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Effect of Heartbeat Sound on the Cardiac and Behavioral Responsiveness to Tactual Stimulation in Sleeping Preterm Infants

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In this study we assessed the effect of heartbeat sound on the heart rate and motor responses evoked by tactual stimulation during sleep. Infants were tested one day in the presence of sound and another day in the absence of sound. The subjects were 30 preterm infants, 15 of whom had participated in a long-term intervention program prior to this experiment. During active sleep the nonintervened infants showed a significant cardiac response only in the presence of heartbeat sound. In this sleep state the sound also improved the discernibility of the motor responses for both groups of infants by reducing spontaneous motor movements. During quiet sleep the sound had no effect on either cardiac or motor responsivity. Additionally, the sound influenced the duration of sleep states for both groups by markedly decreasing the duration of the lengthy first active sleep epoch and increasing the duration of the first quiet sleep epoch.

During the past decade there has been a major effort to explore the effects of monotonous stimulation on human infants. Early investigations had already shown that sustained stimulation with light, sound, or rocking had quieting effects (Sidis, 1908; Weiss, 1934). Recent studies of the physiological concomitants of the observed quieting have shown that sustained stimulation with either human heartbeat sound (HB) or white noise can affect sleep and autonomic nervous system functioning. (For a detailed review see Schmidt, 1975.) In the full-term neonate sleep consists of alternating epochs of active and quiet sleep. Active sleep is characterized by slow and rapid eye movements, frequent motor movements, irregular heart rate and respiration, and a low-voltage fast electroencephalogram (EEG) pattern; quiet sleep is characterized by the absence of eye and motor movements (other than startles), regular respiration and heart rate, and a burst-and-flat or high-voltage EEG with slow frequencies (Anders, Emde, & Parmelee, 1971). Sound stimulation appears to reduce the latency to quiet sleep from sleep onset (Murray & Campbell, 1971) and to increase the duration of quiet sleep (Brackbill, 1970, 1971, 1973, 1975). Sound has also been shown to decrease heart rate and spontaneous motor activity and to produce more regular heart rate and respiration (Brackbill, 1970, 1971, 1973; Brackbill, Adams, Crowell, & Gray, 1966; Spiegler & Ourth, Note 1).

In the preterm the effects of continuous stimulation are of special interest because such stimulation simulates, to some degree, the intrauterine sensory environment. In utero the fetus is provided with rhythmic sound by the maternal vessels and with

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vestibular stimulation by the mother's movements. In the isolette the rhythmic HB sound is replaced by nonrhythmic machine noise, the patterned vestibular stimulation is largely lost, and, in the modern hospital nursery, the baby receives continuous light, day and night. Once out of the isolette, the still immature baby receives an unspecified quality and quantity of sensory stimulation that varies according to hospital or home routines. The differing nature of the extrauterine and intrauterine environments and their possible relevance to the infant's development have been extensively discussed by several authors (Dreyfus-Brisac, 1970a, 1974; Lawson, Daum, & Turkewitz, 1977).

It is unclear to what extent environmental variables contribute to the fact that even around 40 weeks gestational age, preterms still differ from their full-term counterparts in many respects (for review see Parmelee, 1975). In comparison with full-terms preterms of this age group have a longer first active sleep epoch, a higher resting heart rate (Field, Dempsey, Hatch, Ting, & Clifton, 1979), a less developed sleep organization (Dreyfus-Brisac, 1970a, 1974), and weaker cardiac and motor responsiveness to tactual stimulation during sleep (Rose, Schmidt, & Bridger, 1976). Based on current knowledge of the effects of sound on full-terms, it was hypothesized that heartbeat sound may "normalize" several of these parameters, that is, bring them closer to the full-term norm. In particular it was expected that the HB sound would shorten the first active sleep epoch, thereby reducing the latency to quiet sleep; increase the duration of quiet sleep as well; and reduce the preterm's high heart rate levels. With respect to responsivity to superimposed tactual stimuli, the predictions were less clear because the literature contains contradictory observations. Although it has been suggested that continuous auditory stimulation might mask the effect of superimposed sensory input (Gardner & Lidicker, 1959; Wolff, 1967), in a more recent study white noise failed to attenuate the somatosensory evoked response in infants and actually increased certain components of the response (Wolff, Matsumiya, Abroms, Van Velzer, & Lombroso, 1974).

