Developmental Psychology
1979, Vol. 15, No. 4, 406–416

Cardiac and Behavioral Responses to Repeated Tactile and Auditory Stimulation by Preterm and Term Neonates

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Auditory stimuli (a buzzer and rattle) and a tactile stimulus (a plastic filament) were repeatedly presented to 18 term and 18 preterm infants. Both groups initially responded to all stimuli with increased limb movements and heart rate acceleration. However, only the term infants responded to stimulus repetition by decreasing both cardiac and behavioral responses. In addition, they differentially responded to the three stimuli and showed response recovery in both systems. Since a behavioral response decrement was observed without a cardiac response decrement in the preterm group, a second experiment was conducted. Heart rate change during the sucking activity of Experiment 2 revealed an integration between autonomic and motor responsivity of preterm infants comparable to that of term newborns. The lack of cardiac–behavioral response integration during Experiment 1 is discussed in the context of state differences between preterm and term infants as well as potential immaturity or some insult experienced by the preterm infants. The stimulus discrimination and habituation demands of Experiment 1 may have overtaxed the preterm infants' ability to maintain response integration.

The preterm infant's responsivity to tactile and auditory stimuli differs from the term infant's in several ways. First, the magnitude or vigor of response is less than that of term infants (Bench & Parker, 1971; Berkson, Wasserman, & Behrman, 1974; Brown & Bakeman, 1979; Howard, Parmelee, Kopp, & Littman, 1976). Second, the preterm infant may require more intense stimuli before a response is elicited due to a higher threshold for arousal (Rose, Schmidt, & Bridger, 1976). Third, behavioral responses may not be accompanied by heart rate changes, suggesting a lack of integration between autonomic and behavioral systems (Rose et al., 1976). Finally, mixed results on rate of habituation, that is, decreased responding to repeated stimuli, have been reported. Schulman (1970) found similar decrements in cardiac change for term and preterm infants, whereas Eisenberg, Coursin, and Rupp (1966) found no decrement in behavioral responses of two preterm infants. All of these differences in responsivity between term and preterm infants suggest that the preterm may experience environmental stimulation in a qualitatively different way from the term infant.

Much of the work referred to above was limited to measuring responses in a single system to stimuli in a single modality. Hyper- or hyporesponsivity of preterms may vary with the sensory modality and the response elicited, reflecting different levels of maturity in various sensory or response systems. The discrepancy between Schulman (1970) and Eisenberg et al. (1966) concerning habituation may be due to different response systems measured and to the small number

This research was partially supported by Grant HD06753 from the National Institute of Child Health and Development to Rachel K. Clifton and by grants from the Department of Public Health and the National Foundation/March of Dimes to Tiffany M. Field et al.

Special thanks go to the parents of the infants who participated in this study, to the staff of the Baystate Medical Center, and to John Dowd for his assistance.

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of preterm infants tested in both studies. In Experiment 1 of the present study, term and preterm infants at approximately term age were presented with two examples of auditory stimuli and a tactile stimulus. Both behavioral and cardiac responses were used to assess group differences in initial responsivity, decrement in responding over trials, and coordination between the two response systems.

The paradigm used in Experiment 1 was based on the dual-process theory of habituation proposed by Thompson and colleagues (Groves & Thompson, 1973; Thompson, Groves, Teyler, & Roemer, 1973). This paradigm features a series of habituation trials followed by an interposed startle stimulus, and then more presentations of the original stimulus. After response decrement has occurred during the habituation trials, the introduction of a strong stimulus will produce response recovery to subsequent presentations of the original stimulus. This increased sensitivity to the "old" stimulus is called dishabituation. Thompson claims that dishabituation is not a disruption of habituation, "but is rather a superimposed process of sensitization or facilitation" (Thompson & Glanzman, 1976, p. 62). Thompson views both processes as important evidence for behavioral plasticity and hypothesized separate neuronal substrates for the two processes in the central nervous system. Although Thompson's model of habituation has influenced infant research for many years, his speculations about sensitization and the dual-process model have been ignored by developmentalists. To our knowledge, this study is the first attempt, using this paradigm, to assess dishabituation, that is, sensitization, in newborns.

In Experiment 2 we further explored the relation between cardiac and behavioral response systems by measuring heart rate while preterm infants were actively sucking on a pacifier. Since cyclical heart rate changes were found to closely covary with sucking bursts and pauses for term infants (Nelson, Clifton, Dowd, & Field, 1978), this relationship was tested for preterm infants to provide additional data on the integration of cardiac and behavioral systems.

Experiment 1

Method

Subjects

The sample was made up of 18 healthy term newborns and 18 highrisk preterm newborns all born to white, middle-class mothers. The term newborns (12 females, 6 males) were randomly selected from a group of 2- to 3-day-old babies residing in a normal newborn nursery. The criteria for selection were that they be 38–41 weeks gestation, greater than 2,500 g birthweight and free of perinatal complications. The term newborn group averaged 39.9 weeks gestation (SD = 1.3), 3,231 g birthweight (SD = 462) and had 5-minute Apgar scores of 9 or 10.

