Title: Responses of preterm infants to unimodal and multimodal sensory intervention
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Source: ***Pediatric Nursing*.** 23.2 (March-April 1997): p169.
Document Type: Article

Abstract:

Purpose: To examine the immediate responses of preterm infants to two forms of unimodal [auditory only (A) and tactile only (T)] and two forms of multimodal sensory stimulation [auditory, tactile and visual (ATV); auditory, tactile, visual and vestibular (ATVV)]. Method:A convenience sample of 54 clinically stable preterm infants (33-34 postconceptional weeks) was randomly assigned to 1 of 5 experimental groups [Control (C); (A); (T); (ATV); and (ATVV)]. Stimulation was applied for 15 minutes once daily for 4 consecutive days. Results: Outcome measures included pulse (PR) and respiratory rate (RR), oxygen saturation, behavioral state (BS), and body temperature. Repeated measures ANOVA identified significant differences among the groups during intervention for PR (p [less than] .001), RR (p = .01), and BS (p [less than] .02). Infants receiving any intervention with a tactile component showed increasing arousal (change in BS), and increased PR and RR during stimulation. Group T infants had higher proportions of PR, 180 while Group ATVV had higher proportions of PR [less than] 140 (p = .0001). Group ATVV showed increased alertness following stimulation (24%) in contrast to having the least alertness during stimulation (11%). Conclusions: Tactile stimulation alone may be too arousing for these infants while the addition of vestibular stimulation may modulate arousal and facilitate optimal arousal prior to feeding.

Full Text:

Over the last 20 years, both unimodal (one form of sensory stimulation) (Deiriggi, 1990; Katz, 1971; Korner, Kraemer, Haffner, & Cosper, 1975; Korner, Schneider, & Forrest, 1983; Neal, 1977; Rausch, 1981; Salk, 1960; Scafidi et al., 1986, 1990; Solkoff, Yaffe, Weintraub, & Blase, 1969; White & Labarba, 1976) and multimodal (more than one form) (Barnard & Bee, 1983; Kraemer & Pierpont, 1976; Lieb, Benfield, & Guidubaldi, 1980; Rice, 1977; Rose, Schmidt, Riese, & Bridger, 1980; Scarr-Salapatek & Williams, 1973) sensory stimulation have been found to be beneficial for premature infants in terms of growth, motor activity, neurobehavioral function, and autonomic stability. The neuroendocrine mechanisms that facilitate these improvements remain unknown. Unfortunately, little research has documented premature infants' immediate responses to different modes of sensory stimulation and thus consensus is lacking on which type of sensory stimulation should be administered and on how and when it can be delivered safely (Korner, 1990). The purpose of this study was to examine the immediate responses of homogeneous groups of preterm infants to two forms of unimodal sensory stimulation and two forms of multimodal sensory stimulation to determine immediate physiologic and behavioral responses to each form.

Historically, developmental researchers argued that preterm infants were deprived of the auditory, tactile and vestibular stimuli characteristic of the intrauterine environment. Integrated reviews of early intervention report that the effects of replacing the missing stimuli within the NICU environment have been examined, but the "high-tech" elements of the NICU were not reduced, and few have measured the infants' physiologic responses to intervention (Blackburn, 1983; Field, 1980; White-Traut & Goldman, 1988; White Traut, Nelson, Silvestri, Patel, & Kilgallon, 1993). Without data on physiologic response, the safety of the interventions used in the NICU cannot be documented.

Although mental and motor development of preterm infants have improved with the addition of sensory intervention, data from these studies are difficult to compare for a number of reasons. Inconsistent and ill-defined selection criteria led to samples that were not homogeneous or had large ranges of gestational ages. Different modes and/or application of sensory stimuli have been used. Research is also limited by the lack of reported physiologic measures to safeguard the welfare of premature infants. Studies may actually have exposed preterm infants to excessive or inappropriate sensory stimulation in the NICU (Parmelee, 1985). Without recording physiologic data, the degree to which stimulation was excessive cannot be adequately addressed. There has been little research to examine how different forms of stimulation, presented either alone or combined, may affect the preterm infant at the time of intervention. Documentation of such differential responses may assist in planning safe interventions for infants 33-36 weeks, as well as lay the foundation for further research on the responses of very low birth weight infants with specific diagnoses. Therefore, the questions addressed were: (a) How do infants, 33-34 weeks gestational age, compare in their physiologic and behavioral responses to auditory only (female voice), tactile only (light massage), auditory, tactile and visual (eye to eye contact), or auditory, tactile, visual, and vestibular (rocking) stimulation; and (b) are these responses within safe limits?

