Auditory Arousal in Preterm Infants

Kay Lynn Copriviza and Cynthia Gayle Lima

San Francisco State University, San Francisco
University of Wisconsin-Madison

Initially, one might wonder if there is need to test the hearing of infants. Downs and Hemenway (1969) reported that the incidence of hearing impairment at birth was 1 in 1,000. Another study revealed a similar finding that hearing loss occurs in 1 in 1,500 newborns (Downs, 1968). If hearing loss is identified, what action, if any, should be taken?

Because hearing plays an important role in the infant's ability to receive vital information about the environment, to establish normal language processes, and to develop socio-emotional interactions, early identification of hearing loss is extremely important. Matkin (1968) suggested that the pervasive effects of an auditory deficit can be minimized successfully only if an aggressive habilitation program is initiated at an early age. Kendall (1965) reported that not testing at birth may lead to needless delay and such delay may compromise the whole development of the hearing-impaired child.

Gerber (1971) pointed out several reasons why the hearing of neonates should be screened: (a) Birth may be the only possible time to do so, (b) auditory and other neurosensory deficits are present and observable at birth, and (c) auditory deficits identifiable at birth require the earliest possible habilitation. Therefore, there seems to be a consensus that hearing testing should be done on newborns.

The auditory behaviors of full-term infants have been repeatedly studied and have been found to reveal consistent patterns. Eisenberg (1976) has studied the responses of newborns for many years and has noted that speech-like signals seem effective in producing responses in newborns. Eisenberg (1976) also noted that there are two to three times more responses by newborns to frequencies below 4000 Hz than to those above 4000 Hz. Noise bands seem to be more effective than unmodulated pure tones in eliciting neonatal responses (Eisenberg, 1965). Numerous studies have shown that the auditory behavior of neonates varies systematically in accord with an "awake—alert—aware" continuum (Eisenberg, 1965; Eisenberg, Griffin, Corsin, & Hunter, 1964). Eisenberg (1976) and Northern and Downs (1974) reported that infants respond better when the sound source is close to the ear, but not so close as to be distracting. Although we know
this about full-term infants, behaviors of preterm infants are not so firmly established.

Studies of the auditory behavior of preterm infants at birth leads one to conclude that the auditory sensory system is intact and operating in intrauterine stages (Vasiliu, 1968). According to Galambos, Hicks, and Wilson (1981), hearing function improves rapidly in premature infants from about 28 wks gestational age onward, and at term the normal threshold for the test stimulus approximates that of an adult. The question remains as to what normal auditory behavior is in preterms and which auditory stimuli are most effective to elicit responses.

Taylor and Mencher (1972), in a study involving 225 newborns, found that broadband white noise was the optimal stimulus for eliciting neonatal responses. They also observed that infants in light sleep were more responsive than those in deep sleep. Ling, Ling, and Doehring (1970) found a 1/3 octave band centered at 2000 Hz to elicit more responses than one at 3150 Hz or a sine wave.

There have been apparent contradictions in the findings of researchers in regard to the auditory behaviors of preterms. In a comparison of responsiveness of full-term and preterm infants to acoustic stimuli, Bench and Parker (1971) found preterms to exhibit hyperresponsivity. According to Hurlock (1956), the premature infant was found to be highly sensitive to sounds and noises. On the other hand, there are reports in most pediatric journals that preterm infants are generally lethargic and tend to be nonresponsive. For example, Knobloch and Fusamanick (1974) found that the premature infant is generally weak, indifferent, and unresponsive, and under no compulsion to exercise behavior patterns which are undergoing dormant maturation.

From the perspective that it is valuable and critical to test infants' hearing as soon in life as possible, two questions are posed in this paper:

1. Will preterm infants respond more or less frequently than full-terms to specific acoustic stimuli?
2. Will they respond selectively to one of the two stimulus signals used?

The data gathered in this study conducted with preterm infants will be compared to the data of an identical study by Gerber and Mencher (1979), using full-term infants.

SUBJECTS

Eleven preterm infants ranging from a gestational age of 26–35 weeks were observed at 1–18 weeks postpartum. Seven preterms were tested in the intensive care nursery at the Speech, Hearing and Neurosensory Center at Children's Hospital, San Diego, California. Four preterms were at Children's Hospital of Los Angeles, California. Of the 11 infants 6 were girls and 5 were boys. All preterms were in isolettes and were handled only by the nursing staff to move infants within range of testing equipment.
METHODS

Two acoustic stimuli were used in this study. The signals presented were recorded on a Maxell C60 tape and played on a Sony recorder model TC-L10A. One test stimulus was a sine-wave frequency modulated ± 150 Hz, centered around 3000 Hz and having a maximum intensity of 90 dB SPL. The other stimulus used, as recommended and defined by the Nova Scotia Conference (1974, p.), was "a random noise having a low frequency attenuation of 30 dB or more per octave below 750 Hz; a maximum 90 dB SPL at the pinna; a rise-decay time of 5 ms or more; a duration of 0.5-2.0 s; and interest interval minimal of 15 s." All babies received 16 stimulus presentations, 8 presentations of the narrow-band stimulus and 8 presentations of the wide-band stimulus. Prior to testing, the cassette was placed 6 in. (15.2 cm) from a sound-level meter B&K Type 2203 and calibrated to 90 dB SPL. The recorder was then held 6 in. (15.2 cm) from the subject's pinna for testing.