The preterm infants (12 females, 6 males) had a mean gestational age at birth of 33.6 weeks (SD = 2.3) and a mean birthweight of 1,908 g (SD = 437). The 5-minute Apgar scores for the preterm infants ranged from 1–9 (M = 7.88). Half of the preterm infants experienced respiratory distress syndrome (7 mild, 2 severe), and 13 of the 18 infants experienced hyperbilirubinemia (highest serum bilirubin = 14.9, M = 11.6). At the time of testing, the conceptional age of the preterm infants was within the range of term age or 37.4 weeks (SD = 1.2), and their chronological age averaged 23.8 days (SD = 3.5). Their weight at the time of testing averaged 2,187 g (SD = 159).

Apparatus

The study was performed in a room close to the newborn and preterm nurseries. General room illumination was low, and background noise intensity was approximately 62 dB (re 0.0002 dynes/cm^2, using the A scale on a General Radio sound-level meter). Three stimuli were used: a rattle, a buzzer, and a plastic filament. Both auditory stimuli were delivered manually by an experimenter shaking the rattle or pressing a button for the buzzer. These stimuli were presented at a standard distance of approximately 6 inches (15 cm) from the infant's ear, with a measured intensity of 90 dB, that is, 28 dB over the background noise level. Each trial consisted of five brief rattle shakes or button presses delivered over about 2.5 sec.

For the tactile stimulus, a plastic filament (similar to the ordinal number 15 filament from the Semmes-Weinstein aesthesiometer) was used, since that filament was the most effective stimulus of the three filaments used by Rose et al. (1976). This filament had a bending force of approximately 15–20 grams, slightly greater than the most effective stimulus used by Rose et al. (1976). Any excess pressure against the skin is taken up by the bend of the filament, producing a reasonably standardized pressure for each application. As in the Rose et al. (1976) study, the plastic filament was presented to the lower left side of the infant's abdomen; each trial consisted of five rapid presentations of the filament, lasting approximately 2.5 sec.

A startle stimulus was produced by the experimenter lifting one end of the infant's bassinet to a standard height of 6 inches and dropping it back into place. This procedure is used to elicit a startle-like or Moro response during neurological assessments of the newborn (Brazelton, 1973; Prechtl & Beintema, 1964).

Stimulus programming to time intertrial intervals was provided by a BRS 16 mm filmstrip programmer and associated BRS logic modules and peripheral relays. Raw electrocardiogram (EKG) and stimulus onsets were recorded both on a Hewlett Packard 7702B polygraph and a Vetter Model-A FM tape recorder. Heart rate was detected by Beckman miniature electrodes placed in a triangular array on the infant's chest. One active lead was high on the sternum, the other active lead was on the left lateral costal margin, and the ground electrode was on the right lateral costal margin.

Procedure

Following a complete description of the experimental procedures, written permission to test infants was obtained from both the attending pediatrician and from each infant's mother. Immediately after a feeding, the infant was taken in his or her own bassinet to the testing room. Experimenter 1 applied the EKG electrodes, then loosely covered the infant with a blanket and waited until the infant had been observed to be in active sleep for 3 minutes (light sleep with irregular respiration, closed eyes, rapid eye movements, and low activity level, Brazelton, 1973). Experimenter 1 then delivered three series of trials for the buzzer, rattle, and filament stimuli, the order of presentation being completely counterbalanced across infants within the term and preterm groups. Since the research method used was an habituation–dishabituation paradigm, the series was made up of 10 habituation trials of each stimulus followed by one trial of the startle stimulus, then three dishabituation trials of the original stimulus. There was no break between the series for one stimulus and the next, except the usual intertrial interval. A minimum intertrial interval of 20 sec was used; however, the experimenter waited until the infant appeared to be in active sleep with no gross body movements before presenting the next stimulus. As each stimulus was presented, Experimenter 1 pushed a button to record stimulus onset and activate the stimulus programmer to begin timing the next intertrial interval. A tiny light signaled when the next trial could be delivered.

Experiment 2 calibrated the polygraph and monitored the equipment throughout the session. In addition, Experimenter 2 rated the infant's state just prior to the presentation of each stimulus trial using Brazelton's state definitions (Brazelton, 1973). Experimenter 2 noted the number and vigor of both the infant's arm and leg movements that occurred within 5 sec after the stimulus presentation. Number of limbs moved were rated as: 0, no response; 2, movement of upper or lower extremities; 4, movement of all extremities. In addition, a minus sign represented a weak movement of short duration, and a plus sign reflected a vigorous, sustained movement. This rating scale conformed to that of Rose et al. (1976), except that discrete ratings of right and left limbs were omitted because observations of individual limb movements were less reliable than those of upper–lower limb movements. Experimenter 2 also noted on which trial the infant met the Brazelton (1973) shutdown criteria (i.e., no gross body movements to two successive stimulus presentations). Interobserver reliabilities for these behaviors were measured by (Kappa) K, a chance-corrected percentage agreement measure with a statistical base (Bartko & Carpenter, 1976). The K values and p levels for z tests on K were as follows: (a) for state ratings, $K = .79$, $p < .05$; (b) for vigor of arm movements, $K = .88$, $p < .01$; (c) for vigor of leg movements, $K = .83$, $p < .01$; and (d) for Brazelton shutdown ratings, $K = .92$, $p < .005$.