Method

Sample. The infants studied were 54 healthy, clinically stable preterm infants with a mean gestational age of 32 weeks at birth and 33 gestational weeks at entry into the study. After informed consent was obtained, infants were randomly assigned to one of five groups. Birth weight ranged from 1200 to 2353 grams. Infants were eligible for entry into the study if they were not receiving oxygen therapy at entry into the study, were free from congenital anomalies (or suspected congenital anomalies), and were not experiencing necrotizing enterocolitis or seizure disorders. Gestational age was determined within the first day postdelivery and was conducted by a physician blinded to the infants' group assignments (Ballard, Novak, & Driver, 1979). The groups did not differ with regard to gender, birthweight, gestational age at birth, type of delivery, medications received, phototherapy treatment (day 1), Apgar scores at 1 and 5 minutes, postnatal complication scores (PCS) (Littman & Parmelee, 1978), or race (see Table 1). Gestational age for Group T at entry (33.8 weeks) was significantly different from Group ATV (33 weeks).

Table 1. Variables Describing the Sample

Group Variable	Group C	Group A	Group T
	n = 14	n = 9	n = 10
Gestational age (Birth)	32.5(a)(1)(b)	32.4(1.52)	32.4(.51)
Postconceptional age (Entry)(c)	33.3(.49)	33.3(.48)	33.8(1.42)
Birthweight	1685(292.7)	1684(251.9)	1578(117.2)
Weight (Entry)	1637(247.9)	1587(269.2)	1551 (88.4)
PCS(d)	6.5(1.6)	6.4(2)	7.3(1.1)
Apgar 1 min	6.8(1.9)	7.5(1.4)	6.7(1.4)
Apgar 5 min	8.6(.8)	8.7(.5)	7.8(1.2)
Infant Gender (M/F)	7/7	5/4	4/6
Type of Delivery (NSVD/C-SEC)	9/5	3/6	2/8
Infant Race C/B/H/Other	4/8/2/0	2/6/1/0	5/5/0/0

	Group ATV n = 11	Group ATVV n = 10
Gestational age (Birth)	32(.89)	32.5(.53)
Postconceptional age (Entry)(c)	33(0)	33.5(53)
Birthweight	1668(300.1)	1639(226.4)
Weight (Entry)	1616(258.7)	1585(222.9)
PCS(d)	5.8(1.7)	6.8(1.1)
Apgar 1 min	5 9(2.6)	7(.7)
Apgar 5 min	7.8(1.6)	8.6(.5)
Infant Gender (M/F)	8/3	7/3
Type of Delivery (NSVD/C-SEC)	7/4	2/8
Infant Race C/B/H/Other	1/8/2/0	4/3/0/2

(a) Mean score

(b) Standard deviation

(c) p [less than] 0.001

(d) Postnatal Complications Score

Separate power analyses (Cohen, 1988) were computed for each of the dependent variables. Estimates of standard error were obtained from pilot research. A required sample size of 22 was needed to achieve 80% power to detect group differences as small as one standard deviation at the 0.05 level.

Intervention

Infants assigned to the Control group, Group C, received the routine care that infants normally received in the nursery at the time of this study. This included primary nursing care, a structured feeding schedule, and 24-hour open visiting for parents. The nursery environment included continuous fluorescent lights, monitor alarms, and periodic opportunities for stimulation and nonnutritive sucking. Visual stimuli were often placed near the infant.

Group ATVV received auditory stimulation (soothing female human voice) as the researcher massaged the infant for 10 minutes. This was followed by 5 minutes of rocking (vestibular stimulation). Throughout the 15-minute period, the researcher attempted to provide visual stimulation by engaging in eye-to-eye contact with the infant. Findings from previous studies also revealed how premature infants responded to the experimental stimuli, and infant responses were used to modify the stimulation used in this study. Stimulation was provided contingent on infant cues, and was continuously adapted i.e., if an infant exhibited negative cues during the intervention, that part of the technique was not continued and the next portion of the technique was attempted (Burns, Cunningham, White-Traut, Silvestri, & Nelson, 1994). Group ATV received 15 minutes of the auditory, tactile, and visual components of the ATVV, omitting the vestibular (rocking) stimulation. Group A received auditory stimulation, which consisted of 15 minutes of a soothing female voice via tape cassette. The auditory component of the ATVV technique was a tape recording of the investigator's voice. The same tape recording was played for each subject, and the recorder was consistently placed about 6 inches from the infants' ears. Group T received only the tactile component of the ATVV for 15 minutes. Eye contact with the infant was avoided.