The effects of sound were examined for preterm infants who had received routine nursing and medical care and for preterms who prior to testing had received intervention emphasizing tactual stimulation (Rose, Schmidt, Riese & Bridger, in press). Since such stimulation was expected to foster neurobehavioral maturation, it was anticipated that the effects of sound might be more marked for this group.

Method

Subjects

Thirty preterm infants were tested. They were assigned randomly to a nonintervened or an intervened group. Both groups consisted of 8 females and 7 males. Mean gestational age at birth was 32.7 weeks (SD = 1.72 weeks) for the nonintervened and 32.4 weeks (SD = 2.4 weeks) for the intervened group; mean birthweights were 1,548 g (SD = 312 g) and 1,500 g (SD = 278 g), respectively. At the time of testing, the mean conceptional age for the nonintervened group was 37.2 weeks (SD = 1.08 weeks) and the mean chronological age was 32.8 days (SD = 14 days); for the intervened group the respective ages were 37.1 weeks (SD = 1.4 weeks) and 31.4 days (SD = 15 days). The mean 5-minute Apgar score for the nonintervened group was 8.3 (SD = 1.34) and for the intervened group 8.9 (SD = 1.67). Respiratory distress occurred in 17 babies, 8 nonintervened and 9 intervened; 3 of the intervened and 5 of the nonintervened infants required respiratory assistance. There were no sex differences in any of these factors.

The intervention included elements of tactile, vestibular, and auditory stimulation. The infant was massaged according to a systematic regimen, and when well enough to be removed from the incubator, his or her regimen was supplemented with rocking in a rocking chair. Additionally, the infant was talked to periodically throughout the intervention. Intervention was initiated within the first 2 weeks after birth and was administered daily, 5 days a week, for three 20-minute periods. The intervention lasted an average of 13 days (SD = 5.8 days, range = 6–23 days, and Mdn = 14 days) and ended the day before testing. A more detailed description of the intervention program appears in Rose et al. (in press). All infants had been out of the isolette for at least 24 hours prior to testing and were awaiting discharge.

Procedure

Infants were tested after the midmorning feeding in a soundproof neonatal laboratory on two consecutive days. The temperature in the laboratory was kept between 30–31°C, and the illumination was provided by a 60-W light bulb. The electrocardiogram was monitored by a Nacro-Bio Systems

Physiograph. Cardiotachometer recordings were available for some infants.

Once asleep the babies received a series of tactile stimuli, one day under normal laboratory conditions, that is, without sound, and the other day in the presence of a continuous background sound. The sound, which was turned on only once the baby was asleep, was that of a taped human heartbeat; it was played at the rate of 72 beats/minute and measured 79–81 dB at the infant's ear on the C scale of a Bruel and Kjaer Type 1613 sound level meter. The ambient noise level was 60 dB. The heartbeat sound was composed primarily of low frequencies, and the measurements (linear scale) were as follows: 63 Hz, 71–72 dB; 125 Hz, 78 db; 258 Hz, 75–77 dB; 500 Hz, 59–61 dB; and 1000 Hz, 42 dB. The ambient levels at each reading were 58, 50, 42, 28, and 10 dB, respectively. Aside from the presence or absence of sound, the procedure was identical on both days. Sound and no-sound days were counterbalanced within each group.