When an infant cried or awakened, the session was stopped. If the infant returned to active sleep within a few minutes, the session was restarted at Stimulus 1 of the interrupted series. If the infant did not return to active sleep within a few minutes, the session was terminated. Four sessions were terminated due to state changes.

Results

Heart Rate Analyses

To reduce the heart rate data for statistical analyses, the taperecorded EKG was converted from analog to digital information by a Hewlett Packard 2100 computer that timed the interval between each heart beat. Second-by-second averaged heart periods were calculated for 1 sec before and 10 sec following stimulus onset. In calculating the average heart period for each second, every cardiac interval was weighted according to the proportion of the second epoch that it occupied (Graham & Jackson, 1970). This method permitted all heart beats to contribute to the data, rather than selecting certain beats during the time period to be analyzed. These second-by-second weighted average heart periods were then converted to heart rate in beats per minute (bpm) for statistical analyses and graphing. These data were analyzed by analyses of variance and associated orthogonal trend tests on the seconds variable.

Baseline data. Baseline comparisons were made between our preterm and term groups. Two analyses of variance were performed: (a) 1 sec of prestimulus heart rate preceding the first stimulus presentation of the session; (b) 1 sec of prestimulus heart rate averaged over the 30 habituation trials. The data showed a difference in resting heart rate of more than 30 bpm between the two groups of infants. The mean prestimulus value for the first stimulus of the session for term infants was 115.00 bpm (SD = 16.2) and for the preterm group, 147.73 bpm (SD = 13.8). This difference was significant,

$F(1, 34) \doteq 42.59, p < .0001$, indicating that these groups came into the experimental situation with different base-level cardiac rates. This difference remained remarkably stable throughout the session, with the mean prestimulus value averaged over 30 habituation trials for the term infants being 116.53 bpm ($SD = 15.1$) and for the preterm infants, 148.93 bpm ($SD = 17.7$). This difference was also significant $F(1, 34) = 46.75$, $p < .0001$. Given these differences in baseline heart rate, the data were analyzed separately for the two groups.

Habituation trials (1–10). Order of stimulus presentation was analyzed to determine if position in the series affected response. Order was not significant and thus was omitted as a factor in further analyses. For each group separately, the variance in heart rate response to buzzer, rattle, and filament was analyzed with repeated measures on type of stimulus (3), trials (10), and seconds (1 prestimulus, 10 poststimulus onset). For both term and preterm infants, cardiac acceleration indexed by seconds was elicited by all three stimuli: $F(10, 170) = 14.30$ and 19.05, $p < .0001$, for term and preterm infants, respectively; with associated linear trends on seconds, $F(1, 17) = 10.77$ and 26.77, $p < .01$; and quadratic trends, $F(1, 17) = 15.18$ and 12.15, $p < .01$, for the two groups. For term infants, only the heart rate response decreased over the first 10 trials, $F(9, 153) = 2.60, p < .01$; for Trials × Seconds interaction, $F(90, 1530) = 2.19$, $p < .001$. Cardiac acceleration did not totally disappear over trials but decreased in both peak amplitude and duration (see Figure 1). These trial differences in response amplitude and return to baseline level are reflected in three significant trend components for the Trials × Seconds interaction: linear $F(9, 153) = 2.56$, quadratic $F = 2.11$, and cubic $F = 2.66$; all p levels $< .01$. In contrast, preterm infants maintained a peak amplitude of about five beats per minute throughout the 10 repeated trials (see Figure 2).

Again for term infants only, cardiac acceleration differed in response to the three stimuli, $F(2, 34) = 3.15$, $p < .05$; Stimulus × Seconds, $F(20, 340) = 3.59$, $p < .0001$. Peak amplitude for the stimuli are rank ordered, 7 bpm for rattle, 5 bpm for buzzer, and 2.5 bpm for the filament. These response differences are reflected in a reliable quad-