Groups T, ATV, and ATVV received the intervention from an investigator who was trained to [greater than] 85% reliability prior to initiation of the research. During the data collection period, 25% of the ATVV treatments were observed by a third research assistant. A reliability score of 98% was calculated as a percent of agreement between the individual administering the intervention and the third assistant.

Physiologic Measures

The pulse oximeter measured pulse rate (PR) and arterial oxygen saturation (Sa[O.sub.2]) and delivered a digital display of both measures (Novametrix Model #515). PR and Sa[O.sub.2] were recorded from the monitor's digital readings. Reliability of the pulse oximeter was measured weekly by simultaneously monitoring Sa[O.sub.2] with a second pulse oximeter and testing the correlation between the monitors. The reliability of the pulse oximeter was calculated by the technical error of measurement (TEM) (Hamill, Johnston, & Lemeshow 1973), and was 3.5 bpm for PR and .71 % for Sa[O.sub.2]. Agreement between PR (via the pulse oximeter) and heart rate (HR) (via a cardiorespiratory monitor) was also studied. PR and HR were simultaneously recorded and 201 measures were randomly obtained. Percent agreement between the cardiorespiratory monitors and the pulse oximeter was 87.1%. Reliability of PR and HR was calculated as 2.42 bpm by the TEM.

Respiratory rate (RR) was recorded from the digital display of the cardiorespiratory monitor (Hewlett Packard Model #78833A). Reliability was assessed weekly by measuring RR with two cardiorespirogram monitors simultaneously. Reliability was calculated by the TEM (Hamill et al., 1973) as 2.4 respirations per minute. Body temperature (BT) was measured using the monitor mode of the electronic thermometer (IVAC Model # 817).

Behavioral State

Seven categories of infant behavioral state (BS) (Wolff, 1966; Korner, 1972) were measured and included quiet sleep, active sleep, drowsy, quiet alert, active alert, crying, and indeterminant. States were judged by a research assistant, who was trained to reliability of, .85 by the co-investigator prior to initiation of the study. For 25% of the observations, measures of behavioral state were judged by two observers to maintain reliability. Interrater reliability was calculated by measuring percentage of agreement between the two observers divided by the sum of agreements and disagreements, and was maintained at 86%.

Postnatal Complications Scale

Equivalency of the five groups prior to intervention was determined by comparing the infant's medical record with criteria from the Manual for Postnatal Complications (PCS) (Littman & Parmelee, 1978). The PCS measures the occurrence of the following: respiratory distress, hyperbilirubinemia, noninfectious illness or anomaly, temperature disturbance, seizures, mechanical ventilation, surgery, suspected or documented infection or metabolic disease, and time of first feeding. The research assistant was trained to 85% agreement prior to initiation of the study. For a randomly chosen 25% of the subjects, data were obtained by two raters, and interrater reliability was maintained at 96% agreement between two raters.

Procedure

The infants assigned to Groups A, T, ATV, and ATVV received 15 minutes of stimulation once a day for 4 consecutive days. The immediate outcome measures included PR, RR, BT, Sa[O.sub.2], and BS. The times chosen for recording the immediate response variables are presented in Table 2.

Table 2. Data Collection Protocol For Immediate Response Variables

	PRESTIMULATION	STIMULATION
Timeline T1 -T22	1 2 3 4 5 6	7 8 9 10 11 12
Time	0 1 2 3 4 5 Minutes	6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 Minutes
DATA COLLECTED	Every Minute	Every 2.5 Minutes

	POST-STIMULATION	
Timeline T1 -T22	13 14 15 16	17 18 19 20 21 22
Time	15 30 45 60 Seconds	5 10 15 20 25 30 Minutes
DATA COLLECTED	Every 15 Seconds	Every 5 Minutes

The treatments were initiated 1 hour prior to a late-morning feeding for several reasons. First, previous research documented that 33-34 week clinically stable preterm infants responded to ATVV stimulation prior to feeding with an increase in the active alert state, the state most often observed prior to feeding (White-Traut et al., 1993). Secondly, it was thought that the sleep cycle would be interrupted if the intervention was provided 1 hour after feeding. Third, handling infants this young after feeding can easily induce regurgitation.