Sleep State Ratings

Sleep states were continuously assessed by behavioral observations. In studies of full-term infants from this laboratory, active sleep has been defined as a 60-sec period with eyes closed, slow and rapid eye movements, irregular respiration, and variable motor activity. Quiet sleep was defined as a 60-sec period in which eye movements were absent, respiration was regular, and there were no body movements except for isolated startles or jerks (Anders et al., 1971). We have observed, in agreement with Dreyfus-Brisac (1970a), that even at term age the preterm's respiration can at times be slightly irregular in quiet sleep. Therefore the definition of quiet sleep was modified for preterms to include semiregular respiration, provided there were no eye movements and no body movements other than isolated jerks or startles. Otherwise the definitions were the same as those previously used for full-terms, and periods fitting neither category were labeled as *transitional*. Additionally, a 1-min "smoothing" period was adopted; that is, a state change had to exceed one 60-sec rating period to be acknowledged as a new state. Prior to the experiment, a 92% interrater reliability was established concerning the behavioral identification of the sleep states.

Infants were tested for 1 hour after the onset of sleep. The testing time was extended by a maximum of 10 minutes for four infants who entered but did not complete the first quiet sleep epoch during the 60-minute test period.

Tactile Stimulation

Testing began after the infant was in a given sleep state for 3 min. Infants were stimulated tactually with the No. 5.46 plastic filament from the Semmes-Weinstein Aesthesiometer (the number representing the logarithm of the bending force measured in milligrams). On each trial the filament was applied five times on the abdomen in rapid succession, with the duration of stimulation lasting for approximately 2.5 sec. Stimulation trials were alternated between the lower right and lower left side of the abdomen, and each stimulation trial was followed by a control trial in which the stimulus was omitted. The left–right side of the first stimulus was counterbalanced across babies and across sound and no-sound days. Trials began only when the infant was quiescent for at least 10 sec prior to stimulation. In active sleep the infant was considered quiescent when there were no movements or only facial, finger, or toe movements. In quiet sleep the infant had to be motionless. Intertrial intervals were relatively long and variable, generally between 40–60 sec, to minimize the possibility of fatigue, to allow recovery after a response, and to prevent temporal conditioning. A maximum of 10 experimental and 10 control trials were administered within any sleep epoch. Stimulation was then discontinued until a state change occurred.

Scoring

Cardiac measures. Preliminary beat-by-beat analysis in randomly selected infants revealed that where there was a discernible response in active sleep, the response form was that of monophasic acceleration during the first 5 sec. During the next 5 sec, the heart rate either remained at plateau or approached the baseline. In quiet sleep, however, the response tended to be biphasic, with heart rate acceleration during the first 5 sec and deceleration below baseline during the next 5 sec. Neither response form differed as a function of sound condition.

The number of cardiac cycles (R-R intervals), including fractions of a cycle, were counted for all subjects for three consecutive 5-sec periods, that is, one 5-sec prestimulus period and two 5-sec poststimulus periods, and were expressed in beats per minute. Two sets of difference scores were then computed. One set constituted the heart rate change between the prestimulus and the first poststimulus period; the second represented the change between the prestimulus period and the second poststimulus period. Average change scores were computed for each subject in each condition, and all analyses were based on these mean scores.

Behavioral measures. Behavior responses (changes in motor activity) that occurred within the 10-sec period after stimulation were rated on a 5-point scale, representing the number of limbs moved. Ratings ranged from 0 for no limb movement to 4 for movement of all four limbs, including startles and gross body movements. Control trials were rated similarly. A mean behavioral score was computed for each subject in each condition.

Results

Sleep State Measures

Within the first hour of sleep, all 30 infants completed the first sleep cycle (i.e., the first active sleep and quiet sleep epochs) when the heartbeat sound was present, but

Table 1
Sleep Measures in Preterm Infants

	Nonintervened		Intervened	
Measure	Sound absent	Sound present	Sound absent	Sound present
Time elapsed from sleep onset to first quiet sleep				
M	33	18	31	13
SD	12	12	11	7
Duration of first quite slaep				
M	14	17	14	19
SD	5	4	6	6

Note. n = 11 for both groups. Measured in minutes.

only 22 (11 in each group) completed it in the absence of sound. Of the remaining 8 infants, 5 remained in the first active sleep throughout, and the other 3 awoke during the first active sleep and failed to go back to sleep. The analyses presented are based on those 22 subjects who completed the first sleep cycle in both conditions. A preliminary analysis failed to show sex differences; therefore the sexes were combined and 2 × 2 (Group × Sound) analyses of variance were carried out on each sleep measure.