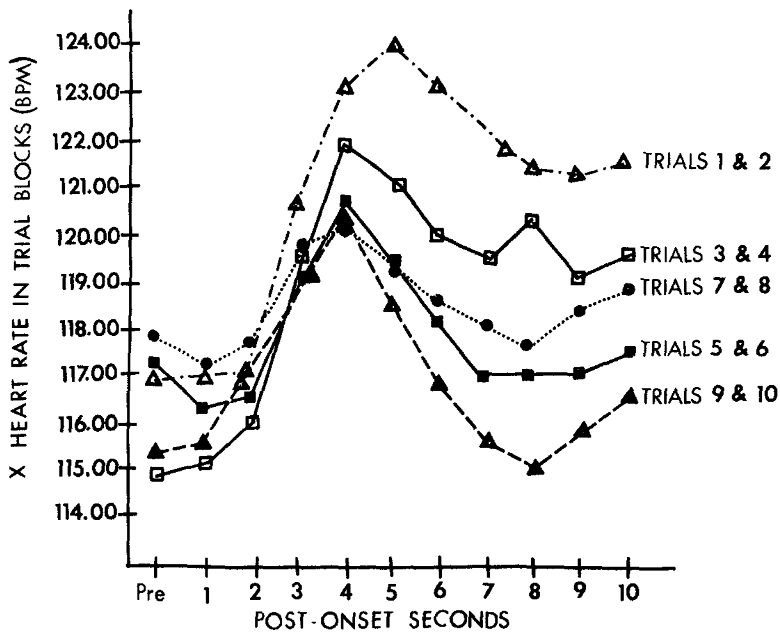

Figure 1. Mean heart rate response of term infants during habituation trials.

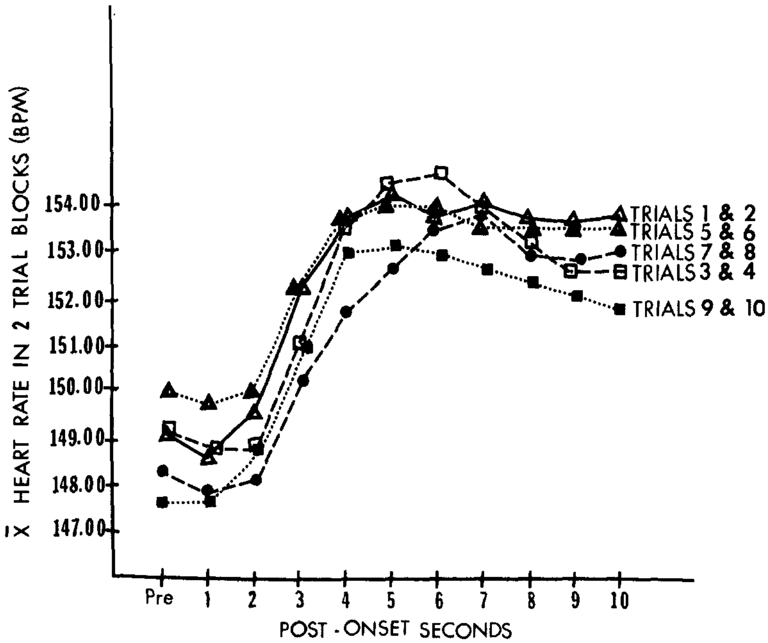

Figure 2. Mean heart rate response of preterm infants during habituation trials.

ratic trend on the Stimulus × Seconds interaction, $F(2, 34) = 5.29$, $p < .01$, indicating that the quadratic nature of heart rate change varied with type of stimulus (see Figure 3).

Startle stimulus trial (11). The response to the startle stimulus for both groups was a rapid increase in heart rate with peak amplitude of 14 bpm over base level for term infants and 15 bpm for preterm infants. A Stimulus × Seconds (3 × 11) repeated measures analysis of variance revealed a significant seconds main effect, Fs(10, 170) = 20.92 and 30.61, $p < .0001$, for term and preterm groups, respectively, with reliable linear and quadratic trends on seconds for both groups ($p < .01$).

Dishabituation trials (12–14). When the original stimulus was re-presented following the startle stimulus, only the term infants showed recovery of the response. The last habituation trial (10) was compared with the first dishabituation trial (12) in a Stimulus × Trials × Seconds (3 × 2 × 11) analysis of variance. Both groups had a reliable cardiac acceleration indexed by seconds to the stimuli, $F(10, 170) = 4.87$ and 11.23, $p < .001$, for term and preterm groups, respectively, with quadratic trends reliable at $p < .01$. However, only the term infants' data showed a Trials × Seconds interaction, $F(10, 170) = 3.69$, $p < .01$; both linear and cubic trends on this interaction are reliable, with Fs(1, 17) = 4.80 and 4.95, respectively, $p < .05$. Response on Trial 10 was a 3.9-bpm acceleration that peaked 4 sec after stimulus onset and returned to baseline by 7 sec. In contrast, response to the same stimulus following the startle stimulus was a 6.5-bpm increase that reached asymptote at 4 sec and returned to baseline around 15 sec. Although preterm infants have a higher amplitude response on Trial 12 relative to Trial 10, this is not a statistically reliable difference. The failure to decrease responding over habituation trials reduced this group's opportunity to show a significant increase during dishabituation.

