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AUDITORY PATTERN PERCEPTION IN HUMAN INFANTS

A Dissertation 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

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May 1982

Psychology

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DEDICATION

To My Parents and My Brothers --

for their continuous encouragement and support of my endeavors, their pride in my accomplishments, their good humor, and, most importantly, for the love they have always unconditionally given.

-- With Appreciation and Love

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ABSTRACT

Auditory Pattern Perception In Human Infants

May 1982

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Directed by: Professor Rachel K. Clifton

Fifty 6- and 12- month-olds were equally assigned to five conditions: two conditions examined frequency discriminations involving the addition of a novel, and the deletion of a familiar, frequency tone; two examined tonal pattern discrimination, infants' abilities to detect a change in the sequence of component tones; and one examined temporal pattern discrimination, infants' abilities to detect a change in temporal grouping of the elements comprising a pattern. Each Frequency and Tonal pattern condition contained discrimination contrasts to examine memory influences on infants' discrimination performance. A Go/No-Go conditioned head-turning paradigm was used, in which successive presentations of an auditory stimulus (S-) comprised a 'background' and head turns toward a change stimulus (S+), which periodically replaced S-, were visually reinforced. For the Frequency and Tonal pattern discrimination conditions, pure tones of 1100 and 1900 Hz were used to construct 9-tone patterns temporally organized into three groupings each of three tones. For the Temporal pattern condition, white-noise bursts were used instead of tones. Across all conditions, patterns were 4.2

sec duration and interpattern intervals were 2 sec. Infants at each age performed discriminations involving the addition of a new, or deletion of a familiar, frequency tone. However, 6-month-olds' performance was significantly poorer for those frequency discriminations imposing the most stringent memory load. Both 6- and 12- month-olds were capable of performing tonal pattern discriminations, but 6-month-olds did not respond reliably on those sequence discriminations imposing the most stringent memory demands. Temporal pattern discrimination performance improved with age. Six month-olds discriminated a change in the number of groupings comprising a pattern, but they did not reliably discriminate changes in the number of elements comprising the three groupings of the background pattern. Twelve month-olds readily performed both types of temporal pattern discriminations. Results are discussed with regard to maturation of the auditory cortex and literature on infant auditory perceptual development.

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CHAPTER I

INTRODUCTION

By definition, a "pattern" is a non-random sequence of events which can in some way be meaningfully extended (Jones, 1978). The task for the perceiver is to recognize that a pattern exists and utilize this information in the service of optimizing perceptual and cognitive processing activity. The goal of the present research is to explore the developing infant's abilities to perceive certain auditory patterns.

An auditory pattern can be generally defined as a sequence of sounds in time organized to form a temporal pattern, a tonal pattern, and an intensity pattern. Temporal pattern perception, otherwise known as the perception of rhythmic grouping (Fraisse, 1978) or rhythmic structure (Cooper & Meyer, 1960), involves the perception of element duration or the silence interval between successive elements. Consider, for example, the following temporal arrangement of nine tones(T):

/TTT/ 1 sec silence /TTT/ 1 sec silence /TTT/

Re-arrangement of these tones results in a new temporal pattern:

/ TTTT / 1 sec silence / T / 1 sec silence / TTTT /

Since silence intertone intervals, tonal duration, and pattern duration remain the same, discrimination of these two temporal patterns must be based on the detection of a new temporal configuration.

Tonal pattern perception refers to perception of the order of events within a sequence of sounds of varying frequency. Consider, for example, the following repeating sequence of high(H) and low(L) frequency tones:

/HLLH/ 1 sec silence /HLLH/

If listeners detect a change when next presented with:

/HLHL/ 1 sec silence /HLHL/

then they can be said to have discriminated between the two tonal patterns; because both sequences comprise the same component tones in the same relative proportions, discrimination between the two auditory patterns must be based on the detection of a change in the sequence or arrangement of these tones. Intensity pattern perception refers to perception of the successive order of elements having different perceived loudness. In the present investigation only temporal and tonal pattern perception will be examined.

There has been very little research investigating the development of auditory pattern perception skills in human infants. Consequently, little is known of the ontogenetic course of the ability to perform these complex discriminations. The paucity of knowledge of infant pattern perception skills is somewhat surprising, since the ability to group elements in an ongoing sequence of sounds on the basis of intervening silence intervals and to recognize the sequence of elements within these groupings plays an important role in the perception of speech, an area in which there has been a tremendous amount of research with infants. Investigators interested in the development of speech perception, however, have primarily examined phoneme perception, that is to say the developing infant's abilities to discriminate one syllable from another (e.g., /pa/ vs /ba/), and the majority of this research has focused upon initial consonant-vowel-coarticulation differences (e.g., /ka/ vs / ga/) (see Jusczyk, 1979 for a review of this literature). Furthermore, researchers interested in infant speech perception have been primarily concerned with examining infants' perception of speech relative to adult speech perception abilities. Consequently, there has been very little research examining age-related changes in perception of speech-sound patterns over the first year of life. The results of investigations of pattern perception skills in non-human animals, however, may provide a basis for formulating hypotheses about understanding of the developing infant's abilities to perform pattern discriminations.

In general, the results of these investigations indicate that pattern discriminations are more difficult for animals to acquire in comparison to intensity or frequency discriminations. Pattern discriminations impose memory demands not present in discriminations which merely involve the detection of new information, thus memory constraints may contribute differentially to limit performance of pattern discriminations, in comparison to simple intensity or frequency discriminations. Moreover, following lesions of the primary auditory cortical regions of the brain, animals permanently lose the ability to learn and perform sequence discriminations. Thus, performance on tests of auditory pattern perception appears to be correlated with cortical intactness.

Since the auditory cortex in the human neonate is immature (Dobbing, 1974; Hecox, 1975), and development of the cortical brain regions proceeds rapidly over the first year of life (Conel, 1963; Lund, 1978), one might expect to find developmental changes in auditory pattern perception in infants as a result of the maturation of these brain regions. In fact, research on other aspects of auditory perception have revealed such developmental differences. Clifton, Morrongiello, Kulig, and Dowd (1981a,b) have found that five-month-olds, but not newborns, correctly turn their head toward precedence effect sounds, although infants at both ages show head orientation to lateralized sound presented from a single loudspeaker; the precedence effect is an auditory illusion the perception of which depends on cortical processing of binaural temporal information (Hochster and Kelly, 1981; Masterton and Diamond, 1964; Wallach, Newman, and Rosenzweig, 1949; Whitfield, Cranford, Ravizza, and Diamond, 1972).

The following sections review in greater detail the non-human animal, human clinical, and developmental literature on frequency, tonal, temporal, and memory constraints in pattern perception.

CHAPTER II

REVIEW OF THE LITERATURE

The literature to be reviewed will be divided according to two general topics: (1) biological constraints in the perception of temporal and tonal patterns, including research investigating brain-behavior relationships in non-human animals and human adults having cortical brain damage, and (2) perception of frequency, temporal and tonal patterns by human infants, and memory influences on infant auditory discrimination performance.

Research Revealing Biological Constraints in the Perception of Frequency and Tonal Patterns

Diamond and Neff (1957) examined the effect that cortical ablation, involving the regions of the brain designated as AI, AII, and Ep, has on cats' abilities to discriminate tonal patterns. Animals were tested using a conditioned avoidance procedure.

As can be seen in Figure 1, there were three discrimination conditions in the experiment. One condition examined a cat's ability to detect a change in the frequency of the pattern component tones (i.e., 800 vs 1000 Hz). Since frequency discrimination has been shown to be unaffected by cortical ablation (Butler, Diamond, & Neff, 1957; Goldberg & Neff, 1961), this control group is an important one because it tests for temporary memory deficits and for the post-operative

Fig. 1. Discrimination Conditions Used By Diamond et al (1957).

FIGURE 1

	NEUTRAL STIMULUS	WARNING STIMULUS	CONDITION LABEL	MANIPULATION
	LLL LLL LLL	H H H L L L L L L	A	FREQUENCY DISCRIMINATION (involving the second element)
e.g.,				
(H) (L)	HHH LLL LLL	H H H L L L L L L	B	PATTERN DISCRIMINATION
(H) (L)	H H H L L L L L L	H H H H H H L L L	C	PATTERN DISCRIMINATION

H = 1000 Hz

L = 800 Hz

cat's ability to perform motorically the avoidance response, and maintain attention sufficient to the task. The two remaining conditions both tested for pattern discrimination, but they differed from one another in an important way. In one (see B in Figure 1), the warning stimulus included a sequence change as well as a change in the relationship among components. Whereas, in the other pattern perception test (see C in Figure 1), the same relationships were maintained, but they occurred in reverse order.

Tones were 900 msec duration and were presented in groups of three with 100 msec between tones of a group, thus each group lasted 2.9 sec. Animals were presented with three groupings, for a duration of approximately 15 sec, followed by the change stimulus. A 2 sec silence interval intervened between any successive group, including between the background and change group.

Diamond et al found that following complete ablation of the auditory cortex, cats were no longer able to perform or relearn either of the pattern discrimination tests; although, they showed no permanent deficit in their ability to perform frequency discriminations involving the same tones and spanning the same silence interval as those used in the pattern discrimination tests. Jerison and Neff (1953) reported comparable results for monkeys using similar stimuli. Following bilateral ablation of the auditory cortex, monkeys showed complete loss of the ability to perform and relearn tonal pattern discriminations, although, frequency discriminations involving the component tones of the patterns could still be relearned.

Diamond, Goldberg and Neff (1962) devised a task incorporating aspects of both frequency and pattern discrimination tests, in an effort to try and determine why cortically ablated animals can perform the former but not the latter types of discriminations. The 'drop-out' frequency discrimination task which they developed is one in which the neutral, or background, stimulus consists of two different frequencies and the change stimulus consists of tones of only one of the frequencies. This task resembles a frequency discrimination in that frequencies of the tones of the neutral and change signals are not identical; the task is similar to a pattern discrimination in that there are no new frequncies introduced on change trials. The temporal and spectral parameters of the stimuli were the same as those that had been used in previous tests of pattern and frequency discrimination in cortically ablated animals (Diamond et al, 1962; Jerison & Neff, 1953). Results revealed that following cortical ablation cats were unable to detect a change from one tonal pattern containing two alternating frequency tones to a new pattern comprising only one of these frequencies. Animals could detect a change in tonal pattern, however, when it involved the introduction of a novel frequency.

Kaas, Axelrod, and Diamond (1967) examined cats' discrimination of interaural order following bilateral cortical ablation. Cats were trained to discriminate between tonal patterns that were created by presenting tones alternately to each ear, thus producing a binaural based pattern comprising 900 msec duration tones with 100 msec silence intertone intervals. Careful testing revealed that following cortical ablation cats were able to perform discriminations on the basis of attending to one ear alone and detecting the addition of a novel frequency tone, but they were impaired in their ability to perform pattern discrimination requiring them to temporally organize the tones presented successively to each ear.

Dewson, Cowey and Weiskrantz (1970) reported impaired performance in monkeys' discrimination of 2-element sequences following unilateral and bilateral ablation of the cortex of the superior temporal gyrus, and there was some evidence that memory deficits following the cortical ablation procedure were primarily responsible for the decline in discrimination performance. Following unilateral ablation of the superior temporal gyrus monkeys reliably performed the sequence discriminations, but performance was inversely related to the duration of time over which these discriminations had to be made. These results suggest that cortical ablation of secondary regions of the auditory cortex influences the time limits over which the listener can perform sequence discriminations, whereas ablation of the primary regions of the auditory cortex (Diamond & Neff, 1953, 1957; Jerison & Neff, 1953) results in permanent deficits to perform sequence discriminations, which are not solely attributable to memory deficits (e.g., these animals could still perform frequency discriminations spanning the same time interval).

Although acoustic properties such as the frequency of a sound appear to be analyzed subcortically, the results from these studies indicate that the discrimination of tonal patterns is a task requiring the auditory cortex. Elliott and Trahiotis (1972), in their extensive review of the cortical lesion literature, concluded that discriminations involving sequencing information are higher-order tasks than those requiring the mere detection of new information, and that these higher-order tasks are particularly susceptible to impairment following cortical damage. Similar impairments have been noted in humans with damage to cortical brain regions.

Chedru, Bastard, and Efron (1978) found that adults with focal lesions of the temporal lobe were severely impaired in their ability to utilize temporal order information to solve a discrimination task. Listeners were presented with two, brief semi-overlapping tones of different frequencies. Normal listeners perceive a single, complex tone having a particular pitch, and consequently are unable to judge the temporal order of the two component events. Reversing the temporal order of these two events results in a new perceived pitch. Changing the frequency of the component tones also results in a pitch change but this is based on frequency not temporal information processing. Chedru et al found that adults with temporal lobe damage were able to perform the frequency based pitch discriminations, but not the temporal based ones, indicating that cortical brain regions could play a critical role in the processing of sequence information in humans.

Jerger, Weikers, Sharbrough, and Jerger (1969), and Swisher and Hirsh (1972), both reported impairments in temporal lobe patients' abilities to judge correctly the temporal order of two successive high and low frequency tones. In comparison to cortically intact adult listeners (Hirsh, 1959), temporal lobe patients needed longer intervals between members of a pair of successive tones in order to judge temporal order accurately.

Developmental Research on the Perception of Frequency and Tonal Patterns

Frequency discrimination has been observed at virtually every age that has been tested. For example, neonates have been shown to discriminate frequencies of 500 and 2000 Hz (Bench, 1969), although they apparently fail to differentiate between two less disparate frequencies, such as 200 vs 500 Hz (Leventhal and Lipsitt, 1964) and 300 vs 700 Hz (Kittner and Lipsitt, 1976). One-month-olds discriminate 200 and 500 Hz tones (Wormith, Pankhurst, and Moffitt, 1975), and 6-week-olds reliably discriminate tones of 1100 and 1900 Hz (Leavitt et al, 1976). Although the evidence suggests that young infants may be limited in the magnitude of the frequency difference that they are capable of discriminating, whether they are more limited than older infants in frequency discrimination abilities has not been systematically investigated. One aim of the present study was to determine if there are developmental changes over the first year of life in infants' abilities to perform 'drop-out' frequency discriminations in comparison to their performance on a standard frequency discrimination task, which involves detection of the addition of a novel frequency tone.

There have been several investigations of infants' abilities to discriminate changes in tonal patterns. With one exception (Jusczyk and Thompson, 1978), all of these studies have tested infants 5-months of age or older. All reveal some pattern discrimination capacities in infants.

An early investigation by Horowitz (1972) tested 6-month-old males using an habituation-dishabituation procedure with heart rate as the dependent measure. The habituation stimulus comprised a 5 sec tone of 400 Hz contiguous with a 5 sec tone of 1000 Hz. Infants reliably discriminated a change involving the first element (i.e., a reversal of the 2-tone sequence or a novel frequency replacing the first element). But, they did not discriminate a change involving the second element (i.e., a novel frequency replacing the second tone). Melson and McCall (1970), tested 5-month-old females with an 8-note tonal sequence followed by a change in the order of tones, and also found evidence of discrimination of a change involving at least the first element. These studies reveal that 5- and 6- month-old infants are capable of performing relatively simple frequency discrimination tests. However, they do not provide evidence for pattern discrimination, as babies may have been responding to the first tone only.

More recently, Chang and Trehub (1977), using an habituation-dishabituation paradigm with heart rate as the dependent measure, obtained evidence indicating 5-month-old infants process at least the first two elements in a tonal sequence. Infants showed cardiac habituation to a repeating sequence of 6 tones, and dishabituation to a change in the sequence of the second through sixth elements. Furthermore, Jusczyk and Thompson (1978), reported that 2-month-old infants were able to discriminate changes in the second syllable of bisyllabic speech stimuli (e.g., /daga/ vs /daba/), which indicates that infants as young as 2 months of age may attend to information beyond the first element in an auditory pattern. One goal of the present study was to examine 6- and 12- month-old infants' abilities to discriminate pattern changes beyond the first and second ordinal positions in a sequence of tones.

Research Revealing Biological Constraints in the Perception of Temporal Patterns

Unlike the tonal pattern perception literature, which consistently reveals auditory cortex involvement in pattern discrimination, research investigating the role of auditory cortex in temporal pattern discriminations has yielded somewhat mixed results.

Symmes (1966) found that monkeys trained to discriminate pulsed from continuous noise lost this ability following cortical ablations, and were not able to relearn the discrimination. Similarly, Allen

(1945) found that cortical ablation resulted in nonreversible loss of the ability of dogs to discriminate between the tapping of a bell at a rate of 1 vs 3 per second. French (1942) reported that bilateral lesions involving most, though not all, of the auditory cortex regions produced deficits in rats' abilities to detect small differences in click rates, although animals could discriminate large differences in click rates.

Cranford and Igarashi (1977) using a Go-No Go conditioned-avoidance procedure, examined the effect of auditory neocortex ablation on the identification of click rates in cats. The results did not reveal any permanent impairment in cats' ability to identify small differences in click rates following bilateral ablation of auditory cortex. All cats could be trained to discriminate click rates of 6/second vs 4/second, both with and without a neutral 5/second background of clicks, indicating that, in cats at least, the presence of functional auditory cortex is not necessary for temporal discriminations of differences in click rates.

The auditory cortex has been shown to play a significant role in the perception of temporal patterns by human adults. Karaseva (1972), examining adult patients with unilateral damage to the temporal lobe, found that listeners had difficulty discriminating rhythmic patterns of clicks when the signals were presented to the ear contralateral to the cortical lesion. Furthermore, patients had the greatest difficulty with faster rhythms, for example when .02 sec duration clicks were presented at .02 sec intervals. Slowing down the rate of presentation of the clicks to intervals of .03-.04 sec or more facilitated performance. Other detrimental effects of cortical lesions on temporal aspects of hearing in adults also have been reported. Lackner and Teuber (1973) reported that adult auditory fusion thresholds (i.e., the perception of one vs two discrete successive acoustic events) were permanently affected following hemisphere lesions. Chapman, Symmes, & Halstead (1955) reported consistently poorer auditory fusion thresholds in cortically lesioned, in comparison to cortically intact, adult listeners.