The latency to quiet sleep was measured by the time (in minutes) elapsed from sleep onset to the inception of the first quiet sleep epoch. As can be seen in Table 1, the sound markedly reduced this latency (from about 32 minutes to 16 minutes), $F(1, 20) = 34.10$, $p < .001$, concomitantly shortening the duration of the first active sleep epoch. The sound also significantly lengthened the first quiet sleep epoch $F(1, 20) = 6.08$, $p < .025$, although this change amounted to an average increase of only about 4 minutes. Due to the shorter first active sleep epoch, the mean duration of the first sleep cycle was shortened from 47 minutes to 34 minutes in the presence of sound, $F(1, 20) = 17.60$, $p < .001$. Due to the 1-minute smoothing periods, transitional sleep was minimal, amounting to less than 4% in either sound condition. All the sleep parameters were similar for the intervened and nonintervened infants.

Baseline Heart Rate Data

In the present study, baseline heart rate was represented by the 5-sec prestimulus period, a time during which the infant was motorically quiescent. A mean prestimulus heart rate was computed for each subject in each sound condition. These values were compared using a Group (2) × Sex (2) × Sound (2) × Stimulus (2) analysis of variance for the first active sleep. In quiet sleep sex was omitted as a factor because not all babies had quiet sleep in both sound conditions and therefore the sample size was smaller (n = 22).

In active sleep there were significant Sex × Sound $F(1, 26) = 7.08$, $p < .025$, and Group × Sex × Sound, $F(1, 26) = 6.62$, $p < .025$, interactions. A Newman-Keuls test ($\alpha = .05$) on the means involved in the triple interaction indicated that the sound significantly decreased the heart rate of the nonintervened females (from M = 162.38 to M = 157.11). Sound also tended to increase the heart rate of the nonintervened males (from M = 153.26 to M = 156.38), although this change was not significant. In the intervened group the mean heart rate stayed between 156–157 in both sexes, regardless of the sound condition. Furthermore, the analysis showed that in the absence of sound, the heart rate of the nonintervened females was significantly higher than that of any other group. In the presence of sound, all cardiac values were similar. In quiet sleep sound did not have significant effects on baseline values (for the nonintervened group, without sound M = 152.90, with sound M = 152.79; for the intervened infants the respective means were 154.25 and 154.82).

Heart Rate Responsivity

Preliminary analysis showed that site of stimulation, that is, left or right side of the abdomen, did not affect heart rate responsivity; therefore, the data were combined for all subsequent analyses.

Active Sleep

The infant's cardiac response to stimulation in the first epoch of active sleep was assessed by two Group (2) × Sex (2) × Sound (2) × Stimulus (2) analyses of variance. In the first analysis (see Figure 1), which examined the difference between the heart rate levels of the prestimulus period and the first poststimulus period, there was a significant effect for stimlus, $F(1, 26) = 64.78$, $p < .001$, and significant Sound × Stimulus, $F(1, 26) = 6.60$, $p < .025$, and Group × Sound × Stimulus, $F(1, 26) = 5.58$, $p < .025$, interactions. The triple interaction indicates that the nonintervened infants failed to respond significantly to the tactile stimulus under normal laboratory conditions but became responsive in the sound condition. In this group the sound significantly altered the heart rate change during both the control and the stimulated periods, decreasing the spontaneous heart rate acceleration of control periods while increasing the tactually evoked heart rate response of stimulated periods. The intervened infants, on the other hand, were responsive whether the background HB sound was present or absent (Newman-Keuls test, $\alpha = .05$). Since there was a significant inverse relationship between the prestimulus heart rate values and the difference scores ($\beta = -.24$, $p < .01$), an analysis of covariance was also done. All of the above results remained significant; in addition, there was a significant Group × Sex × Sound × Stimulus interaction, $F(1, 26) = 4.26, p < .05$, showing that in the absence of sound, the intervened males were more responsive than any other group. Due to the small sample size in each sex group, however, this interaction should be viewed with caution.