Figure 4 shows response before and after the startle stimulus, averaged over all three stimuli. However, response recovery in term infants was shown for the rattle and buzzer but not for the filament. This effect was supported statistically by a main effect of Stimulus, $F(2, 34) = 3.22$, $p < .05$, and interactions of Stimulus × Trials, F(2,

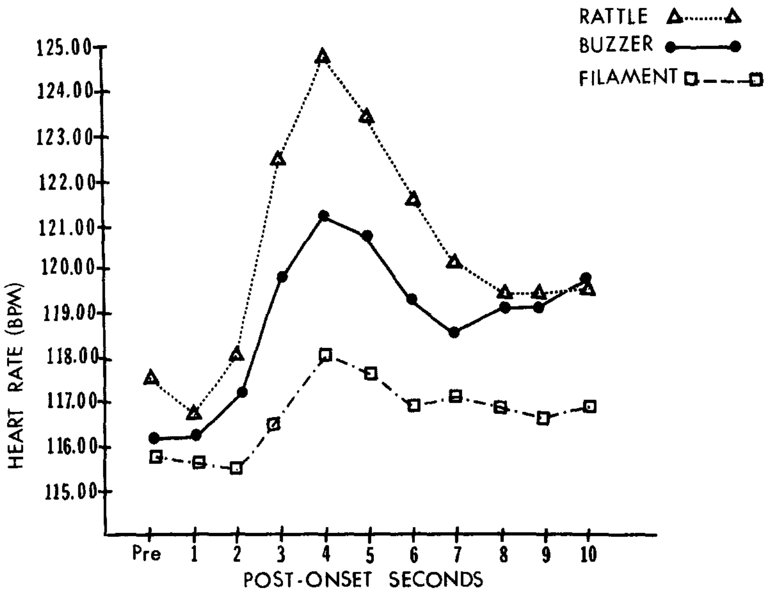

Figure 3. Mean heart rate response of term infants to tactile and auditory stimuli.

34) = 4.12, $p < .05$, and Stimulus × Seconds, $F(20, 340) = 2.95$, $p < .0001$; linear trend $F(2, 34) = 4.41$, $p < .05$. This differential recovery would be predicted from response during habituation trials, as the filament (see Figure 3) consistently elicited less response compared to the other two stimuli.

When all three dishabituation trials (12, 13, and 14) are considered, both groups

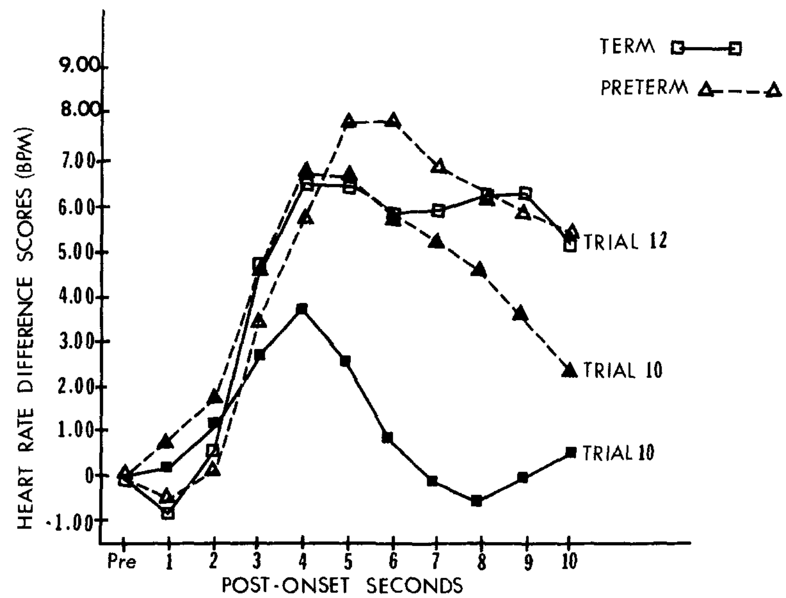

Figure 4. Heart rate difference scores for response before and after the startle stimulus by term and preterm infants. (Difference scores, obtained by subtracting prestimulus from poststimulus onset scores, were necessary when plotting data from both groups because of base-level differences in heart rate.)

show the expected heart rate acceleration, $F(10, 170) = 8.84$ and 13.76, $p < .0001$, for term and preterm groups, respectively; linear trend $Fs(1, 17) = 7.90$ and 12.27, $p < .01$, whereas quadratic trend $Fs(1, 17) = 9.02$ and 21.72, $p < .01$. For term infants only there was a Stimulus × Trials × Seconds interaction, $F(40, 680) = 2.47$, $p < .01$; linear $F(4, 68) = 3.52$ (quadratic $F = 4.24$, $p < .05$). This interaction reflects the differential response recovery to stimuli mentioned above. When Trial 12 was compared to Trial 10, the rattle elicited a 10-bpm heart rate increase over prestimulus level that did not decline over Trials 12–14. Response recovery to the buzzer was also a 10-bpm increase initially, but it declined over Trials 12–14. There was no response recovery to the filament, suggesting that the startle stimulus did not simply activate the infant to respond with equal intensity to all subsequent stimuli.

