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Barbara A. Morrongiello  
*University of Massachusetts Amherst*

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<https://doi.org/10.7275/7n8k-7b97>

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DEVELOPMENTAL CHANGES IN CARDIAC-SOMATIC RELATIONS  
AND INFANTS' ORIENTATION TO COMPLEX SOUNDS AS A FUNCTION OF FREQUENCY

A Thesis Presented

BY

Barbara A. Morrongiello

Submitted to the Graduate School of the  
University of Massachusetts in partial fulfillment  
of the requirements for the degree of

MASTER OF SCIENCE

May 1980

Psychology

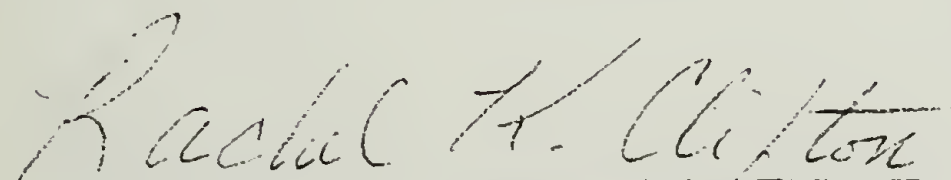
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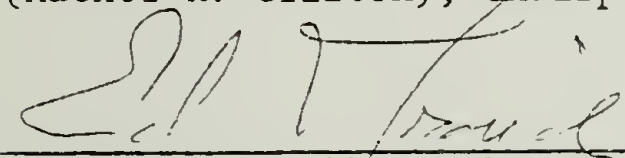
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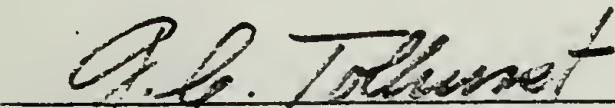
Approved as to style and content by:



(Rachel K. Clifton), Chairperson of Committee



(Edward Tronick), Member



(Gilbert Tolhurst), Member



(Bonnie Strickland), Department Head  
Psychology

## A C K N O W L E D G E M E N T S

I would like to thank my committee members, Drs. Rachel Clifton, Ed Tronick and Gilbert Tolhurst, for their assistance, cooperation, and scholarly comments and criticisms during this research. In particular, I would like to thank Rachel for allowing me to conduct this research independently, and at my own pace.

I also gratefully acknowledge the guidance and friendship of Carolyn K. Rovee-Collier over the past several years. Her continued support and contagious enthusiasm for research have significantly contributed to my professional development.

Collection of the newborn data was carried out with the assistance of John W. Kulig and I am most appreciative of his help.

I wish to particularly acknowledge the help provided by Rick Robson. He served as statistical consultant --- at all hours of the day and night, provided many insightful comments --- in his near habitual re-reading of the manuscript, and was continually supportive and understanding --- despite the many weekends which I spent working on this project to the exclusion of all else.

Finally, I am indebted to the infants and parents who participated in this research and the staff at Baystate Medical Center for making their facilities available for our use. This project was supported by a grant to Rachel from NIH ( # HD06753-06 ).

## A B S T R A C T

The present study investigated how the frequency composition of a complex sound differentially influences newborns' and five month-olds' auditory localization. The stimuli were tape recordings of a rattle, filtered to produce 4 stimulus conditions: low frequency band-pass rattle ( less than 1600 Hz ), mid-frequency band-pass rattle ( 1000-3000 Hz ), high frequency band-pass rattle ( greater than 1800 Hz ), and an unfiltered broad-band rattle. Sound pressure level was varied across trials to eliminate the possibility of any confounding effects as a result of the frequency manipulation. Direction, latency and duration of head turning, alerting and quieting were scored from videotapes of the infant's behavior. Cardiac measures of responding were also taken in order to assess developmentally the nature of cardiac-somatic relations in infants. In general, five month-olds head turned towards sounds more than newborns, and in contrast to the newborns, they turned their heads exclusively in the direction of the sound source. Significant differences in quantitative aspects of headturning towards a sound emerged, the head turning of newborns being longer in latency and duration. Differences in head turning towards the different frequency sounds occurred in newborns and five month-olds. The pattern of results for newborn head turning towards the sounds revealed an order of correct 'localizability' proceeding from low → medium → high/broad frequencies, with no

significant differences in head turning to the high vs broad-band frequency stimuli. Five month-olds showed an order of localizability proceeding from low/medium → high/broad-band frequencies. Cross-age comparisons revealed a developmental increase in head turning towards the low frequency stimulus. Five month-olds showed more alerting and quieting to sounds than newborns, and were as likely to alert as to quiet to a sound. In contrast, newborns showed significantly more alerting than quieting. Cardiac measures of responding revealed that heart rate change varied, at each age, as a function of head turning towards a sound. Newborns responded with cardiac decelerations only on those trials in which they did not head turn. On 'head turn' trials they showed no reliable cardiac response. Five month-olds responded with cardiac deceleration on both 'head turn' and 'no head turn' trials. The magnitude of the deceleration, however, was greater on trials in which they did not head turn. Results are discussed with regard to the development of the auditory system, recent findings on developmental changes in sensitivity to frequency information and literature on cardiac-somatic relations.

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## C H A P T E R I

### INTRODUCTION

The ability to localize a sound in space is an important auditory skill which is present at birth( Muir and Field, 1979 ). Sound localization is primarily a binaural phenomenon in which two major cues enable the organism to determine a sound's location in space: (1) differential intensity at the ears produced by the head acting as a sound shield, and (2) differences in phase due to different times-of-arrival of the sound at the two ears ( Green, 1976 ). Frequency composition of a sound serves essentially to determine which of these two cues are available for the listener's use. When sounds less than 1500 Hz are presented listener's depend on the time-of-arrival difference, and with sounds greater than 3000 Hz the intensity difference at the ears becomes the cue primarily available. Sounds in the 1000-3000 Hz range are most difficult for adults to localize as neither cue is maximally available ( Licklider, 1956 ).

Sound localization has been studied in adults, but very little is known about the development of the ability. There is some evidence of developmental changes in the processing of milli-second time differences over the first several months of life ( Clifton et al, 1980 ) which would suggest that younger infants

would do poorer in localizing sounds comprised of lower frequencies which are dependent upon the listener's use of the time-of-arrival cue. Further, anatomical investigations and electrophysiological recordings suggest that age related changes in responsiveness to different frequency sounds should emerge as a consequence of maturational changes in the auditory structures most responsible for the coding of frequency information ( Hecox, 1975 ).

One purpose of the present study was to determine how the frequency composition of a complex sound influences auditory localization in young infants. Infants were observed at two ages to determine if there are changes in localization of the different frequency sounds over the first 5 months of life. Videotapes of the infant's behavior were made. Heart rate was recorded in order to investigate the nature of the relationship between heart rate change and head turning behavior in young infants. There has been some research with newborns investigating the relationship between cardiac change and sucking but there is nothing currently known about developmental changes in cardiac-somatic relationships.



C H A P T E R I I  
REVIEW OF THE LITERATURE

A review of human anatomical and electrophysiological data makes it apparent that the auditory system is incompletely developed at birth ( see Hecox, 1975, for a complete review ). As one proceeds from the periphery towards more central mechanisms subsequent components of the auditory system are found to be relatively less mature. At the cochlear level, the number of hair cells present at birth is comparable to that of an adult; however, cell differentiation, particularly in the apical region, is incomplete and the most basalward portion of the cochlea continues to develop postnatally ( Bredberg, 1968 ). Though the auditory nerve and lower brainstem structures are well myelinated ( Peiper, 1963; Yakovlev and Lecours, 1967 ), the inferior colliculus and medial geniculate bodies are incompletely myelinated ( Hecox, 1975; Rorke and Riggs, 1969 ), and full myelination is not achieved till some time during adolescence. Axonal and dendritic development continues throughout the first year postnatally and is particularly rapid during the first six months of life ( Conel, 1952 ). In addition, the immaturity of the auditory cortex is reflected in newborn evoked potentials which are of longer latency and lower amplitude than adult evoked potentials ( Barnet, Lodge, and Armington, 1965; Lodge, Armington, Barnet, Shanks, and Newcomb,

1969 ), and by the lack of EEG synchronization between the two hemispheres, which is manifested during the first few months of life ( Dreyfus-Brisac, 1966 ).

In view of the anatomical and the electrophysiological immaturity present in the auditory system at birth one would expect that underlying physiological changes occurring in the developing organism would be manifested in developmental changes in functioning on auditory tasks. However, there is little systematic developmental research on auditory functioning. The earliest research on audition focused exclusively on determining whether or not neonates could hear ( see Pratt, 1954, for a review ). Subsequent research has sought to determine to what aspects of the sound infants are most responsive. There has been a substantial amount of research investigating young infants' auditory competencies but the majority of this research has been concerned with determining auditory thresholds and demonstrating infant auditory discrimination performance.

In general, all of the threshold studies indicate that auditory thresholds decrease with age; though the particular threshold reported varies as a function of the response measured, the stimulus parameters employed, and the age and state of the subjects tested. Infants have been found to respond differentially to stimulus parameters such as duration, repetition rate, inter-stimulus interval, rise time, band width, frequency, and rhythmic

or pulsed vs. continuous sounds. They can discriminate temporal patterns of sound and can segregate an auditory stimulus from background noise. There have also been many demonstrations that infants can discriminate various parameters of speech: voice onset time, place of articulation, and stress ( references for the studies referred to appear in Table 1 ). In contrast, there is little that is conclusively known about young infants' abilities to integrate and utilize binaural information, for example in directional discrimination or sound localization tasks.

The question of whether or not young infants possess the ability to localize sounds in their environment is a long standing one. An early study by Chun, Pawsatt, and Forster (1960), measuring head turning and oculomotor orientation to a buzzer positioned at varying locations around the infant's head, reported that localization responses were not present in infants younger than 26 weeks of age. Similarly, test norms cited 4 - 5 months as the average age at which infants will head turn toward the sound of a hidden rattle or bell ( Bayley, 1969; Catell, 1940 ). Wertheimer (1961), testing a single neonate, argued that 'newborns' will show reliable oculomotor orientation to a toy 'cricket' sounded on either side of the head; however, this result has not been replicated ( Butterworth and Castillo, 1976; McGurk, Turnure, and Creighton, 1977 ).

Leventhal and Lipsitt ( 1964 ) using a habituation-dishabituation paradigm provided evidence for sound localization discrimina-

TABLE 1

## SOME REFERENCES OF RESEARCH ON INFANTS' AUDITORY COMPETENCIES

| Parameter Manipulated   | Subjects' Age | Reference                                                                                                        |
|-------------------------|---------------|------------------------------------------------------------------------------------------------------------------|
| Intensity               | Neonates      | Barnet & Goodwin, 1965<br>Bartoshuk, 1964<br>Engel & Young, 1969<br>Schulman, 1973<br>Steinschneider et al, 1966 |
|                         | Older Infants | Hoversten & Moncur, 1969<br>Sculman & Wade, 1970<br>Trehub et al, 1980                                           |
| Duration                | Neonates      | Clifton et al, 1968<br>Stubbs, 1934                                                                              |
| Repetition Rate         | Neonates      | Bartoshuk, 1962a<br>Beadle & Crowell, 1962                                                                       |
| Inter-Stimulus-Interval | Neonates      | Bartoshuk, 1962b                                                                                                 |
| Rise Time               | Neonates      | Jackson et al, 1971                                                                                              |
| Band Width              | Neonates      | Eisenberg, 1965<br>Hutt et al, 1968                                                                              |
| Frequency               | Neonates      | Birns et al, 1965<br>Eisenberg, 1965<br>Hoversten & Moncur, 1969                                                 |
|                         | Older Infants | Moffitt, 1971<br>Morse, 1972<br>Weir, 1976                                                                       |
| Pulsed vs Continuous    | Neonates      | Brackbill, 1966                                                                                                  |
|                         | Older Infants | Clifton & Meyers, 1969                                                                                           |

TABLE 1 ( continued )

|                        |               |                                                                 |
|------------------------|---------------|-----------------------------------------------------------------|
| Temporal<br>Patterning | Older Infants | Chang & Trehub, 1977<br>Horowitz, 1972<br>McCall & Melson, 1970 |
| Speech<br>Perception:  |               |                                                                 |
| Voice-Onset-Time       | Older Infants | Eimas et al, 1971                                               |
| Place of Articulation  |               | Morse, 1972                                                     |
| Stress                 |               | Kaplan, 1969<br>Morse, 1974                                     |

tion in newborns. However, inadequate control of head position in conjunction with the use of small ear-sized speakers rather than earphones suggests the possibility that infants may have been presented with an intensity, as well as a localization, change. Consequently, it is not clear whether infants were responding to an intensity contrast effect or to a change in the sound's location. Alternatively, though Brown ( 1972 ) 'failed' to obtain evidence of discrimination of a stimulus location change presented through earphones to infants 6 - 9 weeks of age, it may be that use of the 'discrete-trial' heart rate paradigm exceeded the infant's information processing constraints, thus imposing a memory load. If such was the case then the use of a 'no-delay' heart rate paradigm, in which intertrial intervals are eliminated, might have detected the infant's ability to lateralize these sounds. Hammond ( 1970 ), drawing upon clinical examinations of newborn hearing, concluded that repeated head turning towards sound is within the behavioral repertoire of normal neonates. This conclusion is consistent with that of examiners who have administered the Brazelton Neonatal Assessment Scale ( 1973 ) in which newborns are expected to orient to the sound of a bell, rattle, and the human voice.

Reviewing the limited research which has focused on the young infant's ability to discriminate the location of sounds in the environment several things become apparent. Most clearly, the

results are equivocal and any discussion of these results is constrained by experimental incongruities in response measures, auditory stimuli employed, mode of presentation, age, and state of the subjects tested. In addition, each of the studies cited suffer from experimental flaws or anecdotal type of evidence, making discussion of the results considerably more problematic. Results from a recent investigation by Muir and Field ( 1979 ) which eliminates certain previous flaws, demonstrates that newborns do possess the ability to discriminate the direction of a sound in space and will head turn in this direction when certain 'particulars' are present in the testing situation.

In contrast to earlier studies, Muir and Field hand-held the 3 day-old infants throughout the testing session. During inter-trial intervals the experimenter was able to manipulate the infant so as to maintain him/her in an alert and calm state. In addition, the experimental session was arranged to suit the individual infant. Trials were initiated only when the infant was perceived to be in an appropriate state, and were terminated once the infant made a head turn response, or, after 20 seconds if no such response occurred. Unlike earlier newborn studies, the stimulus duration was for a maximum of 20 seconds duration. The finding that the median latency to initiate a head turn was 2.5 seconds with 5.75 seconds to complete a head turn suggests that too brief a stimulus duration and/or time allowed the infant to

respond, may account for the negative findings previous cited ( Butterworth and Castillo, 1976; McGurk, Turnure, and Creighton, 1977 ).

Having established that newborns reliably turn their head in the direction of a sound source, interesting questions now arise as to how parametric manipulations of the stimulus may influence neonates' manifestation of this ability. In considering what parameters of auditory stimulation may be of particular importance for auditory localization in young infants, one very likely possibility is the frequency parameter.

Theories of sound localization report frequency to be a critical factor in determining the processes underlying localization ( Licklider, 1956 ). Localization of low frequency sinusoidal sounds (  $\leq 1500$  Hz ) is said to be dependent upon processing of temporal information ( i.e., the difference in time-of-arrival of the sound at the ears ). Whereas, high frequency sinusoidal sounds (  $\geq 3000$ Hz ) are localized by processing intensity information ( i.e., the difference in intensity of the sound arriving at the ears ). Sounds in the 1000 - 3000 Hz range are poorly localized by adult listeners as neither the time or intensity cue is available maximally ( Mills, 1972 ). Though the precise mechanisms underlying localization of 'complex' sounds are not as well established as for tones, frequency again emerges as an important parameter in localization ( see for example Searle's discussion of



spectral cues provided by the convolutions of the pinna: Searle, Braida, Cuddy, and Davis, 1975; Butler and Belendiuk, 1977; Hebrank and Wright, 1974 ).

Further, there is a fair amount of evidence to support the notion that frequency is an important sound parameter, in eliciting differential responding in neonates and young infants. Eisele and Berry ( 1975 ) using sucking as a conjugate function of changes in sound pressure level found that neonates responded differentially for 3 pulsed tones of varying frequencies ( 1000, 2000, 4000 Hz ). Controlling for rise time and intensity factors Kearsley ( 1973 ) reported differential heart rate changes in newborns to simple and complex sound of varying fundamental frequencies. Maximum cardiac deceleration occurred to frequencies of 500 and 2000 Hz. Similarly, using a High Amplitude Sucking ( HAS ) procedure, Moffitt, Wormith and Pankhurst ( 1975 ) found that 1 month-old infants discriminated both 200 and 500 Hz pure tones. Stratton and Connolly ( 1973 ) using a heart rate habituation paradigm reported that 3 - 5 day-old infants were able to discriminate stimuli on the basis of intensity, pitch, and rise time. As in other studies ( Bartoshuk, 1962; Eisenberg et al, 1966 ), however, discrimination of pitch was complicated by a change in frequency thereby making tenuous any discussion of frequency effects.

These results reveal that neonates and young infants are

capable of discriminations along the frequency continuum. Considering the relative immaturity of the auditory system at birth, one might expect that developmental changes in responsiveness to different frequencies might emerge as a result of developmental changes in certain auditory structures occurring postnatally. Evidence for this notion is provided by a recent study ( Trehub, Schneider, and Endman, 1980 ) in which the testing of 6, 12, and 18 month-old infants, revealed interesting developmental differences in infants' thresholds to octave-band noises with center frequencies at 200, 400, 1000, 2000, 4000, and 10000 Hz. For the 4000 and 10000 Hz stimuli, there were no differences in thresholds for the different age infants, and the thresholds approached those of adults. Thresholds for the lower frequencies, however, were approximately 5 - 8 dB higher in the 6 month-old infants and the infants' thresholds were 20 - 30 dB higher than adult thresholds for the lower frequencies. Inspection of the data provided reveals an orderly increase in infant sensitivity as the frequency of the octave-band stimulation increases, developmental change being greatest for the lower frequencies (  $\leq$  2000 Hz ).

The results of Trehub et al are consistent with the notion that underlying anatomical/physiological changes, for example in the structures associated with the basilar and/or tectorial membranes, may be responsible for the age-related improvement in sensitivity. These results are consistent with earlier discussions

by Hecox ( 1975 ) who posited that postnatal development of the Organ of Corti structures progressively proceeds from the base ( responsible for the coding of higher frequency sounds ) to the apex ( most responsible for the coding of lower frequency sounds ) direction. The relevant anatomical and physiological research, however, is not definitive.

In view of the results of Trehub et al which demonstrates developmental changes in sensitivity along the frequency spectrum, the question arises as to whether or not infants will manifest differential responsiveness as a function of frequency when sounds are played well above thresholds. Specifically, if one were to use a stimulus which is known to be an effective elicitor of head turning responses in young infants, varying the frequency dimension would reveal whether the frequency content of a sound influences young infants' auditory localization discrimination behavior. This is a question of considerable interest in view of recent research with Old World monkeys which demonstrated frequency to be a critical aspect of the stimulus in the elicitation of auditory localization responses ( Brown, 1978; Brown, Beecher, Moody, and Stebbins, 1978 ).

The present study was formulated to address some of the issues which have been raised in the preceding discussion section regarding auditory localization in young infants. The focus of the present study was in assessing how frequency composition of a

sound influences the young infant's manifestation of this ability. In addition, the proposed study was formulated to provide information on the nature of cardiac-somatic<sup>1</sup> relationships which exist in infancy. Though there have been several attempts made in the past to correlate cardiac changes to stimuli with behavioral activity ( Turkewitz, Moreau, Birch, and Davis, 1970 ) for the most part success has been limited to those studies investigating sucking-cardiac relationships ( Crook and Lipsitt, 1976; Lipsitt, Reilly, Butcher, and Greenwood, 1976; Nelson, Clifton, Dowd, and Field, 1978 ).

For many years infant researchers have used cardiac activity as an index of infant cognitive activity. Integrating the hypotheses of Sokolov ( 1963 ) and the Laceys ( Lacey, 1959; Lacey and Lacey, 1974 ), cardiac deceleration has been associated with an orienting system which facilitates stimulus intake and cardiac acceleration with a defensive system which inhibits stimulus intake and mobilizes the organism for activity ( Graham and Clifton, 1966; Graham and Jackson, 1970 ). According to Sokolov ( 1963 ), an orienting response is elicited by weak-moderate stimulation and a defensive response by intense, rapid onset stimulation.

For many years, it appeared that cardiac orienting ( i.e., a deceleratory cardiac response ) might not be developed prior to about 6 weeks of age ( Gray and Crowell, 1968; Rewey, 1973 ).

Though there were many demonstrations of cardiac defense reactions ( i.e., an acceleratory cardiac response ) in newborns, the evidence for cardiac orienting was conflicting. A review of the literature, however, cited inadequate control of the neonate's state in those studies which failed to find neonatal cardiac orienting ( Clifton and Nelson, 1976 ). Subsequent research which explicitly controlled for state and motor activity revealed that cardiac deceleration is a response available during the newborn period ( Adkinson and Berg, 1974; Pomerleau-Malcuit and Clifton, 1973; Sameroff, Cashmore, and Dykes, 1973 ), though the defensive response is more easily elicited ( Reese and Lipsitt, 1976 ).

Generally, neonates ( Pomerleau-Malcuit and Clifton, 1973 ), like older infants ( Berg, Berg, and Graham, 1971 ) and adults ( Berg, Jackson, and Graham, 1975 ), show cardiac deceleration to stimuli when tested in an alert, calm state and cardiac acceleration when tested in a drowsy state. The magnitude of the heart rate response varies with state, the amplitude of the response being greater during sleep than wakefulness ( Graham and Jackson, 1970 ). Age has also been shown to independently affect the cardiac response. Developmentally, a curvilinear relationship between age and the magnitude of heart rate deceleration has been shown to exist independent of differences in pre-stimulus heart rate, with an increase in the cardiac orienting response during the early months of infancy ( Graham, Berg, Berg, Jackson, Hatton,

and Kantowitz, 1970 ).

In addition to state, motor activity emerges also as an important determinant of cardiac responding. The importance of cardiac-somatic relations has been well demonstrated in animals and human adults. However, there is little research with infants which has specifically addressed this issue. Results from a few studies though do suggest a close agreement between the cardiac and motor systems in newborns.

Steinschneider, Lipton, and Richmond ( 1966 ) found that in both cardiac and motor response systems an increase in an auditory stimulus' intensity resulted in responses ( i.e., cardiac acceleration and motor responses ) of greater magnitude and shorter latency. Kearsley ( 1973 ), presenting newborns with simple and complex sounds which varied in intensity, frequency, and rise time, noted that stimuli producing maximum cardiac deceleration were accompanied by reduced head movements while those producing maximum cardiac acceleration were accompanied by increased head movement. Pomerleau-Malcuit, Malcuit, and Clifton ( 1975 ) measured cardiac and behavioral reactivity of newborns to cheek stimulation ( i.e., stroking near the mouth ) which elicited approach ( i.e., ipsilateral head turns ) and ear stimulation ( i.e., an ear pinch which elicited withdrawal responses ( i.e., contralateral head turns ). Cardiac acceleration occurred to both tactile stimuli whenever motor responses were present; the accelerations

being of much greater magnitude to the noxious ear-pinch stimulus. When no overt behavioral response occurred, however, the cheek-stroke stimulus elicited cardiac deceleration while the ear-pinch stimulus elicited acceleratory responses. Because the heart rate response to the ear-pinch stimulus on trials in which no overt movement occurred was of greater magnitude than that to the cheek stimulus when head turning did occur, it does not seem that movement itself was responsible for the observed cardiac acceleratory responses. Rather, the authors suggest that both the autonomic and the motor responses result from efferent processes which are centrally controlled ( see Obrist et al, 1970, for a similar formulation ).

The results from these few studies suggest a close synchronous relationship between behavioral and cardiac responding in newborns. The proposed study sought to assess developmentally the nature of cardiac-somatic relationships in infants. While it is true that cardiac deceleration and somatic quieting are both considered to be components of the orienting response ( Graham and Clifton, 1966; Sokolov, 1963 ), these responses need not occur synchronously, necessarily. Cardiac change is perhaps best described by recognizing it to be a vector of both attentional and somatic influences upon the organism ( Clifton, 1977; Lacey and Lacey, 1974 ). According to this perspective then one would expect changes in cardiac-somatic relationships to occur during the first several

months of life as a consequence of changing somatic and attentional influences on the organism and physiological maturation.

### Hypotheses

Drawing upon the literature reviewed it was predicted that:

- (1) Between newborns and five month-olds there would be a developmental increase in head turning to stimuli of all frequencies, with this increase being most pronounced for the low frequency stimulus.
- (2) At each age, head turning towards a sound stimulus would vary as a function of the frequency composition of the stimulus. The high frequency band-pass stimulus and the unfiltered broad band stimulus were expected to elicit the most head turns, with this effect being most pronounced for newborns.
- (3) Due to neuro-muscular maturation ( see Lund, 1978 ), head turning to a sound by five month-olds would be of significantly shorter latency and duration than that of newborns.
- (4) Heart rate changes in newborns and five month-olds would vary in similar ways as a function of 'head turning' behavior. Heart rate deceleration, which is taken as an index of orienting, would occur to stimuli of all frequencies on trials in which infants



did not head turn. On 'head turn' trials, however, this decelerative response would be of less magnitude, not significant, or would be replaced by an acceleratory response. In addition, developmental changes in cardiac-somatic relationships would result due to physiological maturation and changes in motoric capabilities.

## C H A P T E R I I I

### METHOD

#### Subjects

The sample consisted of 24 neonates ( 15 male, 9 female ) selected from a well baby nursery, and 24 five month-olds ( 12 males, 12 females ) contacted through local published birth announcements. All infants tested were normal, healthy, full-term infants.

The newborn group consisted of Black, Hispanic and Caucasian infants, ranging in age from 8-74 hours old ( M=46.3 hours ). The data of an additional 12 neonates was discarded due to unsatisfactory state (2), experimenter error (2) or unscorable heart rate data (8). Criteria for participation included: (1) greater than 7 hours old; (2) gestational age between 38-42 weeks; (3) birthweight greater than 2500 grams; (4) a 1-minute Apgar score of 7 or more; (5) no major prenatal or any postnatal complications ( e.g. abnormal temperature, excessive weight loss, etc. ); (6) clear amniotic fluid, unless meconium staining was not accompanied by any other negative sign; (7) spontaneous labor; (8) low forceps delivery, unless mid-forceps delivery or caesarian-section were not accompanied by any other negative sign; (9) no abnormal signs on first pediatric examination; (10) singleton

birth; (11) mother between 18 and 40 years of age. Males were tested either before circumcision or at least 24 hours following circumcision.

The five month-old group consisted of Black, Hispanic and Caucasian infants ranging in age from 18-22 weeks-old ( M= 20 weeks ). The data of an additional 7 infants was discarded due to experimenter error (2), unsatisfactory state (4), or unscorable heart rate data (1). Parents were paid for their child's participation.