In the second analysis we examined the difference between the prestimulus period and the second poststimulus period. Here there was a significant stimulus effect, $F(1, 26) = 8.01$, $p < .01$, and a Group × Sex × Stimulus interaction, $F(1, 26) = 6.53$, $p < .025$. Newman-Keuls post hoc tests ($\alpha = .05$) revealed that in this interaction, which collapsed the data across both sound conditions, only the male intervened group maintained the heart rate acceleration during the second poststimulus period. Analysis of covariance led to a similar pattern of results. Inspection of the data showed

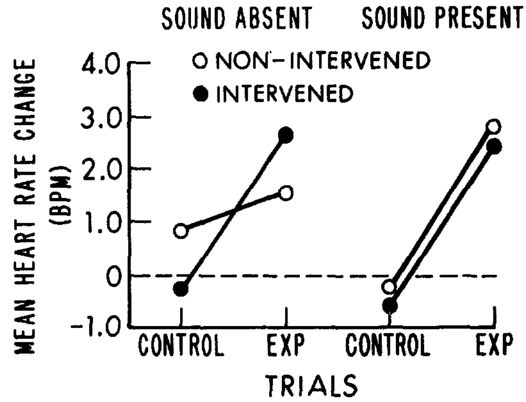

Figure 1. Mean heart rate change scores on control and experimental (EXP) trials during the first epoch of active sleep. (BPM = beats per minute.)

that the nonintervened infants, who failed to show a significant response during the first poststimulus period, did not respond during the second period either. Furthermore, the sound had no consistent effect in this interval.

As noted in the preceding discussion, the nonintervened group failed to show a heart rate response in the absence of sound. To rule out the possibility that averaging over heart rate during the poststimulus period obscured a response, a beat-by-beat analysis was also carried out for this group. This analysis used the first full beat occurring within 1 sec prior to stimulation and the last full beat occurring within each of the 10 poststimulus sec. Cardiotachometer recordings were available for some infants; for others the distance between the R-R intervals was measured in millimeters and converted to a beat-per-minute value. These heart rate values were averaged over infants for each second and the response curves were then plotted in control and experimental conditions. The two curves were virtually the same, showing no heart rate response in either the first or the second 5-sec poststimulus periods.

Since active sleep was longer without sound, a question could also be raised as to whether responsivity was present in the early trials but was diminished in the course of time. To test this possibility an additional analysis was undertaken for the

Table 2
Means of Motoric Responsiveness of Preterm Infants in the Absence and Presence of Background Heartbeat Sound

	Nonintervened				Intervened			
	Sound absent		Sound present		Sound absent		Sound present	
Trials	C	E	C	E	C	E	C	E
First active sleep								
M	.8	1.4	.4	1.7	.7	1.6	.4	1.6
SE	.2	.2	.1	.2	.2	.3	.2	.3
First quite sleep								
M	.1	.5	.1	.4	.1	.5	.1	.6
SE	.1	.3	.1	.1	.1	.2	.1	.2

Note. C = control trials; E = experimental trials.

nonintervened group, equating testing time in the two sound conditions by using an equal number of trials with and without sound. The change scores for the first 5-sec poststimulus period were compared using a Sex (2) × Sound (2) × Stimulus (2) analysis of variance. There was a significant stimulus effect, $F(1, 14) = 16.78$, $p < .005$, and a Stimulus × Sound interaction, $F(1, 14) = 9.43$, $p < .01$, indicating that the sound increased responsiveness even after equating for the length of the sleep state in the two sound conditions. Analysis of covariance led to a similar pattern of results.