Deleterious effects of cortical brain impairments on temporal aspects of auditory perception also have been reported for children. Hochster and Kelly (1981) found that children with temporal lobe epilepsy were impaired in their abilities to perceive the precedence effect illusion (Wallach et al, 1949). These studies indicate that the auditory cortex plays an important role in fine temporal discrimination in humans, and suggest that one might observe developmental changes in auditory temporal discrimination abilities over the first year of life as a result of cortical maturation in young human infants (Clifton et al, 1981a,b).

Developmental Research on the Perception of Temporal Patterns

A literature search revealed three investigations of infants' abilities to discriminate changes in temporal patterns.

Berg (1972) examined 6- and 12- week-old infants' discrimination of patterned stimuli (.8 sec on, 1.2 sec off; .4 sec on, 1.6 sec off) using a cardiac habituation-dishabituation paradigm. Infants at both ages showed habituation of cardiac responses to the repeated presentation of one stimulus pattern, and recovery of responding to a change in temporal pattern.

Demany, McKenzie, and Vurpillot (1977) tested 2- to 3- month-old infants using a habituation-dishabituation paradigm in which infants received auditory reinforcement contingent upon their visual fixations on a simple patterned figure. When infants habituated and looked away from the visual stimulus, the auditory reinforcer was changed to a new temporal pattern. Any resulting increment in fixation of the visual stimulus was taken as an index of discrimination of the auditory temporal patterns.

In the first of three experiments infants were presented with a sequence of five .04 sec tone-bursts having .194 sec between bursts and spanning .936 sec total duration. Once habituation had occurred, this rhythmic sequence was changed by changing the duration of interburst intervals and holding constant the density of sound within the .936 sec interval. A reliable increase in visual fixation following the change in auditory stimulus indicated that infants' discriminated changes in interval durations, that is to say they detected a change in the rate of presentation of these rapidly occurring patterns.

In the second experiment, infants were presented with an auditory pattern consisting of five .04 sec tone-bursts spanning 2.33 sec duration. Following habituation, changes in interburst intervals once again were introduced. Renewed visual fixation indicated that infants discriminated changes in the rate of presentation even when listening to slower rhythmic patterns.

In the final experiment, which is most relevant to the research to be proposed, infants were presented with a sequence of four .04 sec tone-bursts spanning 1.0 sec duration. Following habituation, the order of presentation of the three interburst intervals was changed. Thus, this experiment constituted a true test of infants' temporal pattern perception abilites, since infants had to detect a reversal of the second and third interburst intervals, .291 sec and .582 sec, or vice versa. Infants 2 1/2 months of age were able to reliably discriminate changes in these relatively short, simple temporal patterns.

The results from these three experiments suggest that infants as young as 2- to 3- months of age are sensitive to rhythmic grouping and are capable of performing fine temporal discriminations. However, methodological insufficiencies in this study suggest that a replication experiment should be attempted. A single observer scored infant visual fixations in these studies, and there was no report of the observer wearing masking earphones. Thus, it would seem that the scorer had full knowledge of which test condition and phase of the experiment the infant was in while scoring an infant's visual fixations.

Chang and Trehub (1977) investigated 5-month-old infants' perception of temporal patterns, using an habituation-dishabituation paradigm with cardiac response measures. Infants were presented with a 6-tone stimulus organized into a 2-4 or 4-2 grouping. Tones and intertone intervals were .2 sec with an intergroup interval of .6 sec. Thus, the total duration of a pattern was 1.8 sec. Results indicated that infants reliably discriminated between a 6-tone stimulus organized into a 2-4 vs a 4-2 grouping. However, whether infants performed these discriminations solely on the basis of temporal information cannot be ascertained. Because tones of different frequencies were used in constructing the stimuli, infants may have perceived the grouping of elements in a Gestalt-like fashion abstracting each frequency contour produced by each tonal group. Consequently, detection of a change in tonal pattern resulting from a reversal of the order of presentation of the element groupings may have contributed to infants' dishabituation performance.

These few studies reveal some capacities to perform temporal pattern discriminations in young infants. Berg's study reveals that infants as young as 6-weeks of age are sensitive to rhythmic variation. The results of Demany et al suggest that infants as young as 2-3 months can detect a change in temporal grouping in short, relatively simple patterns(Experiment 3). Chang and Trehub provided evidence to suggest that 5-month-olds can discriminate temporal groupings in 6-tone sequences that span 1.8 sec. In each of these studies, however, the stimuli consisted of tonal elements, thus temporal perception was not evaluated independently of tonal perception. One goal of the present study was to examine temporal pattern perception abilities more closely in order to determine if there are developmental changes over the first year of life in infants' abilities to perform more vs less subtle temporal pattern discriminations. For example, detecting a change in the number of elements comprising a grouping vs a change in the number of groupings comprising a pattern. To eliminate confounding tonal perception with temporal perception, white-noise bursts were used instead of tones, since white-noise is a broadband signal comprising many frequencies.

Memory Influences On Infant Auditory Discrimination Performance

Generally, there has been very little research examining the role that memory plays in infant auditory discrimination performance. The few studies in which this topic has been addressed, however, have all provided evidence to indicate that memory constraints significantly influence infant auditory discrimination performance, particularly in younger infants.

The standard discrete-trials heart rate habituation-dishabituation paradigm has been shown to be a less sensitive measure of discrimination abilities, particularly in young infants, due to the memory load imposed by the lengthy intertrial intervals, which typically range from 20-40 seconds. In an effort to minimize memory load influences on discrimination performance investigators developed the "no-delay", or "no intertrial interval", cardiac paradigm (Leavitt, Brown, Morse, & Graham, 1976, Morse, 1978). In this paradigm the infant hears a lengthy sequence of the familiar sound (e.g., 30 repetitions of /ba/) followed immediately by a novel sound sequence (e.g., 30 tokens of /ga/),with short interstimulus intervals throughout, typically 250-1000 msec in duration. This procedure has been used successfully to study auditory discrimination in 6-week-olds (Leavitt et al, 1976), 12-week-olds (Miller, Morse, and Dorman, 1977; Miller and Morse, 1976), and 16-week-olds (Till, 1976), and, most importantly, it has revealed discrimination abilities at ages at which the typical discrete-trials habituation-dishabituation procedure had failed to do so (Berg, 1974; Brown, 1972; Leavitt et al, 1976; Miller et al, 1976; Miller et al, 1977).

Investigation of memory constraints of the high-amplitude sucking (HAS) paradigm, by Swoboda and his colleagues, have also revealed memory influences on discrimination performance (Swoboda, Morse, and Leavitt, 1976; Swoboda, Kaas, Morse, and Leavitt, 1978). In the HAS procedure the timing between sound presentations is controlled by the infant, consequently the duration of the silence interval, between the last token of the familiar sound and the first token of the novel sound, experienced by infants varies across individuals. Swoboda et al (1976;1978) found an inverse relationship between an individual infant's discrimination performance and the silence duration interval they experienced; over the range of 0-30 sec, the longer the intervening silence interval the poorer was an infant's vowel discrimination performance.

These few studies, which primarily are of speech-sound discrimination performance in infants, indicate the importance of examining the role of memory constraints in investigations of infant auditory discrimination. Since several of these studies reveal more limited memory capacities in younger, in comparison to older, infants, examining the influence of memory constraints on discrimination performance may be particularly important in developmental investigations of infant auditory discrimination capacities. One goal of the present study, therefore, was to examine memory influences on 6-, in comparison to 12-, month-old infants' frequency, tonal, and temporal pattern discrimination performance.

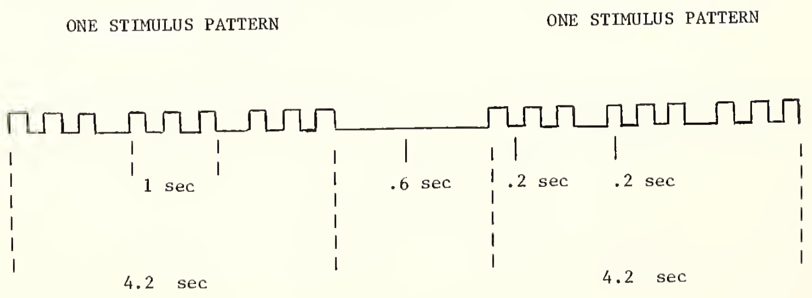
Proposed Research

The purpose of this experiment was to assess 6- and 12- month-old infants' perception of temporal and tonal patterns, their ability to perform various types of frequency discriminations, and how memory constraints influence infant auditory discrimination performance. For all conditions the basic stimulus was fashioned after that used in the non-human pattern perception research (Diamond et al 1957, 1962; Jerison & Neff 1953), and comprised a sequence of nine elements, organized into three groupings, each of three elements (see Figure 2). The total duration of a pattern was 4.2 sec, which is longer than that used in previous studies of tonal pattern perception in infants; in Chang and Trehub's studies (1977, 1977) a pattern consisted of a sequence of 6-tones and was 1.8 sec duration. The patterns used in the present study were similar to those used by Chang and Trehub in that the component tones were .2 sec duration and intertone intervals were .2 sec within a grouping and .6 sec between groupings. Interpattern intervals were 2 sec duration, as in the non-human animal research (Diamond et al, 1957, 1962; Jerison & Neff, 1953); in the Chang and Trehub studies cardiac indices of responding were used, consequently interpattern intervals were long, 15 sec duration, in order to allow heart rate to return to baseline level before the onset of a trial. Since the Chang and Trehub studies revealed some abilities to perform tonal and temporal pattern discriminations in 5-month-old infants, it was thought that extending the duration of the pattern and increasing the number of elements and groupings comprising a pattern would serve to elucidate developmental changes over the first year of life in infants' tonal and temporal pattern perception abilities.

The tonal pattern perception tests examined three aspects of infants' perception of a recurring auditory pattern: (1) their

Fig. 2. Schematic Diagram of a Stimulus Pattern.

FIGURE 2


ONE STIMULUS PATTERN
ONE STIMULUS PATTERN
1 sec
.6 sec
.2 sec
.2 sec
4.2 sec
4.2 sec

perception of the nature of the component tones (e.g., they're all the same frequency); (2) their perception of the sequence of triads comprising a larger pattern; and (3) their perception of the sequence of tones within a triadic grouping. The discrimination conditions designed to examine these aspects of infant pattern perception (Frequency-1 and Frequency-2, Pattern-1, and Pattern-2, respectively) are shown in Table 1.

Frequency-1 and Frequency-2, provided a test of an infant's ability to discriminate among the component tones used in the tonal pattern perception tests. The test patterns (TP) in Frequency-1 all involved the introduction of a new frequency tone, while two test patterns in Frequency-2 involved the deletion of a familiar frequency tone, and two examined infants' abilities to detect a reversal in the ratio of high:low frequency tones. The reader may recall the asymmetry in frequency discrimination which resulted when cats were cortically ablated: operated cats could perform frequency discriminations involving the addition of a novel tonal element, however, they were unable to perform 'drop-out' frequency discriminations (Diamond et al, 1962).

Pattern-1 and Pattern-2 tested different aspects of tonal pattern perception. In Pattern-1, the tonal elements within a triad remained unchanged in all but one test pattern, and it was the sequence of triads within the pattern that was altered. In Pattern-2, the primary pattern change occurred within a triad. Notice too that in both of

TABLE 1

TEST PATTERNS AND TYPE OF DISCRIMINATION FOR EACH CONDITION

CONDITION	BACKGROUND PATTERN[1]			TEST PATTERN[1]				TYPE OF DISCRIMINATION:	MANIPULATION
FREQUENCY-1	LLL	LLL	LLL	(A)	LHL	LHL	LHL	Frequency:	Within triad (all triads)
				(B)	LLL	LLL	HHH		One of three triads changed
				(C)	LLL	HHH	HHH		Two of three triads changed
				(D)	HHH	HHH	HHH		Complete change
				(E)	LLL	LLL	LLL	No Change Control	
FREQUENCY-2	LHL	LHL	LHL	(A)	LLL	LLL	LLL	Frequency:	Within triad (all triads)*
				(B)	HHH	HHH	HHH		Within triad (all triads)*
				(C)	LHL	HLH	LHL		Reversed ratio (1 triad affected)
				(D)	HLH	HLH	HLH		Reversed ratio (all triads)
				(E)	LHL	LHL	LHL	No Change Control	
PATTERN-1	LLL	HHH	LLL	(A)	LHL	LHL	LHL	Sequence:	Within triad (all triads)
				(B)	LLL	HHH	HHH		Reversed ratio (1 triad affected)
				(C)	LLL	LLL	HHH		Triads 2 and 3 reversed
				(D)	HHH	LLL	LLL		Triads 1 and 2 reversed
				(E)	LLL	HHH	LLL	No Change Control	
PATTERN-2	LHL	LHL	LHL	(A)	LLL	HHH	LLL	Sequence:	Within triad (all triads)
				(B)	LHL	LLH	LHL		Within triad (1 triad affected)
				(C)	HLH	HLH	HLH		Reversed Ratio (all triads)
				(D)	LLH	LLH	LLH·		Within triad (all triads)
				(E)	LHL	LHL	LHL	No Change Control	

*This test pattern also constituted a test of infants' abilities to perform 'Drop-out' frequency discriminations.

TABLE 1 (cont'd)

CONDITION	BACKGROUND PATTERN	TEST PATTERN	TYPE OF DISCRIMINATION: MANIPULATION
TEMPORAL	TTT TTT TTT	(A) TTTTTTTTT (B) TTTTT TTTT (C) TT TTTTT TT (D) TTTT T TTTT	Temporal: One long pattern (only 1 group) 5-4 grouping (only 2 groups) 2-5-2 grouping (still 3 groups) 4-1-4 grouping (still 3 groups)

---

[1] L = 1100 Hz pure tone
H = 1900 Hz pure tone
T = white noise burst

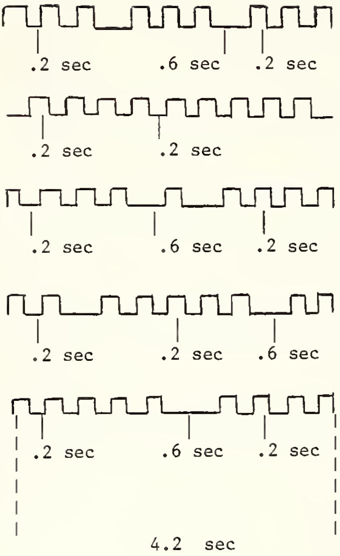
these conditions no new elements were introduced, the primary difference between the background and change patterns involved a change, either intra- or inter- triadic, in the sequence of tones comprising a pattern.

The temporal pattern discrimination test involved changes in grouping from a 3-3-3 pattern to several other types of grouping patterns, such as a 5-4 grouping, which involves a change in the number of groupings comprising a pattern, or a 4-1-4 grouping, which involves a change in the number of elements comprising a grouping. White noise bursts were used instead of pure tones for the temporal pattern discrimination test. Since white noise is a broadband signal, it was expected that a listener's ability to perform temporal pattern discriminations would be independent of the specific spectral characteristics of the signal.

As can be seen in Figure 3, for the Temporal pattern condition the test patterns were selected so that the total duration of the pattern (4.2 sec) remained constant across changes in temporal patterning. The purpose of the temporal pattern perception test was to determine if there were developmental changes in infants' abilities to discriminate changes in the number of groupings comprising a pattern (TP-A, TP-B), and the number of elements comprising a grouping (TP-C, TP-D) for patterns spanning 4.2 sec and consisting of 9 elements and three groupings of elements. In previous studies of infant temporal pattern perception the most extensive pattern used was

Fig. 3. Test Patterns Used in the Temporal Discrimination Condition.

FIGURE 3



BASIC BACKGROUND PATTERN &
NO CHANGE CONTROL :
3 - 3 - 3 GROUPING

CHANGE TO ONE LONG NINE TONE PATTERN

CHANGE TO A 4 - 1 - 4 GROUPING

CHANGE TO A 2 - 5 - 2 GROUPING

CHANGE TO A 5 - 4 GROUPING

a 6-tone sequence consisting of two groupings of elements and spanning 1.8 sec total duration (Chang and Trehub, 1977).

The three most popular response measures that have been used in studies of infant suditory discrimination abilities are: high-amplitude sucking, heart rate, and conditioned head turning. Since 6- and 12- month-olds were to be tested, and it was thought that infants at these ages would not be very tolerant of a nipple held in their mouth, high-amplitude sucking was eliminated from consideration as a response measure. Heart rate also was eliminated from consideration as the dependent measure because it does not provide a means of examining the magnitude of discriminative responding to a stimulus event. A heart rate response to a stimulus event is most meaningfully evaluated as present or absent; attempts at inferring relative discriminability from magnitude of heart rate change is constrained because movement can influence the magnitude and direction of the heart rate response (Morrongiello and Clifton, 1982; Pomerleau-Malcuit, Malcuit and Clifton, 1975), and there are age-related changes in the magnitude and direction of cardiac responding (Graham, Berg, Berg, Jackson, Hatton, and Kantowicz, 1970). Thus, in the present study the primary index of discriminative responding was head orientation toward sound.

In order to evaluate infants' discrimination abilities a Go-No Go conditioned head-turn procedure was used, since this procedure had been used successfully to examine auditory perception abilities in 6-

and 12- month-old infants (Morrongiello, Kulig, and Clifton, Note 1; Trehub, Schneider, & Bull, 1981; Trehub, Schneider, & Endman, 1980; Wilson, Moore, & Thompson, 1976), and Trehub, Schneider, and Bull (1981) have found reinforcement head-turn procedures to be more informative and successful than non-reinforcement head-turn procedures in evaluating infant auditory competencies. In this paradigm, repeated successive presentations of an auditory stimulus (S-) comprise a 'background'. At times when the infant is quiet and facing straight ahead, a change stimulus (S+) periodically replaces the background stimulus. Head turns toward the signal loudspeaker are visually reinforced in the presence of S+, but not S- stimuli. In the present study, the auditory stimulus played from a single loudspeaker located at a 90° angle from the infant's sagittal midline. The visual reinforcer, a mechanical toy encased in a smoked plexiglass box, was located immediately adjacent to the signal loudspeaker and was visible only when turned on. Side of stimulus presentation during testing was counterbalanced by sex across subjects.