Data were recorded at 22 time points. First, a baseline BT was obtained, followed by PR, RR, Sa[O.sub.2] and BS, which were recorded every minute for 5 minutes prior to initiation of each treatment (T1-T6). After T6, the investigator placed her hands in the incubator and administered the assigned intervention. For control infants, her hands were placed on the mattress for the 15-minute period. To maintain blind dependent measures, the research assistant positioned the ear plugs to block out any auditory cues and obstructed her view of the incubator to avoid observing the stimulation techniques. Mean PR, Sa[O.sub.2], and RR were recorded every minute from the monitoring equipment by the research assistant during the prestimulus period and then every 2 fi min during the 15-minute stimulation period (T6-T12). Behavioral state was judged every 2 fi min during the 15minute period (T6-T12). The investigator stopped the intervention for a 10-second interval and placed her hands on the mattress to allow the observer (the research assistant) to rate behavioral state and record the physiologic measures. Body temperature was obtained before T1 and after T22.

After the stimulation technique had been completed at 16 minutes, PR, RR, BS and Sa[O.sub.2] were recorded every 15 seconds for I minute (T12-T16), and then again at 5, 10, 15, 20, 25, and 30 (T17-T22) minutes. BT was measured again at T22. These intervals were chosen to identify base line parameters (T1-T6), how responses changed from initiation of the intervention to completion (T6-T12), if there was any change during the immediate minute postintervention (T12-16), and how the infants recovered over a 30minute period (T13, 17-22).

Data Analysis

Repeated measures ANOVAs were conducted to identify differences over time for each variable during four intervals: baseline (T1-T6), intervention (T6-T12), 1 minute immediately following intervention (T12-T16), and the 30 minutes following intervention (T13, 17-22) (see Tables 3 & 4). PR, RR. Sa[O.sub.2], and BT were analyzed separately using the averaged data. BS was analyzed using percentages of infants in each of the seven state categories. An alpha level of .05 was used for all statistical tests. Inflated degrees of freedom associated with the use of repeated measures were corrected downwards through the use of the Greenhouse-Geisser correction (Geisser & Greenhouse, 1958).

Table 3. Mean Physiologic Response Baseline(T1-6), During(T6-12), and Post Intervention (T12-16;T13,17-22) Values Averaged Over 4 Days

Variable	Group C	Group A	Group T	Group ATV
PR				
T1-6	152.63(a)	140.67	156.36	149.30
	(16.20)(b)	(13.18)	(14.93)	(13.90)
T6-12	151.53	140.55	160.89	154.22
	(17.41)	(13.32)	(16.06)	(15.68)
T12-16	150.91	141.04	157.55	150.44
	(16.67)	(11.43)	(18.21)	(14.86)
T13,17-22	151.56	138.12	155.40	146.77
	(17.22)	(11.08)	(18.33)	(16.12)
RR				
T1-6	39.67	41.17	41.39	39.84
	(15.65)	(17.09)	(18.7)	(17.86)
T6-12	40.22	39.64	37.57	36.29
	(16.65)	(16.01)	(16.08)	(15.49)
T12- 16	39.80	38.55	43.92	38.60
	(17.63)	(15.62)	(18.57)	(15.43)
T13,17-22	40.04	41.18	43.67	41.70
	(16.6)	(16.21)	(18.13)	(17.82)
SA[O.sub.2]				
T1-6	96.09	96.98	96.90	96.14
	(2.33)	(1.60)	(2.31)	(1.63)
T6-12	95.91	96.91	96.97	96.12
(2.45)	(1.99)	(2.05)	(1.82)	(2.38)
T12-16	95.74	96.85	96.92	96.54
(2.36)	(2.37)	(2.14)	(1.62)	(1.96)
T13,17-22	95.90	97.29	97.04	96.19
	(2.32)	(1.41)	(1.75)	(1.66)

Variable	Group ATVV	F(df)	p
PR			
T1-6	150.83	3.19(4,44)	.02(c)
	(15.97)		
T6-12	156.00	5.92(3,132)	.001(c)
	(17.08)	5.37(3,132)	.001(d)