#### Apparatus and Stimuli

Tape recordings of a band-pass, filtered rattle, similar to the rattle used in the Brazelton Neonatal Assessment Scale (1973), served as the stimuli. During recording, the rattle ( a 1.5 x 1 x 3 inch opaque bottle, filled with 25 popcorn kernels ) was shaken so as to match the rythm of the rattle presented to newborns by Muir and Field (1979) in which reliable head turning to sound had been demonstrated.

Band-pass filtering was achieved during the recording phase by means of a Bruel and Kjaer Spectrum Shaper ( Model # 123 ). The rattle was shaken in a sound treated room. A Bruel and Kjaer microphone system ( condensor microphone model # 4132, power supply # 2801 ) transmitted the sound to an amplifier ( Heath AA-14 ) whereupon the amplified sound was passed to the Spectrum Shaper which filtered the various frequency band desired. Filter skirts

had roll-off characteristics of 48 dB per octave. The output of the Spectrum Shaper fed an Ampex tape recorder ( Model # AG500 ).

By this arrangement a master tape was made, comprised of 1 minute samples of each of 4 types of rattle stimuli: (1) low band-pass condition (L) --- comprised of frequencies below 1600 Hz, (2) mid-frequency band-pass condition (M) --- comprised of frequencies between 1000 and 3000 Hz, (3) high band-pass condition (H) --- comprised of frequencies above 1800 Hz, (4) broad-band condition (B) --- unfiltered, comprised of frequencies ranging from 20 Hz to 20000 Hz. The sound spectrographs of all 4 stimuli appear in Appendix 1. The actual experimental stimuli resulted from re-recording from the master tape, using a Revox and Pioneer ( Model # RT701 ) reel-to-reel recorder. This procedure resulted in 4 stimulus tapes, each comprised of a unique stimulus sequence ( A, B, C, D ), according to the following specifications.

Each stimulus sequence ( A, B, C, D ) was comprised of 3 blocks of 4 trials for a total of 12 trials. Each block was comprised of 1 example of each of the 4 trial types: L, M, H, B. Each trial type ( L, M, H, B ) was assigned to occur in the trial 1 position in one of the stimulus sequences ( A, B, C, D ). The remaining 3 trials in block 1 and all trials in block 2 and 3 were subsequently ordered such that: (1) within each stimulus sequence ( A, B, C, D ) a particular trial type ( L, M, H, B ) occurred in a different ordinal position in each block, and (2) summing over

stimulus sequences A, B, C, D each trial type ( L, M, H, B ) occurred once in each of the 12 ordinal positions ( see listing in Appendix 2 ).

Speaker location ( left/right ) followed either the ordering: LRRL-RLLR-LRRL ( i.e. "Left-first" order ), or the mirror image of this order: RLLR-LRRL, etc., ( "Right-first" order ). Within each stimulus sequence ( A, B, C, D ) a L, M, H, B trial occurred at least once from the right and the left. Summing over all stimulus sequences, each trial type occurred 6 times from the right and the left ( see Direction schedule in Appendix 3 ).

To control for loudness differences as a result of the frequency manipulation, sound pressure level ( SPL ) was varied across trials. This was achieved by systematically varying the record volume level when recording the stimuli onto the 4 test tapes. In view of the developmental change in sensitivity to intensity ( Von Bekesy, 1960 ) and the difference in ambient noise level in the 2 test rooms, the selected SPL values for newborns were 76-78-80-82 dB re.0002 dynes/cm<sup>2</sup> ( calibrated using the A scale of a General Radio Sound Level Meter ) and those for five month-olds were 68-70-72-74 dB-A. Pilot testing verified that newborns and five month-olds would respond to each of the different frequency trials ( L, M, H, B ) played at their respective lower and upper SPL values. Within each stimulus sequence ( A, B, C, D ) each trial type ( L, M, H, B ) occurred once at each of 3 different

SPL values. Summing over the sequences A, B, C, D each trial type occurred 3 times at each SPL value ( see SPL stimulus table in Appendix 4 ).

### Procedure

Six subjects at each age were randomly assigned to receive 1 of the 4 possible stimulus sequences ( A, B, C, D ). Three of the 6 subjects at each age received the Right-first order and 3 the Left-first order.

For each age group, heart rate was monitored by means of 3 Beckman Sodium-Chloride electrodes which were placed in a triangular array, at the top of the sternum and at both lateral costal margins. In addition to heart rate, subjects were videotaped for later scoring of the following behaviors: head turning ( direction, latency, duration ), eye movements, alerting and quieting.

The testing of newborns was carried out in a warm, well lit room located nearby to the nursery. Ambient noise level was 47 dB-A measured at the position of the infant's head. Informed written consent was obtained from the infant's mother and the pediatrician.

Neonates were tested when in an alert, calm state, most typically immediately after feeding or after bathing. Few subjects were aroused from sleep for participation in the experiment as we preferred to test infants who were 'spontaneously' awake and alert. During testing the experimenter stood with one leg atop a chair so

as to comfortably support the weight of the infant on her ( his ) leg throughout the test session. Infants were held in a nearly supine position with the neck and head lying in one slightly cupped hand and the buttocks supported by the other hand. The experimenter wore earphones which supplied the rattle sound continuously on all trials, masking stimulus location and type. During intertrial intervals, infants were typically raised to the experimenter's shoulder, rocked, spoken to, etc., in order to maintain the infant in an alert, quiet state. Prior to the onset of each trial, care was taken to insure that the infants were in an alert, quiet state and that their heads were centered. On each trial the stimulus played either until the neonate made a 90° head turn, or, for a maximum of 20 seconds duration. Intertrial intervals were for a minimum of 15 seconds duration and ranged from 15 - 35 seconds ( M= 25 seconds ).

A second experimenter monitored a timer which timed stimulus and intertrial intervals. The second experimenter rated behavioral state, terminated the trial, and initiated a trial when the minimum amount of time had passed and experimenter 1 signalled the infant to be in an appropriate state ( i.e. alert, calm, head centered ). The stimuli were played on a Revox FM tape recorder running at 7½ ips which fed one of the two loudspeakers, i.e., R or L. Heart rate was recorded both on a Hewlett-Packard 7701B polygraph and a Vettor Model-A FM tape recorder. A voice-activated

relay was used in placing a stimulus onset marker onto the heart rate tape.

During the trials neonates were held, with their head equidistant between 2 loudspeakers ( KLH Model # 100 ), located 60 cm from each ear at an angle  $90^{\circ}$  from the infant's midline. A T.V. camera ( Panasonic, Model # WV3085 ) positioned approximately 45 cm above the infant's head, served in videorecording overt behavior during test trials ( Panasonic Portable Video Recorder, Model # NV3085 ). All neonates were loosely swaddled during testing. The complete session lasted less than 12 minutes.

Five month-olds were brought to the infant research laboratory on the University of Massachusetts campus, for one 20-minute session. Written consent was obtained from the parent and parents were paid for participation. Infants were tested in a sound deadened, dimly lit room at a time designated by their mothers as corresponding to an alert play period. Ambient noise level was 28 dB-A, measured at the position of the infant's head.

Infants were placed in an infant seat which was positioned on a table, midway between 2 Acoustic Research ( Model # AR-7 ) speakers. The speakers were located at  $90^{\circ}$  from straight ahead approximately 1 meter horizontal distance from the infant. The table was within a 3-sided white curtain enclosure which functioned to obscure the infant's sight of the surroundings with the exception of the lens of a frontally located, tripod mounted, videocamera

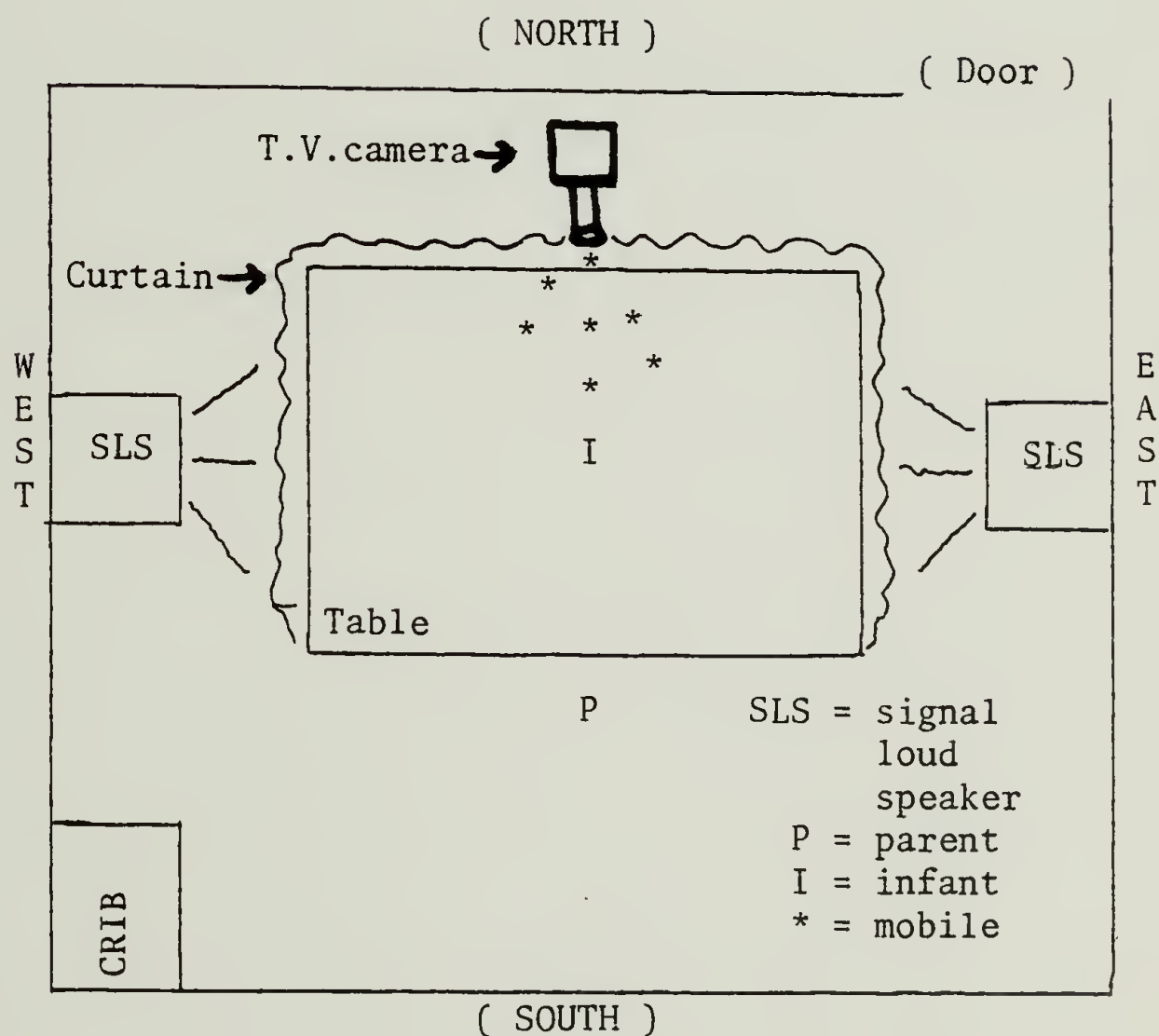


( General Electric, Model # TE-44 ) which served in videorecording the infant's behavior during the test session ( Sony Videocassette Deck Model # VO-2600 ). Several brightly colored cardboard figures were suspended in front of the infant in order to maintain the infant's interest and to direct the infant's attention towards the camera. Parents sat directly behind their infant and were instructed to remain quiet and out of the infant's line of vision during testing ( see Diagram of the testing situation in Figure 1 ).

On each trial the stimulus played for 5 seconds. Intertrial intervals were for a minimum of 15 seconds duration and ranged from 15 - 35 seconds (  $M=25$  seconds ). A stimulus duration of 5 seconds was chosen based upon pilot observations in which durations of 5 and 20 seconds were used, and because previous research has demonstrated that a stimulus of 5 seconds duration is sufficient to elicit reliable cardiac and behavioral responses in 5 month-olds ( Benson, 1979 ). The stimuli were played on a Pioneer reel-to-reel tape recorder ( Model # RT 701 ) and amplified by a Pioneer Sx-434 amplifier. Stimulus programming was provided by a custom built paper tape programmer and peripheral relays. Heart rate was filtered and amplified by a Data Inc., Instrumentation Differential Amplifier ( Model # 1124 ) and then fed to a polygraph consisting of a Hewlett-Packard 7714-04A power supply and a 7700 Series Recorder. The heart rate signal was recorded by a Vettor G-4 Cassette Data Recorder. A stimulus pulse signalling the onset of each trial was

FIGURE 1

Schematic Diagram of the Room Used in the Testing of Five Month-Olds



automatically produced by the paper tape programmer and was simultaneously recorded onto the heart rate cassette tape.

All infants were videotaped for later scoring of behavior. A T.V. monitor ( Sanyo, Model # VM 4130 ) allowed the experimenter to observe the infant's state during the experiment while presenting the stimuli from the equipment room. A microphone ( Astatic, Model # 151 ) and an amplifier ( Pioneer, Model # SX 450 ), located in the testing room, served in audio-recording the infant's vocalizations and stimulus presentations onto the videocassettes.

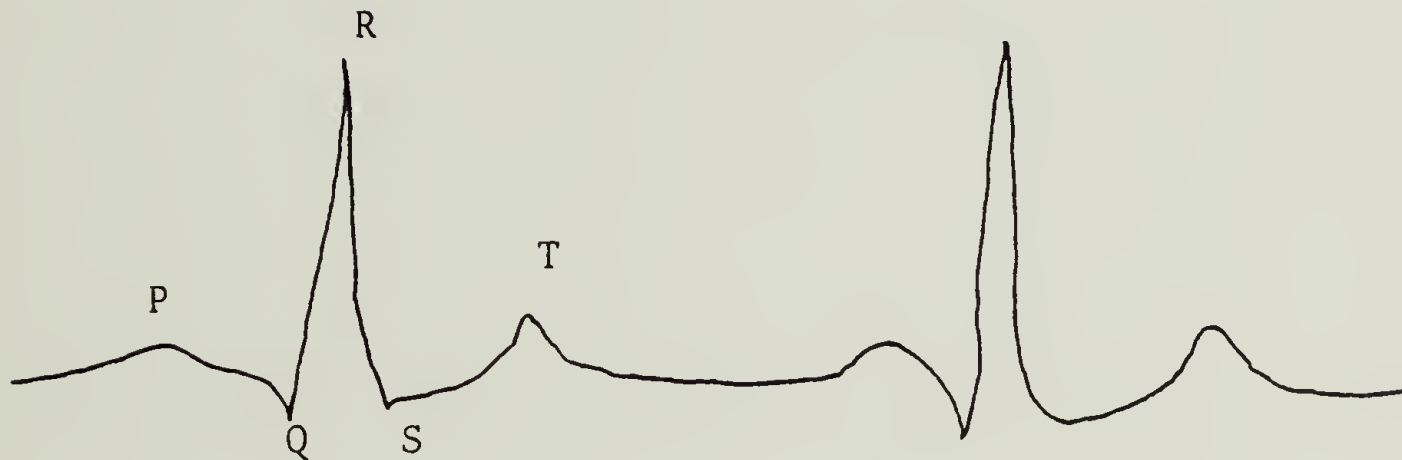
#### Data Reduction

Heart Rate Data. Use of heart rate as a dependent measure involves amplifying and recording the small electrical 2mV signal which is associated with each heart beat. In data reduction, the prominent r-wave is detected electronically and is used as an indicator that a beat has occurred. The intervals of time between successive beats ( i.e., R-R waves ) can then be computed and a measure of heart rate in beats per minute ( bpm ) determined ( see Brener, 1967 for a complete discussion of the heart beat signal and its measurement ). See schematic drawing in Figure 2.

In the present study, the recorded heart rate signal was fed into a Hewlett-Packard 2100A computer which timed the intervals

FIGURE 2

An Example of a Typical Waveform Associated With a Heart  
Beat: two beats are shown with the components of one labelled



between successive beats and computed the weighted average of R-R intervals, in bpm, for each of 1 pre-stimulus and 12 post-stimulus seconds ( the weighted average formula appears in Appendix 5 ). The R-R intervals were weighted in proportion to the total amount of time which they occupied in the second.

As previously mentioned, 9 infants were eliminated from the study due to unscorable, artifactual heart rate data. Artifacts result when other electrical activity, such as that produced by muscle movement, is recorded along with the heart rate signal. Artifacts involving 1 or 2 successive seconds of heart rate data were considered as minor artifacts and in these cases an average rate in bpm was substituted for the particular second in question. The average was based upon the heart rate in the second immediately preceding and following the second of the artifactual heart rate score. Major artifacts were those involving 3 or more successive seconds of heart rate data and in these cases the trial was eliminated from the analysis ( see Appendix 6 ).

The criteria for edits of artifactual data ( taken from Benson, 1979 ) were: (1) no more than 2 consecutive seconds were edited, with averages inserted, (2) two consecutive seconds missing immediately before and after the stimulus onset were not acceptable, (3) no more than 3 seconds in any 1 trial were edited for a trial to be considered acceptable, and (4) if a subject had many edits ( i.e. edits on most trials ) that subject was eliminated from the

study; this happened in 3 cases.

There were 6 criteria used for selectively omitting heart rate trials from inclusion in the analyses, these are as follows:

(1) sneeze, startle, or yawn at stimulus onset, (2) excessive movement during the trial, (3) hiccups during the trial, (4) fussy or sleepy state, (5) sucking ( e.g., on blanket ) during the trial, (6) error head turns ( see listing of the subject's eliminated trials and the reasons for the omissions in Appendix 6 ). Finally, a subject was eliminated from the present study if 4 or more trials of heart rate data were eliminated from analyses for any of the above named reasons.

Behavioral Data. A listing of the behavioral coding scheme used in the present study is given in Appendix 7. The behaviors of primary interest were: head turning ( correct direction, i.e., ipsilateral to the sound, and incorrect direction, i.e., contralateral to the sound ), latency and duration of head turning, alerting and quieting. Latency measures were determined by observing the interval of time which elapsed between the start of a trial and the initiation of a head turn. Duration measures were determined by computing the interval of time which elapsed between the initiation and completion of a head turn. Both latency and duration of head turns were measured to the nearest 0.5 second.

Reliability measures ( computed as the number of agreements

divided by the number of agreements plus disagreements ) were calculated based upon 2 observeers independently scoring the subjects for the behaviors listed in Appendix 7. An error of + 0.5 second was allowed in computing reliability for the latency and duration measures. The obtained reliability coefficients for the behaviors of primary interest are given in Appendix 8.

### Data Analysis

Heart Rate Data. When heart rate is used as a dependent measure the aim in analysis is in detecting reliable second-by-second changes in heart rate to the presentation of the stimulus. Consequently, a significant interaction of the seconds variable with another manipulated variable is of primary concern as this indicates that the heart rate response was different to the different levels of the variable. It is importatnt to realize, however, that statistically speaking a significant seconds effect only indicates that 2 or more of the seconds being analyzed differ from one another. It does not indicate anything about the nature of the difference. Nor does it indicate anything about how representative the averaged heart rate curve is of the individual subjects' curves. Further, the analyses are typically based upon 9-16 data points ( i.e., 9-16 seconds of heart rate data ) per subjects' trial and with such large degrees of freedom, the likelihood of a Type 1 error is escalated.

In the present study, therefore, significant main effects and interactions involving the seconds variable were always followed by trend analyses. These analyses served in identifying the form of the heart rate functions and reducing the degrees of freedom thereby controlling the Type 1 error rate. Only those significant effects involving the seconds variable which were supported by significant trends are discussed.

Only linear, quadratic and cubic trends were tested for as no hypotheses concerning the psychological or physiological meaning of higher order trends were made. A linear trend indicates a uni-directional acceleratory or deceleratory cardiac response. A quadratic trend indicates an initial cardiac acceleration, or deceleration, followed by a return towards baseline, or beyond. A cubic trend indicates a heart rate change followed by a return towards baseline followed by another change in direction.

Though 5 pre-stimulus and 15 post-stimulus seconds of heart rate data were recorded in the present study, only 1 pre-stimulus and 12 post-stimulus seconds per subjects' trial entered into the analyses. Only 1 pre-stimulus second was analyzed as Clifton and Graham ( 1968 ) found that 1 pre-stimulus second accounted for as much of the variance as the average of 5 pre-stimulus seconds. The decision to include only 12 post-stimulus seconds in the analyses was based upon previous research which revealed reliable cardiac responding to occur in newborns ( Pomerleau-Malcuit and Clifton,



1973 ) and five month-olds ( Benson, 1979; Berg, Berg, and Graham, 1971 ) within 12 post-stimulus seconds.

The heart rate data were analyzed using a repeated-measures analysis of variance and subsequent trend tests. The between-subject independent variable was age. The within-subject independent variables were frequency of the stimulus, head turning vs. no head turning, and seconds. Order of stimulus presentation was counterbalanced and did not enter into any of the analyses. The significance level for all tests was set at  $P < .05$ .

Behavioral Data. The behavioral data were analyzed using repeated-measures analysis of variance, t-tests, approximations to a t-test, the Cochran Q-test and Chi Square (  $X^2$  ) tests. Only 'correct' head turns ( i.e., head turns ipsilateral to the sound source ) entered into the analyses as these may be uniquely different from 'incorrect' head turns ( i.e., head turns contralateral to the sound source ) and it did not seem appropriate to average the information derived from 'correct' and 'incorrect' head turns. Further, this decision resulted in the elimination of very little data as newborns made only 10 error head turns out of a total of 135 head turns ( 6 error head turns on L trials, 1 on M, 1 on H, and 2 on B ) and five month-olds did not make any.

The between-subject independent variable was age. Order of

stimulus presentation was counterbalanced and did not enter into any of the analyses. The within-subject independent variables were: frequency, location and SPL of the stimuli. The dependent measures were (1) number of 'right' vs. 'left' head turns toward sound, (2) number of head turns as a function of SPL of the stimulus, (3) number of head turns to each type of stimulus ( L, M, H, B ), (4) mean latency and duration of head turns occurring to each type of stimulus. On all of the analyses a minimal level of  $\underline{P} < .05$  was set as the required level of significance.

Recognizing that a significant overall  $\underline{F}$  value shows only that some difference among the treatment population means exists, multiple paired comparison tests were done subsequent to significant overall  $\underline{F}$  values in order to determine which factors were contributing to the significance of the overall test. To control for escalating the error rate beyond the .05 level, which is a consequence of doing multiple paired comparison tests, Bonferroni- $\underline{t}$  values were used ( Myers, 1972 ). This test statistic takes both Type I ( i.e. false rejections ) and Type II ( i.e. false acceptances ) error rates into account and is most appropriate in situations, as the present, where several contrasts of interest were designated prior to the experiment.

## C H A P T E R I V

### BEHAVIORAL RESULTS

Newborns turned their heads on 47% ( 135 ) of the trials and the range of head turning was 3-8 trials. Of those trials on which they head turned, 7% ( 10 ) trials were errors, that is contralateral to the sound. In comparison, five month-olds head turned towards the sound on 55% ( 158 ) of the trials, the range of head turning being comparable to that in the newborn ( i.e., 3-9 trials ). This difference between newborn and five month-old head turning towards the sound was significant when errors were excluded from the newborn tally (  $\chi^2_1 = 7.5648$ ,  $\underline{P} < .01$  ), as well as when errors were included in the newborn tally (  $\chi^2_1 = 3.8746$ ,  $\underline{P} < .05$  ). Five month-olds turned their heads toward sound significantly more often than newborns, and in contrast to the newborns, they never turned away from the sound source.

#### Preliminary Analyses

Preliminary analyses were done on 'direction' of head turning ( right/left ) to each frequency stimulus ( L,M,H,B ), and incidence of head turning as a function of the SPL of the stimulus. These variables were primarily for control purposes and were of lesser interest. Analyzing them separately simplified the main analysis.

An age (2) x frequency (4) x direction (2) x subjects (24)

analysis of variance did not result in any significant main or interaction effects involving 'direction' ( see Appendix 9, Table 4 ). Newborns and five month-olds were as likely to head turn towards stimuli occurring from the right as from the left ( see Figure 3 ). Defining a 'success' to be a correct head turn on 1 or more of the 3 trials occurring at a particular SPL ( see Appendix 4 ), a Cochran  $Q$ -test revealed no significant differences for newborns (  $Q_3 = .846$ ,  $P > .05$  ) or five month-olds (  $Q_3 = 1.138$ ,  $P > .05$  ) in frequency of head turning towards a sound as a function of SPL ( see Figure 4 ). Consequently, subsequent analyses did not include direction or SPL as variables.

### Primary Analyses

Hypothesis 1: Results. It was hypothesized that between newborns and five month-olds there would be a developmental increase in the incidence of head turning towards stimuli of all frequencies, with this increase being most pronounced for the L frequency stimulus.

