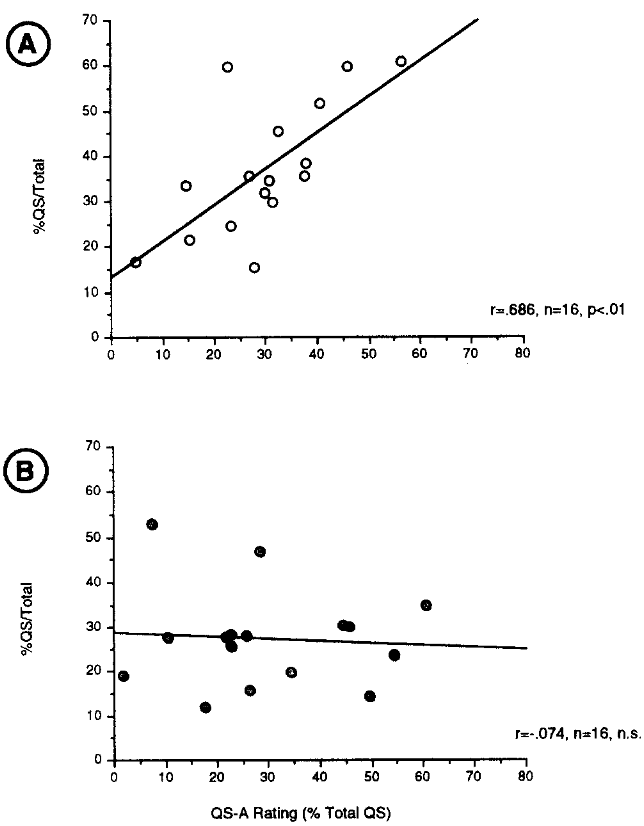

FIG. 2. Correlation between QS-A as a percent of total QS epochs vs. percent of QS in total for (A) BrBr babies and (B) N-BrBr babies at 35 weeks CA.

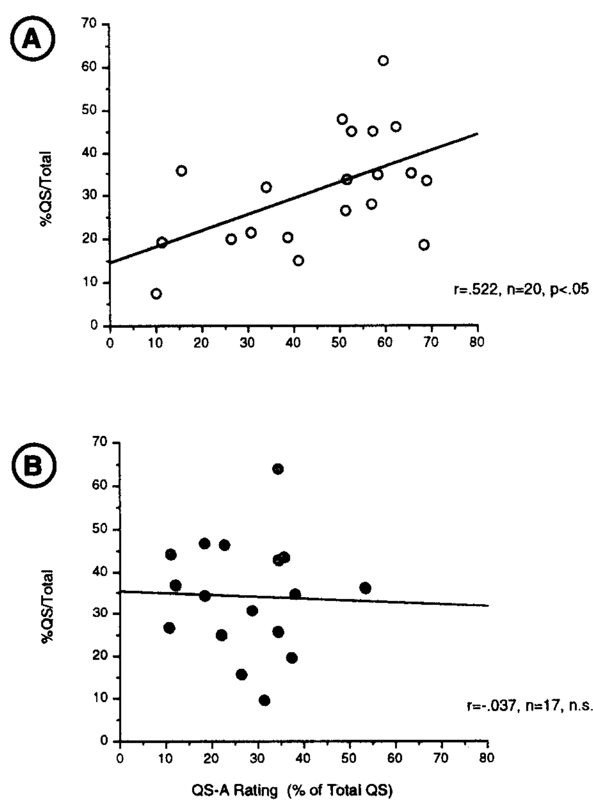

FIG. 3. Correlation between QS-A as a percent of total QS epochs vs. percent of QS in total for (A) BrBr babies and (B) N-BrBr babies at 45 weeks CA.

35 weeks CA, the age of the infants in this study. Their demographic characteristics appeared to be similar to those of the babies in this study. The ratings for QS respiration were defined the same as for this study. The distribution of QSR ratings in that study did not differ significantly from those found in the present study for the N-BrBr infants. Thus, the BrBr babies in this study differ from nonintervention infants in both studies.

At both preterm and postterm ages, for the infants in this study, there was a significant correlation between the amount of QS-A and the amount of QS for the BrBr infants but not for the N-BrBr infants. Only for infants with a breathing bear did more QS mean more regular respiration. The significance of this finding is not readily apparent. In view of their greater regularity of QS respiration at 35 weeks and the increased QS at 45 weeks for the BrBr babies, it is reasonable to speculate that increased regularity of respiration within QS may be antecedent to the normal developmental increase in total amount of QS. From this perspective, an increase in regularity of QS respiration during the preterm period in the babies with a BrBr might play a mediating role in the babies' achieving increased amounts of QS by 45 weeks.