Hypotheses

An hypothesized ordering of difficulty regarding how well infants would perform the four discriminations within each condition appears in Table 2. Generally, it was expected that changes in within-triad variability would be more discriminable than those frequency and pattern discriminations that required the infant to make comparisons

TABLE 2

HYPOTHESIZED ORDERING OF EASE OF DISCRIMINATION OF THE TEST PATTERNS COMPRISING EACH CONDITION

CONDITION	HYPOTHESIZED ORDERING
FREQUENCY-1	A (B & C) D E
FREQUENCY-2	(A & B) C D E
PATTERN-1	A (B & C & D) E
PATTERN-2	A B (C & D) E
TEMPORAL	(A & B) (C & D) E

with the pattern heard 2 seconds previously, i.e., those changes that added greater memory requisites. For example, for Pattern-2 in Table 1, test pattern C was similar to the background pattern in that all three triads comprising a pattern were identical. The only difference between the two patterns was in the sequence of tones within a triad (LHL vs LLH). This contrast necessitated that the infant recognize a difference in tonal sequence between two patterns played 2 seconds apart. For test pattern B (TP-B) the three triads comprising the pattern differed from one another (LHL vs LLH). Thus the infant needed only to recognize a difference in tonal sequence between two triads played .6 sec apart. If infants were truly unable to perform tonal sequence discriminations then it would be expected that they would perform poorly on both discrimination types A and B. If, however, memory constraints interacted with frequency and tonal pattern perception then it would be expected that infants would do poorly with test pattern C while performing well to test pattern B. Several contrasts of this type were included to explore this possibility; a listing of the particular contrasts constructed to explore the memory aspects of the task appears in Table 3. For the Temporal pattern perception condition, it was expected that test patterns A and B would be more discriminable than C and D, since the latter patterns were more similar to the background pattern in that they comprised three groupings of elements.

It was hypothesized that 6-month-olds, in contrast to 12-month-olds,:

TABLE 3

TEST PATTERNS INVOLVING A CHANGE IN WITHIN TRIAD VARIABILITY AND IMPOSING A MEMORY LOAD OF .6 AND 2 SEC FOR EACH CONDITION

CONDITION	BACKGROUND PATTERN	TEST PATTERN INVOLVING A CHANGE IN WITHIN-TRIAD VARIABILITY	TEST PATTERN IMPOSING A MEMORY LOAD OF:	
			.6 sec	2 sec
FREQUENCY-1	LLL LLL LLL	A	B, C	D
FREQUENCY-2	LHL LHL LHL	A, B	C	D
PATTERN-1	LLL HHH LLL	A	—	B, C, D
PATTERN-2	LHL LHL LHL	A	B	C, D

(1) would be able to perform only the easiest tonal and temporal pattern discriminations;

(2) would have greater difficulty with those discriminations imposing the greatest memory load, including frequency discriminations; and

(3) would perform relatively poorly on the frequency drop-out Change trials. No age-related changes were anticipated for those frequency discriminations that did not impose a memory load or involve the deletion of an element.

CHAPTER III

METHOD

Subjects

Fifty infants, 25 males and 25 females, each at 6 months (M=25.3 weeks;Range:22-29 weeks) and 12 months (M=51.2 weeks;Range: 46-60 weeks) of age were assigned in equal numbers by sex to five different test conditions. The data of an additional seven infants, 6 months of age, were discarded due to experimenter error (N=1), unsatisfactory state (N=2), spontaneous head turn level greater than 30% (N=2), and improper head orientation on trials (N=2). The data of an additional five infants, 12 months of age, were discarded due to experimenter error (N=1), unsatisfactory state (N=1), spontaneous head turn level greater than 30% (N=1), and improper head orientation on trials (N=2). Infants were contacted for participation in the study through local published birth announcements by means of an introductory letter and follow-up telephone call. Subject selection was based on the following criteria, verified by a parental interview on the day of testing: (1) born at term; (2) no pre-, peri-, or post- natal complications; (3) no history of ear infections; (4) no suspicion of hearing impairment; (5) no cold on test date; and (6) normal developmental course.

Stimulus and Apparatus

Sinusoidal tones of 1100 and 1900 Hz were used to construct the stimulus patterns for the Frequency and Tonal pattern perception tests shown in Table 1. For the Temporal pattern perception test, white noise bursts were used instead of tones. The rise/decay times of the tones and white noise bursts was controlled at .025 sec by a Grason-Stadler electronic switch.

A stimulus pattern consisted of a sequence of 9 elements, either tones or white noise bursts, organized into three groups of three elements. Each element was .2 sec in duration, with an equal silence interval between members of a triad. A .6 sec silence interval separated triads within a stimulus pattern. Thus, each stimulus pattern comprised three triads and was 4.2 sec total duration. A diagram of a stimulus pattern appears in Figure 2.

Implementation of the study included the preparation of five audio tapes, each corresponding to one of the five test conditions to be described below (see Table 1). Five 'master' tapes (Scotch 207) were prepared using the facilities available at the Electrical and Computer Engineering Department on the University of Massachusetts campus. Three audio oscillators (Wavetek, Wavetek, Exact) were used to produce the 1100 and 1900 Hz pure tones and the white noise bursts, respectively. The output level of each oscillator was set at 2 volts peak-to-peak and a Tektronix dual channel trace oscilloscope was used to monitor the voltage levels during recording. A Hewlett-Packard frequency counter was used to set each oscillator to the exact Hz value specified. A mini-computer (Dec LSI-11) was interfaced with the oscillators via a custom built interface box, and the order of selection of oscillators was completely programmed in advance of recording a test tape. The output of each oscillator passed through the electronic switch which shaped the rise/decay aspects of the signal prior to its being recorded (Revox, A-77). During recording the output of the tape recorder was amplified (Realistic, 31-1982) and fed to a custom built loudspeaker so that the author was able to listen to the tapes as they were being recorded. An implementation block diagram appears in Appendix 1.

Each of these 'master' tapes was then re-recorded, with the record level varied systematically during recording in order that all patterns on a tape produced an average Sound Pressure Level (SPL) of 60 dB when played in the experimental room. The master tapes were played on a Pioneer (RT-701) reel-to-reel tape recorder running at 3 3/4 ips, and the test tapes (Maxell, UD-XL, 35-90B) were recorded on the Revox tape recorder running at 3 3/4 ips.

During a session the Pioneer tape recorder fed an amplifier (Shure, SE-30) which powered a single loudspeaker (Acoustic Research, AR-7), laterally positioned at an angle of 90° approximately 1 m horizontal distance either to the right or the left of the infant's saggital midline. Stimulus programming was controlled by a custom built paper tape programmer and peripheral relays and logic equipment. Stimulus SPL at the position of the infant's head averaged 60 dB-A

(Range:58-62 dB) for all sound patterns (monitored using a General Radio Sound Level meter, A scale). Ambient noise level in the test room was 28 dB-A, measured at the position of the infant's head. An Horizon North Star micro-computer was used to tally observer's responses on trials (Change and No Change Control). An Esterline-Angus event recorder, running at a paper speed of .5 mm per second, was used to record head turn responses throughout the session. This provided an additional record of head turn responses on trials, in the event of a computer malfunction during a test session.

Two visual reinforcers were used: a mechanical dog and monkey; both located side-by-side immediately adjacent to the signal loudspeaker. The toys were enclosed within smoked plexiglass cases and were not visible to the observer until illuminated. Selection of which visual reinforcer was to be presented was determined on-line by the experimenter playing with the baby (Experimenter 1). Typically, for every five trials that the infant received reinforcement, three were the monkey and two the dog; however, there was no pre-determined order of presentation of the visual reinforcers.

Delivery of the visual reinforcer was controlled by peripheral relays and logic equipment. During the Training phase, the activation of the visual reinforcer was controlled exclusively by Experimenter 1; the reinforcer was activated whenever Experimenter 1 button pressed to signify a response during a Change trial. Button presses during non-Change trial periods were recorded automatically on the

Esterline-Angus event recorder, but did not result in the visual reinforcer being activated. During the Testing phase, the reinforcer was activated whenever a second experimenter button pressed simultaneous with Experimenter 1, indicating an agreed response during a Change trial. Of course, during Testing neither experimenter knew when a Change trial was occurring. Experimenter 1 did not have any knowledge of when trials (Change or No Change Control) were occurring; this experimenter pressed her footpedal whenever a head turn response was observed. Experimenter 2 knew when a trial was occurring, but did not know if it was a Change or No Change Control trial; this experimenter was responsible for monitoring several devices throughout the experiment, and consequently only scored head turn responses during trial periods.

The infant's behavior was videorecorded throughout the session by means of a videocamera (General Electric, TE-44; Sony Videocassette Deck, VO-2600) located behind a white curtain positioned directly behind Experimenter 1. The videocamera was located approximately 1 m distance from the infant and displayed a picture of the infant and parent. An audio record of the test session was simultaneously recorded, the audio input coming directly from the headphone jack on the tape recorder. A T.V. monitor (Sanyo, VM-4130) located in the equipment room allowed a second experimenter to observe the infant while controlling the delivery of trials from the adjacent equipment room. A voice-activated relay (Lafayette Instr. Co., 18010), which received a direct input from the tape recorder, controlled an Eico audio-generator (378), the output of which was amplified (Bogen, C-20A) and fed to a custom built loudspeaker, thus providing Experimenter 2 with an index as to when a pattern was playing in the experimental room without his/her listening to what the pattern was. A diagram displaying the test room appears in Figure 4. A block diagram displaying the equipment room appears in Appendix 1.

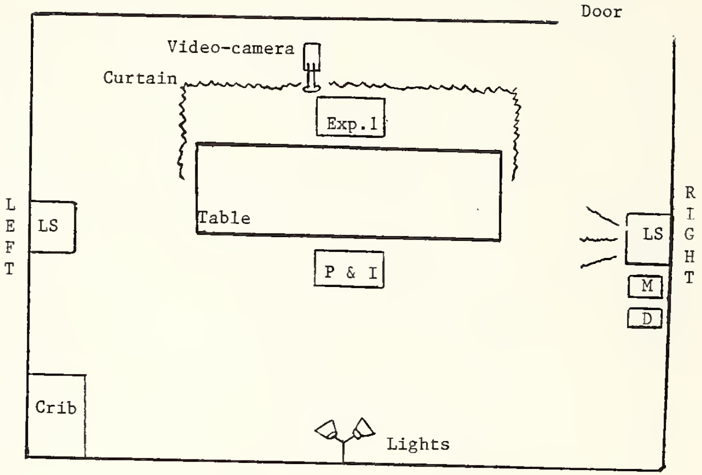
Design

Ten infants (5 male and 5 female) at each age were assigned to each of the five conditions shown in Table 1. For each condition there were four types of Change trials in addition to a No-Change Control trial. The order of presentation of Change and No-Change Control trials was counterbalanced within subjects across blocks, and across subjects within conditions, by a latin square procedure. Thus, each Change and No Change Control trial occurred in each of the five ordinal positions within each of the five blocks of trials. During two Training blocks, given at the start of the experiment, the order of presentation of trials was randomized.

Complete counterbalancing as described resulted in the necessity of five test tapes for each test condition shown in Table 1 (i.e., 25 tapes in total). In order to limit the time spent on stimulus preparation, five tapes, one for each test condition, were constructed such that different portions of a tape were used in fulfilling the

Fig. 4. Schematic Diagram of the Testing Room.

FIGURE 4



LS = Loudspeaker
M = Monkey Visual Reinforcer
D = Dog Visual Reinforcer
P & I = Parent and Infant
Exp. 1 = Experimenter 1

counterbalancing requirements (see Tables 5,6 and 7 in Appendix 1 for further information as to how this was accomplished).

Side of presentation of the signal loudspeaker and reinforcer, either left or right of the infant, was counterbalanced within each condition, resulting in five infants required to turn their head toward the left and five toward the right. Within each group of five infants, at least two were male and two female. Table 8 in Appendix 1 provides a summary of the counterbalancing just described.

Procedure

Infants were brought to the infant research laboratory at the University of Massachusetts campus for one 35-minute session. Infants were tested in a dimly lit sound-attenuated room at a time designated by their parents as corresponding to an alert play period. Following a complete description of the experimental procedures to the parent written informed consent was obtained.

Throughout the session the infant sat on their parent's lap and Experimenter 1 was seated 1 m in front of them. The primary role of Experimenter 1 was to entertain the baby with soundless toys and thus keep the infant facing frontwards with his/her head located midway between the two loudspeakers.

Throughout the session a trial consisting of two repetitions of a test pattern was presented following every three or four repetitions of the background pattern. The number of repetitions of the background pattern was varied in order to prevent the infants from becoming temporally conditioned to respond. A 4-6 sec silence interval followed every trial regardless of type of trial (Change and No Change Control). Experimenter 2 controlled the delivery of these post-trial silence intervals in two ways. If infants responded at anytime during the first repetition of a test pattern then Repetition 1 finished playing and during the 2 sec interpattern silence interval Experimenter 2 turned down the amplifier output to 0 for 4-6 seconds, resulting in the tape inaudibly playing Repetition 2 of a test pattern. If the infant did not respond, or responded during Repetition 2 of a test pattern, then Repetition 2 finished playing and during the 2 sec interpattern silence interval Experimenter 2 stopped the recorder for 4-6 seconds. These silence intervals served two purposes: (1) they prevented the infant from detecting the change back to the background pattern, and possibly turning their head under the wrong stimulus conditions; and (2) they guaranteed that even if infants responded and received reinforcement at the very end of the second repetition of a Change pattern there was no temporal overlap between the visual reinforcer and the background pattern, which would have supported the establishment of the wrong stimulus-response associations.

Experimenter 2 monitored the equipment in a room adjacent to the testing room, observing the infant via the T.V. monitor. The primary responsibilities of Experimenter 2 included: (1) advancing the paper tape reader which was coded to indicate to the computer whether a Change or No Change Control trial was occurring; (2) scoring head turns during each trial during Testing; and (3) controlling the occurrence of a silence interval following each trial. Throughout the entire session, Experimenter 2 listened to a 500 Hz tone, the duration of which was temporally synchronous with the pattern being played to the infant. Thus, Experimenter 2 was able to distinguish between a pattern being played and an interpattern silence interval, but was prevented from hearing which pattern was playing in the experimental room. Since s/he could not hear the pattern being played on trials, s/he was unaware whether a Change or No Change Control trial was being presented when scoring head turn responses.

Training. During the Training phase infants received two blocks of the four different Change trials of the group to which they were assigned. Thus, subjects received a total of eight Change trials (see Table 9 in Appendix 1). Training trial blocks were comparable to Test trial blocks in that the same Change trials occurred equally often in both types of blocks. Training and Test blocks differed, however, in that No Change Control trials were not presented and the order of presentation of trials was randomized within blocks during Training. No Change Control trials were not included because pilot testing indicated that a lengthy sequence of the background pattern seemed to disrupt acquisition of the conditioned response in those infants that failed to spontaneously detect the change on trials.

Beginning with Trial 3 and proceeding through Trial 8 of Training, Experimenter 1 successively reduced the cues she provided to the infant during the first repetition of a test pattern. On Trials 3 and 4, for example, she no longer turned toward or pointed to the loudspeaker, although she continued to cease playing with the infant on Change trials. By Trial 5 or 6, infants typically showed some evidence of having learned the contingency and Experimenter 1 no longer provided any cues that a Change trial was occurring. Pilot testing of these procedures with 10 infants revealed that all infants performed the task without assistance from Experimenter 1 by trial 8 of Training.

During the Training phase of the experiment both the parent and Experimenter 1 helped the infant to orient toward the Change pattern. Recall that on each trial the test pattern was repeated twice. During Repetition 1, Experimenter 1 ceased playing with the toys, pointed, looked, and turned her head toward the loudspeaker. If the infant did not orient toward the loudspeaker Experimenter 1 remained positioned as just described for the second repetition. The parent, who had been instructed in advance, shifted the infant to face the loudspeaker during the second repetition of a test pattern. Once the infant was oriented toward the loudspeaker, one of the two visual reinforcers, either the monkey or dog, was activated for 5 seconds duration. Following this there was a 4-6 seconds silence interval during which time the infant and Experimenter 1 returned to their orientation midway between the loudspeakers. During the Training phase, the delivery of the visual reinforcer was controlled exclusively by Experimenter 1.

Testing. During the Testing phase the following changes in procedures were made: (1) Experimenter 1 and the parent wore headphones over which white noise was presented continuously, thereby preventing them from detecting the occurrence of Change trials, (2) both Experimenter 1 and 2 independently scored head turn responses by means of a footpedal and button press box, respectively, and only agreed head turns on Change trials resulted in activation of the visual reinforcer. Each infant received five blocks of five trials, four Change and one No Change Control trial, per block (see Table 8 in Appendix 1). Each block began with the presentation of the background pattern and ended with the presentation of a test pattern. Between blocks there were a few seconds of silence as the tape advanced to the next block; thus, the last trial of every block was followed by a 4-8 sec silence interval instead of the usual 4-6 sec silence post-trial silence interval. A diagram showing the typical sequence of events during Testing is shown in Figure 5.

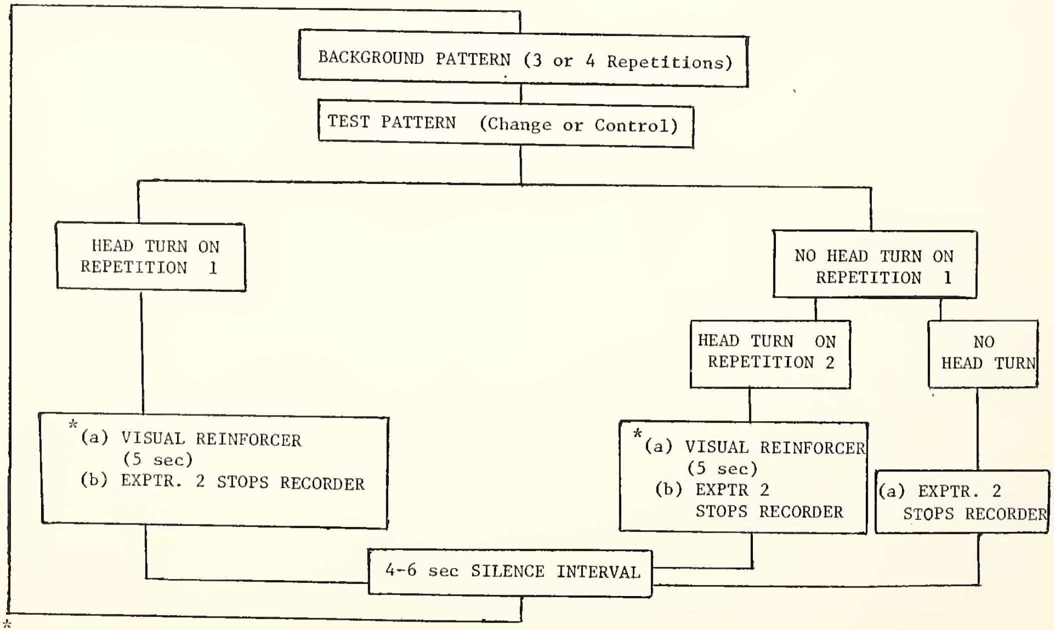
The entire session lasted approximately 30-35 minutes.