The results provide partial support for this hypothesis. An age (2) X frequency (4) X subjects (24) repeated-measures analysis of variance revealed significant main effects of age. (  $F_{1,46} = 9.789$ ,  $P < .005$  ) and frequency (  $F_{3,138} = 18.485$ ,  $P < .001$  ). In general, five month-olds head turned towards a sound more often than did the newborns ( 158 vs. 135 head turn trials, respectively ). Of primary importance was a significant age X frequency interaction

FIGURE 3

Number of Trials on Which Head Turning to the Right and Left Occurred as a Function of Age and Frequency Spectra of the Sound

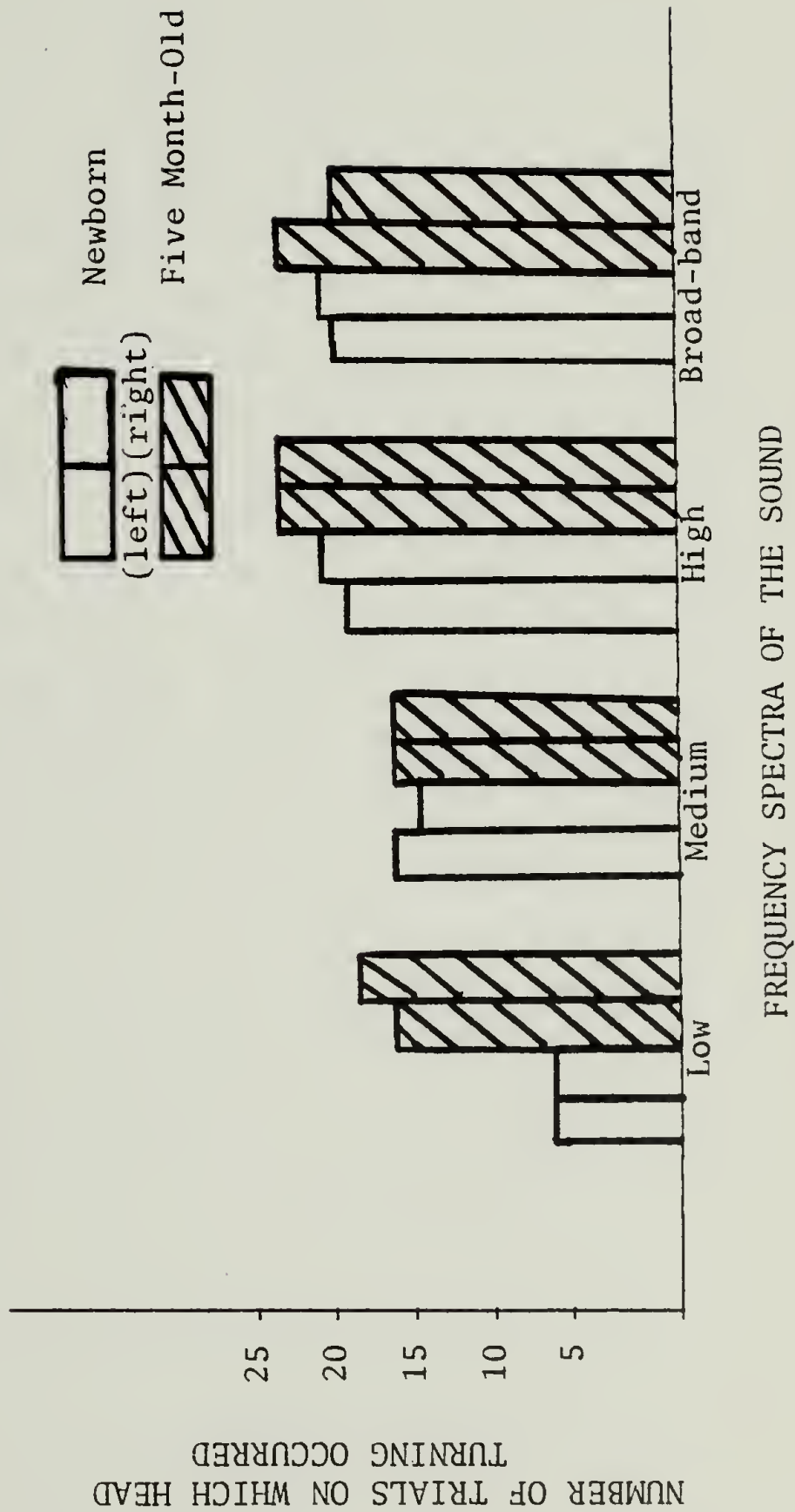
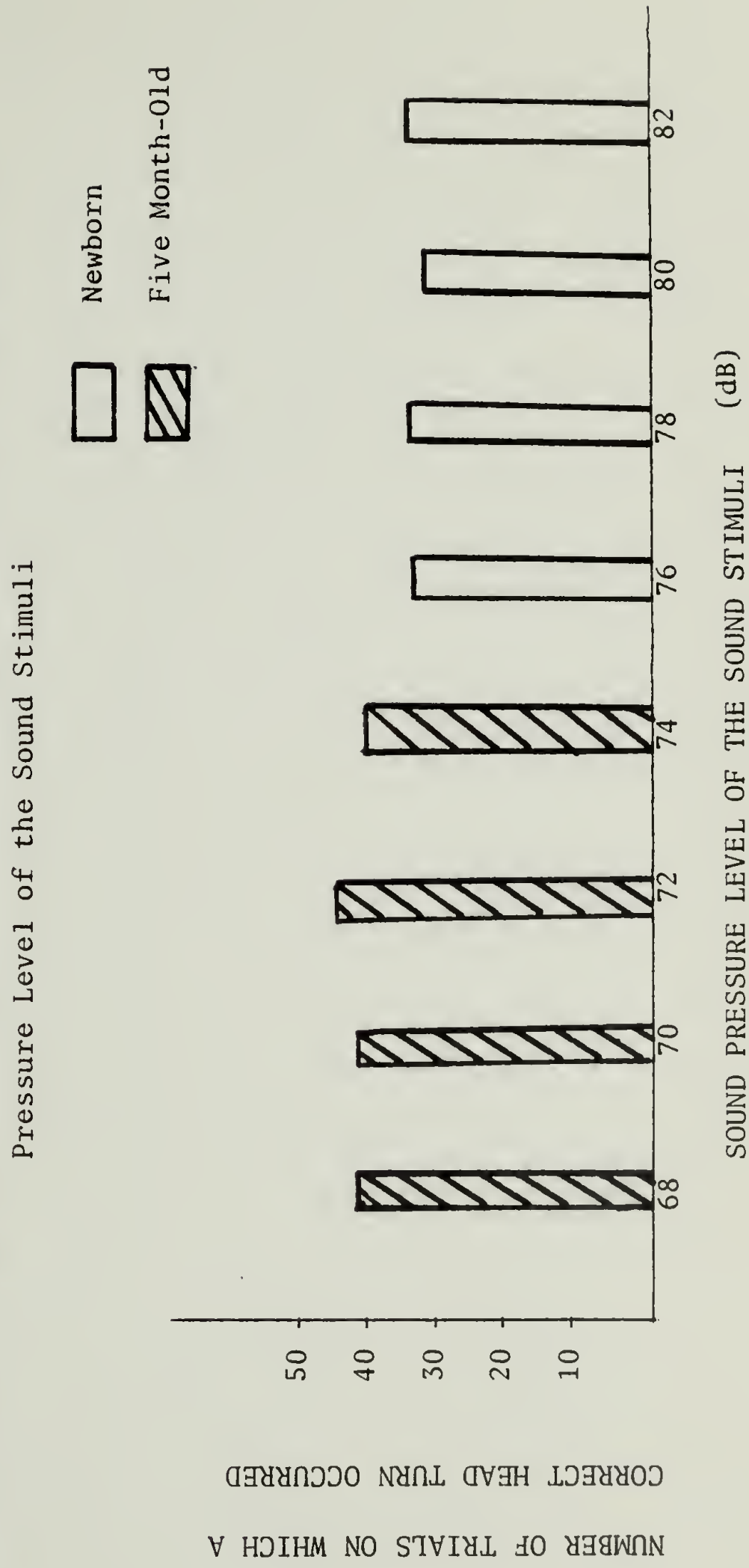


FIGURE 4

Number of Trials on Which a Correct Head Turn Occurred as a Function of Age and Sound



which indicated that head turning varied across age as a function of frequency (  $F_{3,138} = 4.558, P < .005$  ). The analysis of variance ( ANOVA ) table appears in Appendix 10, Table 5.

Subsequent  $t$ -tests compared the mean head turning of newborns and five month-olds to each of the L, M, H, B stimuli. As can be seen in Figure 5, newborns turned their heads towards the L stimulus significantly less than did the five month-olds (  $t_{46} = 4.82, P < .01$  ). Newborns and five month-olds did not, however, differ in mean head turning to the M, H, or B stimuli (  $t_{46} = .26, P > .05$ ;  $t_{46} = 1.56, P > .05$ ;  $t_{46} = .35, P > .05$ , respectively ).

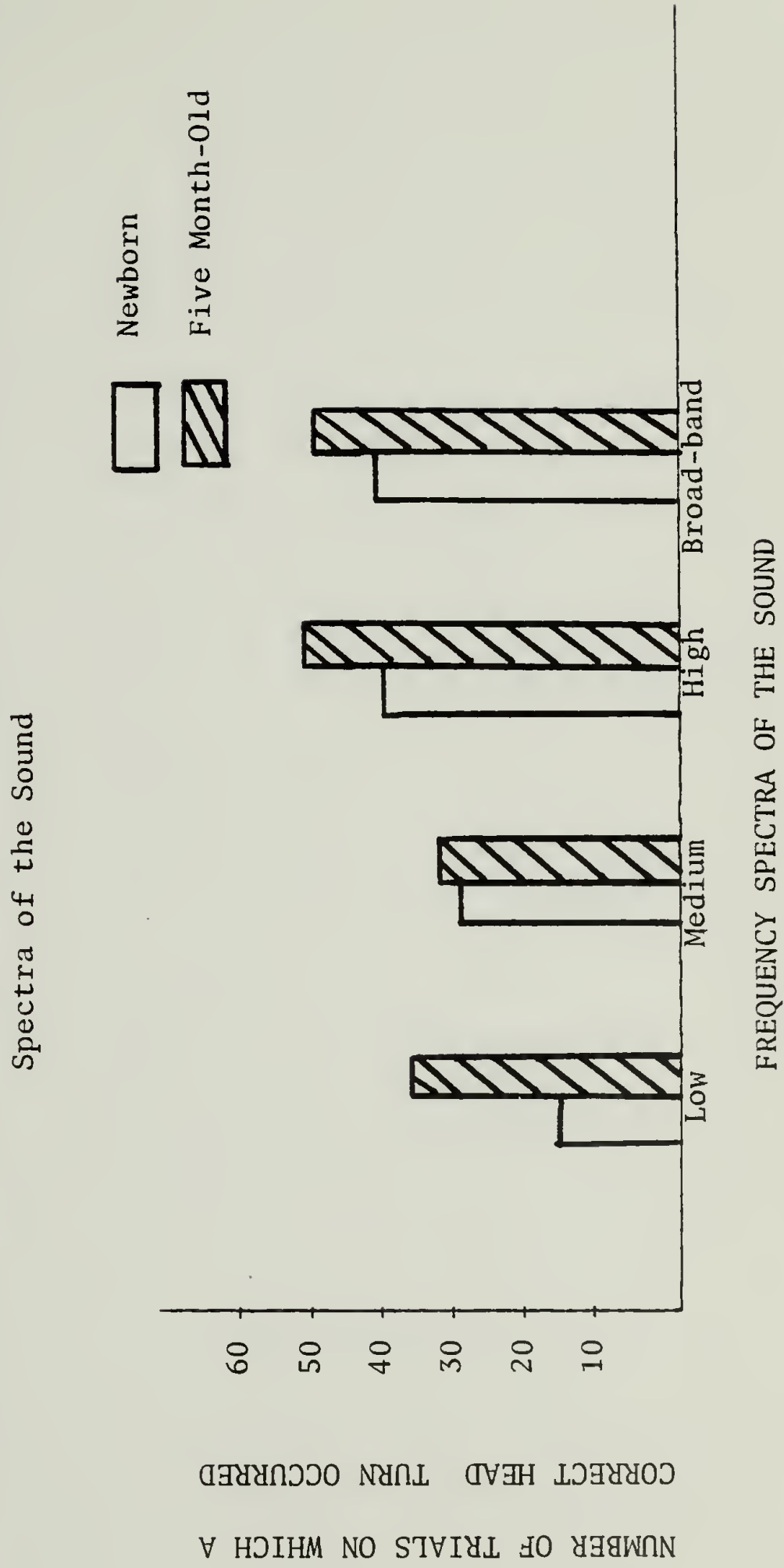
These results partially support Hypothesis 1. Though there was not a developmental increase in head turning towards stimuli of all frequencies, there was a significant developmental increase in head turning towards the L frequency stimulus.

Hypothesis 2: Results. The hypothesis that within each age head turning towards a sound would vary as a function of the frequency of the stimulus was supported. And as predicted, the H and B stimuli elicited the most head turning responses at both ages.

Dependent or matched  $t$ -tests ( Hays, 1973, pp. 424-426 ) were used to do pairwise comparisons of mean head turning to the different frequency stimuli. As can be seen in Figure 5, newborns turned their head significantly less to the L stimulus than the M, H, and B stimuli (  $t_{23} = 6.41, P < .01$ ;  $t_{23} = 6.06, P < .01$ ;  $t_{23} = 6.63,$

FIGURE 5

Number of Trials on Which a Correct Head Turn Occurred as a Function of Age and Frequency





$P < .01$ , respectively ). Head turning to the M stimulus was significantly less than that to the H and B stimuli (  $t_{23} = 3.99$ ,  $P < .01$ ;  $t_{23} = 3.11$ ,  $P < .05$ , respectively ). Head turning to the H vs B stimuli, however, did not significantly differ (  $t_{23} = .44$ ,  $P < .05$  ). These results suggest an order of 'correct localizability' for newborns which proceeds from  $L \rightarrow M \rightarrow H/B$  frequencies, with no significant difference in head turning towards H vs B frequency stimuli. A test of the difference between 'H + B' minus 'L + M' revealed a highly significant difference (  $t_{23} = 5.08$ ,  $P < .01$  ). Newborns turned their heads significantly more to the H and B stimuli than they did to the L and M stimuli ( see Figure 5 ).

Five month-olds turned their heads significantly less to the L frequency stimulus than to the H and B frequency stimuli (  $t_{23} = 3.26$ ,  $P < .05$ ;  $t_{23} = 3.93$ ,  $P < .01$ , respectively ). Head turning to the M stimulus was significantly less than that to the H and B stimuli (  $t_{23} = 3.39$ ,  $P < .05$ ;  $t_{23} = 3.40$ ,  $P < .05$ , respectively ). However, head turning to the L frequency stimulus did not differ from that to the M stimulus (  $t_{23} = .46$ ,  $P > .05$  ), and head turning to the H frequency stimulus did not significantly differ from that to the B stimulus (  $t_{23} = .89$ ,  $P > .05$  ). These results suggest an order of 'correct localizability' for the five month-olds which proceeds from  $L/M \rightarrow H/B$ , with no significant differences in head turning to the L vs M and H vs B frequency stimuli ( see

Figure 5 ). A test of the difference between 'H + B' minus 'L + M' was highly significant indicating that five month-olds, like newborns, turned their heads significantly more to the H and B frequency stimuli than to the L and M frequency stimuli (  $t_{23} = 3.09$ ,  $p < .05$  ).

These results provide support for the ideas expressed in Hypothesis 2. As predicted, head turning towards a sound varied at each age as a function of the frequency of the sound stimulus. At each age, the H and B frequency stimuli elicited significantly more head turning responses than the L and M frequency stimuli, and this difference was most pronounced for newborns.

Hypothesis 3: Results. It was hypothesized that quantitative changes in head turning to a sound would emerge between newborns and five month-olds. Five month-old head turning towards a sound was predicted to be of shorter latency ( i.e., the time from the start of the sound till the initiation of the head turn ) and duration ( i.e., the time from the initiation till the completion of the head turn ) than that of newborns.

The following analyses are based upon the videotaped behavior of 24 five month-olds and 13 newborns. For the remaining 11 newborns which comprised the sample, videotaping equipment was not available for use at the time of testing. Though interobserver reliability on instances of head turning for these 11 newborns was

obtained during the actual test session, measures of latency and duration were not collected.

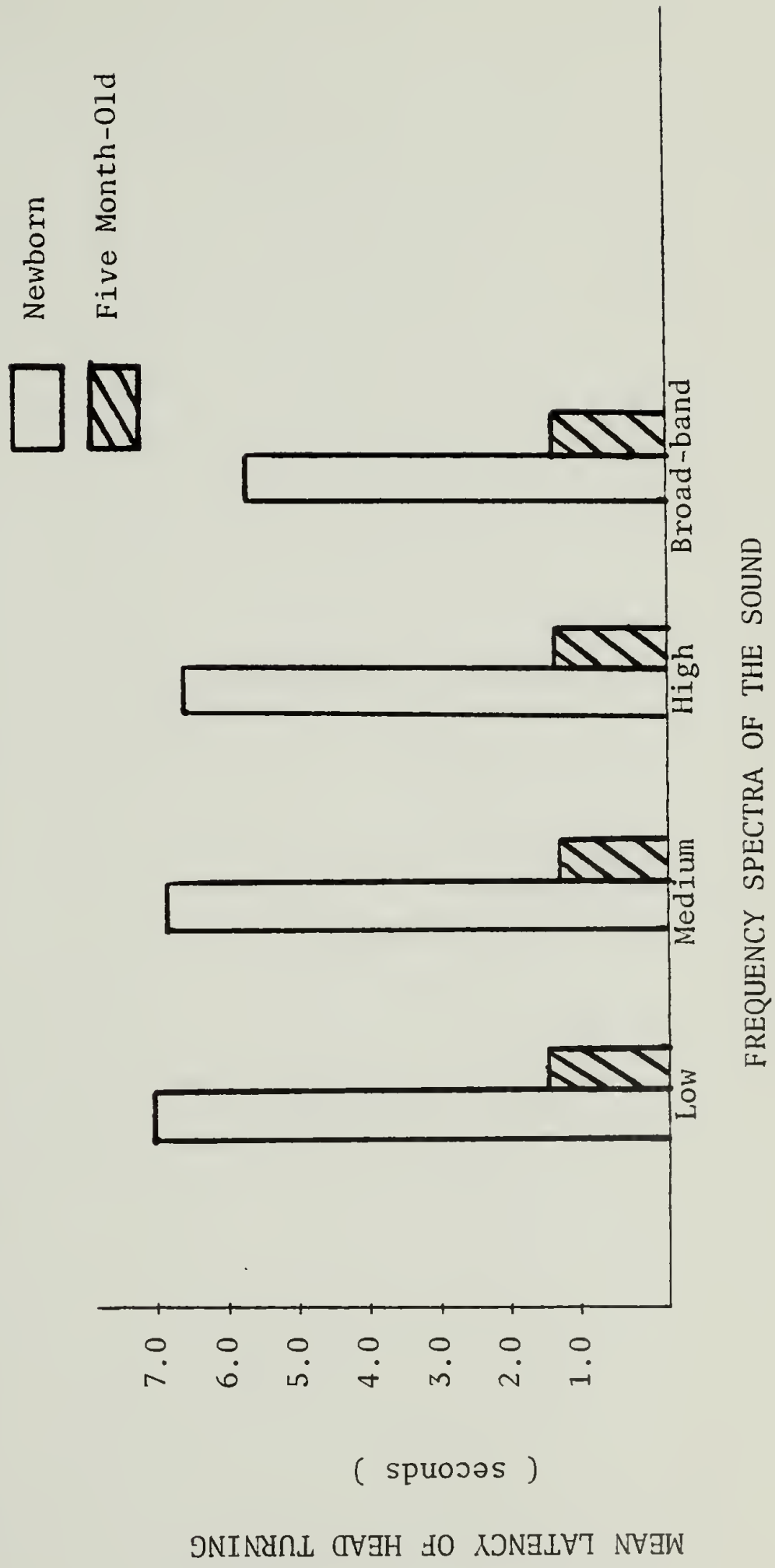
As a consequence of (1) having unequal N for the between-age analyses, and (2) taking a conservative approach and assuming heterogeneity of variance across the 2 populations sampled, an approximation to a Student's t-test was computed. This utilizes 'separate' variance estimates in calculating the t value and a corrected number of degrees of freedom in determining significance ( SPSS, 1977, pp. 269-270 ).

T-tests were done comparing the mean latency of newborns vs five month-old head turning to the L, M, H, and B frequency stimuli. As can be seen in Figure 6, the mean latency of newborn head turning was significantly longer than that of five month-olds to the L, M, H, and B stimuli (  $t_{12.35} = 3.51, P < .05$ ;  $t_{12.62} = 7.01, P < .01$ ;  $t_{12.95} = 6.66, P < .01$ ;  $t_{12.57} = 4.26, P < .01$ , respectively ).

Subsequent tests on the latency data revealed that the latency of head turning did not vary within each age as a function of the frequency of the sound stimulus. For stimuli of all frequencies, the mean latency of head turning for newborns was approximately 6-7 seconds ( see Figure 6 ). Similarly, the mean latency of head turning for five month-olds did not vary significantly across the 4 frequency stimuli; the average latency being approximately 1.5 seconds ( see Figure 6 ). The t-test results

FIGURE 6

The Mean Latency of Head Turning as a Function of Age and Frequency Spectra of the Sound



MEAN LATENCY OF HEAD TURNING

( seconds )

FREQUENCY SPECTRA OF THE SOUND

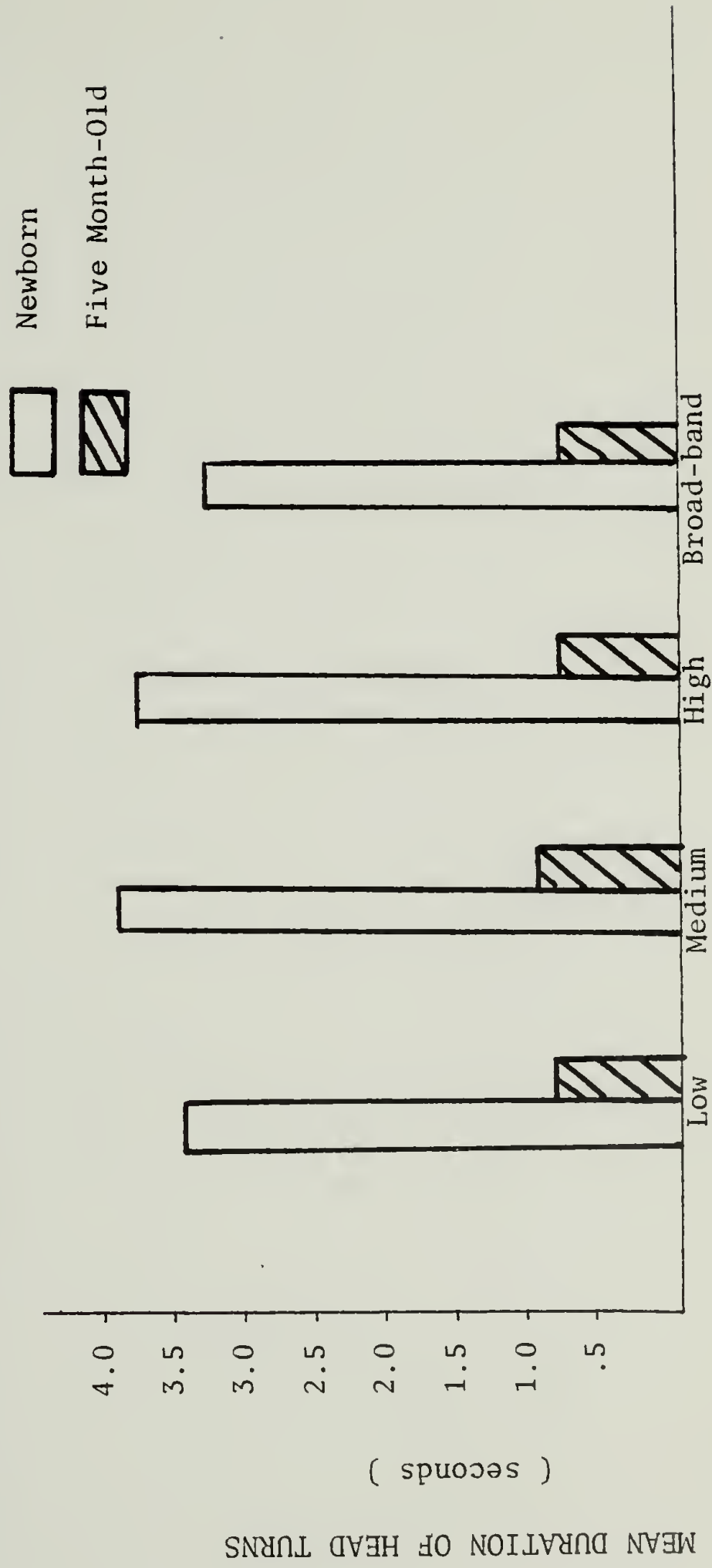
for both ages appear in Appendix 10, Table 6.

Comparisons of the mean duration of newborn vs five month-old head turning to the L, M, H, and B frequency stimuli yielded results similar to those for latency. As can be seen in Figure 7, newborn head turning was significantly longer in duration than that of five month-olds to the L, M, H, and B frequency stimuli (  $t_{12.33} = 3.93, P < .05$ ;  $t_{13.15} = 10.28, P < .01$ ;  $t_{13.90} = 10.08, P < .01$ ;  $t_{13.24} = 7.48, P < .01$ , respectively ). For newborns, the mean duration of head turning to stimuli of all frequencies was 3.5-4 seconds, approximately, whereas that for five month-olds was approximately 1 second. As with the latency data, the mean duration of newborn and five month-old head turning did not vary significantly as a function of the frequency of the stimulus ( see Figure 7 ). The  $t$ -test results for both ages appear in Appendix 10, Table 7.

These results provide support for the predictions made in Hypothesis 3. For all frequency stimuli, five month-old head turning was significantly shorter in latency and duration than that of newborns. Further, the results indicate that newborns and five month-olds are relatively stable in their latency and duration of head turning to a sound. Though the frequency of a sound influences head turning responses in infants it does not differentially influence the initiation and/or completion of a head turn directed toward a sound source.

FIGURE 7

The Mean Duration of Head Turning as a Function of Age and Frequency Spectra of the Sound



FREQUENCY SPECTRA OF THE SOUND

Other Measures of Behavioral Responding: Results. Instances of alerting and quieting were scored from the videotapes of 24 five month-olds and 13 newborns. For 11 additional newborns, alerting and quieting were recorded by 2 observers during testing.

Newborns alerted on 7% (19) of the trials and subsequently head turned on 74% (14) of these trials. Five month-olds alerted on 14% (41) of the trials and subsequently head turned on only 54% (22) of these trials. The difference between newborn and five month-old alerting was significant ( $\chi^2_1 = 9.0043$ ,  $\underline{P} < .005$ ). Newborns and five month-olds did not, however, differ in the incidence of head turning on trials in which they had alerted ( $\chi^2_1 = 2.1695$ ,  $\underline{P} > .05$ ).

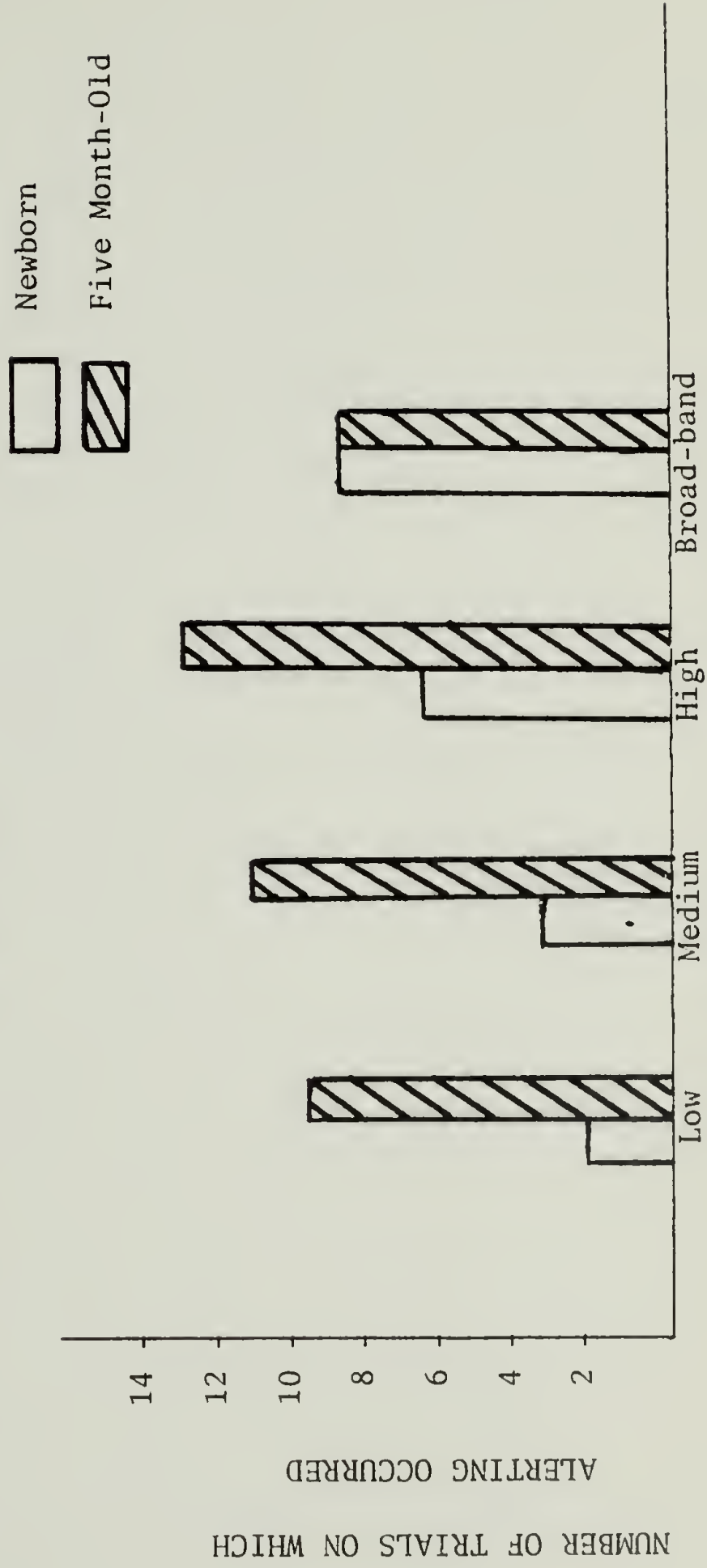
Subsequent analyses on alerting included frequency as a variable. Newborns alerted significantly less than five month-olds to the L and M frequency stimuli ( $\chi^2_1 = 4.82$ ,  $\underline{P} < .05$ ;  $\chi^2_1 = 4.14$ ,  $\underline{P} < .05$ , respectively). Seemingly the attention-getting aspects of the H and B frequency stimuli were equally salient for newborns and five month-olds (see Figure 8).