Behavioral Responsivity

Behavioral responsivity included the following measures: (a) number of limb movements (0, 2, or 4); (b) vigor of movements in upper and lower limbs (no movement, small movements in two limbs, large movements in two limbs, small movements in four limbs, large movements in four limbs); (c) Brazelton shutdown ratings (Brazelton, 1973); and (d) Brazelton state ratings in which 1 = deep (quiet) sleep, 2 = light (active) sleep, 3 = drowsiness. There were no reliable group effects for vigor of movement ($M = 25$ and 22 for term and preterm) or shutdown ratings ($M = 5.8$ and 6.5 for term and preterm). Although nine infants in both term and preterm groups met the Brazelton criterion of shutdown within 10 trials for all three stimuli, only the term infants showed a decrement in cardiac responding over those trials. Since there were no reliable group effects on the Brazelton shutdown or vigor of movement ratings, these measures will not be mentioned further.

Habituation trials (1–10). Since there were no baseline differences in behavioral ratings between term and preterm infants, their data were compared together in a Groups × Stimulus × Trials (2 × 3 × 10) repeated measures analysis of variance. Number of limb movements in response to the stimuli decreased over trials for both term (M Trial 1 = 2.4, Trial 5 = 2.1, Trial 10 = 1.2) and preterm infants (M Trial 1 = 2.5, Trial 5 = 2.1, Trial 10 = 1.4), $F(9, 306) = 5.63$, $p < .0001$. Both groups showed differential responding to the stimuli, $F(2, 68) = 4.11$, $p < .05$, and subsequent t tests suggested a greater response to the rattle than to the other stimuli ($t = 2.18$, $p < .05$). A decrement in behavioral responsivity was shown only to the buzzer and filament, Stimulus × Trials, $F(18, 612) = 2.52$, $p < .001$.

State ratings indicated that both groups were assigned deeper sleep ratings over trials, $F(9, 306) = 2.48$, $p < .01$. It is important to note that this trials effect is not an experimental session effect, as Trials 1–10 were averaged for the three stimuli that were counterbalanced for order. The trials effect reflects a tendency toward deeper sleep as trials progress within each stimulus set, regardless of its position in the session. Term infants appeared to be in slightly deeper sleep ($M = 1.75$ and 1.95 for term and preterm groups, respectively), $F(1, 34) = 4.79$, $p < .05$. Preterm infants remained closer to active sleep (M state rating for Trial 1 = 1.94, Trial 5 = 1.90, and Trial 10 = 1.96), whereas term infants showed a steady trend toward deeper sleep over trials (M rating for Trial 1 = 1.90, Trial 5 = 1.68, Trial 10 = 1.66). This group difference was expressed in a Groups × Trials interaction, $F(9, 306) = 3.42$, $p < .001$.

Startle stimulus trial (11). The infants responded to the startle stimulus with arm and leg movements approximating a Moro response. There were no group differences in this response.

Dishabituation trials (12–14). When the original stimulus was again presented following the startle stimulus, a comparison between responses on Trials 10 and 12 suggested that both groups showed increased limb movements, $F(1, 34) = 9.89$, $p < .005$. A Stimulus × Group interaction, $F(2, 68) = 5.43$, $p < .01$, and subsequent t tests suggested that term infants responded with fewer limb movements to the filament, and preterm infants responded with fewer limb movements to the buzzer ($p < .05$).

Regarding state ratings, both groups were in lighter sleep during the first dishabituation trial ($M = 1.93$) compared to the last habituation trial ($M = 1.81$). Again a group effect suggested that preterm infants were in lighter sleep, $F(1, 34) = 5.77$, $p < .05$. In addition, the term infants experienced a greater change of state from Trial 10 to Trial 12 than did the preterm infants, $F(1, 34) = 4.25$, $p < .05$. Nine term infants changed state between Trials 10 and 12, but only three preterm infants changed state. Although the preterm infants showed an increment in behavioral responsivity, there was no parallel change in cardiac responsivity.

In summary, both groups initially responded to the stimuli with increased limb movements and heart rate acceleration of similar amplitude and duration. Group differences emerged during subsequent trials. The term infants showed: (a) a decrement in cardiac responsivity to all stimuli during habituation trials, and response recovery during dishabituation trials to rattle and buzzer, followed by response decrement only to the buzzer; (b) a decrement of behavioral responsivity to the buzzer and filament, but no recovery of responding to the filament; (c) although a Stimulus × Trials × Groups interaction effect failed to reach significance for state ratings, the term infants showed a trend toward deeper sleep except during the buzzer trials. The preterm infants showed: (a) no decrement or recovery of cardiac responding; (b) a decrement of behavioral responsivity to the buzzer and filament, but no recovery of responding to the buzzer; and (c) less change toward deep sleep than the term infants.