T12-16	151.88	3.32(4,43)	.02(c)
	(13.89)	4.41(4,44)	.001(c)
T13,17-22	151.50	4.29(3,132)	.01(d)
	(14.62)	2.82(6,264)	.02(f)
RR			
T1-6	41.05	0.19(4,43)	NS
	(14.98)		
T6-12	37.77	3.84(3,132)	.1(d)
	(13.91)	1.88(24,264)	.019
T12- 16	40.49	1.27(4,42)	NS
	(16.78)		
T13,17-22	40.03	2.52(6,264)	.02(f)
	(15.19)		
SA[O.sub.2]			
T1-6	97.07	1.46(4,44)	NS
	(1.89)		
T6-12	96.62	1.30(4,37)	NS
(2.45)			
T12-16	96.93	5.41 (4,16)	.001(f)
(2.36)			
T13,17-22	97.23	8.83(4,24)	.001(f)
	(1.69)		

(a) Mean

(b) Standard Deviation

(c) Group interaction

(d) Day interaction

(e) Group by day interaction

(f) Time interaction

(g) Group by time interaction

Table 4. Baseline (T1-6), During (T6-12), and Post Intervention (T12-16, T13,17-22) Behavioral State Percentages Averaged Over 4 Days

T1-6	Group C(a)	Group A	Group T	Group ATV
Sleep	70.4	80.9	59.5	86.0
Alert	4.7	1.4	12.1	5.6
Sleep	76.1	92.6	47.6	74.4
Alert	5.5	0.0	20.8	9.4
T12-16				
Sleep	79.3	92.4	36.0	58.6
Alert	4.9	1.1	33.0	17.7
T13,17-T22				
Sleep	76.1	92.6	47.6	74.0
Alert	4.2	0.0	20.8	6.5

	Group ATVV	F(df)	p

T1-6			
Sleep	79.3	0.79(4,44)	NS
Alert	14.2		
Sleep	68.3	2.86(6,264)	.02(b)
Alert	11.1		
T12-16			
Sleep	48.2	2.21(12,132)	.02(c)
Alert	12.8		
T13,17-T22			
Sleep	68.3	2.67(6,258)	.02(b)
Alert	23.6		

(a) Presented as a percentage

(b) Time interaction

(c) Group by day interaction

Results

Baseline comparisons. One-way analyses of variance (ANOVA) among the five groups were conducted to determine whether the groups were equivalent on the first day prior to initiation of the experimental protocol (T1). There were no significant differences among the five groups for baseline PR, RR, Sa[O.sub.2], BT, or BS. In all groups, mean PR ranged from 142 to 151 bpm, mean RR ranged from 42 to 50 per minute, mean Sa[O.sub.2] ranged from 96 to 98, and mean BT ranged from 97.8 to 98.4 degrees Fahrenheit (36.6 to 36.9 degrees Celsius). The majority of infants were in sleep states (Group C: 71.4%, Group A: 77.8%, Group T: 70.%, Group ATV: 81.8%, Group ATVV: 100%) prior to initiation of data collection. The absence of statistically significant baseline differences on Day 1 at Time 1 suggested that the infants were not different prior to intervention.

Baseline repeated measures ANOVA comparisons for T1-T6 (for all 4 days) failed to reveal significant differences among the five groups for RR, Sa[O.sub.2] and BS (see Tables 3 & 4). In these analyses, "sleep" included both active and quiet sleep states, while "alert" included both the quiet and active alert states. A significant Group effect was identified for PR (p = .02). Group T had the highest mean PR, followed by Groups C and ATVV. There were no changes over the 4day study.

Responses to intervention. Repeated measures ANOVAs over the time interval T6-T12, with T6 serving as a baseline measure, revealed significant responses to stimulation for all dependent measures except Sa[O.sub.2]. Infants in Groups T and ATV showed increasing alertness, increased PR, decreased RR, and changes in BS toward alertness (see Tables 3 & 4). A significant Group effect was identified for PR (p [less than] .001), reflecting a modest increase for Groups T, ATV, and ATVV. In general, infants showed stronger responses on successive days, indicated by significant main effects for days for PR (p [less than] .001) and RR (p = .01). A Time effect was identified for BS (p [less than] .02), reflecting increasing alertness as intervention proceeded for Groups T and ATV. Group ATVV showed a decline in alertness. A Group-by-Time interaction for RR (p = .01) was followed up with individual comparisons that revealed increasing RR over Time for Groups T, ATV, and ATVV when compared with controls.