In summary, the results of this study provide further evidence that exposure to the breathing bear has a positive impact on the neurobehavioral development of infants. The results also provide support for the premise that the infant's breathing (an irregular oscillator) will entrain to that of a breathing bear (a regular oscillator, or zeitgeber) (11) under the conditions that the rate of breathing of the bear reflects that of the individual infant.

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REFERENCES

1. Abraham, R. H.; Shaw, C. D. Dynamics—The geometry of behavior. Santa Cruz, CA: Aerial Press, Inc.; 1982.
2. Anders, T. State and rhythmic processes. J. Am. Acad. Child Psychiatry 17:401–420; 1978.
3. Barnard, K. E.; Bee, H. L.. The impact of temporally patterned stimulation on the development of preterm infants. Child Dev. 54:1156–1167; 1983.
4. Booth, C. L.; Thoman, E. B.; Leonard, H. L. Sleep states and behavior patterns in preterm and fullterm infants. Neuropediatrics 11:354–365; 1980.
5. Gander, P. H.; Kronauer, R. E.; Czeisler, C. A.; Moore–Ede, M. C. Modeling the action of zeitgebers on the human circadian system: Comparisons of simulations and data. Am. J. Physiol. 247:R427–R444; 1984.
6. Gorski, P. A.; Huntington, L.; Lewkowicz, D. J. Handling preterm infants in hospitals: Stimulating controversy about timing stimulation. In: Infant stimulation: For whom, what kind, and how much?, Skillman, NJ: Johnson & Johnson; 1987:43–51.
7. Holditch–Davis, D. The development of sleeping and waking states in high-risk preterm infants. Inf. Behav. Dev. 13:513–531; 1990.
8. Hoppenbrouwers, T.; Hodgman, J. E.; Harper, R. M.; Sterman, M. B. Temporal distribution of sleep states, somatic activity, and autonomic activity during the first half year of life. Sleep 5:131–144; 1982.
9. Korner, A. F.; Schneider, P. Effects of vestibular-proprioceptive stimulation on the neurobehavioral development of preterm infants: A pilot study. Neuropediatrics 14:170–175; 1983.
10. Kramer, M.; Chamorro, I.; Green D.; Kundson, F. Extra tactile stimulation of the premature infant. Nurs. Res. 24:324–333; 1975.
11. Kronauer, R. E.; Czeisler, C. A.; Pilato, S. F.; Moore–Ede, M. C.; Weitzman, E. D. Mathematical model of the human circadian system with two interacting oscillators. Am. J. Physiol. 242:R3–R24; 1982.
12. Parmelee, A. H., Jr.; Stern, E. Development of states in infants. In: Clemente, C. D.; Purpura, D. P.; Mayer., F. E., eds. Sleep and the maturing nervous system. New York: Academic Press; 1972:199–228.
13. Scadafi, F. A.; Field, T. M.; Schanberg, S. M.; et al. Effects of tactile/kinesthetic stimulation on the clinical course and sleep/wake behavior of preterm neonates. Inf. Behav. Dev. 9:91–105; 1986.
14. Scarr–Salapatek, S.; Williams, M. The effects of early stimulation on low birthweight infants. Child Dev. 44:94; 1973.
15. Thoman, E. B. Sleep and wake behaviors in the neonates: Consistencies and consequences. Merrill Palmer Q. 21:295–317; 1975.
16. Thoman, E. B.; Glazier, R. C. Computer scoring of motility patterns for states of sleep and wakefulness: Human infants. Sleep 10:122–129; 1987.
17. Thoman, E. B.; Graham, S. Self-regulation of stimulation by premature infants. Pediatrics 78:855–860; 1986.
18. Thoman, E. B.; Ingersoll, E. W. The human nature of the youngest humans: Prematurely born babies. Semin. Perinatol. 13:482–494; 1989.
19. Thoman, E. B.; Ingersoll, E. W.; Acebo, C. Prematures seek rhythmic stimulation and the experience facilitates neurobehavioral development. J. Dev. Behav. Pediatr. 12:11–18; 1991.
20. Thoman, E. B.; Korner, A. F.; Kraemer, H. C. Individual consistency in behavioral states in neonates. Dev. Psychobiol. 9:271–283; 1976.
21. White, J.; LaBarba, R. The effects of tactile and kinesthetic stimulation on neonatal development in the premature infant. Dev. Psychobiol. 9:569–577; 1976.
22. Winfree, A. T. Biological rhythms and the behavior of populations of coupled oscillators. J. Theor. Biol. 16:15–42; 1967.