Experiment 2

Since preterm infants did not show corresponding response decrements in cardiac and behavioral responding, Experiment 2 investigated the Rose et al. (1976) suggestion that autonomic and behavioral systems may not be integrated in the premature infant. Although limb movements might be uncoordinated with cardiac reactivity, another behavior such as nonnutritive sucking might be. A very close correspondence between sucking and heart rate change has been demonstrated for full-term newborns (Lipsitt, Reilly, Butcher, & Greenwood, 1976; Nelson et al., 1978), with sucking burst onsets accompanied by acceleration and end of bursts accompanied by deceleration. Because of the extreme regularity of coupling found between these two systems, heart rate change during sucking bursts appeared to be an additional, appropriate test of autonomic-behavioral integration for the preterm infant.

Method

Subjects

Twelve preterm infants were recruited for Experiment 2. The birth data from both preterm infant groups were analyzed to determine the comparability of the samples of Experiments 1 and 2. There were no significant differences between these samples on any of the birth measures. The preterm infants (7 females, 5 males) of Experiment 2 averaged 33.2 weeks ($SD = 2.7$) at the time of birth and 37.9 weeks conceptional age at the time of testing. They had a mean birthweight of 1,921 g ($SD = 411$) and a test weight of 2,202 g ($SD = 138$). The 5-minute Apgar scores for the preterm sucking infants ranged from 1–9 with a mean of 7.75. Half of the preterm infants experienced respiratory distress syndrome (3 mild, 3 severe) and 9 of the 12 infants experienced hyperbilirubinemia (highest serum bilirubin = 15.5, $M = 11.5$). The preterm samples were similar to each other and to the sample used for the study by Rose et al. (1976).

Procedure

The preterm infants recruited for Experiment 2 were tested in the same setting already described in Experiment 1. For sucking, a "binky" pacifier nipple was connected to a transducer by flexible plastic tubing. The pacifier was held passively in the infant's mouth by an experimenter.

As in the previous experiment, the infant was seen immediately after feeding, and the procedure was not started until the infant was judged to be in active sleep. Three minutes of sucking and heart rate were then recorded. An event marker designated the onset of each sucking burst on the Vetter magnetic tape to coordinate retrieval of heart rate data with individual bursts. Ten sucking bursts were selected from each infant's polygraph record according to the following criteria, adapted from Nelson et al. (1978): (a) each burst had to be a minimum of 5.4-sec duration; and (b) the pause prior to the sucking burst had to be a minimum of 2-sec duration. The heart rate that occurred during the selected sucking bursts was then retrieved and analyzed.

Results

A 2 (sex) × 15 (seconds) (5 preburst onset sec and 10 postburst onset sec) repeated measures analysis of variance revealed a significant seconds effect, $F(14, 154) = 19.41$, $p < .001$. At sucking burst onsets cardiac rate increased, reached a peak within 3 sec, and decreased when sucking stopped. This cardiac change closely approximated full-term infants' response in Nelson et al. (1978), although peak acceleration was less for preterm infants (4 bpm) than it was for the term infants (10 bpm). Both groups showed a close integration of heart rate change and sucking, indicating that both activities cycled together.

Discussion

Cardiac acceleration to both tactile and auditory stimuli has been previously reported for sleeping term newborns (Campos & Brackbill, 1973; Pomerleau-Malcuit & Clifton, 1973), and for preterm infants tested at 36 weeks conceptional age (Schulman, 1970). However, Rose et al. (1976) reported that term newborns responded with heart rate acceleration and increased limb movements to tactile stimuli, but that preterm infants showed no reliable heart rate change and only weak behavioral responses to the most intense tactile stimulus. Rose et al. (1976) noted that preterm infants were less responsive than term newborns to stimuli in both behavioral and autonomic response systems. They wondered if preterm infants were unable to maintain vigorous responding to stimuli, or if they had a higher threshold than term babies. Our data, together with Rose's, suggest that the threshold hypothesis is correct. All three of our stimuli elicited cardiac responses from both groups, and these responses were larger heart rate accelerations than those reported for Rose's term infants to their most intense stimulus. We selected our tactile stimulus on the basis of Rose's data, with our plastic filament having a bending force slightly greater than their most intense stimulus. In addition, Rose et al. (1976) used only tactile stimuli, and the tactile stimulus was less effective than auditory stimuli in eliciting responses from our term infants. The above considerations suggest that group differences appear when stimuli are at or below threshold; but when stimuli are well above threshold, preterm and term infants will respond vigorously in both behavioral and autonomic systems.