Within-age comparisons were done using the Cochran  $\underline{Q}$ -test, with a 'success' defined to be alerting on 1 or more of the 3 trials for the L, M, H, and B stimuli. As can be seen in Figure 8, newborns varied significantly in their alerting to the different frequency stimuli ( $\underline{Q}_3 = 7.1143$ ,  $\underline{P} < .05$ ), showing a linear increase in alerting to the L  $\rightarrow$  M  $\rightarrow$  H  $\rightarrow$  B frequency stimuli.

FIGURE 8

Number of Trials on Which Alerting Occurred as a Function of Age and Frequency Spectra

of the Sound



FREQUENCY SPECTRA OF THE SOUND



A test of five month-old alerting to the different frequency stimuli was not significant ( $Q_3 = 1.7778, P > .05$ ).

Quieting was extremely infrequent in newborns, occurring on only 1 trial. Five month-olds, however, quieted on 17% (49) of the trials and subsequently head turned on 59% (29) of these trials. This difference between newborn and five month-old quieting to a sound was highly significant ( $X_1^2 = 50.46, P < .0001$ ).

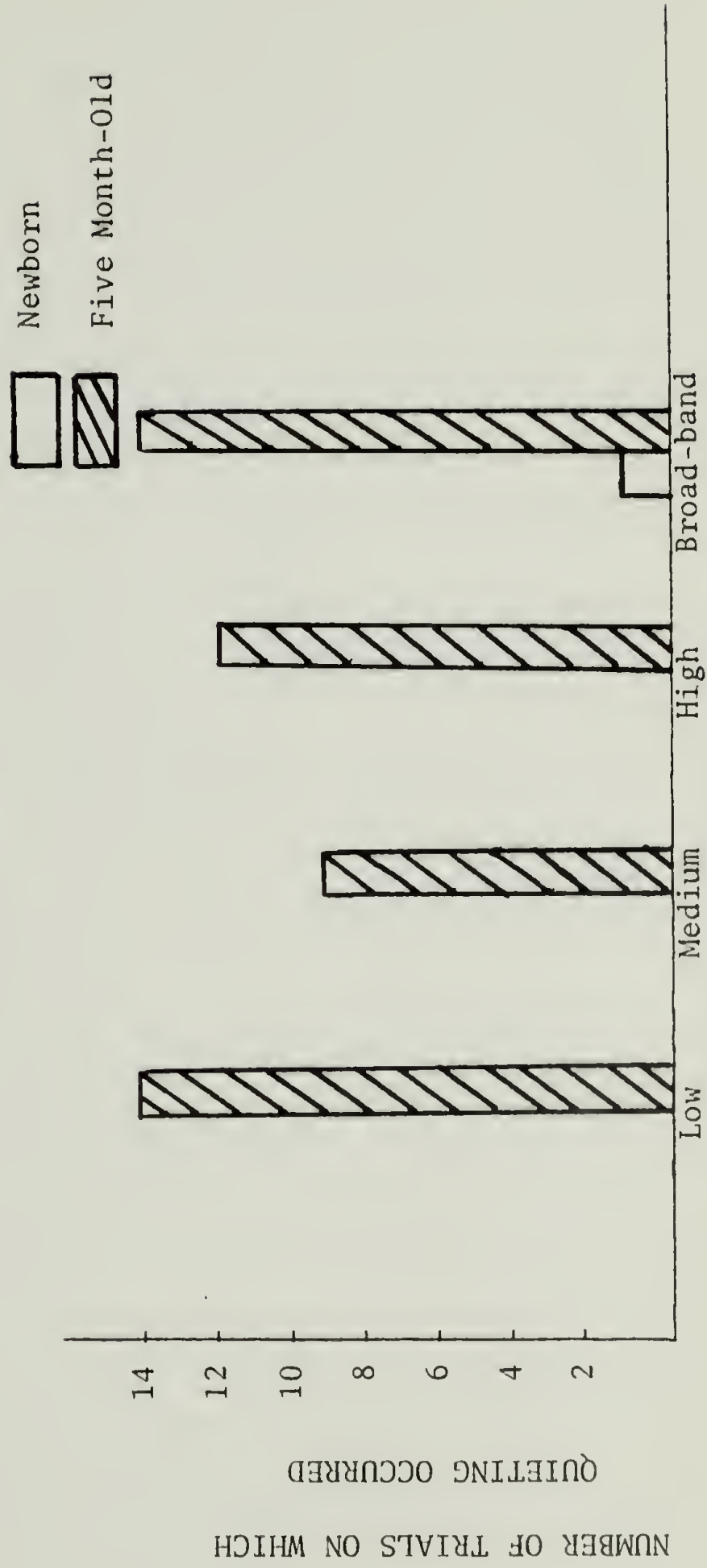
Subsequent analyses on quieting included frequency as a variable. Obviously, no cross-age comparisons of quieting to the different frequency stimuli were done. Within age comparisons were done using a Cochran  $Q$ -test, with a 'success' defined as 1 or more quieting trials for the L, M, H, and B stimuli. As can be seen in Figure 9, five month-olds did not significantly differ in quieting to the different frequency stimuli ( $Q_3 = 2.2979, P < .05$ ).

A comparison of the incidence of alerting (14%) vs quieting (17%) in five month-olds did not reveal a significant difference ( $t_{23} = .1866, P > .05$ ). Further, five month-olds did not significantly vary in subsequent head turning on alerting (53%) vs quieting (59%) trials ( $t_{23} = .6960, P > .05$ ). It appears that five month-olds were as likely to alert as to quiet to the onset of a sound stimulus, and subsequently head turned on a comparable proportion of alerting and quieting trials. Combining alerting and quieting to index behavioral responsivity to stimulus onset, five month-olds reacted on 31% (90) of the trials. In

FIGURE 9

Number of Trials on Which Quieting Occurred as a Function of Age and Frequency Spectra

of the Sound



FREQUENCY SPECTRA OF THE SOUND

comparison, newborns reacted on only 7% (20) of the trials. This difference in newborn and five month-old behavioral responsiveness to stimulus onset was highly significant ( $\chi^2_1 = 55.05$ ,  $P < .0001$ ).

In order to determine if there were any changes in newborn or five month-old responsivity during the test session ( e.g., behavioral habituation ), Cochran  $Q$ -tests were performed on the head turning, alerting and quieting data. The session was divided into 3 blocks of 4 trials and a score was computed for each subject for each block.

For head turning, a 'success' was defined as one or more head turn trials within a block. Neither newborns ( $Q_2 = 1.000$ ,  $P > .05$ ) or five month-olds ( $Q_2 = 1.28$ ,  $P > .05$ ) showed any evidence of significant variability in their distribution of head turning during the test session ( see Figure 10 ).

For alerting, a 'success' was defined as one or more alerting trials within a block. Neither newborns ( $Q_2 = .7500$ ,  $P > .05$ ) or five month-olds ( $Q_2 = .8765$ ,  $P > .05$ ) varied significantly in the incidence of alerting over trials ( see Figure 11 ).

Due to the lack of quieting behavior observed in newborns, only the five month-olds quieting data were analyzed. As can be seen in Figure 12, quieting did not significantly vary during the test session for five month-olds ( $Q_2 = 4.3077$ ,  $P > .05$ ).

These results substantiate that neither newborns or five month-olds showed any evidence of behavioral habituation or

FIGURE 10

Number of Trials on Which Head Turning Occurred as a Function of Age and Trial Block

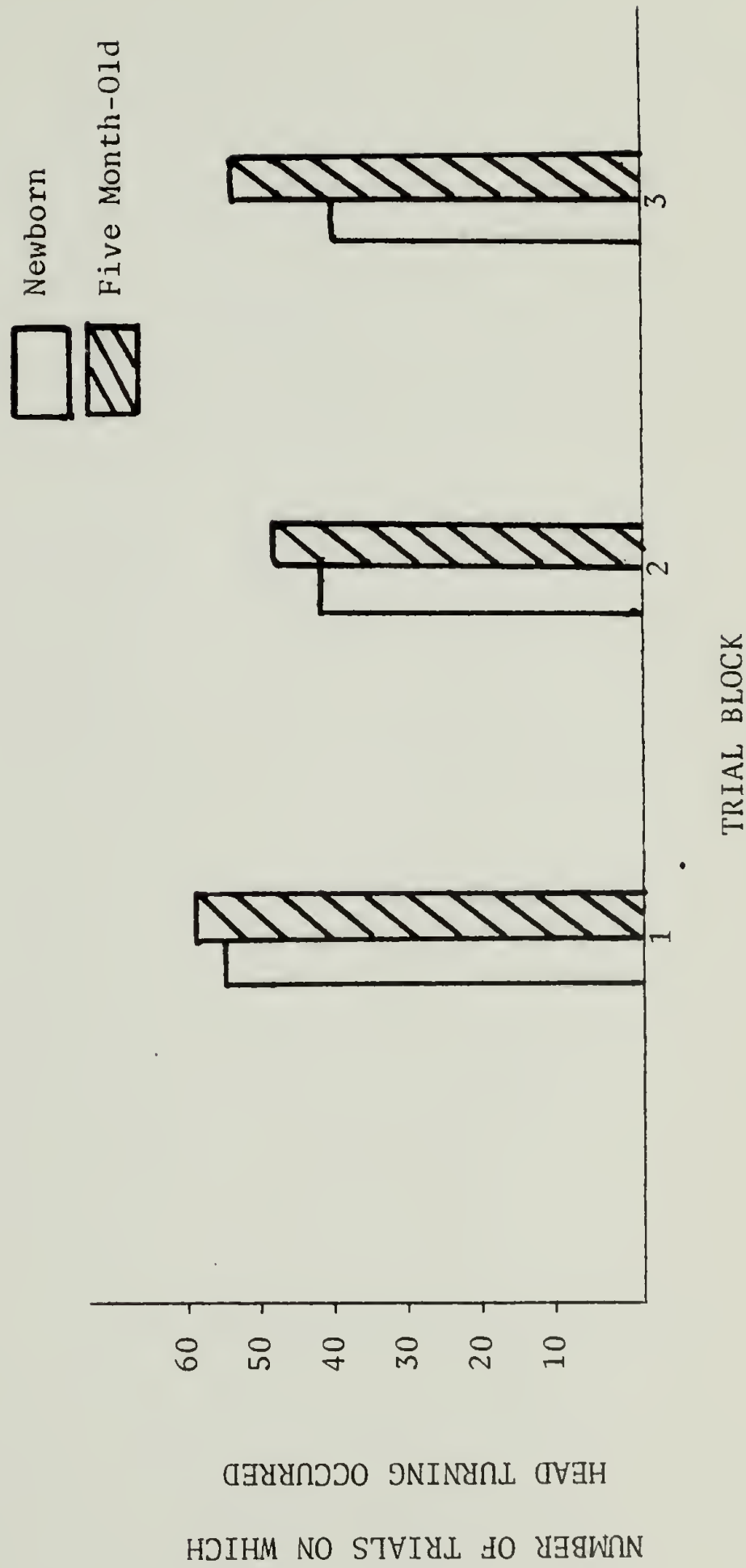


FIGURE 11

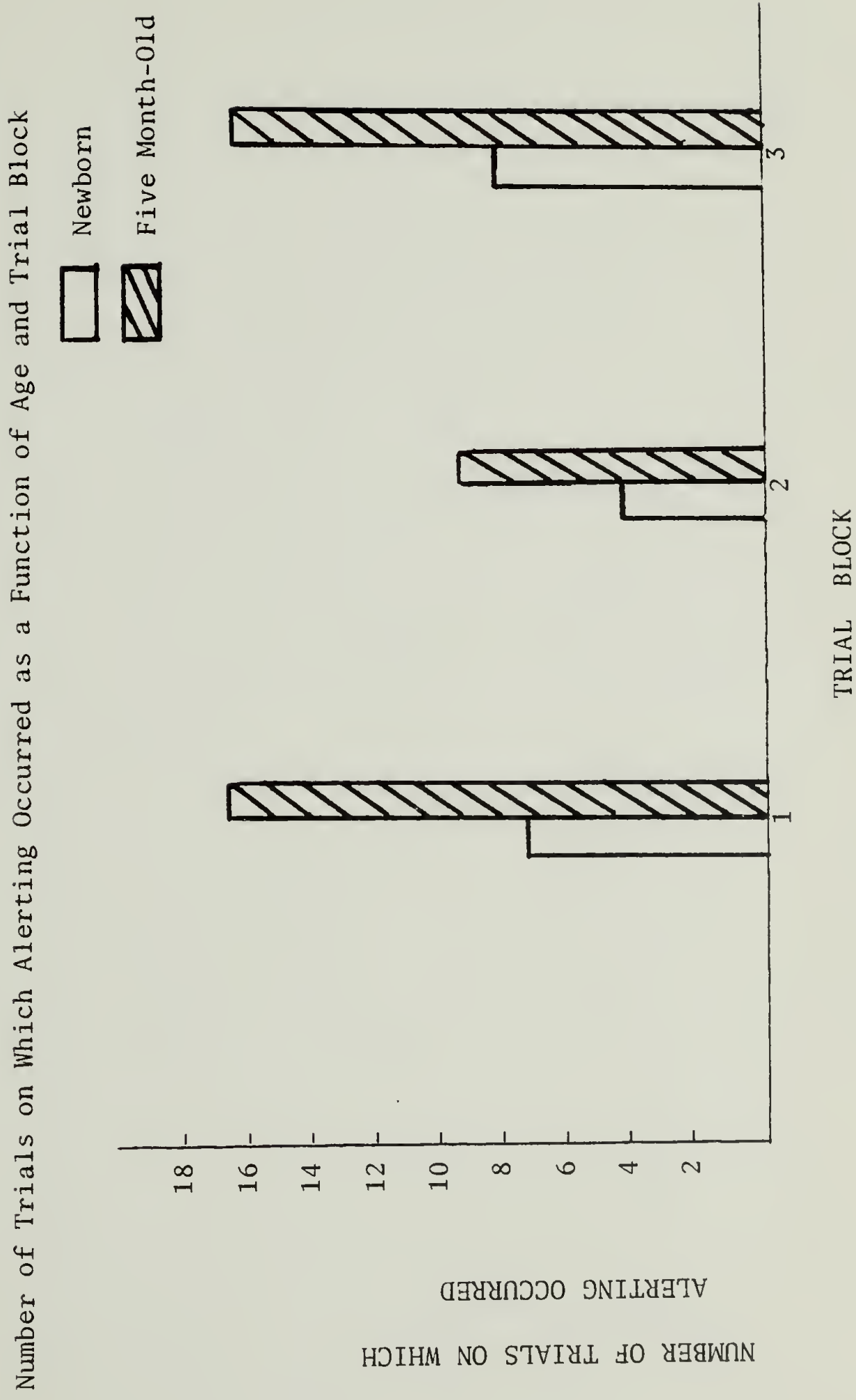
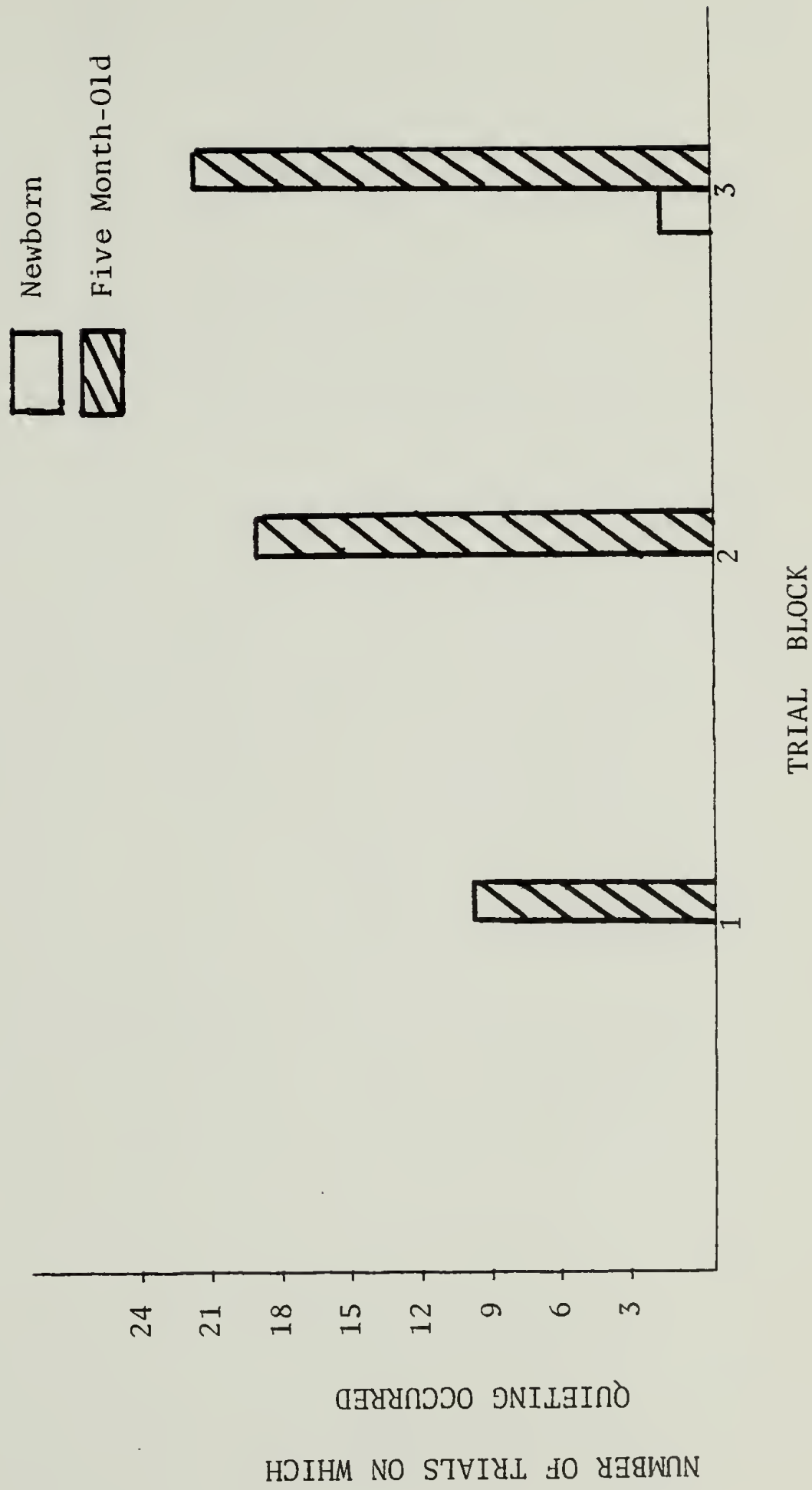


FIGURE 12

Number of Trials on Which Quieting Occurred as a Function of Age and Trial Block



changes in responsivity during the test session. Consequently, differences observed in newborn and five month-old head turning to the different frequency stimuli cannot be attributed to differential changes in responsivity during the test session.

### Summary of the Results

The following is a summary of the behavioral results:

(1) Averaging over frequency of the stimulus, five month-olds head turned to a sound significantly more than newborns, and in contrast to newborns, they head turned exclusively in the direction of the sound source.

(2) There was a significant developmental increase in head turning only to the L frequency stimulus. This result partially supports Hypothesis 1.

(3) The pattern of results for five month-olds' head turning to a sound reveals an order of 'localizability' which proceeds from L/M → H/B, with no significant difference in head turning to the L vs M and H vs B frequency stimuli. This result provides support for Hypothesis 2.

(4) The pattern of results for newborn head turning towards a sound reveals an order of 'localizability' which proceeds from L → M → H/B, with no significant difference in head turning to the H vs B frequency stimuli. This result supports Hypothesis 2.

(5) Significant differences in quantitative aspects of head

turning towards a sound emerged between newborn and five month-olds. As predicted in Hypothesis 3, five month-old head turning was of shorter latency and duration than that of newborns. And, the latency and duration of head turning did not, at either age, vary as a function of the frequency of the stimulus.

(6) Overall, five month-olds alerted and quieted significantly more than did newborns. For five month-olds there were no differences in the frequency of alerting vs quieting to a sound, and, subsequent head turning occurred on a comparable proportion of alerting and quieting trials. For newborns, however, there was significantly more alerting than quieting to a sound. Cross-age paired comparisons revealed five month-olds alerted significantly more than newborns to the L and M frequency stimuli.

(7) Analysis of the distribution of head turning, alerting, and quieting trials provided no evidence for behavioral habituation or changes in responsivity across trials in newborns or five month-olds.



## C H A P T E R V

### HEART RATE RESULTS

#### Preliminary Analyses

Preliminary analyses were done on the pre-stimulus ( i.e., baseline ) heart rate in order to determine if differences existed as a function of age or trials. A main effect of age can result due to the shift from lower to higher basal heart rate level, which occurs with maturation over the first several months of life ( Ziegler, 1951 ). Differences in baseline heart rate can occur, across trials, as a result of changes in the infant's state of arousal over the test session. This difference involving the trials factor is most important because the initial level of heart rate can affect the direction and magnitude of heart rate change, independent of stimulus factors ( Wilder, 1958 ).

The mean pre-stimulus heart rate level as a function of age and trials appears in Figure 13. An age (2) X subject (24) X trials (12) repeated-measures analysis of variance performed on the data revealed a significant difference in initial heart rate level as a function of age (  $F_{1,46} = 11.9777$ ,  $P < .01$  ), the averaged pre-stimulus heart rate level of newborns being significantly less than that of the five month-olds ( see Table 2 ). A significant age X trials interaction (  $F_{11,506} = 2.9507$ ,  $P < .01$  ) indicated

TABLE 2

THE AVERAGE PRE-STIMULUS HEART RATE ( BPM ) BY AGE<sup>\*</sup>

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Age Group

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Newborns

Five Month-Olds

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131.54

144.77

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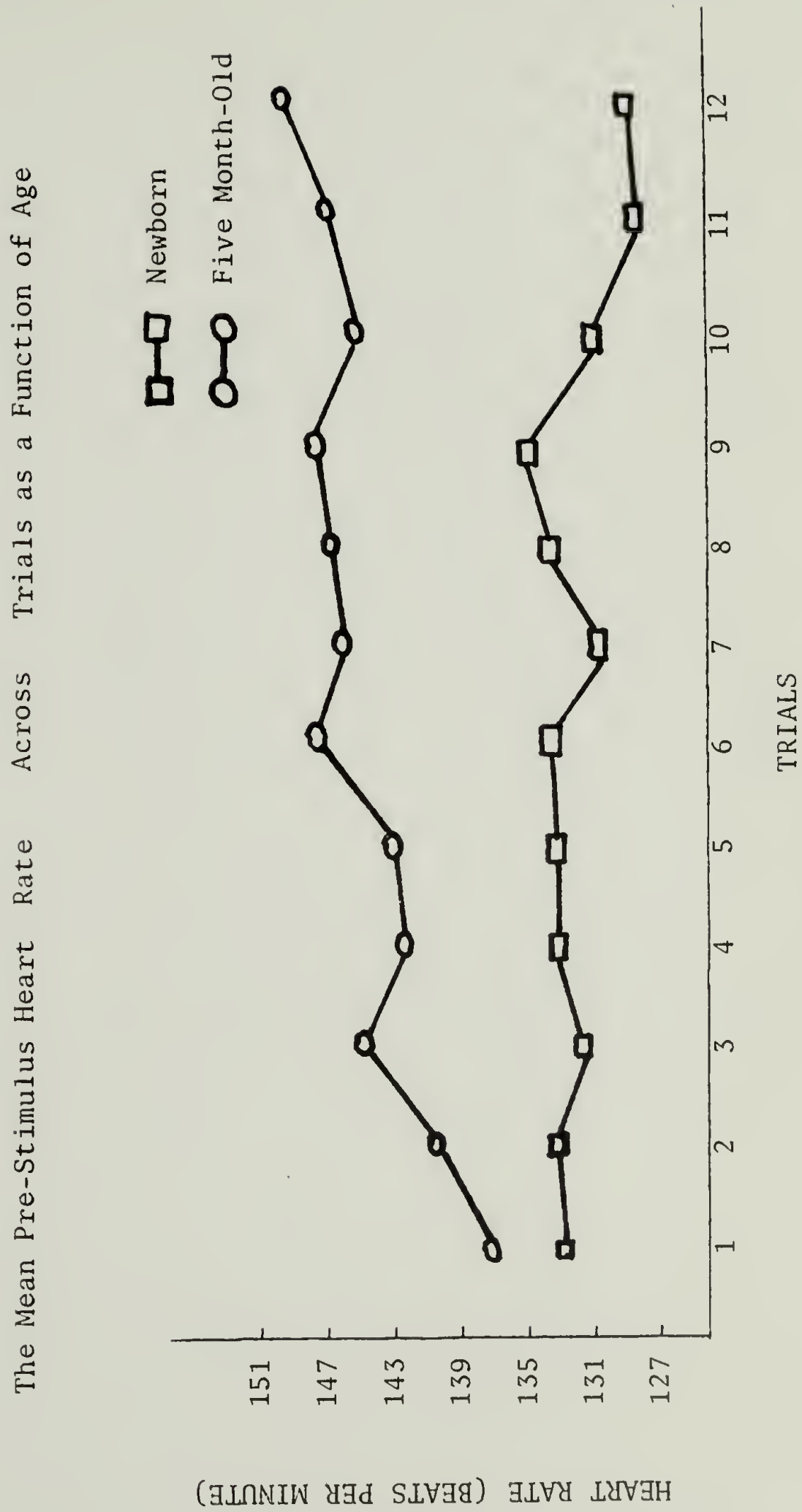
<sup>\*</sup>N = 48, equally divided by age

that the pre-stimulus heart rate level of newborns vs five month-olds differed across trials, with this difference being in the linear (  $F_{1,46} = 12.9398$ ,  $P < .01$  ) and cubic (  $F_{1,46} = 4.1109$ ,  $P < .05$  ) components. Across trials, the baseline heart rate level of newborns ranged from 127-135 bpm, and that for five month-olds ranged from 137-149 bpm. The ANOVA table appears in Appendix 11, Table 8.