Data Reduction

The videorecord of infants' activity during the test session was scored by the author for the following: (1) head position at the start

Fig. 5. Flow Chart Depicting the Typical Course of Events During Testing.

FIGURE 5



*Omitted on Control Trials

of a trial ('center', 'ipsi-' or 'contra-' lateral to the sound source); (2) whether the "first" or "second" repetition of a test stimulus was responded to; (3) the incidence of spontaneous head turns occurring to the background stimulus during inter-trial intervals; (4) the incidence of orienting head turns, that is, a head turn occurring at sound onset, to the first presentation of the background stimulus following an interblock silence interval; and (5) the infant's state on each trial (i.e., 'calm', 'fussy'). Reliability (computed as the number of agreements divided by the number of agreements plus disagreements) for these behaviors was obtained for 70% of the subjects, equally distributed among conditions at each age. The reliability coefficients are given in Table 10 in Appendix 1.

Trials on which infants were fussy or had their head positioned off center at the start of a trial were excluded from the analyses. Elimination of subjects' data was based on two naive, independent observers coding the complete videorecord of a subject and reliably selecting trials representative of either of these two exclusion criteria. Table 4 provides a complete listing of the type and number of trials eliminated for each subject by group at each age.

The following criteria were used arbitrarily to exclude a subject's complete data set from the final analysis: (1) two or more of the five trials of the same type of test pattern could not be used due to either improper head orientation at the start of a trial or fussy state; (2) a total of five or more trials (i.e., one of each

TABLE 4

TRIALS ELIMINATED FROM THE FINAL ANALYSIS FOR INFANTS IN EACH CONDITION AT EACH AGE

AGE (months)	CONDITION	SUBJECT	TYPE OF TRIAL ELIMINATED: TP-A	TP-B	TP-C	TP-D	TP-E	REASON FOR ELIMINATION[1]
6	FREQUENCY-1	1			x			HOR
		2				x		HOR
		3	x					FSY
				x				HOR
		4			x			HOR
	FREQUENCY-2	1			x			HOR
						x		HOR
		2		x				FSY
					x			FSY
		3				x		HOR
		4			x			HOR
						x		FSY
	PATTERN-1	1			x			HOR
		2	x					HOR
					x			HOR
		3		x				FSY
					x			FSY
		4	x					HOR
		5			x			HOR
		6	x					FSY
		7				x		HOR
	PATTERN-2	1	x					HOR
						x		HOR
	TEMPORAL	1				x		HOR
		2	x					FSY
					x			FSY
							x	HOR
		3	x					FSY
					x			FSY

TABLE 4 (cont'd)

AGE (months)	CONDITION	SUBJECT	TYPE OF TRIAL ELIMINATED: TP-A	TP-B	TP-C	TP-D	TP-E	REASON FOR ELIMINATION
						x		HOR
		4		x				HOR
12	FREQUENCY-1	1		x				HOR
					x			HOR
		2					x	HOR
		3			x			FSY
		4			x			HOR
		5		x				HOR
						x		HOR
							x	HOR
	FREQUENCY-2	1		x				HOR
						x		HOR
		2	x					HOR
		3			x			FSY
		4	x					HOR
	PATTERN-1	1			x			HOR
		2		x				HOR
	PATTERN-2	1		x				HOR
		2				x		HOR
		3	x					HOR
		4	x					HOR
					x			HOR
		5	x					HOR
						x		HOR
	TEMPORAL	1			x			HOR
		2		x				HOR
					x			HOR

TABLE 4 (cont'd)

AGE (months)	CONDITION	SUBJECT	TYPE OF TRIAL ELIMINATED:					REASON FOR ELIMINATION
			TP-A	TP-B	TP-C	TP-D	TP-E	
		3			x			HOR
							x	HOR
						x		HOR

[1] HOR = Head Orientation

FSY = Fussy

type) could not be used due to improper head orientation at the start of a trial or fussy state; and (3) spontaneous head turns on more than 30% of the background patterns. These criteria resulted in elimination of the data of seven subjects, four 6-month-olds and three 12-month-olds.

For each subject, the proportion of trials on which Experimenters 1 and 2 agreed that a head turn occurred was determined for each of the four types of Change trials and the No Change Control trial. Reliability for Experimenter 1 and 2 scoring a head turn response on test trials, computed on 70% of the subjects equally divided among conditions, was 92% for 6-month-olds. Since the 12-month-olds were reinforced for responding to about 92% of the test trials regardless of condition, the exact reliability for Experimenters 1 and 2 scoring a head turn response was not computed.

Data Analysis

The behavioral data were analyzed using repeated measures analysis of variance, T-tests, approximations to the T-test, and Newman-Keuls paired comparison tests. The between-subject independent variables were: age (6- and 12- months) and group (Frequency-1, Frequency-2, Pattern-1, Pattern-2 and Temporal). The within-subject independent variable was type of test pattern (TP-A, TP-B, TP-C, TP-D, TP-E). Order of presentation of test patterns was counterbalanced within subjects, and across subjects within groups, and did not enter into any of the analyses. The dependent measures were: (1) proportion of head turn responses on trials (Change and No Change Control) as a function of test pattern, group, and trial block of Testing; (2) proportion of head turn responses on trials occurring during the first vs second repetition of the stimulus as a function of age, group, and trial block of Testing; (3) proportion of orienting head turns occurring during the first presentation of the background stimulus following an interblock interval as a function of age, group and trial block of the session; and (4) proportion of spontaneous head turns occurring during the remainder of the background stimulus as a function of age, group, and trial block of the session. Statistical analyses concerning head turns on Change trials were performed on the incidence of reinforced head turns, not head turns scored from the videorecords, although concordance between these two indices of discriminative responding was quite high (99.5%).

A minimal level of $P<.05$ was set as the required level of significance for each of the analyses. In performing cross-age T-test comparisons heterogeneity of variance was assumed, and an approximation to the Student's T-test was computed. This latter test utilizes separate, rather than pooled, variance estimates in calculating the T-value, and a corrected number of degrees of freedom in determining significance (SPSS, 1977, Pp.269-270). In performing within-age T-test comparisons Bonferroni T-values were used, in order to control for escalation of the error rate beyond the .05 level

(Myers, 1980). 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 such as the present in which several contrasts of interest were designated prior to the experiment (see Table 2).

CHAPTER IV

RESULTS

The results for each of the four dependent measures will be presented successively. Within each section the results from cross-age comparison tests will first be presented, followed by those from within-age tests.

Responding on Test Trials

No Change Control Trials. In order to determine if the incidence of head turning on No Change Control trials varied over blocks as a function of group and/or age, an age(2) x group(5) x block(5) repeated-measures analysis of variance (RM-ANOVA) was performed. The only significant result was the finding that the 12-month-olds responded on Control trials more than the 6-month-olds, 21% vs 10%, respectively ($F=11.97(1,90), p<.009$).

In order to determine if there were reliable differences in the incidence of responding on Control trials in comparison to Change trials, pairwise contrasts were performed for each age; T-test results appear in Appendix 2. For 12-month-olds, the average incidence of responding on Control trials (21%) was significantly less than that which occurred to each test pattern within every group (see Figures 6-10). In other words, the 12-month-olds reliably performed all discriminations. The same was true for the 6-month-olds with a few

Fig. 6. Proportion of Reinforced Head Turns on Test Trials at Each Age as a Function of Type of Test Pattern for the Frequency-1 Condition.

FIGURE 6

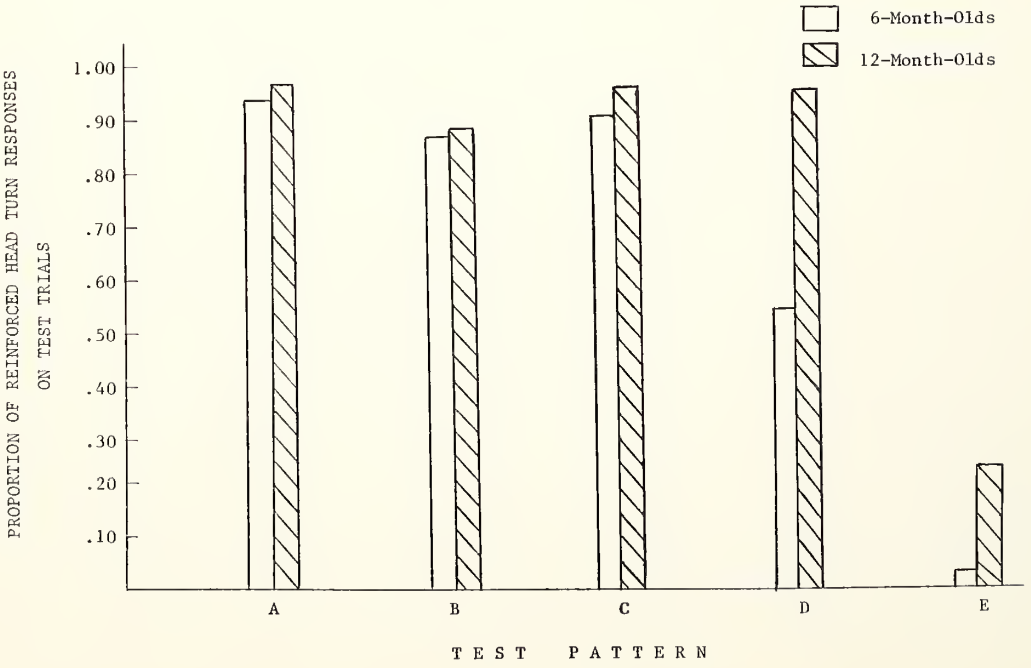

6-Month-Olds
12-Month-Olds
PROPORTION OF REINFORCED HEAD TURN RESPONSES ON TEST TRIALS
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
A
B
C
D
E
TEST PATTERN

Fig. 7. Proportion of Reinforced Head Turns on Test Trials at Each Age as a Function of Type of Test Pattern for the Frequency-2 Condition.

FIGURE 7

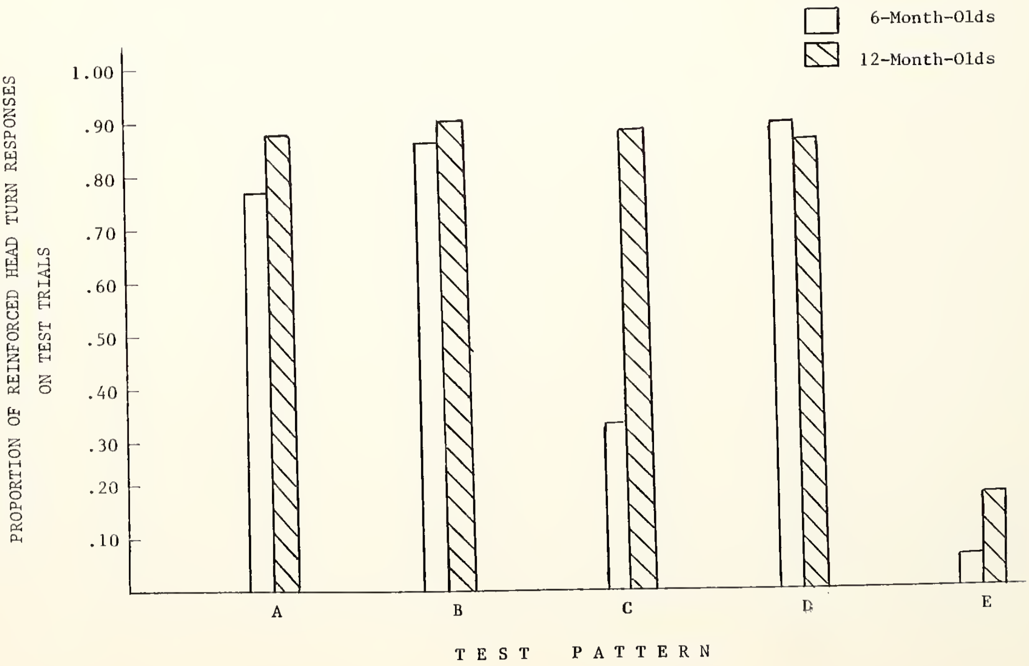

6-Month-Olds
12-Month-Olds
PROPORTION OF REINFORCED HEAD TURN RESPONSES ON TEST TRIALS
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
A
B
C
D
E
TEST PATTERN

Fig. 8. Proportion of Reinforced Head Turns on Test Trials at Each Age as a Function of Type of Test Pattern for the Pattern-1 Condition.

FIGURE 8

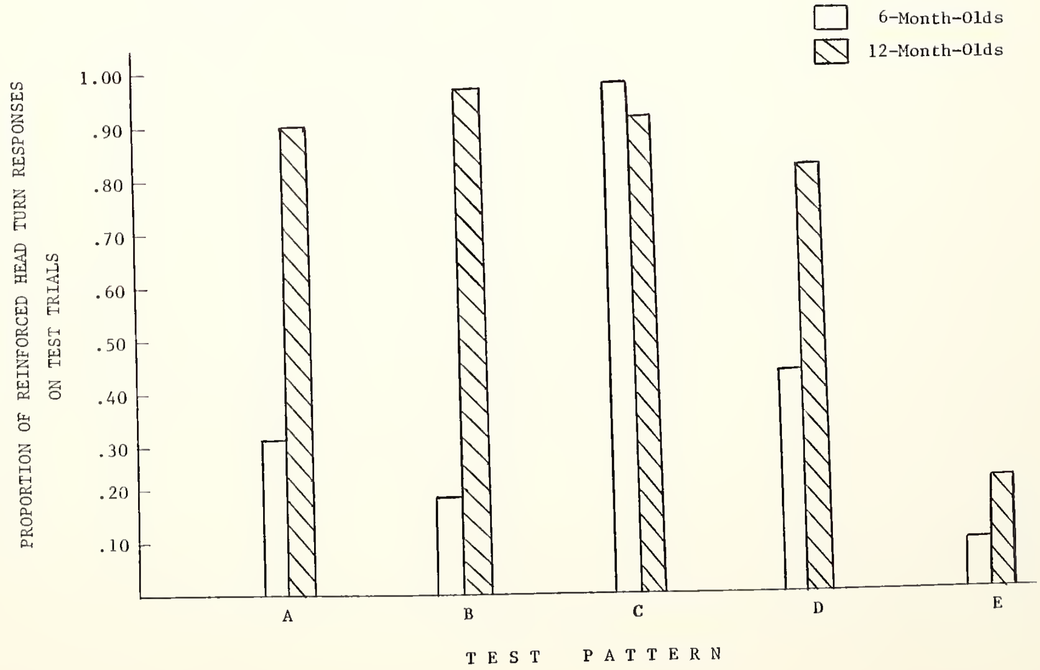

6-Month-Olds
12-Month-Olds
PROPORTION OF REINFORCED HEAD TURN RESPONSES ON TEST TRIALS
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
A
B
C
D
E
TEST PATTERN

Fig. 9. Proportion of Reinforced Head Turns on Test Trials at Each Age as a Function of Type of Test Pattern for the Pattern-2 Condition.

FIGURE 9

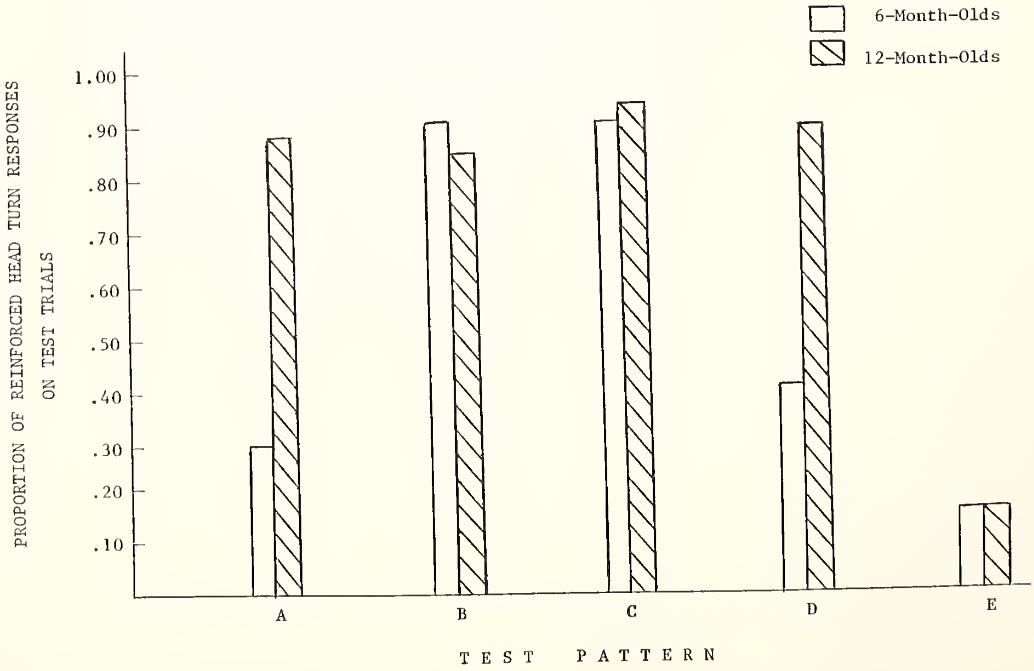
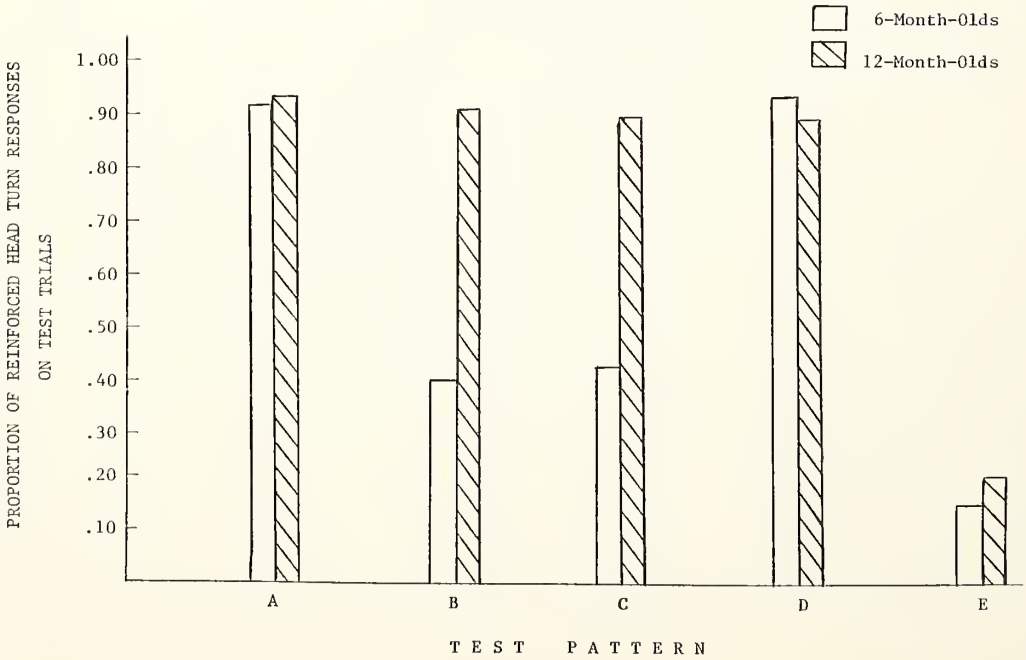

6-Month-Olds
12-Month-Olds
PROPORTION OF REINFORCED HEAD TURN RESPONSES ON TEST TRIALS
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
A
B
C
D
E
TEST PATTERN

Fig. 10. Proportion of Reinforced Head Turns on Test Trials at Each Age as a Function of Type of Test Pattern for the Temporal Condition.