Responses during the first minute postintervention. The highest PR was seen in Group T while the lowest was seen in Group A. PR for Groups ATV and ATVV were not different from controls. There were no significant effects for RR. Groups T, ATV, and ATVV showed very slight but significant increases in Sa[O.sub.2] levels. For BS, Group T showed the most alertness, while ATV and ATVV showed moderate levels of alertness when compared to Groups C and A. Repeated measures ANOVAs for T12-T16 revealed a Group effect for PR ($p = .02$), a main effect of Time for Sa[O.sub.2] (p [less than] .001), and a Group by Day interaction effect for BS ($p = .02$).

Responses during the 30 minutes postintervention. PR and RR decreased, while Sa[O.sub.2] increased slightly for all groups within the 30 minutes. No changes in BT were identified. Repeated measures ANOVAs of T13, 17-22 confirmed a Group main effect for PR (p [less than].001), main effects of Time for PR ($p = .02$), RR ($p = .02$), and Sa[O.sub.2] (p [less than] .001). PR decreased over the 4 days ($p = .01$). A Time effect was identified for BS ($p = .02$), reflecting a gradual reduction of arousal following the cessation of intervention. Except for the ATVV group, alertness evolved into sleep within the first 5 minutes postintervention, although this trend failed to reach significance.

Behavioral state response. Infants receiving the auditory-only intervention responded with an increase in quiet sleep (11.8% quiet sleep at baseline, to 29% quiet sleep postintervention), while infants assigned to Groups T and ATV responded with an increase in alert states during intervention averaged over the 4 days of the study. Control infants receiving no stimulation at all actually slept less (76%). Group ATVV exhibited a unique sleep pattern involving only a gradual increase in alertness during intervention (11%, 240 observations), followed by increasing alertness that was sustained over the 30-minute postintervention (24%, 280 observations) (see Table 4). It appears that the addition of vestibular stimulation facilitated arousal following cessation of the intervention.

Variability of autonomic responses. Inspection of the data revealed differences between groups in variability of PR and RR categorized as low, intermediate, and high. Only Groups T and ATVV had sufficient variability to warrant further analyses of PR and RR. Many PR observations in group T exceeded 180 bpm (67 of 880, or 7.1%), while the ATVV group, which also included a tactile component, rarely included pulse rates over 180 (35 of 770, 4.5 %), almost 40% less than the T group). Crying was not a factor, as the groups did not differ in their low incidence of crying. By contrast, the ATVV group included 30% more PR observations under 140 bpm (159, 20.6%) than the T group (122, 13.9%). A chi-square was performed on the distribution of high, intermediate, and low rates in the two groups, and revealed a significant difference, [chi square] (2)= 18.096, $p = .0001$ (see Table 5). A similar comparison of the distributions of respiration rates also yielded a significant difference, [chi square] (2) = 10.213, p [less than] .01. Follow-up l-tests were performed to compare groups T and ATVV on subject-by-subject proportions of PR over 180 and under 140. Similar analyses were performed for respiratory rates below 30 and greater than 60. No significant differences were identified between Groups T and ATVV.

Table 5. Distribution of Autonomic Responses

	Low	Intermediate	High	Total
PR	<140	140 - 180	>180	N
Group T	122	691	67	880
Group ATVV	159	576	35	770
RR	<30	30 - 60	>60	N
Group T	251	499 1	30	880
Group ATVV	193	493	84	770

PR	[chi square] (df)	p
Group T		
Group ATVV	[chi square](2) = 18.096, p<.0001	

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RR
 Group T
 Group ATVV      [chi square] (2) = 10.213, p<.01
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Discussion

Preterm infants in this study had differing immediate physiologic and behavioral responses to Auditory Only; Tactile Only; Auditory, Tactile, and Visual; and Auditory, Tactile, Visual, and Vestibular interventions. In addition, the time-sampling procedure documented that infants' physiologic responses remained broadly within normal limits in all five groups, suggesting they were not compromised physiologically. However, questions are raised about the Tactile Only group because of the greater incidence of PR [greater than] 180 bpm in this group.