Quiet Sleep

The responsivity in quiet sleep was analyzed by a Group (2) × Sound (2) × Stimulus (2) analysis of variance. With respect to the first poststimulus period, there was only a significant stimulus effect, $F(1, 20) = 6.76$, $p < .025$, indicating a small heart rate acceleration of slightly more than 1 beat for each group in each sound condition (means ranged from 1.07 to 1.25). In the second poststimulus period, again there was only a significant stimulus effect, $F(1, 20) = 9.79$, $p < .01$, this time indicating a heart rate deceleration ($M = -1.60$), which again was similar for both groups and in both sound conditions. Thus in quiet sleep there was a biphasic response with acceleration in the first 5 sec and deceleration below baseline in the second 5 sec, and the sound had no significant effect. Analysis of covariance led to a similar pattern of results.

Behavioral Responsivity

The effect of sound on behavior during the first active sleep epoch was evaluated by a Group (2) × Sex (2) × Sound (2) × Stimulus (2) analysis of variance. The analysis showed a significant stimulus effect, $F(1, 26) = 66.14$, $p < .001$, and a significant Stimulus × Sound interaction, $F(1, 26) = 4.93$, $p < .05$. As can be seen in Table 2, the interaction was caused by a reduction in the spontaneous motor activation in the sound condition; the means for the stimulated periods were similar whether sound was present or absent. During quiet sleep most infants did not show any movements during the poststimulus periods of control conditions, and some infants even failed to respond to tactual stimulation. Because of the high incidence of no response and the resulting skewedness of the distribution, nonparametric tests were used to compare behavioral responsivity in this sleep state (Friedman's two-way analysis of variance). Separate analyses were carried out for the nonintervened and intervened groups. Each analysis included the mean behavioral values of the control and experimental trials of sound and no-sound conditions. There were significant effects for the nonintervened group, $\chi_r^2\ (3) = 16.88$, $p < .001$, and also for the intervened group, $\chi_r^2\ (3) = 9.35$, $p < .01$.

The results indicated that the two groups of infants responded to the tactile stimulus, and that there was no differential response as a function of sound. The babies in both groups appeared to be behaviorally less responsive in quiet sleep than in active sleep.

Discussion

The application of HB sound during the first hour of sleep had a major impact on the preterms' sleep states, motility patterns, and cardiac responsiveness, with the sound bringing the functioning of preterms closer to that commonly reported for full-terms without sound. In the absence of HB sound, the duration of the preterm's first active sleep epoch was nearly twice as long as that of the full-term. In the presence of HB sound, the duration of this period was markedly reduced and became comparable to that of full-terms, which has been reported to be between 17–19 minutes (Ashton, 1971; Murray & Campbell, 1971; Rose et al., in press; Schmidt & Birns, 1971). The first epoch of active sleep seems to differ from the subsequent active sleep epochs in several aspects. In full-terms the EEG pattern contains more high-voltage slow waves than that of the later epochs, in which a low-voltage fast EEG pattern predominates; therefore, the EEG differentiation between active and quiet sleep is less marked in the early than in the later sleep cycles (Dreyfus-Brisac 1970b, 1974; Roffwarg, Muzio, & Dement, 1966). According to observations in the laboratory of both full-terms and preterms, this first epoch also contains more gross body movements and fewer rapid eye movement bursts than do later epochs. Polygraphic studies would probably indicate that the first epoch of active sleep is the least well organized in both full-term and preterm infants. It thus is probable that sound, by shortening this epoch, improved the preterm's sleep.

There are no data available as to the length of individual sleep epochs while the preterm is in the incubator. Since the motor noise of the incubator represents a form of monotonous sound stimulation, however, it is conceivable that it affects sleep similarly to the HB sound. Thus the lengthy first active sleep may become manifest only after the preterm has been transferred to the crib. If this is the case, then HB or other monotonous sound may be of benefit in bridging this environmental change. Dreyfus-Brisac (1974) suggested that the environmental change from the isolette to the crib should be more gradual.