FIGURE 10


6-Month-Olds
12-Month-Olds
PROPORTION OF REINFORCED HEAD TURN RESPONSES
ON TEST TRIALS
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
A
B
C
D
E
TEST PATTERN

important exceptions. Six-month-olds did not reliably discriminate pattern changes involving a re-sequencing of triads; for Pattern-1 (Figure 8), the incidence of responding to TP-C and TP-D, both of which involved a re-sequencing of triads, was comparable to that for Control trials. For Pattern-2 (Figure 9), responding to TP-D, which involved a re-sequencing of tones within each triad, did not differ from Control trials. Lastly, 6-month-olds did not reliably detect temporal pattern changes involving a change in the number of elements in a grouping; as can be seen in Figure 10, there was no difference in the incidence of responding on TP-C, TP-D, and Control trials.

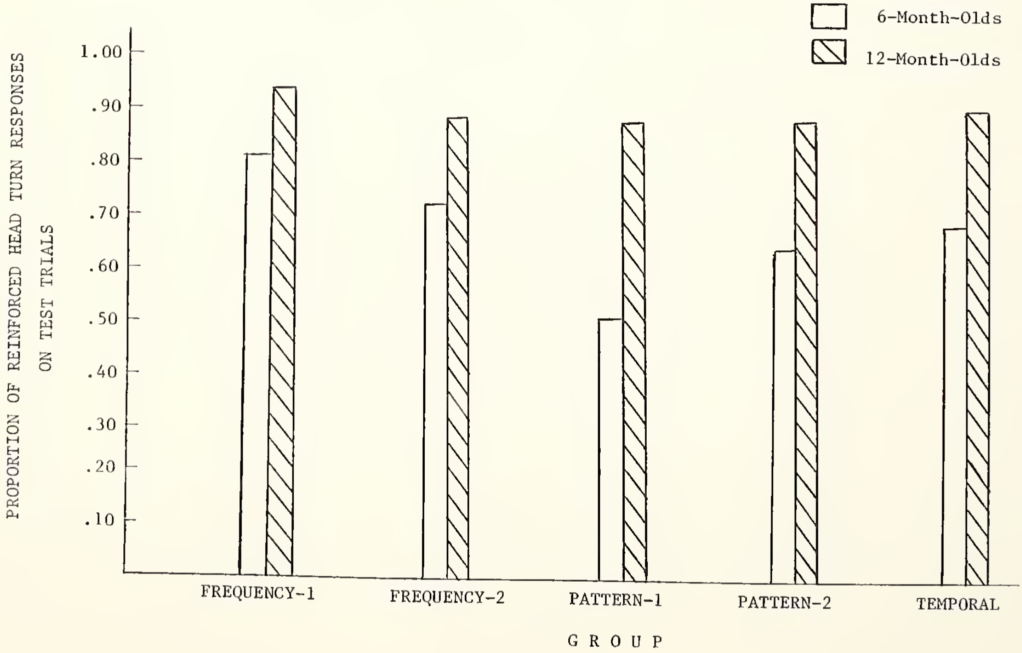
In summary, 6-month-olds responded reliably to each of the frequency discriminations, although they performed significantly less well on those frequency discrimination imposing the most stringent memory demands (Frequency-1: TP-D; Frequency-2: TP-D). They responded reliably on tonal pattern discriminations that involved a reversal of the ratio of high:low frequency tones, or a change in within triad variability (Pattern-1: TP-A, TP-B; Pattern-2: TP-B, TP-A, TP-C). However, responding on pattern discriminations that involved a change in the sequence of tones or triads and that imposed stringent memory demands was not above chance level (Pattern-1: TP-C, TP-D; Pattern-2: TP-D). Finally, 6-month-olds did not respond reliably to those subtle temporal discriminations that involved a change in the number of elements comprising a grouping (TP-C, TP-D), although they had no difficulty detecting changes in the number of groupings comprising a temporal pattern (TP-A, TP-B).

Change Trials: Group and Age Differences. In order to determine if the incidence of head turn responses on Change trials varied over blocks as a function of group and/or age, an age(2) x group(5) x blocks(5) RM-ANOVA was performed; the results of this analysis appear in Appendix 3. In general, 12-month-olds responded on Change trials more often than did the 6-month-olds (92% vs 67%, respectively), a reliable age difference (F=230.96(1,90), p<.00005). The magnitude of difference between the 6- vs 12- month-old's level of responding, however, varied over groups (Age x Group: F=8.03(4,90) p<.00005). As can be seen in Figure 11, the age difference was greatest for the Pattern-1 condition and least for the Frequency-1 condition (age difference = 40% and 14%, respectively). For each of the five conditions the 12-month-olds responded on test trials significantly more than did the 6-month-olds; T-test results appear in Appendix 3.

There was a fair amount of variability across groups in the incidence of responding on Change trials over blocks (Group x Block: F=2.73(16,360), p<.0005); see Figure 27 and trend test paired comparison results in Appendix 3. These results, while interesting, are not directly relevant to any of the proposed hypotheses and have little impact on the conclusions to be drawn from this study. The more important finding regarding group performance over blocks was the finding that there was not a reliable age x group x block interaction, which indicates that infants at each age showed a similar pattern of responding over test trial blocks as a function of group. Thus, the

Fig. 11. Proportion of Reinforced Head Turns on Change Trials at Each Age as a Function of Condition.

FIGURE 11


6-Month-Olds
12-Month-Olds
PROPORTION OF REINFORCED HEAD TURN RESPONSES ON TEST TRIALS
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
FREQUENCY-1
FREQUENCY-2
PATTERN-1
PATTERN-2
TEMPORAL
GROUP

age differences in responding for each group are not a result of changes in performance over blocks occurring differentially at one age (e.g., habituation of responding by the 6-month-olds).

In order to determine if the frequency of responding varied across groups at either age, a group(5) x block(5) RM-ANOVA was performed separately on the data of the 6- and 12- month-olds. Results indicated that the incidence of responding varied significantly across groups for the 6-month-olds ($F=13.5(4,45)$, $p<.00005$), but not for the 12-month-olds. On the average, 12-month-olds responded on 92% of the Change trials, regardless of group. Whereas, the incidence of responding by 6-month-olds varied over groups between 50% and 81% (see Figure 11). A Newman-Keuls test, performed on the 6-month-old data, revealed the following ordering of groups: (1) the Pattern-1 group showed the lowest incidence of responding (50%), and this was significantly less than that shown by each of the four other groups; (2) the Frequency-2, Pattern-2 and Temporal groups showed comparable amounts of responding (73%, 64%, and 68%, respectively); and (3) the Frequency-1 group showed the greatest amount of responding (81%), and this was significantly greater than that which occurred in each of the other groups, with the exception of Frequency-2. The Newman-Keuls table appears in Appendix 3.

Change Trials: Differences Within Groups. As mentioned previously, for 12-month-olds the incidence of responding did not vary as a function of group; infants in all groups responded on about 92% of the Change trials regardless of test pattern (see Figure 11). In contrast, 6-month-olds showed significant differences in the incidence of responding across groups, suggesting that they performed some discriminations better than others. In order to examine discrimination performance more closely, a test pattern(4) RM-ANOVA was performed separately on the data of each of the five groups of 6-month-olds. Results revealed that for each group the incidence of responding varied as a function of test pattern (see Appendix 3). Pairwise contrasts of the test patterns comprising each group revealed several interesting results (see Appendix 3); to facilitate understanding of the following discussion, the reader is referred to Table 1 for a description of the test patterns comprising each group.

Analysis of Frequency-1 group's data (Figure 6) indicated that infants 6-months of age are quite good at performing frequency discriminations regardless of where in the signal the change occurs (throughout or towards the end), or how much of the signal is affected (1/3 vs 2/3); these conclusions are based on the finding that infants responded reliably, and equally often, to TP-A (94%), TP-B (86%), and TP-C (91.5%). However, an intervening silence interval of 2 seconds (sec) between the background and Change pattern imposes a memory load sufficient to cause a significant decrement in 6-month-old infants' frequency discrimination performance; infants responded to TP-D (52%) significantly less than to TP-A, TP-B, and TP-C. For TP-A, TP-B, and TP-C infants can perform the frequency discriminations on the basis of comparison with the tone heard .2 or .6 sec earlier. For TP-D, however, infants must detect the frequency change after a 2 sec silence interval, and 6-month-olds apparently have difficulty with this. These results differed slightly from the hypothesized ordering of difficulty (see Table 2).

As can be seen in Figure 7, discrimination performance of the Frequency-2 group did not support the hypothesized ordering of test patterns (see Table 2). Results revealed that 6-month-olds are as capable of detecting a frequency change involving the deletion of a familiar frequency (TP-A, TP-B), as when the change involves a change in the ratio of high:low tones in one of the three triads (TP-C); infants responded reliably, and equally often, to TP-A (78%), TP-B (88%), and TP-C (91%). The results also provide additional evidence that a 2 sec silence interval between the background and change stimulus adversely affects 6-month-old infants' frequency discrimination performance; infants responded significantly less to TP-D (34%), in which a reversal of the ratio of high:low tones occurred in each triad, in comparison to each of the other three discriminations. Infants performed quite well to TP-C, which involved detection of a change in frequency composition between two successive triads (.6 sec intervening silence interval). Whereas, they performed quite poorly to the same discrimination when a 2 sec silence interval intervened between the background and change triad (TP-D).

Results for the Pattern-1 group (Figure 8) indicated that infants

6-months of age have difficulty performing pattern discriminations that involve a re-arrangement of the original tonal sequence (TP-C, TP-D), or a reversal of the ratio of high:low frequency tones comprising the sequence (TP-B); statistical tests indicated that there was no significant difference in the incidence of responding to TP-C (32.5%), TP-D (20.5%), and TP-B (42.5%). Although, it may be recalled that responding to TP-C and TP-D, which involved a re-arrangement of the original tonal sequence, was at chance level, whereas responding to TP-B, which involved a reversal of the ratio of high:low frequency tones, was low but reliably above chance level. Responding to TP-A (98%), which involved a change in within triad variability, was significantly higher than that which occurred to the three other test patterns, each of which required the infant to detect a change following an intervening silence interval of at least 2 sec duration. These results differed slightly from the hypothesized ordering of test patterns (see Table 2).

As can be seen in Figure 9, results for the Pattern-2 group replicated those cited earlier, indicating that infants 6-months of age have difficulty performing tonal pattern discriminations, particularly when a 2 sec silence interval intervenes between the background and change pattern (TP-C, TP-D). The incidence of responding to TP-D (30%) vs TP-C (41%) was not statistically significant. Although, responding to TP-D, which involved a change in the sequence of elements within each triad, was not above chance level, whereas responding to TP-C, which involved a reversal of the ratio of High:low tones in all three triads, was low but above chance level. Infants responded at comparable levels to TP-A (92%) vs TP-B (92%), both of which involved changes that affected only one of the three triads of a pattern. The incidence of responding to TP-A and TP-B was significantly greater than that which occurred to TP-C and TP-D. Apparently, whether the pattern change involves changes in the sequence of triads, as in Pattern-1, or in the sequence of elements within a triad, as in Pattern-2, makes little difference in terms of how well 6-month-olds perform pattern discrimination; if a 2 sec silence intervenes, then on both types of tonal pattern discriminations they perform poorly.

Results for the Temporal group (Figure 10) matched the hypothesized ordering of test patterns (see Table 2), and revealed that 6-month-olds are quite good at performing Temporal pattern discriminations when the number of grouping of elements are changed (TP-A, TP-B). However, discrimination performance is significantly poorer when the number of elements comprising a grouping changes (TP-C, TP-D); infants responded at comparable levels to TP-D (40.5%) vs TP-C (44.5%) and to TP-A (93.5%) vs TP-B (95.5%), and the incidence of responding to TP-A and TP-B was significantly greater than that which occurred to TP-C and TP-D, both of which were at chance level.

It had been hypothesized that for each condition developmental changes in the incidence of responding would occur, reflecting improved discrimination and/or memory abilities. As previously mentioned, reliable age differences in the incidence of responding were obtained for each group (see Appendix 3: Table 14). To determine if the incidence of responding varied for test patterns as a function of age, an age(2) x test pattern(4) RM-ANOVA was performed separately on the data of each of the groups. Results revealed reliable age differences for each group in responding to the four test patterns (see Appendix 3).

In order to determine which test patterns the 6- and 12-month-olds responded to differently, cross-age pairwise contrasts were performed; T-test results appear in Appendix 3. As can be seen in Figure 6, for Frequency-1, 12-month-olds', in contrast to 6-month-olds', discrimination performance was not at all adversely affected by a 2 sec memory load; 12-month-olds responded significantly more than 6-month-olds to TP-D. Figure 7 shows that for Frequency-2 12-month-olds responded significantly more than 6-month-olds to TP-A and TP-D, once again indicating that they have no difficulty performing discriminations that span a 2 sec silence interval. As can be seen in Figure 8, several age differences emerged for the test patterns comprising Pattern-1. Twelve-month-olds were quite good at performing tonal pattern discriminations, regardless of whether the change involved a change in the ratio of high:low frequency tones (TP-B) or a re-arrangement of the original tonal sequence (TP-C, TP-D); 12-month-olds responded significantly more than 6-month-olds to

TP-B, TP-C, and TP-D. Results from the Pattern-2 group once again indicated that, unlike the 6-month-olds, the 12-month-olds' pattern discrimination performance was not influenced by a 2 sec memory load. As can be seen in Figure 9, 12-month-olds responded significantly more than 6-month-olds to TP-C and TP-D. Lastly, for the Temporal groups, Figure 10 reveals significantly more responding to the temporal patterns involving a change in the number of elements in a grouping, that is TP-C and TP-D, by 12-month-olds in comparison to 6-month-olds.

Responding on Repetition 1 vs 2

In order to determine if the incidence of responding to Repetition 1 vs 2 of a stimulus varied over test trial blocks as a function of age and/or groups, an age(2) x group(5) x blocks(5) RM-ANOVA was performed; results from this analysis appear in Appendix 4. Results indicated that the incidence of responding over blocks to Repetition 1 vs 2 varied across groups as a function of age (Age x Group x Block: F=1.95(16,360), P<.0156); see Figures 28 and 29 in Appendix 4.

In order to determine if the incidence of responding to Repetition 1 vs 2 of the stimulus varied over blocks as a function of group at either age, a group(5) x block(5) RM-ANOVA was performed separately on the 6- and 12- month-old's data. Results revealed that the pattern of responding over blocks to Repetition 1 vs 2 of a stimulus did not vary as a function of group at either age (see

Figures 28 and 29, respectively). As can be seen in Figures 12-16, regardless of group, 6- and 12- month-olds responded to Repetition 1 of the stimulus about 72% and 65% of the time, respectively.

In order to determine if the two ages differed in responding to Repetition 1 vs 2 of a stimulus across blocks, an age(2) x block(5) RM-ANOVA was performed separately on the data of each condition. Results revealed reliable age differences in the incidence of responding over blocks to Repetition 1 vs 2 for the Pattern-2 condition (Block x Age: F=4.03(4,72), p<.0054); these age differences are shown in Figure 15. Six and 12-month-olds did not differ, however, in the incidence of responding over blocks to Repetition 1 vs 2 for the Frequency-1 (Figure 12), Frequency-2 (Figure 13), Pattern-1 (Figure 14), and Temporal (Figure 16) conditions. The average incidence of responding to Repetition 1 for the 6- vs 12- month-olds was: 90.5% vs 78% for Frequency-1; 73% vs 66.5% for Frequency-2; 65.5% vs 62% for Pattern-1; 70% vs 62% for Pattern-2; and 61% vs 59% for the Temporal condition.

Although there was not a reliable age effect indicating significantly greater responding to Repetition 1 of a test pattern by 6-, in contrast to 12-, month-olds, this pattern of differences was present across each of the five conditions. Reviewing the videorecords of each infant it was apparent that upon detecting the test stimulus (i.e., alerting and revealing facial expressions suggestive that they had detected the test stimulus), 6-month-olds,

Fig. 12. Proportion of Reinforced Head Turns to Repetition 1 of a Stimulus Pattern at Each Age as a Function of Test Trial Block for the Frequency-1 Condition.