Three investigators observed the preterm infant's behavior. The arousal response, as defined by the Nova Scotia Conference on the Early Identification of Hearing Loss, entails movement of the eyes and of at least one limb occurring within 2½ s after stimulus onset and observed by at least two independent observers on a minimum of 2 out of 8 trials. Each observer marked a plus sign if an arousal response was noted and a minus sign if there was no observable response. A zero was recorded if the infant was in a state of unrest and a definite response to the acoustic stimulus could not be determined. A single trial was considered a positive response only if at least two of the three investigators were in agreement.

RESULTS

Table 1 includes personal data on each of the subjects tested. Data are listed in order of gestational age. As shown, information is given as to sex, gestational age, number of responses to wide-band stimuli, number of responses to narrow-band stimuli, postpartum age, birth weight, weight at the time of test, Apgar scores, peak bilirubin level, and the presence or absence of respiratory distress syndrome. Cells containing slashes represent information that was not available to the researchers. Infants numbered 1, 2, and 3 were triplets.

Table 2 contains a distribution of responses from both the Gerber and Mencher (1979) full-term study and the present preterm study. Results are divided among aspects of sex stimulus properties, including data for both sexes to each stimulus and overall responses of full-terms and preterms to each stimulus.

As can be seen in Table 2 the full-term study consisted of 20 boys and 27 girls. The preterm study contained 5 boys and 6 girls. Row 2 shows the distribution of responses of each sex in each study to the wide-band stimuli. Percentages were obtained by determining the number of responses out of total presentations. In

Copriviza, Lima: Auditory Arousal in Preterm Infants 5
the full-term study the males responded to 25% of the presentations of the wide-band stimuli; the females responded 18%. The preterm male infants responded to 23% of the wide-band stimuli and females responded to 31%.

Full-term boys responded to 19% and girls to 10% of the narrow-band stimuli. Preterm boys responded to 25% and girls to 17% response pattern to the narrow-band stimuli.

Table 1. Personal data on each of the 11 infants studied.

<table>
<thead>
<tr>
<th>Infant number</th>
<th>Sex</th>
<th>To wide-band stimuli</th>
<th>To narrow-band stimuli</th>
<th>Post-partum age (wks)</th>
<th>Birth weight (gm)</th>
<th>Weight of test Apgar score</th>
<th>Peak bili level</th>
<th>Presence of RDS</th>
<th>Gestational age at birth (wks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>F</td>
<td>2</td>
<td>0</td>
<td>18</td>
<td>840</td>
<td>1830</td>
<td>5.9</td>
<td>norm</td>
<td>yes</td>
</tr>
<tr>
<td>11</td>
<td>F</td>
<td>3</td>
<td>3</td>
<td>17</td>
<td>770</td>
<td>1760</td>
<td>4.7</td>
<td>norm</td>
<td>no</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1470</td>
<td>1520</td>
<td>4.6</td>
<td>norm</td>
<td>no</td>
</tr>
<tr>
<td>1</td>
<td>M</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1360</td>
<td>1588</td>
<td>-</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>1412</td>
<td>1750</td>
<td>-</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1471</td>
<td>1758</td>
<td>3.5</td>
<td>norm</td>
<td>yes</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1760</td>
<td>1843</td>
<td>-</td>
<td>low</td>
<td>no</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1588</td>
<td>1658</td>
<td>6.8</td>
<td>norm</td>
<td>no</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td>1860</td>
<td>2570</td>
<td>4.8</td>
<td>14</td>
<td>yes</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1889</td>
<td>1921</td>
<td>7.8</td>
<td>10.8</td>
<td>yes</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1900</td>
<td>1810</td>
<td>6.5</td>
<td>8.6</td>
<td>yes</td>
</tr>
</tbody>
</table>

Table 2. Distribution of responses for number of infants tested according to sex and term.