The HB sound also moderately increased the duration of the first quiet sleep epoch, although the average duration of quiet sleep in the absence of HB sound was not far from that of the full-term norm (16–18 minutes, Ashton, 1971; Murray & Campbell, 1971). The relatively small increase in quiet sleep in the present study may be due to the moderate intensity of the stimulus. In full-terms sounds of moderate intensity are sometimes ineffective (Ashton, 1971; Murray & Campbell, 1971) in comparison to those of greater intensity (at least up to 85 dB; Schmidt, 1975).

Although the HB sound had a marked effect on sleep, it had only a restricted effect on baseline heart rate levels, that is, on the motorically quiescent prestimulus periods. Even in the presence of sound, the preterms' resting heart rate generally remained 30 beats higher than that of the full-terms, although the HB sound did somewhat decrease the baseline heart rate levels during active sleep for those infants whose resting heart rate was in the highest ranges (nonintervened females). The HB sound may have a more pronounced effect on heart rate levels when periods not preselected for quiescence are examined (Brackbill, 1971; Brackbill et al., 1966).

Additionally, the HB sound decreased spontaneous motor movements, although again only in active sleep. Although previous studies have shown a decrease in motility in full-terms due to monotonous stimulation, motility has generally been averaged over various neurophysiological states. Since the amount of motility in the neonate differs from state to state and the monotonous stimulation changes the duration of neonatal states, the extent to which motility changes are secondary to state changes has remained unclear. In the present study the HB sound effect was evaluated separately within each state. HB sound decreased motility within active sleep, which contains considerable spontaneous fluctuation, but not in quiet sleep, in which motility is sparse.

The nonintervened preterms did not display a significant cardiac response to tactual stimulation during active sleep in the absence of HB sound, replicating previous findings of this laboratory (Rose et al., 1976, in press), but they became responsive in the presence of HB sound. The mechanism whereby sound increases cardiac responsiveness during active sleep is unclear. Prechtl and Lenard (1967) suggested that active sleep in the neonate is "the least organized behavioral state with a high amount of noise in various brain mechanisms" (p. 491). Since sound decreased the level of spontaneous motor activity and the occurrence of spontaneous heart rate accelerations, one might hypothesize that HB sound actually reduced the level of noise in this sleep state and thereby enhanced receptivity to external stimulation. The fact remains, however, that even in the absence of HB sound, both full-terms and the intervened preterms exhibited a significant cardiac response in active sleep (Rose et al., in press), although the level of spontaneous motor activity for both groups was similar to that of the nonintervened babies. It is conceivable that a more mature (i.e., full-term) or a less compromised (i.e., intervened preterm) organism is capable of better functioning, even in the presence of a high level of internal noise. Future detailed analyses of sleep parameters would provide more information about the extent to which HB sound alters other aspects of sleep, like eye movements, EEG, respiration, and muscle tone. Such recordings might help to elucidate further the mechanisms whereby HB sound increases cardiac responsivity.

During quiet sleep the HB sound did not alter either the baseline heart rate or the spontaneous motility, and cardiac responsivity was similarly unaltered. Wolff had hypothesized (1967) that quiet sleep induced by HB sound would be physiologically different from quiet sleep occurring spontaneously. This does not appear to be the case for the cardiac and motor responsiveness of preterms, at least given the parameters of sound stimulation used herein, which were sufficient to dramatically alter their active sleep.

In assessing the effects of HB sound stimulation during testing, the present study included a group that had previously received a multimodal intervention, stressing tactual and vestibular stimulation. That intervention (Rose et al., in press) increased the preterm's cardiac responsivity in active sleep, bringing it to about the full-term level. The introduction of the HB sound during testing affected cardiac responsivity in much the same way as the intervention did and, in addition, affected sleep parameters. A follow-up study of the intervened infants also showed long-term gain for this group, in that visual recognition memory assessed at 6 months of age was enhanced (Rose, 1980, in press). Since the HB sound was not used for any protracted period prior to testing, we could not evaluate the developmental gains that might result from such use.