FIGURE 12

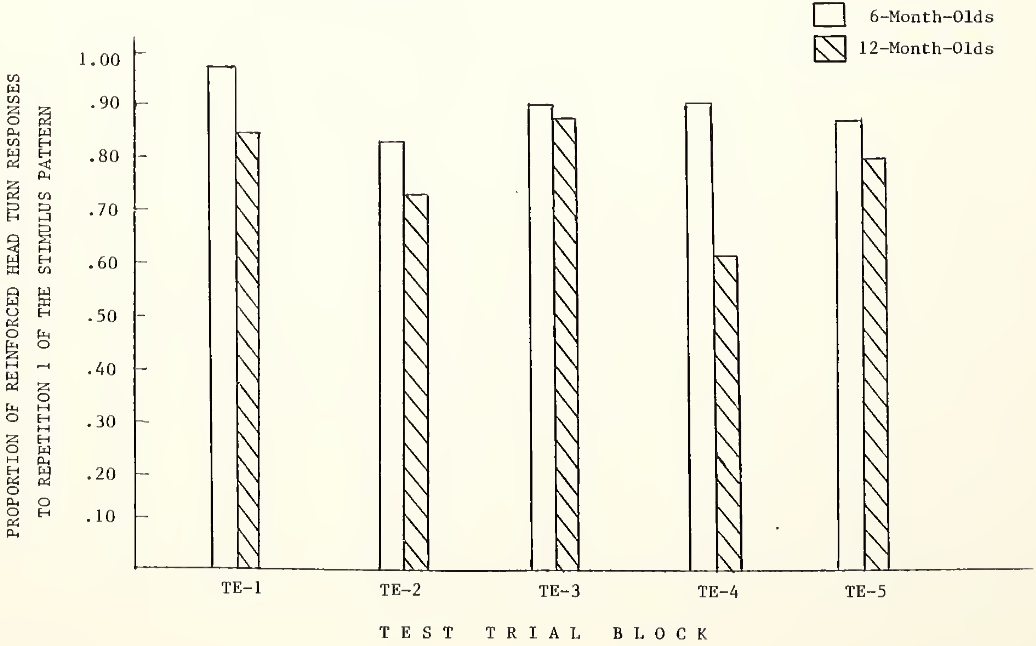

6-Month-Olds
12-Month-Olds
PROPORTION OF REINFORCED HEAD TURN RESPONSES
TO REPETITION 1 OF THE STIMULUS PATTERN
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
TE-1
TE-2
TE-3
TE-4
TE-5
TEST TRIAL BLOCK

Fig. 13. Proportion of Reinforced Head Turns to Repetition 1 of a Stimulus Pattern at Each Age as a Function of Test Trial Block for the Frequency-2 Condition.

FIGURE 13

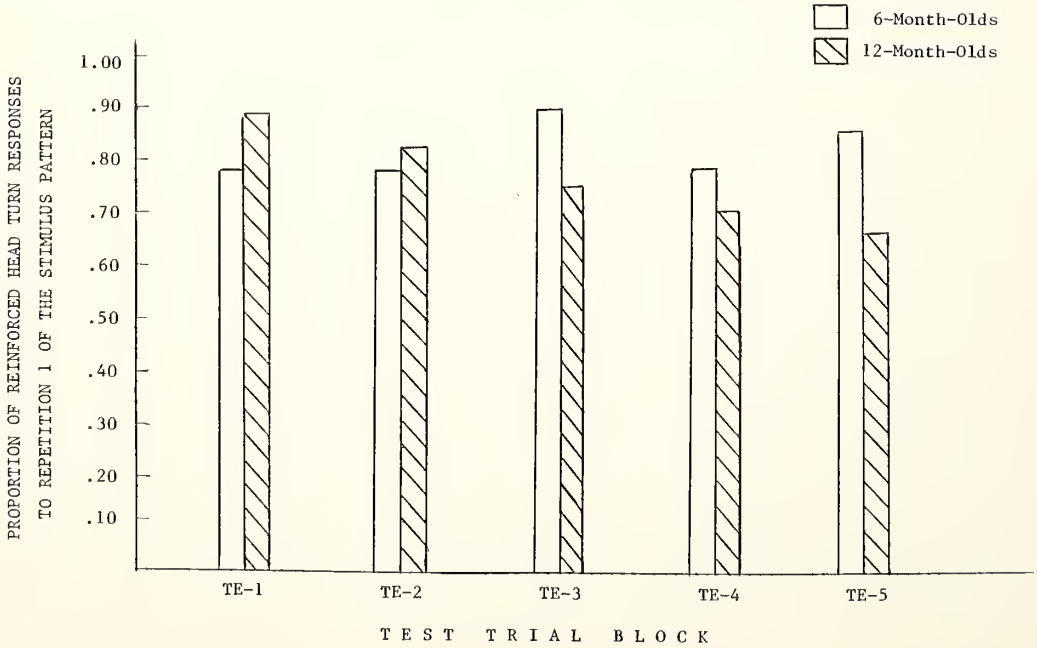

6-Month-Olds
12-Month-Olds
PROPORTION OF REINFORCED HEAD TURN RESPONSES
TO REPETITION 1 OF THE STIMULUS PATTERN
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
TE-1
TE-2
TE-3
TE-4
TE-5
TEST TRIAL BLOCK

Fig. 14. Proportion of Reinforced Head Turns to Repetition 1 of a Stimulus Pattern at Each Age as a Function of Test Trial Block for the Pattern-1 Condition.

FIGURE 14

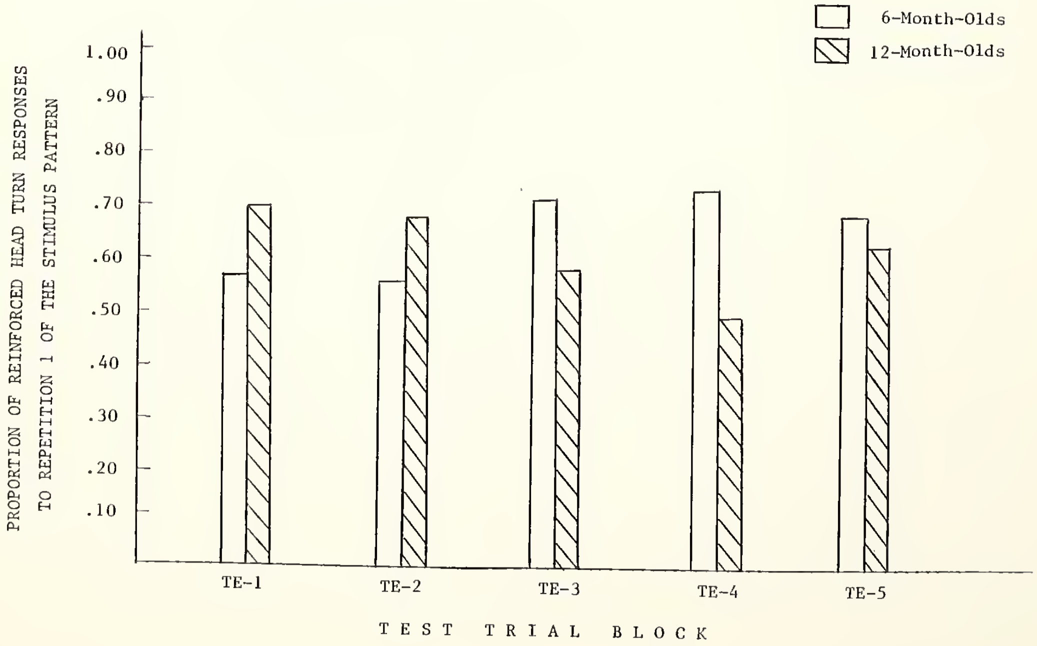

6-Month-Olds
12-Month-Olds
PROPORTION OF REINFORCED HEAD TURN RESPONSES
TO REPETITION 1 OF THE STIMULUS PATTERN
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
TE-1
TE-2
TE-3
TE-4
TE-5
TEST TRIAL BLOCK

Fig. 15. Proportion of Reinforced Head Turns to Repetition 1 of a Stimulus Pattern at Each Age as a Function of Test Trial Block for the Pattern-2 Condition.

FIGURE 15

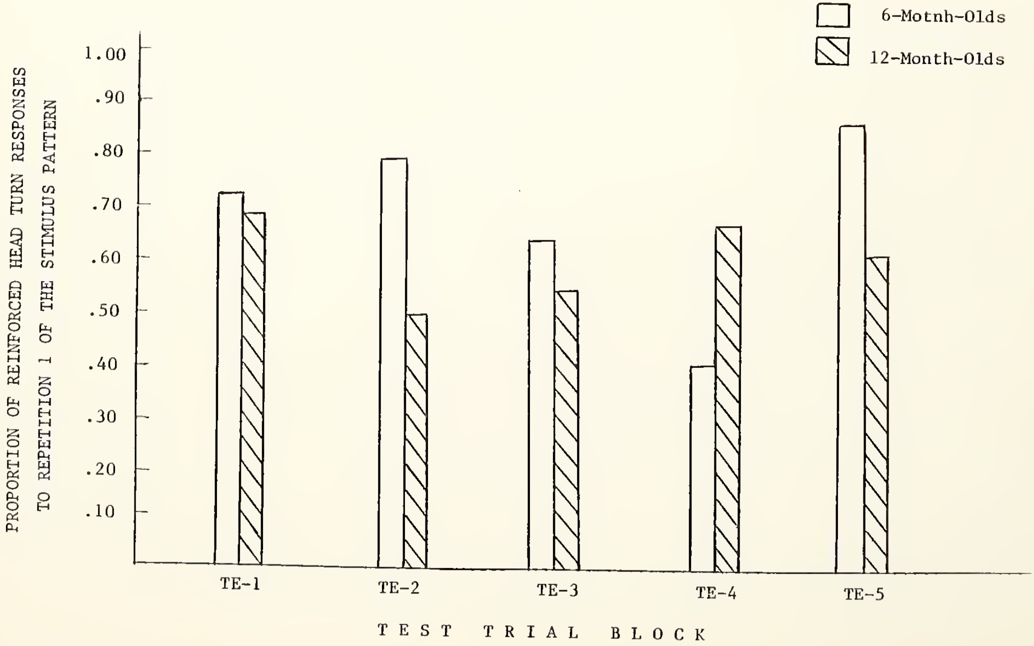
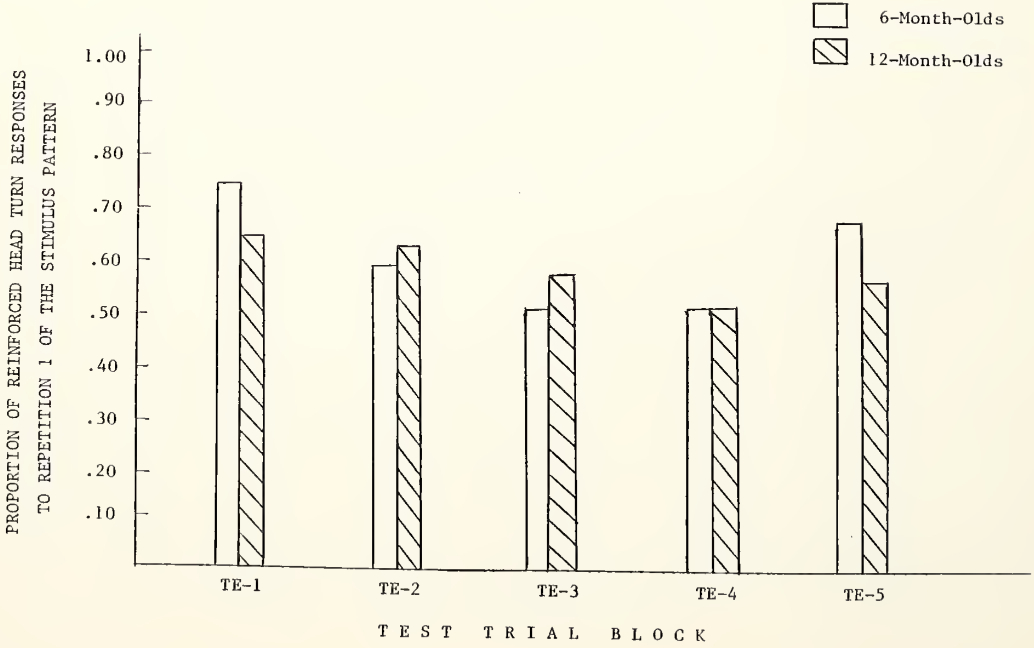

6-Motnh-Olds
12-Month-Olds
PROPORTION OF REINFORCED HEAD TURN RESPONSES TO REPETITION 1 OF THE STIMULUS PATTERN
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
TE-1
TE-2
TE-3
TE-4
TE-5
TEST TRIAL BLOCK

Fig. 16. Proportion of Reinforced Head Turns to Repetition 1 of a Stimulus Pattern at Each Age as a Function of Test Trial Block for the Temporal Condition.

FIGURE 16


6-Month-Olds
12-Month-Olds
PROPORTION OF REINFORCED HEAD TURN RESPONSES
TO REPETITION 1 OF THE STIMULUS PATTERN
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
TE-1
TE-2
TE-3
TE-4
TE-5
TEST TRIAL BLOCK

more often than 12-month-olds, immediately disengaged from Experimenter 1 and showed head orientation toward the signal loudspeaker and visual reinforcer. In contrast, 12-month-olds more slowly disengaged from Experimenter 1 and the toys provided in order to orient toward the signal loudspeaker and visual reinforcer.

Spontaneous Head Turns

In order to determine if the incidence of spontaneous head turns varied over Training and Test trial blocks as a function of group and/or age, an age(2) x group(5) x block(7) RM-ANOVA was performed; the results appear in Appendix 5. Twelve-month-olds generally made more spontaneous head turns than 6-month-olds, 9% vs 6%, respectively; a significant age difference ($F=33.03(1,90)$, $p<.00005$).

As shown in Figures 17-21, the incidence of spontaneous head turns over blocks varied across groups as a function of age (Age x Group x Block:$F=2.17(24,540)$, $p<.0011$). In fact, analyzing separately the data of each condition revealed that for each group the incidence of spontaneous head turns varied over blocks as a function of age (see Appendix 5). Inspection of this data revealed that for each condition the difference in the incidence of spontaneous head turns between Training Block 1 and 2 was greater for the 6- than for the 12-month-olds. The differences for the 6- and 12- month-olds, respectively were: 7% vs 5% for Frequency-1; 16% vs 3% for Frequency-2; 13% vs 5% for Pattern-1; 10% vs 2% for Pattern-2; and 12% vs .1% for the Temporal condition.

Fig. 17. Proportion of Spontaneous Head Turns at Each Age as a Function of Training (TR) and Test (TE) Trial Block for the Frequency-1 Condition.

FIGURE 17

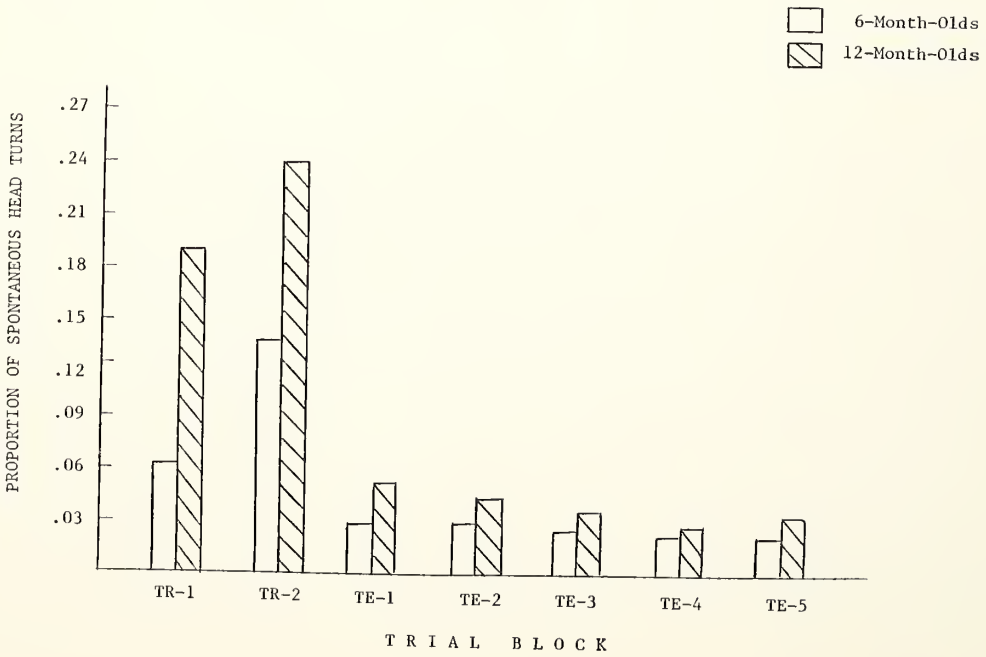

6-Month-Olds
12-Month-Olds
PROPORTION OF SPONTANEOUS HEAD TURNS
.27
.24
.21
.18
.15
.12
.09
.06
.03
TR-1
TR-2
TE-1
TE-2
TE-3
TE-4
TE-5
TRIAL BLOCK

Fig. 18. Proportion of Spontaneous Head Turns at Each Age as a Function of Training (TR) and Test (TE) Trial Block for the Frequency-2 Condition.