In order to determine the factors responsible for the age X trials interaction, a subject (24) X trials (12) repeated-measures analysis of variance was performed separately on the pre-stimulus heart rate level across trials at each age. Newborns showed no systematic variations in pre-stimulus level across trials. The analysis for five month-olds, however, revealed a significant trials effect (  $F_{11,253} = 2.7892$ ,  $P < .01$  ), which was supported by a significant linear trend (  $F_{1,23} = 8.5735$ ,  $P < .01$  ). The pre-stimulus heart rate level of five month-olds increased significantly across trials ( see Figure 13 ). The ANOVA table appears in Appendix 11, Table 9.

The results for newborns support the inference that there were no significant changes in the newborn's state during the test session. This is consistent with this author's observations during testing and with analyses of the behavioral data which revealed no significant changes in newborn responsiveness ( i.e., alerting, quieting, head turning ) across trial blocks (see pp. 53-57).

FIGURE 13



The linear increase in baseline heart rate for five month-olds, however, indicates an increase in state of arousal during the test session. This too is consistent with this author's observations; during the course of the test session five month-olds tended to show increased body movement and fussiness, etc. Recall, however, that analyses of the behavioral data of the five month-olds revealed no significant changes in responsivity ( i.e., alerting, quieting, head turning ), as a function of trial block ( i.e., first, middle, last 4 trials of the test session ). Therefore, though the results from the analysis of the five month-old baseline heart rate level suggests an increase in state of arousal during the test session, this increased arousal did not, in any overt way, influence the occurrence of the behaviors of primary interest. The difference in pre-stimulus heart rate level across trials, however, could have affected the heart rate response which occurred to the stimuli.

#### Primary Analyses

The main reason for recording heart rate in the present study concerned cardiac-somatic relations and developmental changes in these relationships. Consequently, the questions of interest were whether the heart rate response would vary on 'head turn' vs 'no head turn' trials, and whether this effect would differ for newborns vs five month-olds. Frequency of the stimulus ( L, M, H, B ) was also entered as a variable in the heart rate analyses as differences

had emerged between newborns and five month-olds in head turning to the different frequency stimuli and previous research reported differential cardiac responding as a function of the frequency of the signal ( Kearsley, 1973 ).

As a consequence of the distribution of head turning as a function of frequency, separate analyses were done on the data of two major subsets of subjects. Problems arose because (1) the newborns did not head turn a great deal, particularly to the low-pass stimulus, and (2) five month-olds did not, as expected, habituate over the course of the test session; rather, they tended to head turn a great deal to all frequencies. There were only 14 newborns and 14 five month-olds that provided scorable heart rate data on a 'head turn' and 'no head turn' trial to each of the L, M, H, and B stimuli. The remaining newborns did not yield heart rate data for 'head turn' trials to certain frequency stimuli, particularly the L stimulus, and, the remaining five month-olds did not provide heart rate data for both 'no head turn' and 'head turn' trials to various frequency stimuli.

One major subset of subjects was the 14 newborns and five month-olds who provided heart rate data on 'head turn' and 'no head turn' trials to each of the L, M, H, and B stimuli. As each of these subjects had different numbers of trials for the different head turn (2) X frequency (4) combinations, a single trial was selected for each subject for each of the 8 cells. Whenever a

subject had more than 1 trial of heart rate data for a particular cell ( e.g., 2 heart rate trials for 'head turn' to M stimulus ), 1 trial was randomly selected by using the trial index numbers ( i.e., numbers between 1 and 12 ) and sequences of random numbers; selecting the trial on the basis of which of the trial index numbers appeared first in a random sequence of the numbers 1-12.

The second major subset of subjects was that of 22 newborns and 21 five month-olds who provided heart rate data on a 'head turn' and 'no head turn' trial to each of the M, H, and B stimuli. This grouping of 43 subjects included the 28 subjects previously discussed. However, the same trials for the M, H, and B stimuli did not necessarily enter into these analyses. Trials were selected for all 43 subjects as previously described. It should be noted, however, that in many cases a subject had only a single trial of heart rate data for a particular head turn X frequency combination. This was due to the problems described initially in this section and the fact that heart rate trials were stringently selected for inclusion in the analyses ( see the omission criteria on p 32 ). A listing of the heart rate trials eliminated from the analyses, and the reasons for the omission, appears in Appendix 6.

Hypothesis 4: Results. It was hypothesized that heart rate change in newborns and five month-olds would vary, in similar ways, as a function of head turning behavior. Cardiac deceleration was

expected to occur on 'no head turn' trials, indicating attention to the stimulus. On trials in which a 'head turn' occurred, however, this deceleratory response was predicted to be of less magnitude, not significant, or replaced by an acceleratory response.

Results: 14 Newborns and 14 Five Month-Olds. The heart rate responses of the newborns and five month-olds on 'head turn' vs 'no head turn' trials supported hypothesis 4 and revealed a developmental change in heart rate response on 'head turn' trials.

An age (2) X subjects (14) X head turn (2) X frequency (4) X seconds (13) repeated-measures analysis of variance revealed that the average heart rate varied as a function of age due to differences in pre-stimulus, baseline level ( $F_{1,26} = 6.6197$ ,  $P < .01$ ). The average heart rate for newborns was 129.51 bpm, which was significantly below the 141.17 bpm average obtained for five month-olds. As can be seen in Figures 14 and 15, heart rate change differed for 'head turn' vs 'no head turn' trials (seconds X head turn,  $F_{12,312} = 10.845$ ,  $P < .01$ ). On 'no head turn' trials both newborns and five month-olds responded with cardiac deceleration. On 'head turn' trials, however, newborns showed no significant heart rate change and five month-olds responded with cardiac deceleration (seconds X head turn X age,  $F_{12,312} = 9.3284$ ,  $P < .01$ ). Trend tests revealed this age difference in heart rate change on 'head turn' trials to be in the quadratic component



FIGURE 14

The Average Heart Rate Change on No Head Turn Trials as a Function of Age

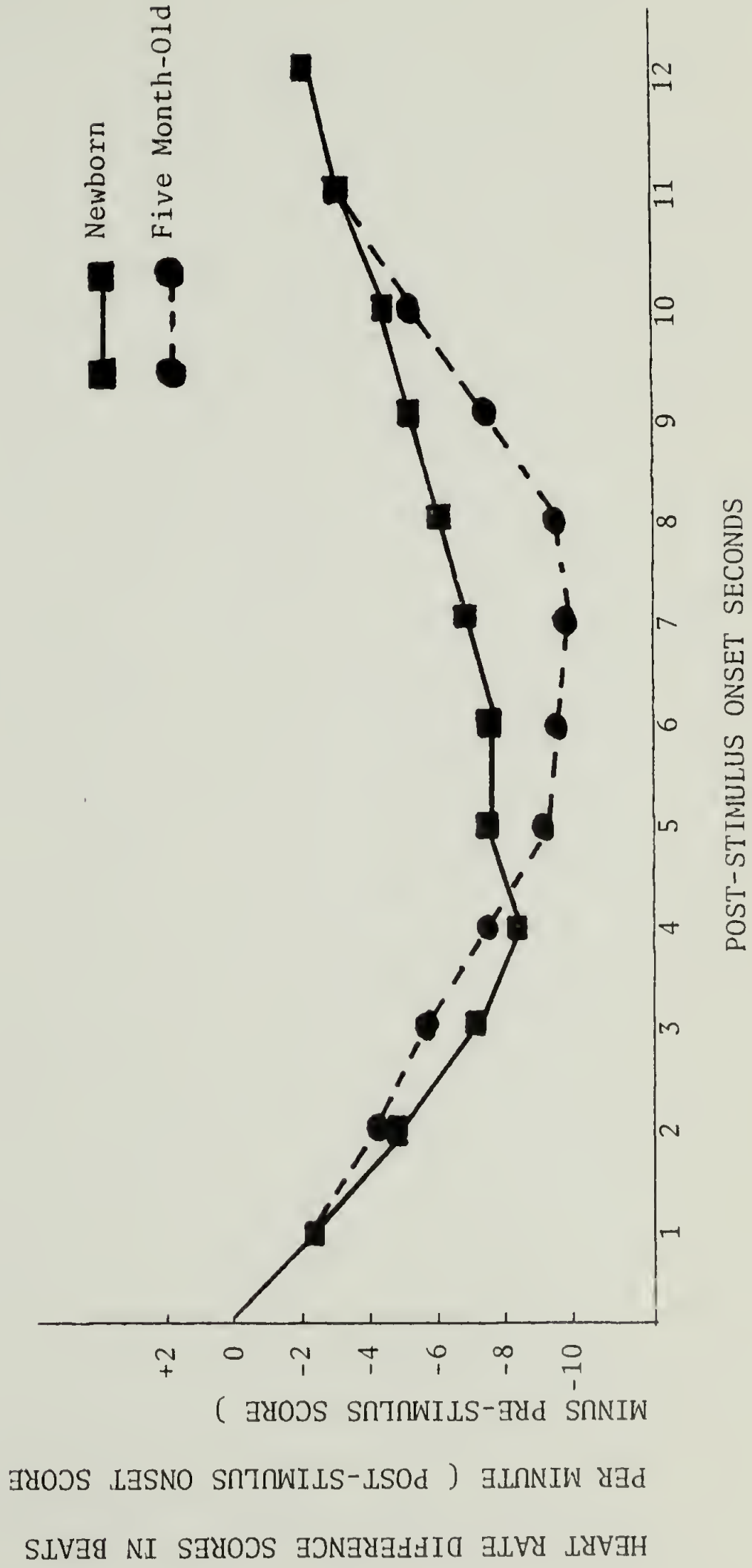
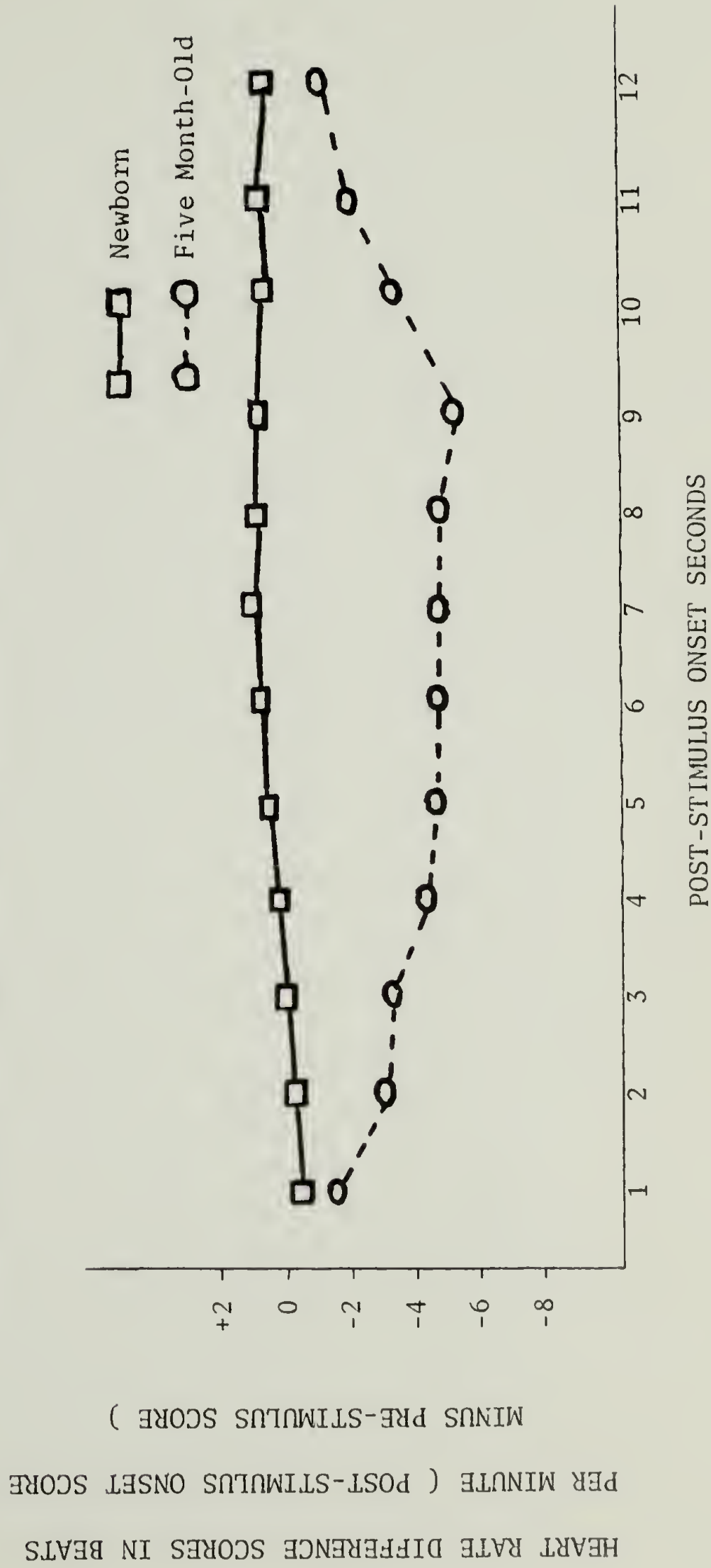


FIGURE 15

The Average Heart Rate Change on Head Turn Trials as a Function of Age



(  $F_{1,26} = 35.4833$ ,  $P < .01$  ); five month-olds responded with cardiac deceleration which was followed by a return to baseline, while newborn heart rate showed no reliable directional changes. There were no significant main effects or interactions involving frequency of the stimulus. The ANOVA table appears in Appendix 12, Table 10.

A cross-age analysis was performed on the heart rate data on 'no head turn' trials ( see Appendix 12, Table 11 ). The averaged heart rate varied significantly across age (  $F_{1,26} = 6.4813$ ,  $P < .05$  ); the average for newborns being significantly less than that for five month-olds ( see Table 3 ). There were no significant differences, however, in heart rate response as a function of age. As can be seen in Figure 14, both age infants responded to the stimulus with cardiac deceleration on trials in which they did not head turn. Though the magnitude of the deceleration did not differ as a function of age, the time course of the heart rate response did differ somewhat for newborns vs five month-olds ( see Figure 14 ). The peak deceleration for newborns occurred at the fourth post-stimulus second and was 8 bpm. Five month-olds reached a peak deceleration of 9 bpm at the seventh post-stimulus second.

Cross-age comparisons of the average heart rate on 'head turn' trials revealed a main effect of age due to the difference in pre-stimulus, baseline level (  $F_{1,26} = 5.9746$ ,  $P < .05$  ). The average heart rate for newborns was 130.64 bpm, which was signifi-

TABLE 3

THE AVERAGE HEART RATE ( BPM ) BY TYPE OF TRIAL AND AGE \*

| Type of<br>Trial | Age Group |                 |
|------------------|-----------|-----------------|
|                  | Newborns  | Five Month-Olds |
| Head Turn        | 130.64    | 140.99          |
| No Head Turn     | 128.39    | 141.36          |

\* N = 28, equally divided by age

cantly less than the 140.99 bpm average obtained for five month-olds ( see Table 3 ). The heart rate response of newborns and five month-olds differed on 'head turn' trials, as indicated by a seconds X age interaction (  $F_{12,312} = 1.8420$ ,  $P < .05$  ) which was supported by a significant quadratic trend (  $F_{1,26} = 5.4487$ ,  $P < .05$  ). The ANOVA table appears in Appendix 12, Table 11.

As can be seen in Figure 15, five month-olds responded with cardiac deceleration on trials in which they head turned. Newborns, however, did not show any reliable cardiac response on 'head turn' trials. For five month-olds a peak deceleration of  $5\frac{1}{2}$  bpm occurred at post-stimulus second 7. In contrast, the average value of heart rate during head turning trials for newborns varied less than 1 bpm over the 12 seconds ( see Figure 15 ).

Within-age analyses of the heart rate responses on 'head turn' vs 'no head turn' trials revealed several interesting results. A subjects (14) X head turn (2) X frequency (4) X seconds (13) repeated-measures analysis of variance was performed separately on the heart rate data of the newborns and the five month-olds.

The heart rate response of newborns varied significantly as a function of head turning, as indicated by a significant head turn X seconds interaction (  $F_{12,156} = 17.3347$ ,  $P < .01$  ) which was supported by significant quadratic (  $F_{1,13} = 52.1811$ ,  $P < .01$  ) and cubic (  $F_{1,13} = 9.3201$ ,  $P < .01$  ) trends. There were no

significant main effects or interactions involving frequency of the stimulus. The ANOVA table appears in Appendix 12, Table 12.

As can be seen in Figure 16, on 'no head turn' trials newborns showed significant cardiac deceleration to the stimulus, as indicated by a significant seconds effect ( $F_{12,156} = 15.3055$ ,  $P < .01$ ), which was supported by significant quadratic ( $F_{1,13} = 51.019$ ,  $P < .01$ ) and cubic ( $F_{1,13} = 12.0316$ ,  $P < .01$ ) trends. On 'head turn' trials however, they showed no reliable cardiac response. The ANOVA table appears in Appendix 12, Table 13.

In contrast to newborns, five month-olds showed cardiac deceleration on 'head turn' trials, as indicated by a significant seconds effect ( $F_{12,156} = 1.8194$ ,  $P < .05$ ) which was supported by a quadratic trend ( $F_{1,13} = 4.7270$ ,  $P < .05$ ), as well as on 'no head turn' trials ( $F_{12,156} = 11.3477$ ,  $P < .01$ ; quadratic trend:  $F_{1,13} = 60.1340$ ,  $P < .01$ ). This is depicted in Figure 17, and the ANOVA table appears in Appendix 12, Table 14.

The subjects (14) X head turn (2) X frequency (4) X seconds (13) analysis of variance resulted in a significant seconds X head turn interaction ( $F_{12,156} = 2.0839$ ,  $P < .05$ ) which was supported by a significant quadratic trend ( $F_{1,13} = 6.6536$ ,  $P < .05$ ). This indicates that the magnitude of cardiac deceleration varied significantly for the five month-olds as a function of head turning. As can be seen in Figure 17, on 'no head turn' trials a peak deceleration of 9 bpm was reached at post-stimulus second 7. On

FIGURE 16

The Average Heart Rate Change for Newborns on Head Turn and No Head Turn Trials

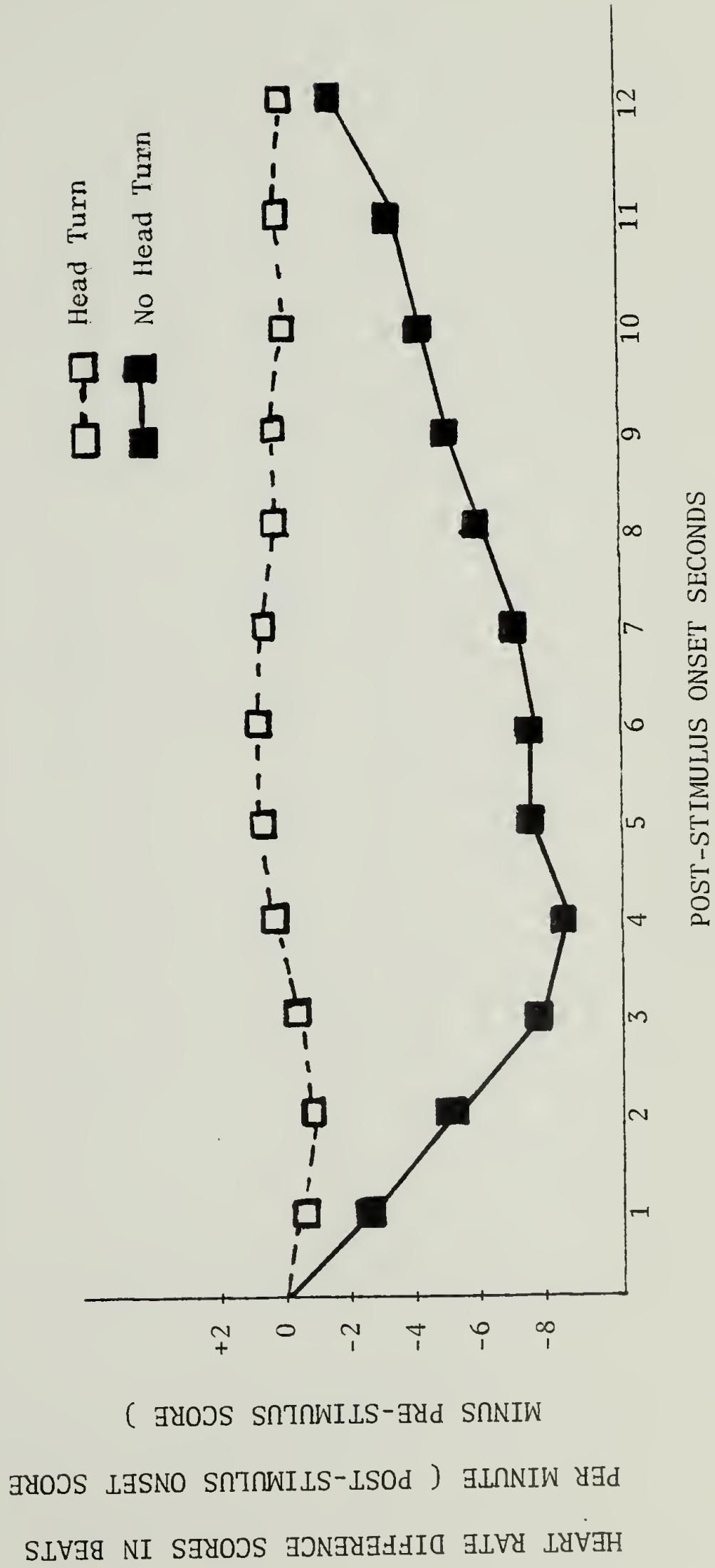
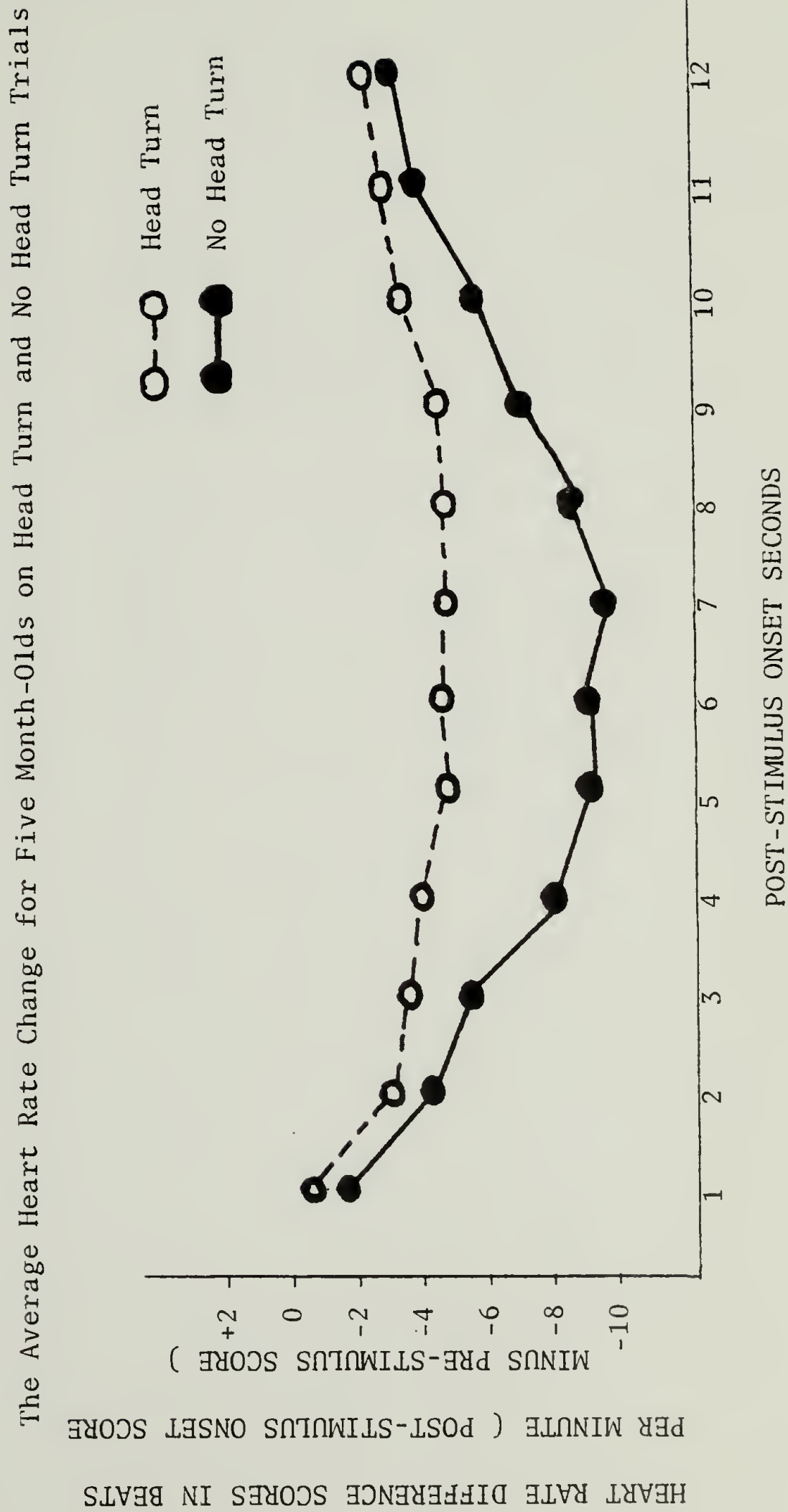


FIGURE 17





'head turn' trials, however, the peak deceleration was only  $5\frac{1}{2}$  bpm, and it also occurred at the seventh post-stimulus second. The stability of the time course of cardiac orienting in five month-olds is striking ( see Figure 17 ). There were no significant main effects or interactions involving frequency. The ANOVA table appears in Appendix 12, Table 12.

These results suggest a developmental change over the first several months of life in the nature of cardiac-somatic relationships. In the newborn period head turning seemingly precludes cardiac orienting to a stimulus which has clearly elicited the infant's attention ( see Figure 16 ). In five month-olds, however, cardiac orienting to a stimulus occurs regardless of whether or not the infant head turns. However, the magnitude of the deceleratory response of the five month-olds is influenced by head turning. Cardiac deceleration is of significantly greater magnitude on trials in which the infant does not head turn ( see Figure 17 ).