The findings of a 6 bpm increase in HR, a 4-respiration per minute decrease in RR, and .45% decrease in Sa[O.sub.2] replicate and extend recent demonstrations of the safety of the ATVV. White-Traut and Goldman (1988) reported that 35-week infants had a mean 12 bpm increase in HR and a mean of 5 breaths per minute RR increase while receiving the ATVV, whereas 33-week infants had a 6.5 bpm increase in PR (White-Traut et al., 1993). These studies suggest that 35-week infants are more capable of strong autonomic responses to tactile stimulation than 33-week infants (Henna Stark, Cohen, & Saul, 1995).

The infants in this study were most likely to show pulse rates over 180 and respiration rates over 60 with Tactile Only intervention, suggesting that strong autonomic activation should be explored further in any study of tactile only intervention. High pulse and respiration rates may interfere with feeding and may be an especially important consideration in studies of brain injured or otherwise compromised infants who tend to show autonomic liability. Since HR and blood pressure are inevitably linked, and fluctuations in blood pressure may place premature infants at risk for brain hemorrhage (Perry et al., 1990), it would appear that physiologic monitoring must be included during tactile interventions to determine level of autonomic arousal.

Behavioral state differed among the five groups. Infants in Group A responded with an increase in quiet sleep, the most restful state. Quiet sleep reduces energy expenditure and subsequently improves weight gain (Chuman, 1983), and is also considered the most advanced state ontogenetically (Parmelee & Sigman, 1983). Further research is needed to replicate current findings and to question whether soothing auditory stimuli might increase the percent time spent in quiet sleep and improve weight gain patterns if provided on a regular basis during each sleep cycle. Infants assigned to the tactile groups experienced more alertness during and following intervention than Groups A and C. The highest percentage of alertness (24%) was maintained during T13, T17-22 by Group ATVV, with Group T following close behind (21%). Changes in behavioral state in both 35week (White-Traut & Pate, 1987) and 33-week infants receiving the ATVV (White-Traut et al., 1993) have been reported.

These data provide new information regarding the utility of the ATVV. The benefit of adding vestibular stimulation when compared to the T and ATV protocols was that the infant's increased arousal was obtained more often after the intervention, rather than during the intervention. The soothing effects of vestibular stimulation on both full-term and premature infants are well documented and, as these results suggest, might be used to modulate responding. In other words, vestibular stimulation may be used in conjunction with auditory, tactile and visual stimulation to help the premature infant organize behavior, particularly prior to feeding. Feeding is the time for infants to be alert and interact with their caregivers and not show elevated heart rates and associated respiratory rates that can interfere with feeding (Ainsworth, 1973). Future research should further explore the role of vestibular stimulation, and evaluate whether the modulation of behavioral state using sensory interventions prior to feeding can improve feeding behaviors, weight gain patterns, and attentional responding. Clinical practice should include monitoring of physiologic arousal and clinicians should more carefully control the modulation of behavioral state, e.g., using soothing vestibular stimulation, to optimize feeding and social interactions. We find that tactile stimulation alone is most stimulating with the probability of HR, [is greater than] 180 possibly indicating unacceptably high levels of arousal.

We suggest that the ability to maintain a moderate physiologic response might be necessary for the quiet alert state to occur. The faster pulse rates of Group T infants suggest that tactile only stimulation may involve more arousal than is needed to promote enduring alert states. The consistent behavioral and moderate physiologic responses of the ATW group support this type of multimodal intervention for preterm infants at this age and health state.

Future empirical questions involve the types of infant populations that may benefit from ATW intervention. Preterm infants who are recovering from brain hemorrhages or periventricular leukomalacia are less capable of benefiting from potentially stressful stimulation and may be in greater need of contingent stimulation, for example, in promoting attentional responding. The moderate physiologic responses identified in this and previous studies (White-Traut et al., 1993), and its ecologic validity (White-Traut et al., 1994) support further evaluation of the ATW intervention with CNS-injured premature infants.

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Acknowledgment: This research was funded by the March of Dimes Birth Defects Foundation, Grant # 12-223, a Biomedical Research Support Grant # S07RR05776, and the Novametrix Company. This research received the Outstanding Clinical Research Paper Award by NAACOG, 1992. The authors would like to acknowledge Kristen Burns, Karen Kopischke, Christine O'Malley, and Kimberly Stieglitz for their assistance with data collection, and Guo-Guang Gu and Badar Iqbal for their assistance with data management.