FIGURE 18

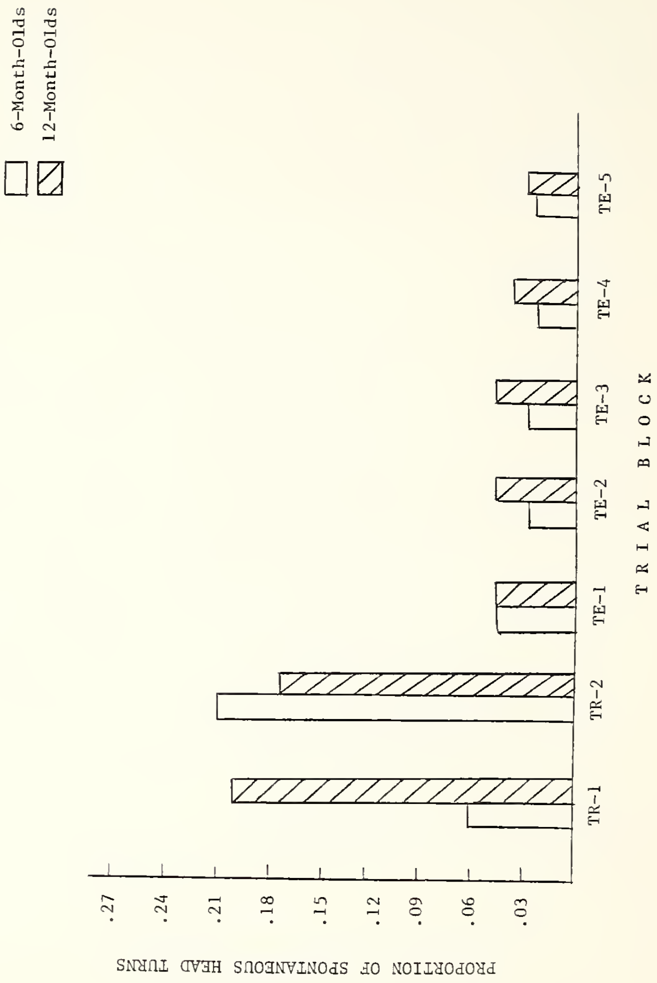

☐ 6-Month-Olds
▨ 12-Month-Olds
PROPORTION OF SPONTANEOUS HEAD TURNS
.27
.24
.21
.18
.15
.12
.09
.06
.03
TR-1
TR-2
TE-1
TE-2
TE-3
TE-4
TE-5
TRIAL BLOCK

Fig. 19. Proportion of Spontaneous Head Turns at Each Age as a Function of Training (TR) and Test (TE) Trial Block for the Pattern-1 Condition.

FIGURE 19

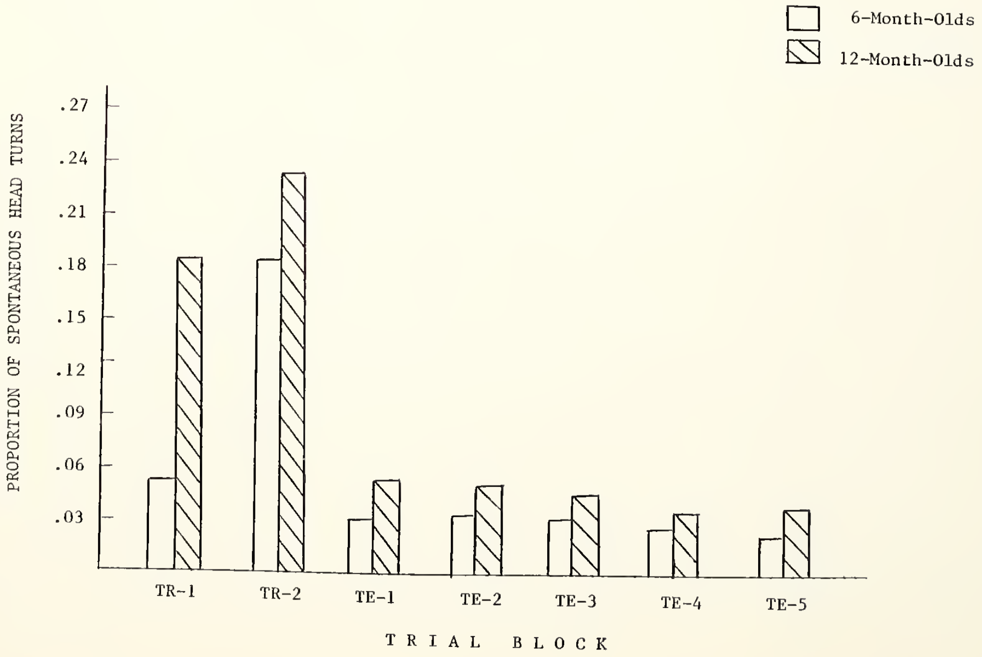

6-Month-Olds
12-Month-Olds
PROPORTION OF SPONTANEOUS HEAD TURNS
.27
.24
.21
.18
.15
.12
.09
.06
.03
TR-1
TR-2
TE-1
TE-2
TE-3
TE-4
TE-5
TRIAL BLOCK

Fig. 20. Proportion of Spontaneous Head Turns at Each Age as a Function of Training (TR) and Test (TE) Trial Block for the Pattern-2 Condition.

FIGURE 20

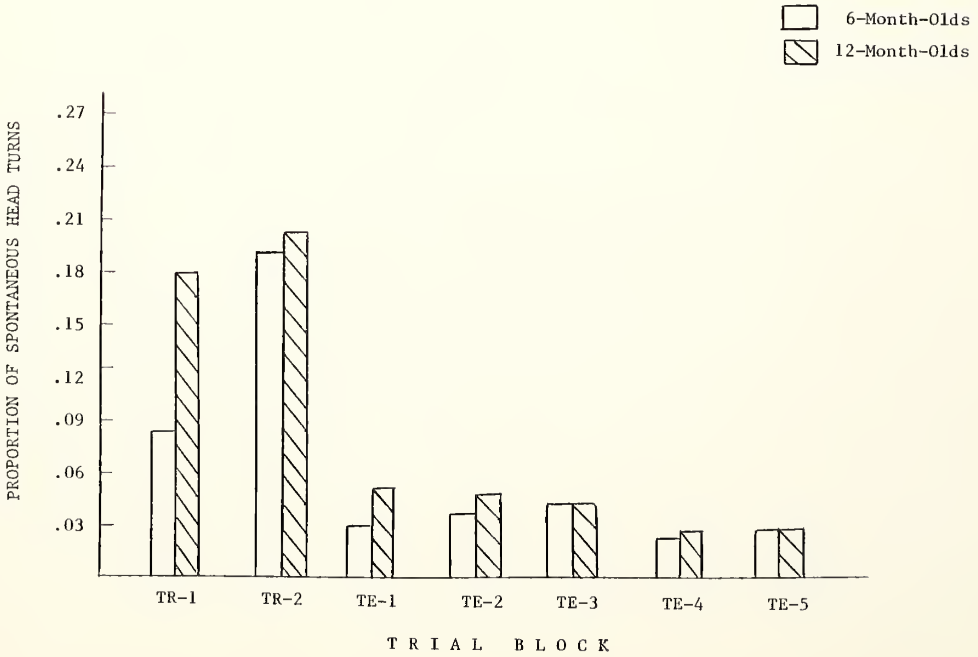
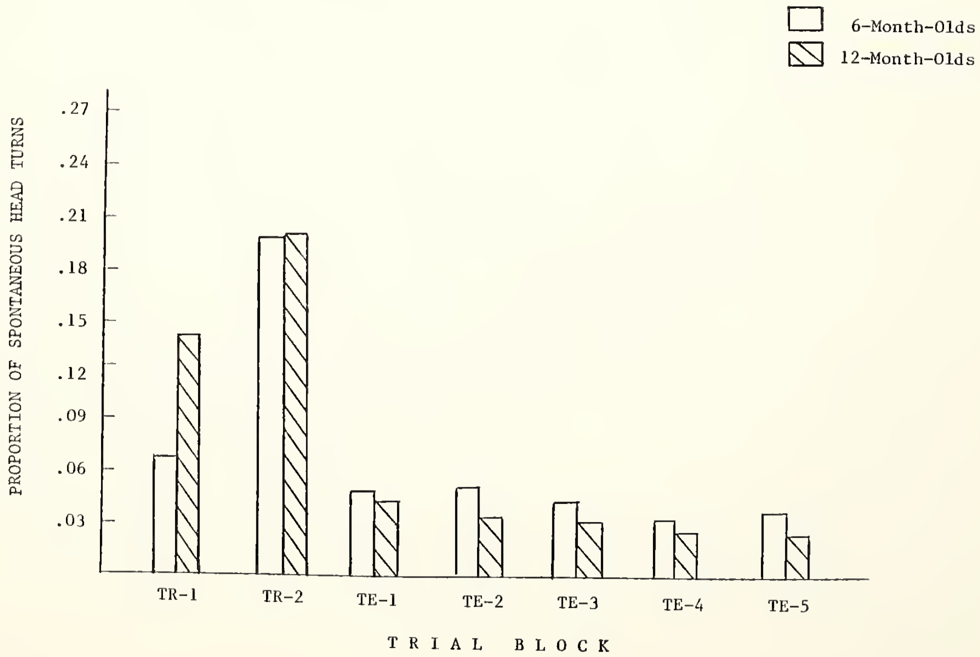

□ 6-Month-Olds
▨ 12-Month-Olds
PROPORTION OF SPONTANEOUS HEAD TURNS
.27
.24
.21
.18
.15
.12
.09
.06
.03
TR-1
TR-2
TE-1
TE-2
TE-3
TE-4
TE-5
TRIAL BLOCK

Fig. 21. Proportion of Spontaneous Head Turns at Each Age as a Function of Training (TR) and Test (TE) Trial Block for the Temporal Condition.

FIGURE 21


☐ 6-Month-Olds
▨ 12-Month-Olds
PROPORTION OF SPONTANEOUS HEAD TURNS
.27
.24
.21
.18
.15
.12
.09
.06
.03
TR-1
TR-2
TE-1
TE-2
TE-3
TE-4
TE-5
TRIAL BLOCK

In order to determine if the incidence of spontaneous head turns over blocks varied as a function of group within each age, a group(5) x block(7) RM-ANOVA was performed separately on the 6- and 12-month-old data. For 6-month-olds, the incidence of spontaneous head turns over blocks did not vary as a function of condition. As shown in Figure 22, there were comparable changes in the incidence of spontaneous head turns over blocks for all groups, as indicated by a reliable block effect ($F=116.09(6,270)$, $p<.00005$), with a supporting quadratic trend over blocks reflecting their showing an increase in spontaneous head turning during Training followed by a decrease in spontaneous head turns over Testing blocks ($F=9.34(1,45)$, $p<.0039$). In contrast, Figure 23 shows that for the 12-month-olds the incidence of spontaneous head turns over blocks varied across groups (Block x group:$F=1.76(24,270)$, $p<.0174$). The results of trend test comparisons of group performance over blocks appear in Appendix 5.

As can be seen in Figure 22 and 23, several consistent patterns emerged regarding the incidence of spontaneous head turns over blocks at each age. There was a strong tendency for infants, particularly the 6-month-olds, to show an increase in the incidence of spontaneous head turns during Training. This apparently reflected their interest in observing the visual reinforcer, and probably made important contributions to their learning the stimulus-response contingency. In learning the task it would seem equally important to recognize the conditions under which a head turn results in the visual reinforcer

Fig. 22. Proportion of Spontaneous Head Turns by 6-Month-Olds in Each Condition as a Function of Training (TR) and Test (TE) Trial Block.

FIGURE 22

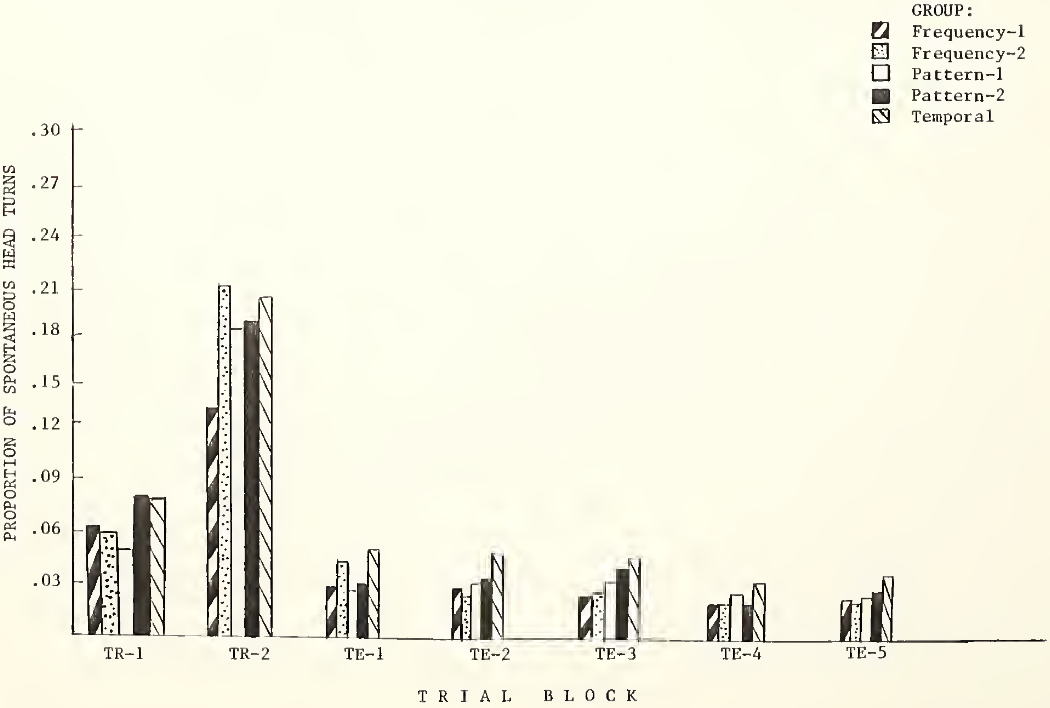
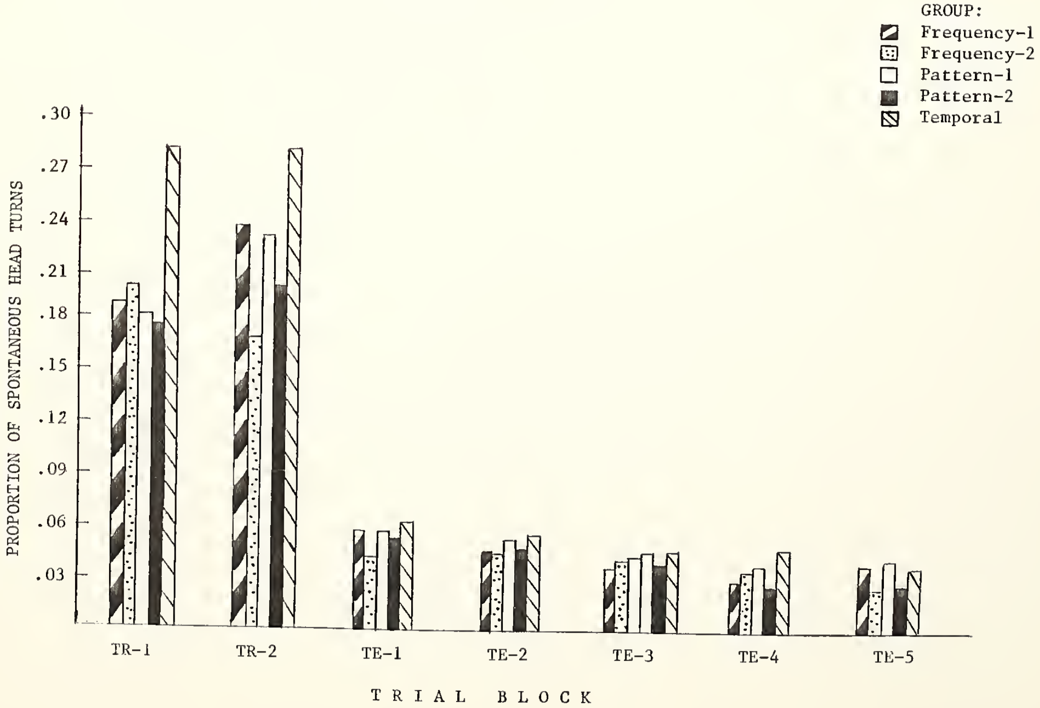

GROUP:
Frequency-1
Frequency-2
Pattern-1
Pattern-2
Temporal
PROPORTION OF SPONTANEOUS HEAD TURNS
.30
.27
.24
.21
.18
.15
.12
.09
.06
.03
TR-1
TR-2
TE-1
TE-2
TE-3
TE-4
TE-5
TRIAL BLOCK

Fig. 23. Proportion of Spontaneous Head Turns by 12-Month-Olds in Each Condtion as a Function of Training (TR) and Test (TE) Trial Block.

FIGURE 23


GROUP:
Frequency-1
Frequency-2
Pattern-1
Pattern-2
Temporal
PROPORTION OF SPONTANEOUS HEAD TURNS
.30
.27
.24
.21
.18
.15
.12
.09
.06
.03
TR-1
TR-2
TE-1
TE-2
TE-3
TE-4
TE-5
TRIAL BLOCK

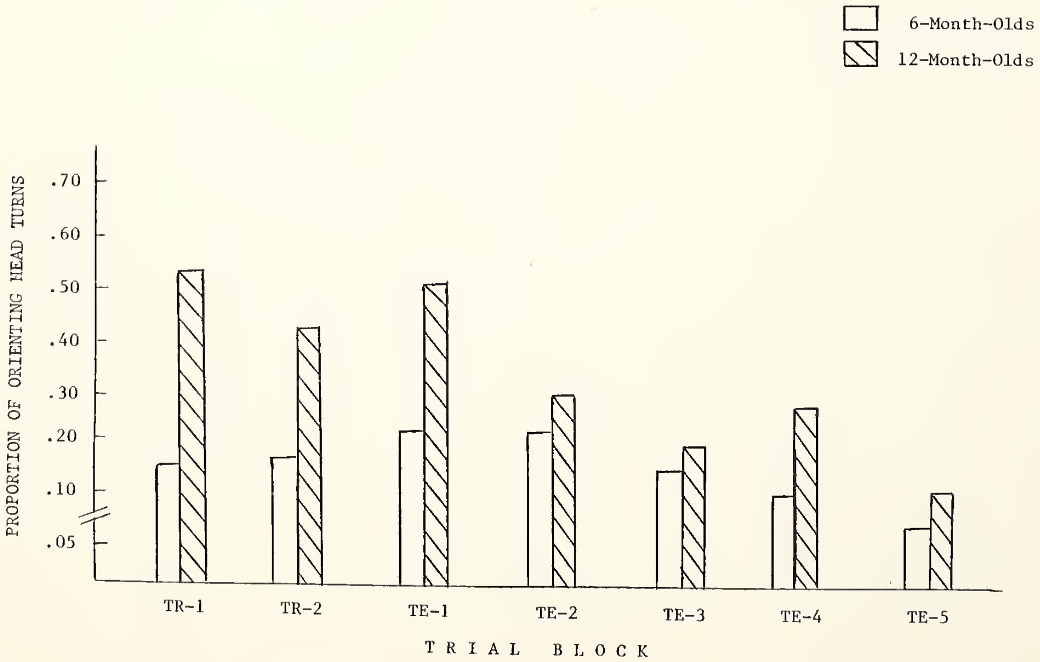
and those conditions under which a head turn produces no observable effect. Subsequent to this increase in spontaneous head turn level during Training Block 2, there was a drop in the incidence of spontaneous head turns in Testing Block 1, presumably reflecting learning of the contingency. Over the five testing blocks infants tended to show a decrement in the incidence of spontaneous head turns, which suggests that infants at both ages remembered the contingency over the course of the test session, even in those groups where the 6-month-olds performed poorly on several of the discrimination types, thus having minimal exposure to the visual reinforcer (e.g., Pattern-1, Pattern-2, Temporal).