Results: 22 Newborns and 21 Five Month-Olds. The following results are consistent with those previously described and support hypothesis 4. The heart rate responses of the newborns and five month-olds varied as a function of head turning. The results indicated a developmental change in the heart rate response on 'head turn' trials, and also revealed a significant developmental increase in the magnitude of cardiac orienting on 'no head turn'

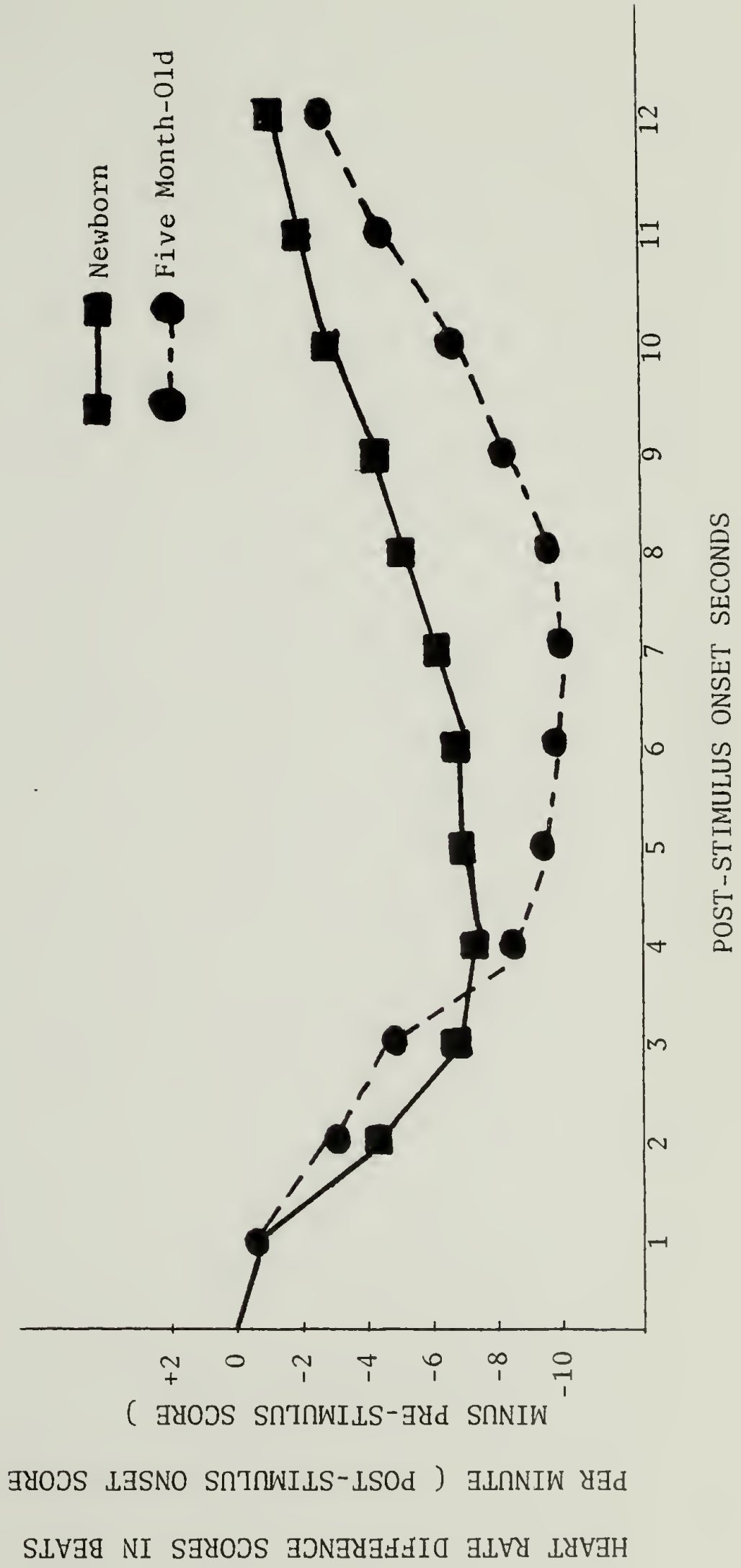
trials.

An age (2) X subjects (22,21) X head turn (2) X frequency (4) X seconds (13) repeated-measures analysis of variance was performed on the data ( see Appendix 12, Table 15 ). The average heart rate varied significantly as a function of age due to the difference in pre-stimulus, baseline level (  $F_{1,41} = 6.7161, p < .05$  ). In contrast to the 131.25 bpm average for newborns, the average heart rate for five month-olds was 142.03 bpm. A significant head turn X seconds X age interaction (  $F_{12,492} = 2.5922, p < .01$  ), which was supported by a cubic trend (  $F_{1,41} = 7.5352, p < .01$  ), indicated that the heart rate responses on 'head turn' and 'no head turn' trials differed significantly across the two ages ( see Figures 18 and 19 ). There were no significant main effects or interactions involving frequency of the stimulus. The ANOVA table appears in Appendix 12, Table 15.

Cross-age comparisons of the heart rate of newborns vs five month-olds on 'no head turn' trials revealed a main effect of age (  $F_{1,41} = 9.2405, p < .01$  ). The average heart rate level of newborns was 130.65 bpm in comparison to the 143.29 average for five month-olds. Newborns and five month-olds both responded with cardiac deceleration on trials in which they did not head turn ( see Figure 18 ). The orienting response of the five month-olds, however, was significantly greater in magnitude than that of the newborns. This is indicated by a significant seconds X age

FIGURE 18

The Average Heart Rate Change on No Head Turn Trials as a Function of Age



interaction (  $F_{12,492} = 4.1384$ ,  $p < .05$  ) which was supported by significant quadratic (  $F_{1,41} = 4.1937$ ,  $p < .05$  ) and cubic (  $F_{1,41} = 6.7507$ ,  $p < .05$  ) trends. For the five month-olds a peak deceleration of 11 bpm occurred on post-stimulus second 7. In contrast, the peak deceleration of newborns, which occurred on the fourth post-stimulus second, was only  $6\frac{1}{2}$  bpm ( see Figure 18 ). The ANOVA table appears in Appendix 12, Table 16.

Cross-age comparisons of the heart rate of newborns vs five month-olds on 'head turn' trials revealed a significant difference in the averaged heart rate on 'head turn' trials as a function of age (  $F_{1,41} = 9.2054$ ,  $p < .01$  ). The average heart rate level of newborns was 130.65 bpm in comparison to the 143.29 bpm average for five month-olds. Both newborns and five month-olds responded with cardiac deceleration on trials in which they did not head turn ( see Figure 18 ). The orienting response of the five month-olds, however, was significantly greater in magnitude than that of the newborns. This is indicated by a significant seconds X age interaction (  $F_{12,492} = 4.1384$ ,  $p < .05$  ) which was supported by significant quadratic and cubic trends (  $F_{1,41} = 4.1937$ ,  $p < .05$ ;  $F_{1,41} = 6.7507$ ,  $p < .05$ , respectively ). For the five month-olds a peak deceleration of 11 bpm occurred on post-stimulus second 7. In contrast, the peak deceleration of newborns, which occurred on the fourth post-stimulus second, was only  $6\frac{1}{2}$  bpm ( see Figure 18 ). The ANOVA table appears in Appendix 12, Table 16.

Cross-age comparisons of the heart rate of newborns vs five month-olds on 'head turn' trials revealed a significant difference in the average heart rate on 'head turn' trials as a function of age (  $F_{1,41} = 4.3072$ ,  $p < .05$  ). The average for newborns was 131.87 bpm, whereas, that for five month-olds was 140.76 bpm. A seconds X age interaction (  $F_{12,492} = 4.3224$ ,  $p < .01$  ), which was supported by a quadratic trend (  $F_{1,41} = 11.4732$ ,  $p < .01$  ) indicated that the heart rate response of newborns and five month-olds differed significantly on 'head turn' trials. As can be seen in Figure 19, newborns did not show any reliable heart rate response on 'head turn' trials, the average heart rate varying within 1 bpm across 12 seconds. Five month-olds, however, responded with cardiac deceleration on 'head turn' trials, a peak deceleration of  $6\frac{1}{2}$  bpm occurring at post-stimulus second 5. The ANOVA table appears in Appendix 12, Table 16.

Within-age analyses of the heart rate responses on 'head turn' vs 'no head turn' trials were performed on the data of the newborns and the five month-olds. The design for both analyses was a subjects (22,21) X head turn (2) X frequency (4) X seconds (13) repeated-measures design.

As can be seen in Figure 20, the heart rate responses of newborns differed significantly as a function of head turning. This was indicated by a significant head turn X seconds interaction (  $F_{12,252} = 14.9792$ ,  $p < .01$  ), which was supported by significant

FIGURE 19

Average Heart Rate Change on Head Turn Trials as a Function of Age

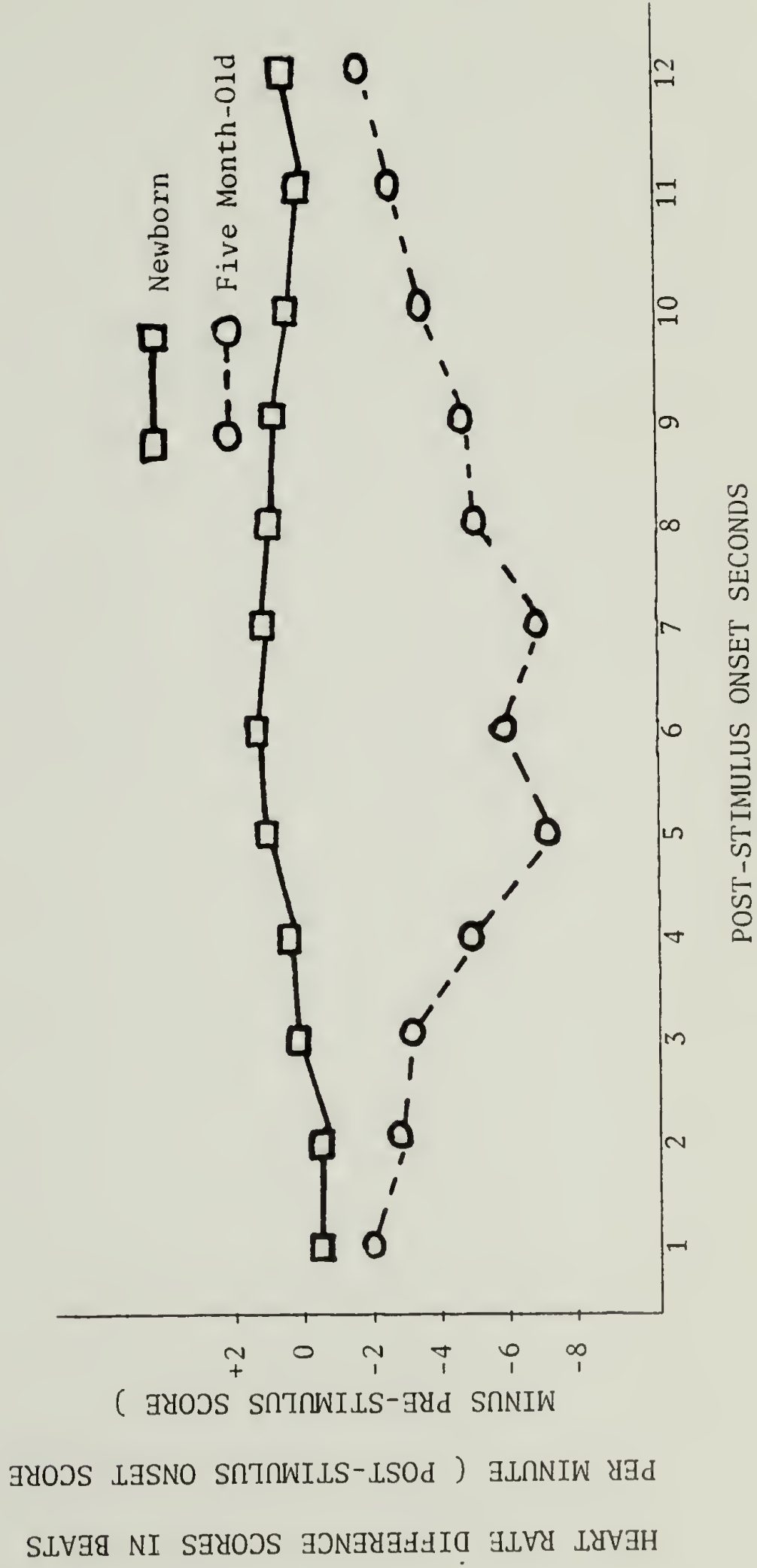
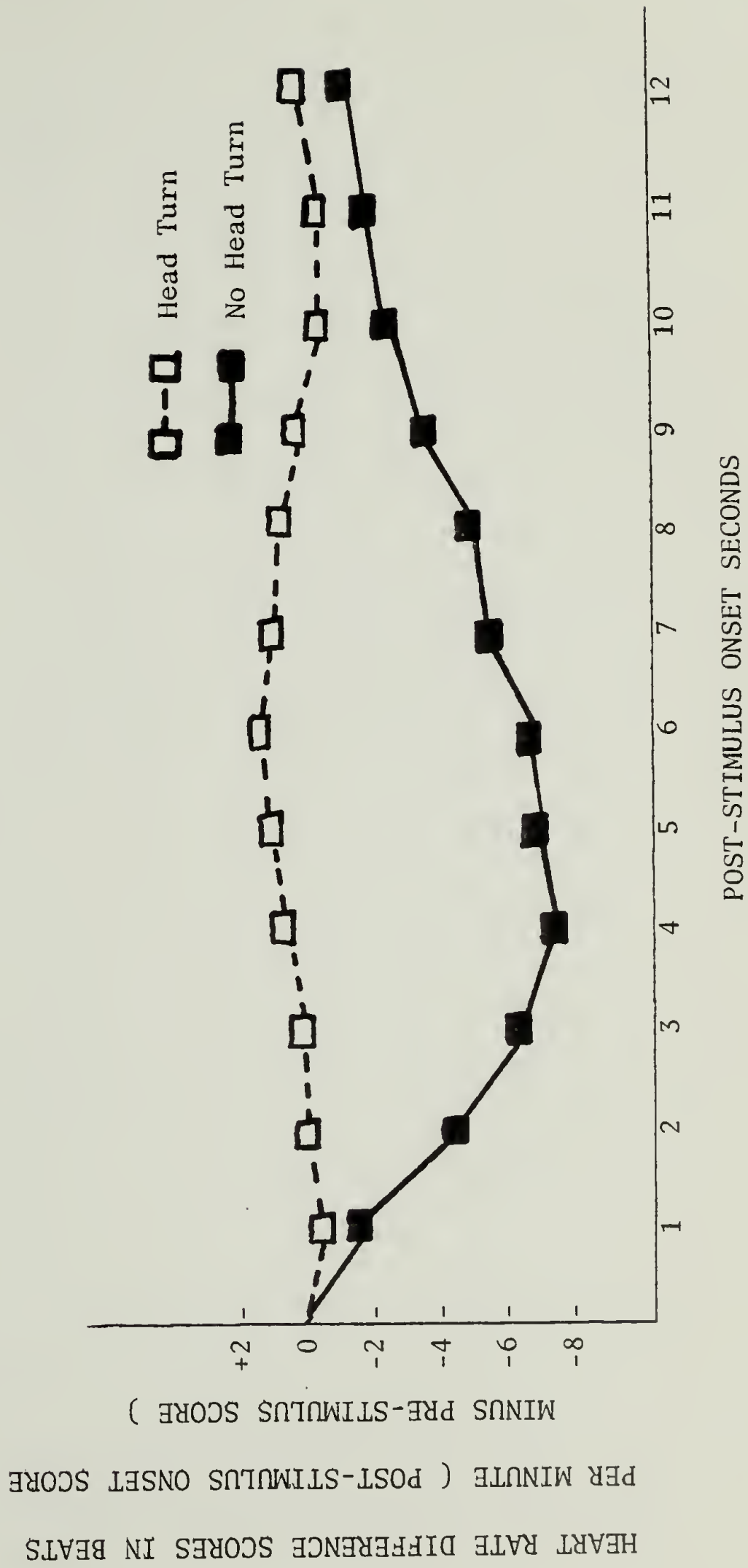


FIGURE 20

Average Heart Rate Change for Newborns on Head Turn and No Head Turn Trials



HEART RATE DIFFERENCE SCORES IN BEATS

PER MINUTE ( POST-STIMULUS ONSET SCORE

MINUS PRE-STIMULUS SCORE )

quadratic and cubic trends (  $F_{1,21} = 72.7587$ ,  $P < .01$ ;  $F_{1,21} = 9.3798$ ,  $P < .01$ , respectively ). The ANOVA table appears in Appendix 12, Table 17. Newborns did not show any reliable heart rate responses on 'head turn' trials. However, a significant seconds effect (  $F_{12,240} = 14.9698$ ,  $P < .01$  ) which was supported by quadratic and cubic trends (  $F_{1,21} = 61.5963$ ,  $P < .01$ ;  $F_{1,21} = 11.1719$ ,  $P < .01$ , respectively ) revealed reliable cardiac orienting on trials in which neonates did not head turn ( see Figure 20 ). The ANOVA table appears in Appendix 12, Table 18.

Like the newborns, five month-olds showed significant cardiac orienting on 'no head turn' trials, as indicated by a significant seconds effect (  $F_{12,240} = 17.7142$ ,  $P < .01$  ), which was supported by linear and quadratic trends (  $F_{1,20} = 5.6629$ ,  $P < .02$ ;  $F_{1,20} = 74.1963$ ,  $P < .01$ , respectively ). In contrast to newborns, however, the five month-olds also responded with cardiac deceleration on trials in which they head turned ( see Figure 21 ). This is indicated by a significant seconds effect (  $F_{12,240} = 3.6706$ ,  $P < .01$  ) which was supported by a quadratic trend (  $F_{1,20} = 9.1604$ ,  $P < .01$  ). The ANOVA table appears in Appendix 12, Table 19. A significant head turn X seconds interaction (  $F_{12,240} = 2.6423$ ,  $P < .01$  ), which was supported by a quadratic trend (  $F_{1,20} = 5.0348$ ,  $P < .05$  ), indicated that the heart rate deceleration on 'head turn' trials was of significantly less magnitude than that which occurred on 'no head turn' trials ( see



FIGURE 21

The Average Heart Rate Change for Five Month-Olds on Head Turning and No

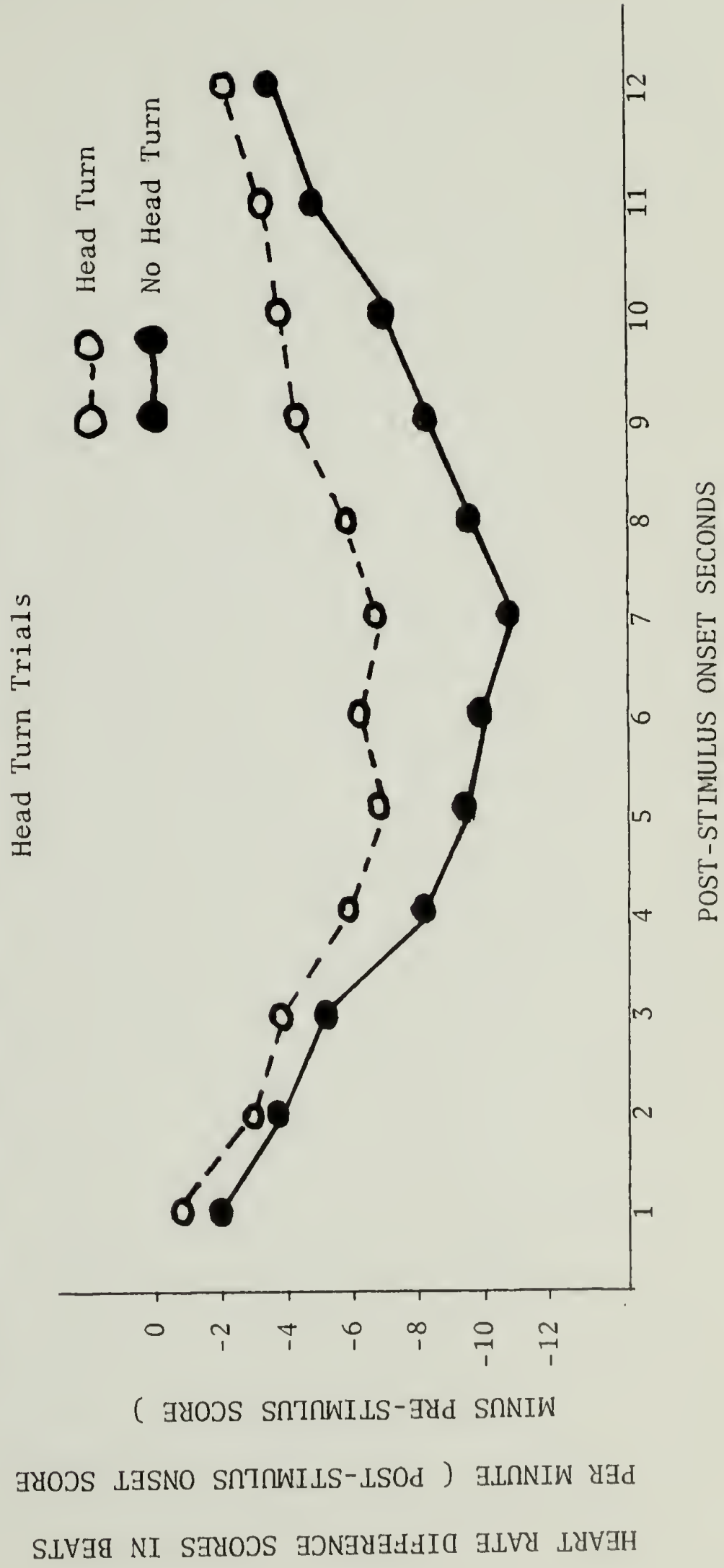


Figure 21 ). The ANOVA table appears in Appendix 12, Table 17. The peak deceleration on 'no head turn' trials was 11 bpm and this occurred on the seventh post-stimulus second. The peak deceleration on 'head turn' trials, however, was  $6\frac{1}{2}$  bpm and this occurred on the fifth post-stimulus second ( see Figure 21 ).

These results are consistent with those discussed previously on a smaller N, and offer support for Hypothesis 4. Both newborns and five month-olds showed differences in cardiac responding as a function of head turning, and the results indicate a developmental change in the nature of cardiac-somatic relationships. Newborns showed cardiac deceleration only on those trials in which they did not head turn ( see Figure 20 ). Similarly, five month-olds responded with cardiac deceleration on 'no head turn' trials. And in the present analyses, the magnitude of this deceleration was significantly greater for five month-olds ( see Figure 18 ). On 'head turn' trials, newborns showed no reliable cardiac response. The five month-olds, however, responded with cardiac orienting, though the magnitude of this deceleration was significantly less than that which occurred on 'no head turn' trials ( see Figure 21 ).

#### Summary of the Results

The following is a summary of the heart rate results:

(1) The heart rate response of newborns varied as a function of head turning. On 'head turn' trials they did not show any

reliable cardiac response. On 'no head turn' trials they showed cardiac deceleration. These results are consistent with Hypothesis 4.

(2) The heart rate response of five month-olds also varied as a function of head turning. In contrast to newborns, however, cardiac deceleration occurred on 'head turn' as well as on 'no head turn' trials. However, cardiac orienting was of greater magnitude on 'no head turn' trials. These results are consistent with Hypothesis 4.

(3) There was a developmental change in cardiac-somatic relationships, as indicated by the shift from no response in newborns to cardiac deceleration in five month-olds on 'head turn' trials. This result is consistent with Hypothesis 4 and suggests a close relationship between age ( i.e., maturational level ) and the effect of head turning on magnitude of the heart rate response.

(4) The analyses of the 43 subjects ( 22 newborns and 21 five month-olds ) revealed a developmental increase in the magnitude of cardiac orienting on 'no head turn' trials. That this difference did not reach significance in the analyses of the 28 subjects ( 14 newborns and 14 five month-olds ) is seemingly a result of the reduced power of the test due to the smaller number of subjects' data entering the analyses.

(5) The stability of the time course of the heart rate response in newborns and five month-olds is striking and differs

across age. The peak deceleration of newborns occurred by the fourth post-stimulus second, whereas, that for the five month-olds occurred at the seventh post-stimulus second.

(6) In contrast to earlier reports ( Kearsley, 1973 ) there were no significant differential changes in heart rate as a function of the frequency of the stimulus.

## C H A P T E R V I

### DISCUSSION

The findings of the present study will be discussed with regard to the initial hypotheses and the relevant literature.

#### Behavioral Results

Hypothesis 1: Developmental Changes in Head Turning Towards Each of the L, M, H, B Stimuli. The results of the present study provide partial support for Hypothesis 1. In general, there was significantly more head turning towards sound in five month-olds than in newborns, and in contrast to newborns, five month-olds head turned exclusively in the direction of the sound source. Five month-olds head turned more than newborns to each of the L, M, H, B stimuli, however, the only difference which reached significance was the age difference in head turning towards the L frequency stimulus.

This result is consistent with the pattern of results of Trehub et al (1980) which revealed developmental changes in sensitivity to lower frequency octave-band noises ( $\leq 2000$  Hz) in infants between 6 and 12 months of age. Trehub et al sought to determine the thresholds of 6-, 12-, and 18- month-old infants for octave-band noises with center frequencies at 200, 400, 1000, 2000, 4000 and 10000 Hz. The threshold functions for the 12- and 18- month-old infants proved to be very similar across the 200 - 10000 Hz

frequency range. Six month-olds, however, were 5-8 dB less sensitive than the older infants to the lower frequencies ( $\leq$  2000 Hz). At the higher frequencies (4000 and 10000 Hz), however, there were no differences between the three age groups. And in fact, adult and infant thresholds were more comparable for these frequencies than for the lower frequencies; the difference between adult and infant thresholds being on the order of 20-30 dB across the 200-2000 Hz frequency range. The present study extends the age over which this difference is present, and indicates that even when sounds are played well above threshold, the younger infants are less behaviorally responsive (as indicated by head turning and alerting) to sounds of lower frequency spectra.

The fact that there were no significant main or interaction effects involving frequency in the heart rate analyses is an important result. This indicates that despite the reduction in behavioral responsivity in newborns to the L stimulus, this stimulus was as effective as the M, H, B stimuli in eliciting the neonate's attention (as indicated by cardiac change). Consequently, the differences which emerged between newborns and five month-olds in head turning to the L stimulus does not seem attributable to attentional differences, per se. It should be noted that the present heart rate results are inconsistent with those of Kearsley (1973) who reported differential heart rate change as a function of frequency. Exposing newborns to simple (i.e., pure tones) and

complex ( i.e., white noise bursts ) sounds which varied in frequency, rise time and intensity, Kearsley obtained maximum cardiac deceleration to pure tones of 2000 Hz and white noise bursts of 500 Hz, and maximum cardiac acceleration to tones and noise bursts of 1000 Hz.

The behavioral results of the present study, as well as those of Trehub et al (1980), are consistent with the notion that underlying structural changes associated with the basilar and/or tectorial membrane areas may be responsible for the age-related changes in responsivity to sounds as a function of frequency. Hecox (1975) has suggested that postnatal development of the basilar membrane is greatest in the base ( responsible for the coding of high frequency sounds ) to apex ( most responsible for the coding of lower frequency sounds ) direction. The behavioral results obtained are consistent with this notion. However, considerable further anatomical and physiological research is necessary to truly confirm Hecox' hypothesis.

Hypothesis 2: Differential Head Turning at Each Age as a Function of Frequency.