<table>
<thead>
<tr>
<th>Responses</th>
<th>Full-term boys</th>
<th>Full-term girls</th>
<th>Preterm boys</th>
<th>Preterm girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>To wide-stimuli</td>
<td>(40/160)</td>
<td>(38/216)</td>
<td>(9/40)</td>
<td>(15/48)</td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>18%</td>
<td>23%</td>
<td>31%</td>
</tr>
<tr>
<td>To narrow stimuli</td>
<td>(31/160)</td>
<td>(21/216)</td>
<td>(10/40)</td>
<td>(8/48)</td>
</tr>
<tr>
<td></td>
<td>19%</td>
<td>10%</td>
<td>25%</td>
<td>17%</td>
</tr>
<tr>
<td>To wide-band stimuli (both sexes)</td>
<td>(78/376)</td>
<td>(78/376)</td>
<td>(24/88)</td>
<td>(27%)</td>
</tr>
<tr>
<td></td>
<td>21%</td>
<td>21%</td>
<td>27%</td>
<td></td>
</tr>
<tr>
<td>To narrow-band stimuli (both sexes)</td>
<td>(52/376)</td>
<td>(52/376)</td>
<td>(18/88)</td>
<td>(20%)</td>
</tr>
<tr>
<td></td>
<td>13%</td>
<td>13%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>To both stimuli</td>
<td>(71/320)</td>
<td>(59/432)</td>
<td>(19/80)</td>
<td>(23/96)</td>
</tr>
<tr>
<td></td>
<td>22%</td>
<td>14%</td>
<td>24%</td>
<td>24%</td>
</tr>
<tr>
<td>Total responses of both sexes to both stimuli</td>
<td>(130/752)</td>
<td>(130/752)</td>
<td>(42/176)</td>
<td>(24%)</td>
</tr>
<tr>
<td></td>
<td>17%</td>
<td>17%</td>
<td>24%</td>
<td></td>
</tr>
</tbody>
</table>

6 Journal of the National Student Speech Language Hearing Association, 1984
In combining the response of both sexes to the wide-band stimuli, 21% of the presentations to full-term infants elicited responses while 27% of the presentations to preterm infants elicited responses. Combining the responses of both sexes to the narrow-band stimuli, the response rates for full-term and preterm infants were 13% and 20%, respectively.

In looking at the responses of boys and girls to both stimuli, 71 responses of 320 presentations (22%) were observed for full-term boys. Full-term girls responded to 59 of the 432 presentations (14%). For preterm infants, both male and female responses were 24%.

Finally, the total number of responses of full-term infants and preterm infants to both stimuli was obtained. Full-term infants responded 130 times out of 752 presentations, or 17% of the time, and the responses from preterm infants were 42 out of 176 presentations, or 24%.

**DISCUSSION**

The results of this study provide us with some insight to the questions previously posed about the auditory behaviors of preterms. First, in considering whether preterms would respond more or less frequently than full-terms to specific acoustic stimuli, the data reveal a marked difference between the number of responses in each population. The preterms responded more frequently overall to both stimuli. Second, in comparing the infants' responses to narrow-band noises, we found that like the full-terms, preterms respond more readily to wide-band than to narrow-band stimuli.

These findings lead to a number of considerations. First, if preterms respond more frequently to acoustic stimuli than do full-terms, the criteria for a preterm "pass" should be more stringent than that for full-terms. Presently, 2 responses out of 8 is considered a "pass" in a healthy full-term infant (Nova Scotia Conference, 1974). Perhaps the criteria for a "pass" in a preterm should be modified as a function of gestational age at the time of birth and the time of testing.

It is known that severely hearing impaired pre-term infants do not respond to the acoustic stimuli used in the study. Two infants did not respond at all to either of the stimulus signals. Both were later tested using auditory brainstem responses and were found to be hearing-impaired. The data from these two infants were not included in the study. Infant 5 in this study also showed no responses. At the time of testing the researchers felt the infant was in a deep sleep state, as she had just been fed.

Since wide-band signals have been found in two separate studies (the present study and Gerber & Mencher, 1979) to elicit more responses from both preterm and full-term infants, we suggest that the narrow-band signal be eliminated from the screening procedures. The wide-band stimulus has been found to be effective for the purposes intended in these procedures. We feel that the next issue to be dealt with is that of refining the screening procedures and imposing more strin-
gent clinical standards and normative data with which to categorize responses. By decreasing the 90 dBA signal to around 60–70 dBA we might be able to detect those infants with moderate hearing losses.

Although the number of infants examined was small, the results are nevertheless suggestive. It is evident that preterm infants do respond more frequently than full-term infants when examined in the same experimental paradigm and with the same signals. The preterm infants used in this study are heterogeneous; for example, subjects 10 and 11 are older in postpartum age than the other subjects. Because of these subgroups and the small number of subjects, this study is to be just the first in a series of such studies.

Much research needs to be done in the area of infant auditory behavior to accomplish the fine tuning that will provide pediatric clinics with accurate screening procedures for infants. It is felt that effective hearing screening is imperative and should be a routine part of any medical diagnosis of the newborn infant. This is crucial if habilitation is to be implemented at the most opportune time—that is, the earliest possible time for the infant.

ACKNOWLEDGMENTS

This study was conducted while the authors were undergraduates in the Department of Speech at the University of California at Santa Barbara. The authors wish to acknowledge the assistance of Professor Sanford E. Gerber.

REFERENCES


8 Journal of the National Student Speech Language Hearing Association, 1984