The preterm infants' failure to show habituation of cardiac responding may be due to the limited number of trials presented. Preterm infants might eventually decrease responding if given additional trials, but the group difference in rate of habituation would still be of interest. Perhaps simple recognition of stimulus onset is reflexive, but modulation of a different stimulus may require more complex modes of information processing. Likewise, the maintenance of cardiac and behavioral response integration during the stimulus discrimination and habituation tasks of Experiment 1 may be beyond the preterm's ability, whereas the simple reflex activity of sucking during Experiment 2 required less ability to maintain integration between the two response systems. Since these babies were sleeping, the habituation and stimulus discrimination shown by term infants is unlikely to have cortical origin, and similar effects have been demonstrated in an anencephalic infant (Graham, Leavitt, Strock, & Brown, 1978).

Since these preterm infants, like those of the Rose et al. (1976) study, were tested at a slightly younger conceptional age than the term infants and had also experienced respiratory distress and hyperbilirubinemia, we cannot draw conclusions about causation from either study. This confounding of immaturity and medical condition highlights the importance of conducting these procedures with additional control groups, namely, preterm babies tested at 37 weeks who had no respiratory distress or hyperbilirubinemia, and healthy babies born at 37–38 weeks who were considered to be full term by the attending pediatrician.

Although larger magnitude cardiac responses were elicited by the auditory relative to the tactile stimuli, we cannot conclude that term infants are more sensitive to auditory stimuli in general because intensity was not equated across modalities. However, if one lets the infant's response magnitude define apparent stimulus intensity (see Figure 3), then the rank ordering is rattle, buzzer, and filament, with rattle being most "intense." According to Thompson's dual-process theory (Thompson & Glanzman, 1976), increasingly intense stimuli result in relatively greater sensitization or dishabituation, whereas lower intensity stimuli may produce only habituation. In fact, only the two apparently most intense stimuli as measured by response magnitude, the rattle and buzzer, did produce response recovery during dishabituation trials. Furthermore, the response to buzzer declined over the three trials, but the response to rattle was maintained for three trials at the same level of responding as on Trial 1 of the habituation series. Future studies might test Thompson's sensitization hypothesis more explicitly by presenting a series of the same stimulus varying only in intensity.

A final consideration must be given to how sleep states may have affected our results, particularly group differences in cardiac responsivity. Unfortunately we did not require agreement of state ratings prior to stimulus presentations. Since the interobserver reliability for sleep state ratings was only .79, some trials were presented by one experimenter, whereas the other noted quiet as opposed to the criterion active sleep. Some researchers have reported that responsivity is comparable in quiet and active sleep (Rose, Schmidt, & Bridger, 1978), whereas others have found differences (Schaefer, 1975; Taylor & Mescher, 1972). Clifton and Nelson (1976) pointed out that the effect of state change on responding depends on the stimulus, the response, and the direction of state change, so that generalized predictions about increased or decreased responses following a state change cannot be made. In any case, our data do not appear to suggest a spurious effect produced by shifts into deeper sleep by the term group. Specifically, our term infants showed habituation of cardiac acceleration to all three stimuli, but response recovery only to buzzer and rattle. Following recovery there was response decrement only to the buzzer. Examination of state ratings indicated virtually no change in sleep state across the buzzer trials; however, there was a considerable change to deeper sleep across the rattle trials. If a state change toward deeper sleep was responsible for response decrement over trials in the term group, the response to rattle should have shown the most "habituation." To conclude, habituation of cardiac responses by the term but not the preterm group is unlikely to be related to differences in state. However, the necessity for careful consideration of state effects in any study comparing term and preterm infants seems clear.

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Received January 22, 1979 ■

Manuscripts Accepted
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Individual Differences in the Pattern of Habituation at 5 and 10 Months of Age. Robert B. McCall (Center for the Study of Youth Development, Boys Town, Nebraska 68010).

Lack of Acceptance of Reciprocity Norms in Preschool Children. Thomas J. Berndt (Department of Psychology, Box 11A Yale Station, New Haven, Connecticut 06520).

Importance of Task Content for Family Interaction Research. Scott W. Henggeler (Department of Psychology, Memphis State University, Memphis, Tennessee 38152), Charles M. Borduin, J. Douglas Rodick, and Joseph B. Tavormina.

Methodological Considerations in the Forbidden Toy Paradigm. Harry L. Hom, Jr. (Department of Psychology, Southwest Missouri State University, Springfield, Missouri 65802) and Fred R. Maxwell, Jr.

Comparison of Masculine and Feminine Personality Attributes and Sex-Role Attitudes Across Age Groups. Janet T. Spence (Department of Psychology, University of Texas, Austin, Texas 78712), and Robert L. Helmreich.

Development of Structure and Strategy in Two-Dimensional Pictures. Jessica Beagles-Roos and Patricia Marks Greenfield (Department of Psychology, University of California, 405 Hilgard Avenue, Los Angeles, California 90024).

Comparing the Defining Issues Test and the Moral Dilemma Interview. William J. Froming (Department of Psychology, University of Florida, Gainesville, Florida 32611) and Edgar B. McColgan.