In recent intervention studies in which different modalities of stimulation were applied in a unimodal or multimodal approach, there have been reports of increases in weight gain (Kramer & Pierpoint, 1976), cardiac responsivity (Segall, 1972), and neurobehavioral maturation (Katz, 1971; Neil, 1968); reductions in apneic spells (Korner, Kraemer, Haffner, & Cosper, 1975); and a faster developmental increase in quiet sleep (Barnard, 1972). It should be noted, however, that a specific effect is sometimes found in one study, but not in another (Cornell & Gottfried, 1976). It is unclear whether failures to find the same gain in different studies are due to differences in sample characteristics or to differences in the relative effectiveness of the different interventions. Most of the pioneering studies have assessed developmental gains, rather than the immediate effects of the intervention stimulus or its components. One might hypothesize that the most efficacious interventions would be those leading to an immediate improvement in several types of functioning. The design and interpretation of further intervention studies would benefit if both the short- and long-term effects of the different types and patterns of stimulation were assessed on various psychophysiological or behavioral variables.

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Manuscripts Accepted for Publication

Development in Moral Judgment Research. James R. Rest (330 Burton Hall, 178 Pillsbury Drive Southeast, College of Education, University of Minnesota, Minneapolis, Minnesota 55455).

Developmental Change in Perceived Control: Recognizing Noncontingency in the Laboratory and Perceiving It in the World. John R. Weisz (Department of Psychology, University of North Carolina, Davie Hall 013A, Chapel Hill, North Carolina 27514).

Developmental Stability of the Relative Influence of Genes and Environment of Specific Cognitive Abilities During Childhood. Hsiu-zu Ho (Institute for Behavioral Genetics, University of Colorado, Boulder, Colorado 80309), Terryl T. Foch, and Robert Plomin.

The Role of Cognitive Development in Children's Explanations and Preferences for Skin Color. Audrey Clark (Department of Home Economics, California State University, Northridge, 18111 Nordhoff Street, Northridge, California 91330), Dennis Hocevar, and Myron H. Dembo.

Development of Altruistic Behavior: Empirical Evidence. Daniel Bar-Tal (School of Education, Tel-Aviv University, Tel-Aviv, Israel), Amiram Raviv, and Tzipora Leiser.

Cognitive Determinants of Wariness Toward Unfamiliar Peers. Joseph L. Jacobson (Department of Psychology, 764 Mackenzie Hall, Wayne State University, Detroit, Michigan 48202).

Mental Manipulation of Spatial Information in Young and Elderly Adults. James F. Herman (Department of Psychology, Washington University, St. Louis, Missouri 63130) and Andrew C. Coyne.

Subitizing and Counting Skills in 3-Year-Olds. Irwin W. Silverman (Department of Psychology, Bowling Green State University, Bowling Green, Ohio 43403) and Arthur P. Rose.

Selective Information Use in the Development of Search Behavior. Catherine Sophian and Henry M. Wellman (Department of Psychology, Mason Hall, University of Michigan, Ann Arbor, Michigan 48109).

Concept Categorization in 1- to 2-Year-Olds. Gail S. Ross (Perinatology Center, Cornell University Medical Center, 525 East 68th Street, New York, New York 10021).

Development of Young Children's Prosocial Moral Judgment: A Longitudinal Follow-Up. Nancy Eisenberg-Berg (Department of Psychology, Arizona State University, Tempe, Arizona 85281) and Karlsson Roth.

Significance of Speech to Newborns. Harriet L. Rheingold (Department of Psychology 013A, University of North Carolina, Chapel Hill, North Carolina 27514) and Judith L. Adams.

Masculinity and Femininity in Children: Development of the Children's Personal Attributes Questionnaire. Judith A. Hall (Department of Psychology, Johns Hopkins University, Baltimore, Maryland 21218) and Amy G. Halberstadt.

(Continued on page 192)