Both newborns and five month-olds varied in the incidence of head turning as a function of the frequency of the stimulus. The pattern of results for newborn head turning toward sound revealed an order of localizability which proceeded from L → M → H/B, with no significant differences in head turning to the H vs B frequencies. Five month-old head turning to a sound

revealed an order of localizability which proceeded from L/M → B/H, with no significant differences in head turning to the L vs M and H vs B stimuli. These results are similar to the threshold results of Trehub et al (1980).

The data of Trehub et al (1980) reveals an orderly increase in infant sensitivity as the frequency of octave-band stimulation increased between 200-10000 Hz. Similarly, in the present study both newborns and five month-olds showed increased behavioral responding to the higher frequencies. At both ages the H and B stimuli elicited the greatest number of behavioral responses, and there were no significant differences in newborn or five month-old head turning or alerting to these stimuli. These results indicate the effectiveness of the H and B stimuli in maximally eliciting behavioral responses in newborns as well as five month-olds. Further, the results are consistent with those of Trehub et al which indicated no differences in the thresholds of infants 6-18 months of age for higher frequency sounds ( $\geq 4000$  Hz); the infant's thresholds approaching those of adults.

### Hypothesis 3: Developmental Changes in Latency and Duration of

Head Turning Towards Sound. The hypothesis of quantitative changes in head turning towards sound across ages was supported. As predicted, newborn head turning was of significantly longer latency and duration than that of five month-olds. The latency (  $M=6.5$  seconds ) and



duration (  $M=3.5$  seconds ) measures obtained for newborns in the present study are inconsistent with those previously reported in the literature; Muir and Field (1979) obtained a median latency of 2.5 seconds ( range: 1-3 seconds ) and a median duration of 5.75 seconds ( range: 4.5-7.0 seconds ) for ipsilateral head turns. This difference in results, however, seems attributable to differences in scoring systems. Muir and Field assign a latency score on the basis of the time interval from the onset of the sound till the initiation of the first 'head movement'. In the present study, however, latency was timed till the initiation of a 'head turn'. Similarly, Muir and Field timed duration from the initiation of 'head movement' till the completion of the 'maximum head turn'. However, in the present study duration of a head turn was the duration of time from the initiation till the completion of a 'head turn'. The present results are consistent with those previously obtained by the same scoring system, in which a mean latency of 7.5 seconds and a mean duration of 3.5 seconds was measured for newborn ipsilateral head turns ( Clifton, Morrongiello, Kulig, and Dowd, submitted ).

In the present study, the latency and duration of head turning did not vary, at either age, as a function of the frequency of the stimulus. This indicates the stability of newborns and five month-olds in latency and duration of head turning towards sound. Though frequency of a sound influenced the incidence of

head turning in infants, it did not differentially influence the speed with which infants initiated and/or completed a head turn directed towards a sound source. This suggests that response parameters such as latency and duration of head turning are determined by the infant's level of neuro-muscular maturation; qualitative aspects of stimulation having little determining influence on these parameters.

#### Alerting, Quieting & Changes in Responsivity During the Test Session.

Though there were no specific hypotheses involving alerting and quieting in the present study, several interesting results emerged.

In general, five month-olds alerted and quieted significantly more than did the newborns. There was no difference, however, in alerting to the H and B stimuli, which indicates that the attention-getting aspects of these stimuli were equally salient for newborns and five month-olds.

Five month-olds showed no difference in the frequency of alerting vs quieting to sound, and subsequent head turning occurred on a comparable proportion of alerting and quieting trials. In contrast, 'quieting' was extremely infrequent in newborns, occurring on only 1 trial, and newborns showed more tendency to head turn on those trials in which they had alerted. These results suggest that 'alerting' and 'quieting', as measures of responding

in infants, may be more informative in the testing of five month-olds than newborns. 'Quieting', in particular, did not appear to be a response available during the newborn period. This finding is not surprising if one considers that (1) 'quieting', by definition, entails 'inhibitory' processes operating at some level in the nervous system, and (2) maturation of the cerebral cortex has been implicated as a necessary pre-requisite to increases in inhibitory processes in the nervous system. It is well established for example, that the disappearance of transient reflexes in infants parallels anatomical and functional maturation of those areas in the cerebral cortex which inhibit activity of the corresponding lower regions ( Lund, 1978, Pp.9 ). Similarly, adults who have experienced cerebral cortex insult often show certain primitive reflexes ( e.g., grasping reflex, sucking reflex ); presumably a result of release from cortical inhibition. One plausible explanation then for the relative lack of quieting in newborns may derive from cortical immaturity.

Neither newborns or five month-olds showed any evidence of behavioral habituation or changes in responsivity during the test session, as indicated by measures of head turning, alerting and quieting over trials. In the sense that infants experienced a 'change' along at least one stimulus dimension (either frequency, intensity, and/or location) on every trial one would not expect habituation to occur. This result is important, however, because it indicates that differences observed in newborn and five month-old

head turning to the different frequency stimuli cannot be attributed to differential changes in responsivity during the test session.

### Heart Rate Results

Hypothesis 4: Heart Rate Change on 'Head Turn' and 'No Head Turn' Trials. The hypothesis that heart rate change would vary in similar ways at each age as a function of head turning behavior was supported. Both newborns and five month-olds showed cardiac deceleration on trials in which they did not head turn. On 'head turn' trials newborns did not show any reliable cardiac response but five month-olds responded with cardiac deceleration. The deceleratory response of the five month-olds, however, was of greater magnitude on those trials in which they did not respond motorically. The magnitude of the deceleratory response of five month-olds was significantly greater than that of newborns, which is consistent with previous reports of greater decelerations in older infants (Graham, Berg, Berg, Jackson, Hatton, and Kantowitz, 1970). Further, the time course of the heart rate response varied across age. The peak deceleration for newborns occurred at the fourth post-stimulus second, whereas, that for five month-olds occurred at the seventh post-stimulus second.

These results reveal a developmental change in the nature of cardiac-somatic relationships in infants. In neonates, the motor

action of head turning seemingly precludes the occurrence of cardiac deceleration. In contrast, at five months of age, the influence of head turning on the magnitude of the cardiac response is greatly reduced; reliable cardiac orienting occurring regardless of motor involvement. Furthermore, the observations that newborns and five month-olds showed cardiac decelerations on trials in which they did not head turn supports the notion that autonomic measures of responding can yield information which is not available from observations of somatic responses alone ( McCall and Kagan, 1967b ).

One additional point is particularly informative in the data regarding the cardiac-somatic relationship. Comparison of the time course of cardiac responses relative to the latency of motor activity does not indicate any synchronous relationship between the two events. For five month-olds, cardiac deceleration began immediately, irrespective of the subsequent occurrence of behavioral responding ( see Figures 17 and 21 ), and the deceleratory response trend continued uninterrupted, despite the occurrence of a head turn between post-stimulus second 1-3. Furthermore, though the average latency of newborn head turning was 6.5 seconds, newborns showed no evidence of cardiac deceleration prior to the onset of a head turn ( see Figures 16 and 20 ). Clearly, motor activity influences cardiac activity in infants, however, these results demonstrate that the relationship is not a time locked one,

per se. Overt movement does not necessarily 'cause' cardiac acceleration. Rather, it appears that neural events 'preceeding' the overt movement are sufficient to block cardiac deceleration. This is consistent with Obrist's postulation that cardiac change reflects overall state of muscular preparatory activity and is not merely a secondary consequence of overt motor activity ( see Obrist, Weeb, Sutterer, and Howard, 1970; 1970 ).

Previous research has shown 'state' to have a critical influence upon the nature of cardiac change in infants ( Graham and Jackson, 1970; Pomerleau-Malcuit and Clifton, 1973 ). The present results demonstrate that motor activity is also an important determinant of infant cardiac activity. These results are consistent with the demonstration that sucking activity influences newborn cardiac activity in quite predictable ways. Cardiac accelerations and decelerations have been found to occur at the onset and offset of non-nutritive sucking, respectively; heart rate change in relation to tonal stimuli varying directly with ongoing sucking activity ( Nelson, Clifton, Dowd, and Field, 1978 ). Kearsley (1973) presenting infants with auditory stimuli, reported a close correspondence between head movements and cardiac response in newborns; cardiac deceleration was accompanied by decreased head movements, and cardiac acceleration by increased head movements. Similarly, Pomerleau-Malcuit, Malcuit, and Clifton (1975) obtained cardiac acceleration in newborns on trials in which infants head

turned towards a tactile, cheek-stroke stimulus. On trials in which infants did not head turn, however, cardiac deceleration occurred. These results are consistent with the hypothesis that head turning exerts a strong influence upon the nature of heart rate change in newborns.

The present study extends these results to infants five months of age. The results indicate that the influence of head turning on magnitude of cardiac response is still present, though greatly reduced in five month-old infants. It should be noted, however, that in the present study cardiac acceleration did not occur under any condition at either age. In newborns, head turning precluded the occurrence of any reliable cardiac change, it did not, as in the Pomerleau-Malcuit, Malcuit and Clifton study, accompany cardiac acceleration. This difference may be attributable to two important methodological differences between the two studies. First, different sensory modalities were stimulated in order to elicit a head turn response; auditory in the present study and somesthetic in the Pomerleau-Malcuit, Malcuit and Clifton study.(1975). Secondly, infants were tested in different states of wakefulness.

Graham and Jackson (1970) have noted that the auditory and somesthetic systems are not equally well developed in the neonate; use of auditory stimuli activating a sensory system which is less mature than the somesthetic system ( Conel, 1952 ). Further, that infants show differential cardiac responding to auditory and

somesthetic stimulation is supported by the results of an earlier study investigating neonatal cardiac response to tactile, auditory, and vestibular stimulation in awake and sleeping states, before and after feeding ( Pomerleau-Malcuit, and Clifton, 1973 ) In sleeping infants, cardiac acceleration occurred to the vestibular and tactile stimuli, the cardiac response being of greater magnitude to the tactile stimulus. There was no reliable cardiac response to the auditory stimulus. For the awake infants tested before feeding, heart rate deceleration occurred in response to the auditory and vestibular stimuli, however, infants continued to respond to the tactile stimulus with cardiac acceleration. Awake infants tested after feeding showed no reliable cardiac response to any stimulus. These results suggest that cardiac acceleration may more readily occur to tactile stimulation, regardless of the infant's state of wakefulness. Unfortunately, no statement about the infant's behavior is provided in the article.

Regarding the state variable, in the present study infants were tested in an alert, calm state. In the Pomerleau-Malcuit, Malcuit and Clifton (1975) study, infants were tested in light or deep sleep ( specified as State 1 or 2 in Precht1, Akiyama, Zinkin, and Keer Grant, 1968 ). This difference between the two studies may be particularly important, as the magnitude and direction of cardiac responses have been shown to vary as a function of state; cardiac acceleration or a biphasic response ( i.e., ac-



celeration followed by deceleration ) being much more prevalent, and cardiac change in general, being of greater magnitude, during sleep states ( see Clifton and Nelson, 1976 for a complete review ). The hypothesis that sensory modality and state differences are responsible for the differences between the present investigation and the Pomerleau-Malcuit, Malcuit and Clifton (1975) study seems a plausible one. Further investigation is necessary, however, to determine the precise nature of neonatal cardiac responses as a function of state, sensory modality stimulation and behavioral activity level.

The findings of the present study reveal close coupling in cardiac-somatic responses in infants and a developmental change in the nature of cardiac-somatic relations over the first several months of life. The results illustrate the need for paying close attention to motor activity, as well as state, in investigations of newborns involving cardiac measures of responding. Further, although reliable cardiac responses can be obtained from five month-old infants irrespective of considerations of motor activity ( Benson, 1979 ), the present results indicate cardiac change of significantly greater magnitude when motor activity is reduced. This pattern of results is relevant to the Lacey's notion of a 'vectorial' heart rate response.

According to Lacey and Lacey (1974), cardiac change is best described as a vector of the varying demands ( e.g., somatic, attentional, cognitive ) placed upon the organism. In interpreting

cardiac change, the Lacey's argue the necessity of considering the "total transaction of the subject with his environment". Clifton (1977) has discussed the relevance of this approach in considering infant heart rate change and the results from the present investigation seems best described in light of this approach.

During the newborn period somatic demands are high in order to maintain physiological equilibrium ( e.g., body temperature ) and attentional deceleration occurs only when the neonate shows no behavioral responses. Head turning imposes additional demands on the organism's system ( e.g., energy expenditure ) and thereby pre-empts attentional deceleration. Infants five months of age are more developed and organized physiologically and have greater motoric capabilities. As a consequence, head turning imposes less demand on the organism and attentional deceleration occurs reliably. That cardiac deceleration is of less magnitude when the five month-old head turns is consistent with the notion that behavioral responding does impose some demands on the infant's system, even at five months of age.

#### Suggestions For Future Research

The findings of the present investigation reveal developmental changes in the nature of the relationship between heart rate change and behavior. Future research should seek to specify the nature of cardiac-somatic relationships across many stimulus conditions

and ages in order to provide more information relevant to the Lacey's notion of a vectorial heart rate response. For example, the Bayley Scales of Infant Development (1969) cites 3.9 months as the age at which 50% of the infants tested will head turn in the direction of an occluded bell or rattle and suggests that 95% of all infants tested will do so at 6 months of age. Conceivably, head turning is of insignificant consequences in infants 6 months of age ( i.e., in terms of demands on the organism's system ), in which case, according to the Lacey hypothesis, one should observe little difference in the magnitude of cardiac response on head turn and no head turn trials. Additionally, it would be of interest to know what the heart rate is doing when neonates and young infants 'spontaneously' turn their heads; without any particular stimulus eliciting their attention.

In considering the present results relative to previous research ( Pomerleau-Malcuit, Malcuit, and Clifton, 1975 ), it was suggested that heart rate acceleration may be the more characteristic response of newborns to tactile stimulation; whereas, cardiac deceleration may more readily occur to auditory stimulation in awake neonates. Research is needed on the nature of heart rate change as a function of the sensory modality which is stimulated.

Finally, future research on auditory competencies in young infants should use the knowledge gained from the results of the present investigation in selecting a stimulus. Previously, researchers

have argued the necessity of using 'complex' auditory stimuli ( e.g., speech ), as opposed to 'simple' sine wave sounds, in testing young infants ( Eisenberg, 1965 ). The results of this study suggest that complexity in and of itself is not the only thing to be considered; frequency composition of the complex stimulus is also a critical parameter.

## FOOTNOTES

- <sup>1</sup> Throughout this paper 'somatic' activity is used in reference to striate muscle activity; this seems to be the standard interpretation of the term in the psychophysiological literature ( Clifton, 1977; Obrist, Sutterer, and Howard, 1970 ).

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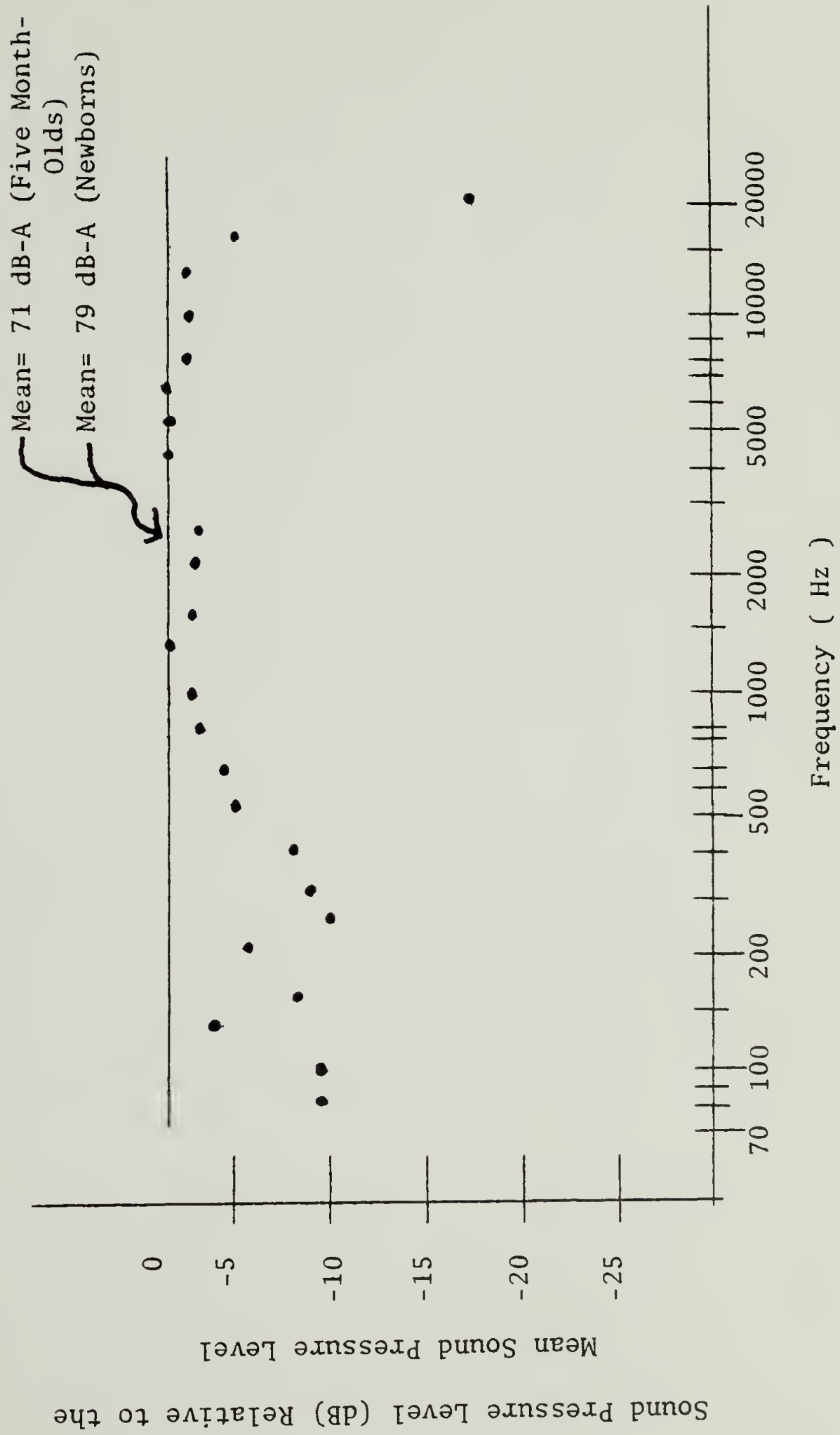
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A P P E N D I X 1

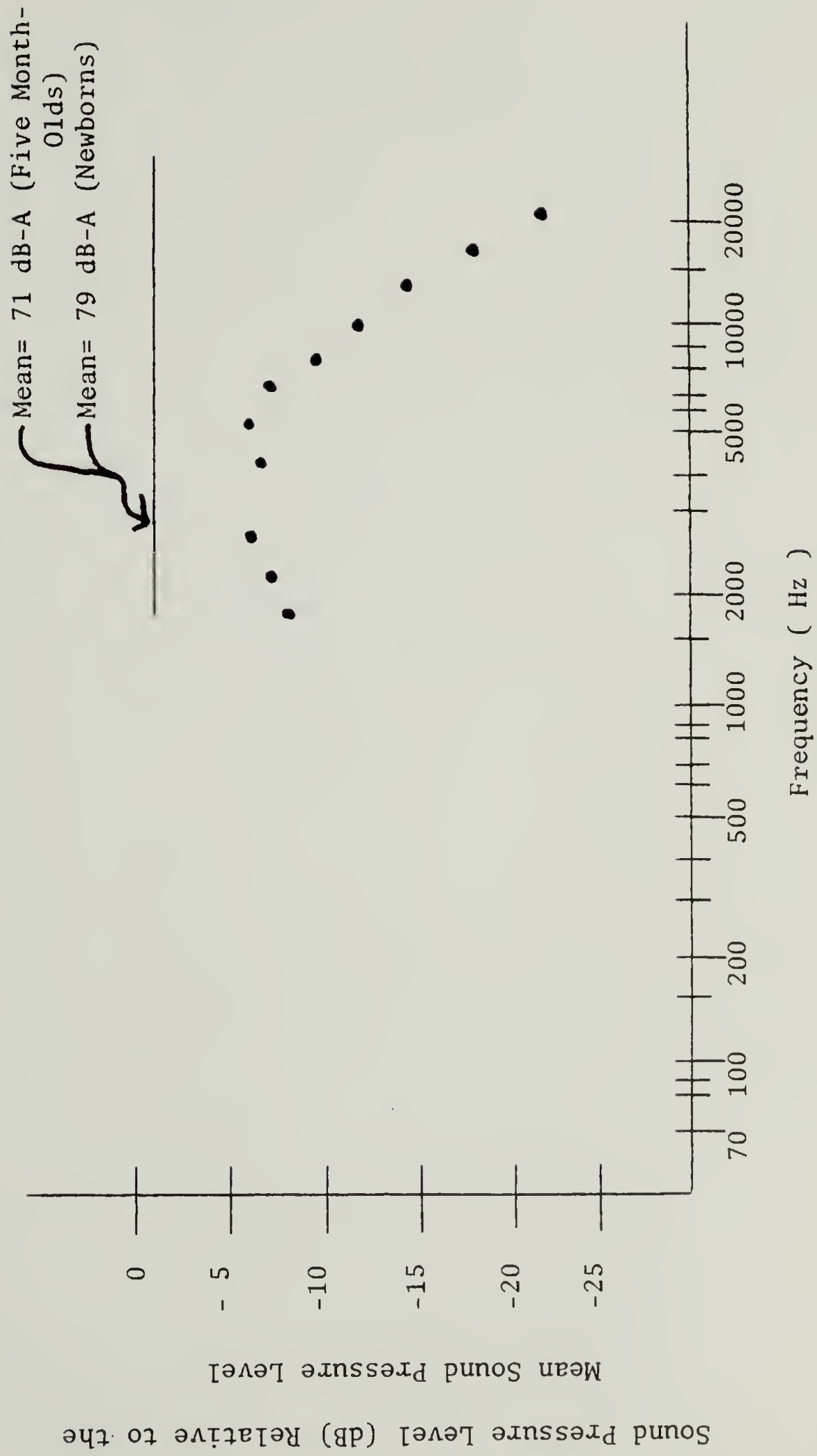
SOUND SPECTROGRAPHS OF THE STIMULI ( L, M, H, B )  
AND THE BACKGROUND NOISE PRESENT DURING THE NEWBORN TESTING

RESULTS OF A ONE-THIRD OCTAVE-BAND ANALYSIS OF THE BROAD-BAND UNFILTERED RATTLE

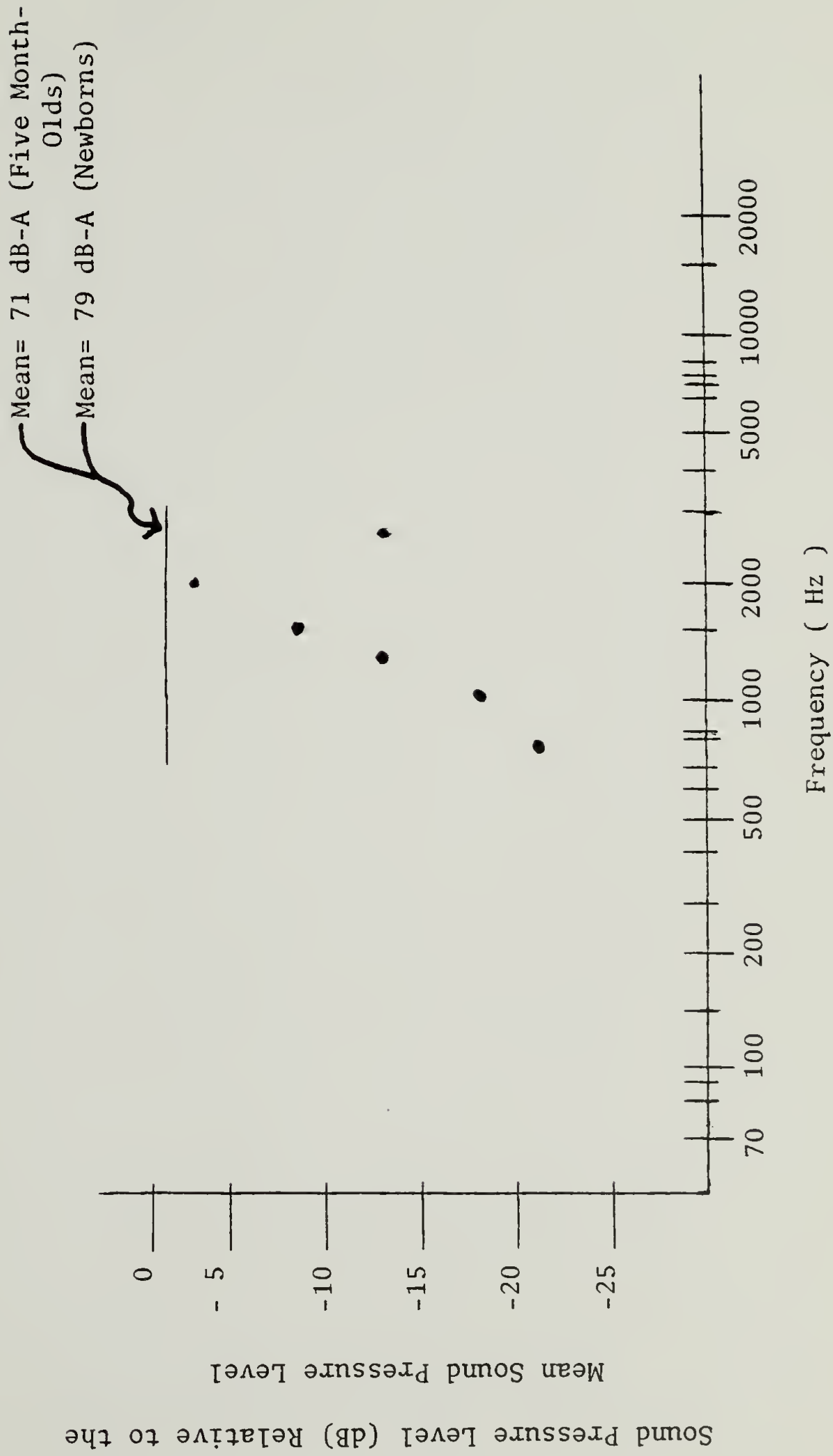




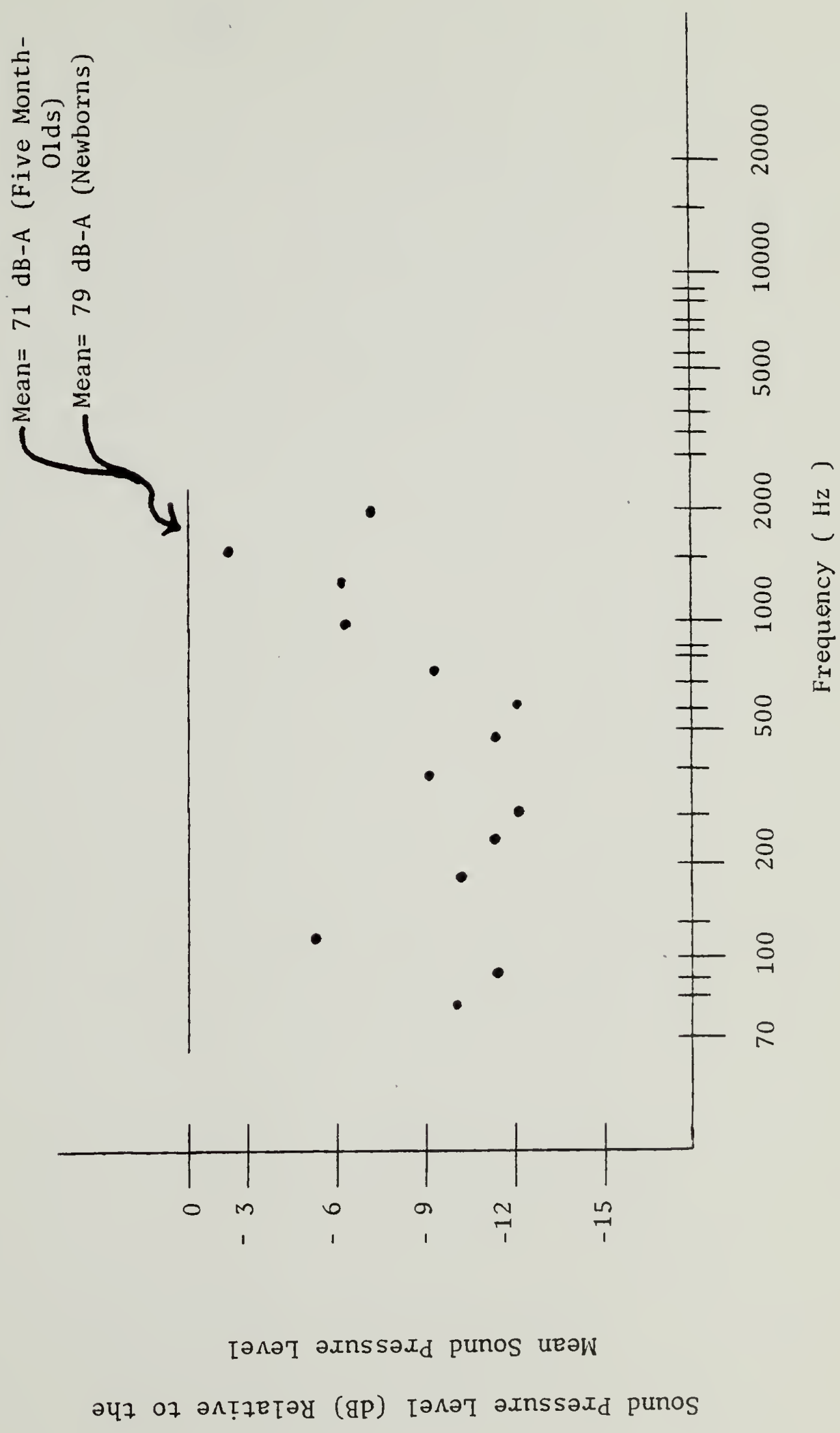
RESULTS OF A ONE-THIRD OCTAVE-BAND ANALYSIS OF THE HIGH FREQUENCY BAND-PASS RATTLE SOUND



RESULTS OF A ONE-THIRD OCTAVE-BAND ANALYSIS OF THE MID-FREQUENCY BAND-PASS RATTLE SOUND



RESULTS OF A ONE-THIRD OCTAVE-BAND ANALYSIS OF THE LOW FREQUENCY BAND-PASS RATTLE SOUND





A P P E N D I X 2

A LISTING OF THE STIMULUS SEQUENCES A, B, C, D

| Stimulus<br>sequence | Trial Number   |   |   |   |   |   |   |   |   |    |    |    |
|----------------------|----------------|---|---|---|---|---|---|---|---|----|----|----|
|                      | 1              | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| A                    | B <sup>1</sup> | L | M | H | H | M | L | B | M | B  | H  | L  |
| B                    | H <sup>2</sup> | M | L | B | B | L | M | H | L | H  | B  | M  |
| C                    | M <sup>3</sup> | B | H | L | L | H | B | M | H | M  | L  | B  |
| D                    | L <sup>4</sup> | H | B | M | M | B | H | L | B | L  | M  | H  |

- 1) B = broad-band, unfiltered rattle noise
- 2) H = high frequency band-pass filtered rattle noise
- 3) M = mid-frequency band-pass filtered rattle noise
- 4) L = low frequency band-pass filtered rattle noise

A P P E N D I X 3

NUMBER OF TRIALS OF EACH TYPE ( L, M, H, B )  
OCCURRING FROM THE RIGHT AND LEFT SPEAKER

Number of Trials of Each Type Occurring from the Right and Left

(summing over stimulus sequences A, B, C, D)

|                   | Low<br>Left/Right | Medium<br>Left/Right | High<br>Left/Right | Broad<br>Left/Right |
|-------------------|-------------------|----------------------|--------------------|---------------------|
| Right-first order | 6/6               | 6/6                  | 6/6                | 6/6                 |
| Left-first order  | 6/6               | 6/6                  | 6/6                | 6/6                 |
| Overall           | 12/12             | 12/12                | 12/12              | 12/12               |



A P P E N D I X 4

DISTRIBUTION OF L, M, H, B TRIALS OCCURRING AT EACH SPL  
VALUE (dB-A) FOR STIMULUS SEQUENCES A, B, C, D

Distribution of L, M, H, B Trials Occurring at Each SPL Value (dB-A)

for Stimulus Sequences A, B, C, D

|                                                          | 68 (76) | 70 (78) | 72 (80) | 74 (82) |
|----------------------------------------------------------|---------|---------|---------|---------|
| A                                                        |         |         |         |         |
| L                                                        | 0       | 1       | 1       | 1       |
| M                                                        | 1       | 1       | 1       | 0       |
| H                                                        | 1       | 0       | 1       | 1       |
| B                                                        | 1       | 1       | 0       | 1       |
| B                                                        |         |         |         |         |
| L                                                        | 1       | 1       | 0       | 1       |
| M                                                        | 1       | 0       | 1       | 1       |
| H                                                        | 1       | 1       | 1       | 0       |
| B                                                        | 0       | 1       | 1       | 1       |
| C                                                        |         |         |         |         |
| L                                                        | 1       | 1       | 1       | 0       |
| M                                                        | 0       | 1       | 1       | 1       |
| H                                                        | 1       | 1       | 0       | 1       |
| B                                                        | 1       | 0       | 1       | 1       |
| D                                                        |         |         |         |         |
| L                                                        | 1       | 0       | 1       | 1       |
| M                                                        | 1       | 1       | 0       | 1       |
| H                                                        | 0       | 1       | 1       | 1       |
| B                                                        | 1       | 1       | 1       | 0       |
| Total number of trials (summing over stimulus sequences) |         |         |         |         |
| L                                                        | 3       | 3       | 3       | 3       |
| M                                                        | 3       | 3       | 3       | 3       |
| H                                                        | 3       | 3       | 3       | 3       |
| B                                                        | 3       | 3       | 3       | 3       |

Note: the numbers in parentheses are the SPL values used in testing newborns

A P P E N D I X 5

THE FORMULA FOR COMPUTING A WEIGHTED AVERAGE OF HEART RATE  
IN BEATS PER MINUTE (BPM) FOR ONE SECOND

The formula for computing a weighted average  
of heart rate in bpm for 1 second

$$60 \sum_{i=1}^N P_i \left[ \frac{1}{IBI_i} \right]$$

$N$  is the total number of interbeat intervals within the second.

$P_i$  is the proportion of the second which the  $i^{\text{th}}$  interbeat interval occupies ( i.e., the weight ).

$IBI_i$  is the time in seconds between R-waves in the  $i^{\text{th}}$  interbeat interval.

A P P E N D I X 6

A LISTING OF THE TRIALS OF HEART RATE DATA ELIMINATED  
FOR EACH SUBJECT AND THE REASON FOR THE OMISSION

Trials of Heart Rate Data Eliminated for Each Subject Due  
to Startling (ST), Sneezing (SN), Sleepiness (SL), Fussiness (F),  
or Too Many Edits (E)

| <u>Subject Number</u> | <u>Trial Number</u> | <u>Cause for Elimination</u> |
|-----------------------|---------------------|------------------------------|
| Newborns              |                     |                              |
| 1                     | 6,7,12              | F                            |
| 2                     | 3,12                | F                            |
|                       | 7                   | E                            |
| 3                     | 2                   | ST                           |
| 7                     | 8                   | E                            |
| 8                     | 9                   | SN                           |
|                       | 11                  | ST                           |
| 11                    | 7                   | F                            |
| 12                    | 9                   | E                            |
| 13                    | 12                  | SL                           |
| 14                    | 10                  | SL                           |
| 19                    | 2                   | ST                           |
| 20                    | 1                   | F                            |
| 21                    | 8,9                 | F                            |
| 22                    | 2,12                | ST                           |
| 23                    | 7                   | F                            |
| 24                    | 1                   | E                            |
| Five Month-Olds       |                     |                              |
| 2                     | 1                   | ST                           |
| 3                     | 2                   | E                            |
| 4                     | 1                   | ST                           |
| 5                     | 8                   | ST                           |
| 6                     | 2                   | ST                           |
| 7                     | 2                   | E                            |
| 9                     | 12                  | F                            |
| 12                    | 12                  | F                            |
| 14                    | 2                   | ST                           |
| 16                    | 2                   | ST                           |

## Appendix 6 ( continued )

|    |   |    |
|----|---|----|
| 17 | 1 | ST |
| 19 | 5 | F  |
| 20 | 2 | E  |
| 22 | 8 | E  |
| 24 | 1 | ST |

A P P E N D I X 7

CODING SCHEME USED IN THE VIDEO-SCORING OF  
NEWBORN'S AND FIVE MONTH-OLD'S BEHAVIOR



Coding scheme used in the scoring of  
newborn's & five month-old's behavior

Behavioral Categories

- 1) Head Turn Behavior
- 2) Eye Movement Behavior
- 3) Other Behavior

Head Turn Behavior Category ( L = left; R = right)

This is a complex category of behaviors with many distinctions made. The listing below should help clarify these:

$L_s / R_s$  = slight head turns ( i.e., a head turn  $> 10^\circ$  and  $< 30^\circ$   
in one direction )

$L / R$  = average head turn ( i.e., a head turn  $> 30^\circ$  and  
 $< 90^\circ$  in one direction )

$L_t / R_t$  = terminate the sound head turns ( i.e., a full head  
turn of  $90^\circ$  in one direction )

u = movement of the head upwards but not to the R or L

R (u) = movement of the head to the R and upwards

L (u) = movement of the head to the L and upwards

v = vasillation head movement ( i.e., a series of 2+  
R and L in any sequence within one trial. Typically, this  
involves very slight head movements. )

j = a subcode that may accompany any of the above codes  
indicating a jerky, as opposed to the typical smooth,

head turn movement ( e.g.,  $R_{s/j}$  = slight, jerky R turn )

0 = no head movement

### Eye Movement Behavior Category

O = open eyes

C = closed eyes

F = fluttering of the eyes opened and closed

V = vascillation of the eyes ( i.e., moving the eyes about to and fro, as though looking around )

A = alerting ( i.e., eye widening immediately following the onset of the sound. This should be used in conjunction with one of the preceding codes so as to specify how the infant maintained his/her eyes after alerting.

Ex. A-O = alerted & kept eyes open

A-V = alerted & then looked about )

### Other Behavior Category

Mvg = moving about ( hands, arms, etc. )

Mtg = mouthing

Vrb = verbalizing

Crg = emitting cries

CrF = cry face

Fsy = fussy ( i.e., cry face, and increased movement; crying)

Slp = sleepy

Hcp = hiccups

Qtg = quieting

This is a dynamic category, so to speak, and behaviors may be added to those listed above, depending on the individual infants observed.

A P P E N D I X 8

RELIABILITY COEFFICIENTS FOR THE PRIMARY  
BEHAVIORAL CATEGORIES

Reliability Coefficients for the Primary Behavioral Categories

|              | Newborn | Five Month-Old | Overall |
|--------------|---------|----------------|---------|
| Head Turning |         |                |         |
| Direction    | .95     | .96            | .96     |
| Latency      | .91*    | .96            | .94     |
| Duration     | .91*    | .97            | .94     |
| Alerting     | .95     | .95            | .95     |
| Quieting     | 1.00    | .96            | .98     |

\*Based on the data of 13 newborns

A P P E N D I X 9

PRELIMINARY ANALYSIS OF THE BEHAVIORAL DATA

Table 4: Analysis of Variance of Head Turning Right vs Left as a  
Function of Age and Frequency

Table 4

Analysis of Variance of Head Turning Right vs Left  
as a Function of Age and Frequency\*

| Source           | df | Mean Square | <u>F</u> | <u>P</u> |
|------------------|----|-------------|----------|----------|
| Frequency        | 3  | 4.24566     | 10.55805 | .00001   |
| Direction        | 1  | .00260      | .00648   | .93591   |
| Age              | 1  | 3.19010     | 10.25664 | .00247   |
| Dir X Freq       | 3  | .07899      | .19644   | .89879   |
| Age X Dir        | 1  | .06510      | .16190   | .68768   |
| Age X Freq       | 3  | 1.08038     | 2.66234  | .03484   |
| Age X Dir X Freq | 3  | .08594      | .21371   | .88687   |

Note: the design of the analysis was an age (2) X frequency (4) X direction (4) X subjects (24) repeated-measures design

\*N = 48, equally divided by age

A P P E N D I X 1 0

PRIMARY ANALYSIS OF THE BEHAVIORAL DATA

Table 5: Analysis of Variance of Head Turning as a Function of Age and Frequency

Table 6: The T-Test Values for Within Age Contrasts of Latency Scores for Head Turning to the Different Stimuli

Table 7: The T-Test Values for Within Age Contrast of Duration Scores for Head Turning to the Different Stimuli



Table 5

Analysis of Variance of Head Turning  
as a Function of Age and Frequency\*

| Source     | df | Mean Square | F        | P      |
|------------|----|-------------|----------|--------|
| Age        | 1  | 6.02083     | 9.78940  | .00304 |
| Freq       | 3  | 8.70139     | 18.48557 | .00001 |
| Age X Freq | 3  | 2.14583     | 4.55869  | .00445 |

Note: the design of the analysis was an age (2) X frequency (4) X subject (24) repeated-measures design

\*N = 48, equally divided by age

TABLE 6

THE T-TEST VALUES FOR WITHIN AGE CONTRASTS OF LATENCY SCORES  
FOR HEAD TURNING TO THE DIFFERENT STIMULI

| Contrast of<br>Interest | Age Group                    |                        |
|-------------------------|------------------------------|------------------------|
|                         | Five Month-Olds <sup>*</sup> | Newborns <sup>**</sup> |
| L vs M                  | .54                          | .07                    |
| L vs H                  | .52                          | .34                    |
| L vs B                  | .88                          | 1.19                   |
| M vs H                  | .00                          | .56                    |
| M vs B                  | .41                          | 1.19                   |
| H vs B                  | .51                          | .66                    |

\* Each test is based on 23 degrees of freedom

\*\* Each test is based on 12 degrees of freedom

TABLE 7  
 THE T-TEST VALUES FOR WITHIN AGE CONTRAST OF DURATION SCORES  
 FOR HEAD TURNING TO THE DIFFERENT STIMULI

| Contrast of<br>Interest | Age Group                    |                        |
|-------------------------|------------------------------|------------------------|
|                         | Five Month-Olds <sup>*</sup> | Newborns <sup>**</sup> |
| L vs M                  | .59                          | .67                    |
| L vs H                  | .27                          | .28                    |
| L vs B                  | .10                          | .12                    |
| M vs H                  | .45                          | .85                    |
| M vs B                  | .73                          | 1.46                   |
| H vs B                  | .25                          | .87                    |

\* Each test is based on 23 degrees of freedom

\*\* Each test is based on 12 degrees of freedom

A P P E N D I X 1 1

PRELIMINARY ANALYSIS OF HEART RATE DATA

Table 8: Analysis of Variance of Pre-Stimulus Heart Rate across  
Trials as a Function of Age

Table 9: Analysis of Variance of Pre-Stimulus Heart Rate across  
Trials at Each Age

Table 8

Analysis of Variance of Pre-Stimulus Heart Rate across Trials  
as a Function of Age\*

| Source       | df | Mean Square | <u>F</u> | <u>P</u> |
|--------------|----|-------------|----------|----------|
| Age          | 1  | 25195.60973 | 11.97701 | .001     |
| X Linear     | 1  | 2101.68727  | 12.93980 | .001     |
| X Cubic      | 1  | 328.52386   | 4.11094  | .048     |
| Trials X Age | 11 | 247.46372   | 2.95069  | .001     |

Note 1: the design of the analysis was an age (2) X subjects (24) X trials (12) repeated-measures design

Note 2: only those effects and interactions which were significant at  $\underline{P} < .05$  are listed

\*N = 48, equally divided by age

Table 9

Analysis of Variance of Pre-Stimulus Heart Rate  
across Trials at Each Age\*

| Age                 | Source   | df | Mean Square | F       | P    |
|---------------------|----------|----|-------------|---------|------|
| Newborns            | -----    |    |             |         |      |
|                     |          |    |             |         |      |
| Five Month-<br>Olds | Trials   | 11 | 263.17284   | 2.78920 | .002 |
|                     | X Linear | 1  | 1984.82439  | 8.57349 | .008 |

Note 1: the design of the analysis was a subjects (24) X trials (12) repeated-measures design

Note 2: Only those effects and interactions which were significant at  $P < .05$  are listed

\*N = 24, in each age group

A P P E N D I X 1 2

PRIMARY ANALYSIS OF HEART RATE CHANGE

- Table 10: Analysis of Variance of Heart Rate Change on Head Turn and No Head Turn Trials as a Function of Age and Frequency ( L, M, H, B )
- Table 11: Analysis of Variance of Heart Rate Change of Newborns vs Five Month-Olds on No Head Turn and Head Turn Trials
- Table 12: Analysis of Variance of Heart Rate Change at Each Age as a Function of Head Turning and Frequency ( L, M, H, B )
- Table 13: Analysis of Variance of Heart Rate Change of Newborns on No Head Turn and Head Turn Trials
- Table 14: Analysis of Variance of Heart Rate Change of Five Month-Olds on No Head Turn and Head Turn Trials
- Table 15: Analysis of Variance of Heart Rate Change on Head Turn and No Head Turn Trials as a Function of Age and Frequency ( M, H, B )
- Table 16: Analysis of Variance of Heart Rate Change of Newborns vs Five Month-Olds on No Head Turn and Head Turn Trials

Table 17: Analysis of Variance of Heart Rate Change at Each Age as a Function of Head Turning and Frequency ( M, H, B )

Table 18: Analysis of Variance of Heart Rate Change of Newborns on No Head Turn and Head Turn Trials

Table 19: Analysis of Variance of Heart Rate Change of Five Month-Olds on No Head Turn and Head Turn Trials



Table 10

Analysis of Variance of Heart Rate Change on Head Turn and No Head Turn Trials  
as a Function of Age and Frequency (L,M,H,B)<sup>\*</sup>

| Source              | df | Mean Square | <u>F</u> | <u>P</u> |
|---------------------|----|-------------|----------|----------|
| Age                 | 1  | 98955.27285 | 6.61967  | .016     |
| Seconds             | 12 | 639.58473   | 12.21468 | .000     |
| X Age               | 12 | 135.83927   | 2.59424  | .003     |
| X Quadratic         | 1  | 1008.69435  | 8.80888  | .006     |
| Head Turn X Seconds | 12 | 259.29617   | 10.84500 | .000     |
| X Age               | 12 | 223.03730   | 9.32848  | .004     |
| X Quadratic         | 1  | 2864.14226  | 35.48331 | .000     |

Note 1: the design of the analysis was an age (2) X subject (14) X head turn (2) X frequency (4) X seconds (13) repeated-measures design

Note 2: Only those effects and interactions which were significant at  $P < .05$  are listed

<sup>\*</sup>N = 28, equally divided by age

Table 11

Analysis of Variance of Heart Rate Change of Newborns vs Five Month-Olds  
on No Head Turn and Head Turn Trials\*

|              | Source  | df | Mean Square | <u>F</u> | <u>P</u> |
|--------------|---------|----|-------------|----------|----------|
| No Head Turn | Age     | 1  | 15302.62257 | 6.48133  | .017     |
|              | Seconds | 12 | 211.63368   | 23.71632 | .000     |
| Head Turn    | Age     | 1  | 11624.27277 | 5.97463  | .022     |
|              | Seconds | 12 | 38.75262    | 2.83763  | .010     |
|              | X Age   | 12 | 22.53979    | 1.84202  | .039     |
|              | X Quad  | 1  | 244.70743   | 5.44872  | .028     |

Note 1: the design of the analysis was an age (2) X subjects (14) X seconds (13) repeated-measures design

Note 2: only those effects and interactions which were significant at  $P < .05$  are listed

\*N = 28, equally divided by age

Table 12

Analysis of Variance of Heart Rate Change at Each Age  
as a Function of Head Turning and Frequency (L,M,H,B,)\*

| Age                 | Source          | df | Mean Square | F        | P    |
|---------------------|-----------------|----|-------------|----------|------|
| Newborns            | Seconds         | 12 | 153.70076   | 5.16785  | .000 |
|                     | Head Turn X Sec | 12 | 207.64451   | 17.33473 | .000 |
|                     | X Quad          | 1  | 2273.50020  | 52,18110 | .000 |
| Five Month-<br>Olds | X Cubic         | 1  | 136.45477   | 9.32014  | .009 |
|                     | Seconds         | 12 | 621.72325   | 8.29161  | .000 |
|                     | Head Turn X Sec | 12 | 74.68896    | 2.08391  | .021 |
|                     | X Quad          | 1  | 784.23500   | 6.65358  | .023 |

Note 1: the design of the analysis was a subjects (14) X head turn (2) X frequency (4) X seconds (13) repeated-measures design

Note 2: Only those effects and interactions which were significant at  $P < .05$  are listed

\*N = 14, in each age group

Table 13

Analysis of Variance of Heart Rate Change of Newborns  
on No Head Turn and Head Turn Trials\*

| Source       | df | Mean Square | F        | P    |
|--------------|----|-------------|----------|------|
| No Head Turn |    |             |          |      |
| Seconds      | 12 | 87.46072    | 15.30551 | .000 |
| X Quad       | 1  | 915.39014   | 51.01901 | .000 |
| X Cubic      | 1  | 113.98287   | 12.03158 | .000 |
| Head Turn    |    |             |          |      |
|              |    |             |          |      |

Note 1: the design of the analysis was a subjects (14) X seconds (13) repeated-measures design

Note 2: only those effects and interactions which were significant at  $P < .05$  are listed

\*N = 14

Table 14

Analysis of Variance of Heart Rate Change of Five Month-Olds  
on No Head Turn and Head Turn Trials\*

|              | Source  | df | Mean Square | F        | P    |
|--------------|---------|----|-------------|----------|------|
| No Head Turn | Seconds | 12 | 137.67932   | 11.34773 | .000 |
|              | X Quad  | 1  | 1534.95530  | 60.13401 | .000 |
| Head Turn    | Seconds | 12 | 27.01428    | 1.81944  | .024 |
|              | X Quad  | 1  | 279.40202   | 4.72703  | .033 |

Note 1: the design of the analysis was a subjects (14) X seconds (13) repeated-measures design

Note 2: Only those effects and interactions which were significant at  $P < .05$  are listed

\*N = 14

Table 15

Analysis of Variance of Heart Rate Change on Head Turn and No Head Turn Trials as a  
Function of Age and Frequency ( M,H,B ) \*

| Source                    | df | Mean Square | F        | P    |
|---------------------------|----|-------------|----------|------|
| Age                       | 1  | 97412.24810 | 6.71612  | .013 |
| Seconds                   | 12 | 850.60072   | 17.48342 | .000 |
| Head Turn X Age           | 1  | 2898.57300  | 5.97382  | .019 |
| Seconds X Age             | 12 | 250.63370   | 5.15158  | .000 |
| X Quadratic               | 1  | 1845.34657  | 12.78790 | .001 |
| Head Turn X Seconds       | 12 | 285.18415   | 10.52832 | .000 |
| X Quadratic               | 1  | 3133.33733  | 33.50841 | .000 |
| Head Turn X Seconds X Age | 12 | 70.21808    | 2.59220  | .002 |
| X Cubic                   | 1  | 384.50185   | 7.53519  | .009 |

Note 1: the design of the analysis was an age (2) X subjects (22,21) X head turn (2) X frequency (3) X seconds (13) repeated-measures design

Note 2: only those effects and interactions significant at  $P < .05$  are listed

\*N = 43; 22 newborns and 21 five month-olds

Table 17

Analysis of Variance of Heart Rate Change at Each Age as a Function of Head Turning  
and Frequency ( M,H,B )\*

| Age                 | Source            | df | Mean Square | F        | P    |
|---------------------|-------------------|----|-------------|----------|------|
| Newborns            | Seconds           | 12 | 149.08138   | 5.52755  | .000 |
|                     | Head Turn X Sec12 |    | 260.71442   | 14.97920 | .000 |
|                     | X Quad            | 1  | 2670.49703  | 72.75872 | .000 |
| Five Month-<br>Olds | X Cubic           | 1  | 304.89262   | 9.37979  | .006 |
|                     | Seconds           | 12 | 933.90141   | 13.07671 | .000 |
|                     | Head Turn X Sec12 |    | 98.46115    | 2.64299  | .002 |
|                     | X Quad            | 1  | 771.11011   | 5.03484  | .036 |

Note 1: the design of the analyses was a subjects (22,21) X head turn (2) X frequency (3)  
X seconds (13) repeated-measures design

Note 2: only those effects and interactions which were significant at  $P < .05$  are listed

\* N = 22 newborns and 21 five month-olds

Table 18

Analysis of Variance of Heart Rate Change of Newborns on No Head Turn and Head Turn Trials

|              | Source    | df | Mean Square | F        | P    |
|--------------|-----------|----|-------------|----------|------|
| No Head Turn | Seconds   | 12 | 130.94346   | 14.96978 | .000 |
|              | X Quad    | 1  | 1345.67487  | 61.5963  | .000 |
|              | X Cubic   | 1  | 182.69905   | 11.17199 | .003 |
| Head Turn    | - - - - - |    |             |          |      |

Note 1: the design of the analysis was a subjects (22) X seconds (13) repeated-measures design

Note 2: only those effects and interactions which were significant at  $P < .05$  are listed

\* N = 22



Table 19

## Analysis of Variance of Heart Rate Change of Five Month-Olds on No Head Turn and Head

## Turn Trials\*

| Source       | df | Mean Square | F        | P    |
|--------------|----|-------------|----------|------|
| No Head Turn |    |             |          |      |
| Seconds      | 12 | 266.34877   | 17.71421 | .000 |
| X Lin        | 1  | 241.02493   | 5.66285  | .027 |
| X Quad       | 1  | 2609.44821  | 74.19631 | .000 |
| Head Turn    |    |             |          |      |
| Seconds      | 12 | 77.77208    | 3.67062  | .000 |
| X Quad       | 1  | 807.10375   | 9.16042  | .007 |

Note 1: the design of the analysis was a subjects (21) X seconds (13) repeated-measures design

Note 2: only those effects and interactions which were significant at  $P < .05$  are listed

\* N = 21