Orienting Head Turns

In order to determine if the incidence of orienting head turns varied over Training and Testing blocks as a function of group and/or age, an age(2) x group(6) x block(7) RM-ANOVA was performed (see Appendix 6). In general, 12-month-olds showed more orienting head turns than 6-month-olds, 34% vs 15%,respectively (see Figure 24), which was a reliable age difference (F=15.99(1,90), p<.0002). The incidence of orienting head turns varied over blocks, however, as a function of age, with this difference being in the linear trend over blocks. Although infants at each age showed a reliable decrement in the incidence of orienting head turns over blocks (see Appenidix 6), the magnitude of the decline over blocks differed across age, the

Fig. 24. Proportion of Orienting Head Turns Averaged Over Conditions at Each Age as a Function of Training (TR) and Test (TE) Trial Block.

FIGURE 24


6-Month-Olds
12-Month-Olds
PROPORTION OF ORIENTING HEAD TURNS
.70
.60
.50
.40
.30
.20
.10
.05
TR-1
TR-2
TE-1
TE-2
TE-3
TE-4
TE-5
TRIAL BLOCK

12-month-olds showing a greater decline in orienting head turns over blocks, relative to the 6-month-olds (Age x Block:F=2.98(6,540), p<.0073; Linear:F=8.29(1,90), p<.0051).

Summary of the Results

The following is a summary of the major results:

(1) Infants 6- and 12- months of age had no difficulty performing frequency discriminations that involved either the addition of a novel frequency tone, or, the deletion of a familiar frequency tone. These results did not support the hypothesis that younger infants would perform more poorly than older infants on frequency discriminations involving the deletion of a familiar frequency tone.

(2) There was no clear evidence of a developmental change in auditory sequencing discrimination abilities for tonal patterns between infants 6- and 12- months of age. Twelve-month-olds were capable of performing discriminations when pattern changes involved changes in the sequence of triads (Pattern-1), or, changes in the sequence of elements within triads (Pattern-2). Six-month-olds showed more limited capacities to perform those pattern discriminations that involved a change in the sequence of elements within a triad when the pattern change occurred following a 2 sec intervening silence interval, although 6-month-olds performed these discriminations as well as the 12-month-olds when the pattern change occurred following a .6 sec intervening silence interval. Six-month-olds did not respond

reliably on those pattern discriminations that involved a re-sequencing of the triads comprising a pattern. But, this performance deficit most likely reflected their inability to overcome the memory load these discrimination conditions imposed, and not their inability to perform tonal sequence discriminations per se.

(3) Developmental changes in temporal pattern perception were obtained. Twelve-month-olds were capable of performing pattern discriminations when pattern changes involved changes in the number of element groupings (TP-A, TP-D), or, changes in the number of elements within each grouping (TP-C, TP-D). Six-month-olds were capable of performing temporal pattern discriminations involving changes in the number of element groupings, but performed at chance level at detecting the more subtle pattern changes that involved variation in the number of elements comprising each grouping. These results are consistent with the hypothesis that younger infants would not perform as well as older infants on the more subtle temporal pattern discriminations (TP-C, TP-D).

(4) Developmental changes in memory constraints also emerged. Each of the frequency and tonal pattern discrimination conditions contained at least one test pattern that required the infant to detect a change in triad over a 2 sec silence interval. Twelve-month-olds had no difficulty performing these discriminations. However, 6-month-olds' performance was significantly poorer on those frequency and pattern discrimination conditions imposing a memory load. These results are

consistent with the hypothesis that younger infants, in comparison to older infants, would perform more poorly on those discriminations imposing more stringent memory demands.

(5) Infants at each age responded to Repetition 1 of a test pattern more often than Repetition 2, and the incidence of responding over test trial blocks to Repetition 1 of a stimulus did not vary, at either age, as a function of group.

(6) The incidence of spontaneous head turns varied over blocks. All infants, with the exception of 12-month-olds in the Frequency-1 group, showed an initial increase in spontaneous head turn level as they were learning the task during Training, and an abrupt decrease in spontaneous head turn level between Training and Testing, presumably reflecting their having learned the stimulus-response-reinforcer contingency. The 12-month-olds in the Frequency-2 group showed a high level of spontaneous head turn level throughout Training, and an abrupt decrease in spontaneous head turn level between Training and Testing.

(7) Generally, 12-month-olds made more orienting head turns than 6-month-olds. Infants at each age showed a decrease in orienting head turns over blocks, however, this linear decrement over blocks was significantly greater for the 12-month-olds, in comparison to the 6-month-olds.

CHAPTER V

DISCUSSION

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

Frequency Discrimination

It had been hypothesized that younger infants, in comparison to older infants, would perform poorly on those frequency discriminations that involved the deletion of a familiar frequency tone. This hypothesis was based on the premise that the younger infants were more immature cortically, and that an intact, developed cortex was necessary for performing 'drop-out' frequency discriminations (Diamond et al, 1962). Six month-olds were expected to perform as well as 12-month-olds on those frequency discriminations that involved the addition of a novel frequency tone and did not impose stringent memory demands.

The results from the present investigation did not provide any evidence that 6-month-olds performed more poorly than 12-month-olds on drop-out frequency discriminations. If an intact, developed cortex is essential to performing drop-out frequency discriminations, as the non-human animal data suggests, then the present results would indicate that the cortex is sufficiently developed by 6-months of age to support performance of such frequency discriminations.

In reviewing the developmental literature one finds evidence that infants can perform frequency discriminations that involve the addition of a novel frequency tone as early as in the newborn period (see review in Appleton, Clifton and Goldberg, 1975). The present study provides the first demonstration that infants can perform drop-out frequency discriminations. Future studies might seek to examine drop-out frequency discrimination abilities in newborns and infants younger than 6-months of age, in an effort to determine if there are developmental changes in infants' ability to perform drop-out frequency discriminations, relative to infants' performance on discriminations involving the addition of a novel frequency tone. In the present study, infants 6- and 12- months of age performed equally well on drop-out frequency discriminations and discriminations involving the addition of a novel frequency tone.

Tonal Pattern Discrimination

It had been hypothesized that younger infants, in comparison to older infants, would perform successfully on only the easiest of the tonal pattern discriminations, if any. The easier tonal pattern discriminations were considered to be those in which: (1) the ratio of high:low frequency tones was reversed (Frequency-2: TP-C, TP-D Pattern-1: TP-B; Pattern-2: TP-C); and (2) the pattern change resulted in a change in within triad variability (Pattern-1: TP-A, Pattern-2: TP-A). Due to more limited cortical development the 6-month-olds, in contrast to the 12-month-olds, were not expected to perform the more difficult tonal pattern discriminations that involved either a re-sequencing of triads (Pattern-1: TP-C, TP-D) or a re-sequencing of elements comprising a triad (Pattern-2: TP-B, TP-D). ,pp The results obtained provided some support for this hypothesis, and revealed significant memory influences on the younger infants's sequence discrimination performance. On the simple pattern discriminations, which involved a change in within triad variability or in the ratio of high:low frequency tones, six month-olds responded at very high levels when the pattern changes occurred over a .6 sec intervening silence interval. However, for those simple pattern discriminations that required them to detect a change in pattern over a 2 sec silence interval, they responded reliably, but at significantly lower levels. Twelve-month-olds responded at very high levels on each of the simple tonal pattern discriminations, regardless of whether the pattern change occurred following a .6 or 2 sec intervening silence interval.

On the more difficult tonal pattern descriminations, which involved a re-sequencing of either triads or elements comprising a triad, 6-month-olds did not respond reliably if the pattern change occurred following a 2 sec intervening silence interval. Although, they had no difficulty detecting a change in the order of elements comprising a triad when these pattern changes occurred following a .6 sec silence interval (Pattern-2: TP-B). In contrast, 12-month-olds responded at comparably high levels to each of the more difficult pattern discriminations, regardless of whether the pattern change occurred following a .6 sec or 2 sec intervening silence interval.

The results indicate that the 6-month-old's pattern discrimination performance was more adversely affected by the memory demands of the task than was the 12-month- old's discrimination performance. Infants at both ages showed comparable levels of responding for tonal pattern discriminations that did not impose stringent memory demands. If an intact, developed cortex is necessary for performing tonal pattern discriminations, as the non-human animal data indicate, then the present results suggest that the cortex is sufficiently developed by 6-months of age to support performance of such pattern discriminations.

Earlier research on infant auditory perception abilities suggested that young infants could detect changes in the order of presentation of successive acoustic events. In several of these studies, however, infants may have been responding to a change in the first element only (Horowitz, 1972; Melson and McCall, 1970); thus, these studies do not constitute a true test of infants' tonal pattern perception abilities. Of the remaining studies, the most relevant, for purposes of comparison with the present study, is an investigation by Chang and Trehub (1977) in which they obtained evidence that 5-month-old infants could discriminate a change in the order of presentation of at least the first two elements in a 6-tone pattern. The present results suggest that under certain listening conditions infants 6- and 12- months of age can detect a change beyond the first two elements of a pattern (e.g., Pattern-1: TP-B).

Temporal Pattern Discrimination

It had been hypothesized that 6-month-olds, in contrast to 12-month-olds, would perform only the easiest of the temporal pattern discriminations, namely those that involved a change in the number of groupings (TP-A, TP-B). Due to more limited cortical development, it was expected that 6-month-olds, in contrast to 12-month-olds, would perform poorly on the more subtle temporal pattern discriminations involving a change in the number of elements comprising a grouping (TP-C, TP-D). To perform the former type of discrimination, infants need to abstract information about the overall temporal configuration of the pattern (e.g., that it comprises three groups of events), and to detect a change in this temporal configuration (e.g., a change to two groups of elements). To perform the latter type of discrimination, however, infants must have abstracted not only the overall temporal configuration of the pattern, but the details as well, namely how many elements comprise each of the three groupings. This type of discrimination demands greater temporal resolution by the auditory stimulus and an integration of auditory skills, and thus was considered to be a more difficult discrimination than the mere detection of a change in the number of groupings of elements.

The results obtained supported the hypothesized order of difficulty of these two types of temporal discriminations. Six-month-olds did not respond reliably to those temporal pattern discriminations that involved a change in the number of elements comprising a grouping, although they performed as well as 12-month-olds in reliably discriminating changes in the number of groupings. Twelve-month-olds discriminated both types of pattern change, performing at comparably high levels to all temporal pattern discriminations. If an intact, developed cortex plays an important role in the perception of temporal patterns, then the present results suggest that there are cortical changes between 6- and 12- months of age which result in improved abilities to process temporal patterns. Although 6-month-olds obviously abstracted information regarding the overall temporal configuration of a pattern, they apparently did not differentiate groupings of elements as well as 12-month-old listeners.

The results from the present study differ somewhat from those obtained by Chang and Trehub (1977) in which 5-month-olds discriminated reliably between a 4-2 and 2-4 temporal grouping. However, there are several important differences between these two investigations, which may be responsible for the variation in results obtained. Perhaps, the most significant difference is the type of stimulus patterns used in each study. In the present study a pattern played for 4.2 sec and comprised three groupings of elements. This type of stimulus complex is presumably more difficult for infants to process and keep in auditory short-term memory than that used by Chang and Trehub in which a pattern played for 1.8 sec and comprised only two groupings of elements. Moreover, the type of sound differed in the two investigations. In the present study, white noise bursts were used in order to assess temporal pattern perception abilities independent of an infant's ability to process the spectral aspects of the auditory signal. In contrast, Chang and Trehub used a set of six pure tones occupying two octaves, one below and one above middle C (523 Hz). These six tones were grouped into a 2-4 pattern and on change trials infants received the same tonal sequence with a change to a 4-2 grouping. Under these circumstances it is possible that detection of a change in frequency contour (i.e., the pattern of rising and falling frequencies over time) contributed to infants' temporal pattern perception performance. Finally, the two studies differed in the kind of response measures utilized. The present study employed a conditioned head-turn paradigm in evaluating infant temporal pattern discrimination abilities; whereas, Chang and Trehub utilized cardiac measures of discriminative responding. It is possible the different response measures could be differentially sensitive in reflecting temporal pattern discrimination abilities in young infants, although there is no direct evidence on this topic at the present time.

Demany et al (1977), in Experiment 3, found that 2 1/2-month-olds reliably discriminated a change in the sequence of silence intervals between four very brief tone bursts, thus indicating some temporal pattern perception abilities in young infants. Their experiment differed from the present one, however, in that their temporal pattern was 1 sec duration, which is considerably shorter than the 4.2 sec duration patterns used in the present study, and their pattern consisted of only four very brief elements, in contrast to the nine elements comprising a pattern in the present study. Furthermore, they used tones in constructing their stimulus patterns, thus they did not evaluate temporal pattern perception completely independently of tonal perception. Certainly, additional developmental research is needed in order to determine how infants' abilities to perform temporal pattern discriminations are influenced differentially by the composition and duration of the patterns themselves.

Memory Constraints

Each of the Frequency and Tonal Pattern discrimination conditions contained at least one test stimulus to reveal if memory demands of the task were in any way adversely affecting discrimination performance. As can be seen in Table 3, each of the Frequency and Tonal Pattern discrimination conditions contained at least one test stimulus requiring that the infant detect a change in triad following an intervening 2 second silence interval (Frequency-1: TP-D; Frequency-2: TP-D; Pattern-1: TP-B,TP-C,TP-D; Pattern-2: TP-C, TP-D). In contrast, other test stimuli necessitated that infants detect a change in triad over a .6 sec silence interval (Frequency-1: TP-B, TP-C; Frequency-2: TP-C; Pattern-2: TP-B). It had been hypothesized that younger infants, in comparison to older infants, might perform more poorly on those discriminations that imposed more stringent memory demands.

The results obtained provided some support for this hypothesis. Six-month-olds' discrimination performance was poorer for those test patterns imposing a memory load of 2 sec, than for those testing for the same discrimination ability but only imposing a memory load of .6 sec (e.g., Frequency-1: TP-D vs TP-B and TP-C; Frequency-2: TP-C vs TP-D; and Pattern-2: TP-B vs TP-D). Twelve-month-old discrimination performance was not differentially affected by the 2 sec vs .6 sec memory demands of the task.

The present results reveal constraints in young infants' auditory short-term memory and stand in contrast to the results of investigations of infants' visual recognition memory, in which infants have been shown to recognize a familiar visual stimulus over as long an interval as 2 weeks (Fagen, 1973; Sullivan, 1980). Precisely why such differences in memory capacities exists between the visual and auditory modalities remains open to speculation, particularly since there has been so little research examining infants' memory for auditory events. However, since we are a species in which vision is the dominant sense, the visual modality might possess abilities superior to those of the remaining sensory modalities. For example, although adults more rapidly process auditory information than visual information when information from the two modalities conflict, adults give priority to the visual based information in acting on the environment (Colavita, 1974). Certainly, additional research is needed on infants' short-term and long-term memory of information deriving from the different sensory modalities.

Although there has been very little research examining the role of memory in infant auditory perception abilities, the results of the present investigation suggest that memory constraints might be an important contributing factor in evaluating infant auditory discrimination abilities, particularly when developmental comparisons of discrimination abilities are being made. The results also reveal that not all types of auditory discrimination performance are similarly affected by the memory demands of a task.

In the present study, 6-month-olds had difficulty performing frequency discriminations when they were required to detect a frequency change over an intervening silence interval of 2 sec, under these circumstances infants responded reliably above chance levels, but significantly poorer than for those frequency discriminations that did not impose such memory demands.

In the case of tonal pattern discrimination performance, 6-month-olds reliably discriminated a reversal in the ratio of high:low frequency tones, but performance was significantly poorer when the ratio reversal occurred following a 2 sec intervening silence interval (Frequency-2: TP-D vs TP-C; Pattern-1: TP-B; Pattern-2:

TP-C). For tonal pattern discriminations that involved a re-sequencing of component triads, 6-month-olds performed at chance level, most likely because each of these discriminations required that the infant detect a change in pattern following an intervening silence interval of at least 2 sec duration (Pattern-1: TP-C, TP-D). For tonal pattern discriminations that involved a change in the sequence of elements comprising a triad, 6-month-olds performed at chance level when required to detect the sequence change following a 2 sec silence interval, and they performed as well as the 12-month-olds when the change occurred following a .6 sec silence interval (Pattern-2: TP-D and TP-B, respectively). Surprisingly, discrimination performance for pattern changes that resulted in changes in within triad variability were unaffected by memory demands of the task; 6-month-olds had no difficulty performing discriminations involving changes in within triad variability when the pattern changes occurred following a 2 sec intervening silence interval (Pattern-1: TP-A; Pattern-2: TP-A).

On the surface it may seem surprising that 6-month-olds were able to perform any of the temporal pattern discriminations, since each of these discriminations required the infant to detect a change in the temporal configuration of a pattern heard 2 sec earlier. However, analysis of the frequency, tonal, and temporal discrimination tests suggests a memory explanation for the pattern of results obtained across all three experimental conditions.

In order to perform frequency and tonal pattern discriminations infants must recognize a particular frequency, or particular sequence of different frequency tones, over time. That is to say, there is specific detailed knowledge about the frequency aspects of a stimulus that must be kept in auditory short-term memory. In contrast, temporal pattern discriminations can be performed at two levels. The first involves detection of a change in the overall temporal configuration of the pattern (i.e., number of groupings), which in fact infants at both ages were able to do. The second involves detection of a change in the specific aspects of a grouping (e.g., a change in the number of elements or duration of elements in a grouping). In order to perform the latter types of temporal discriminations specific detailed knowledge about temporal aspects of the stimulus must be kept in auditory short-term memory. Six-month-olds did not reliably perform such discriminations. Thus, across the frequency, tonal, and temporal pattern conditions younger infants performed poorly on those discriminations requiring that they keep specific, detailed frequency or temporal information in auditory short-term memory.

A hierarchical ordering of discrimination capacities, analagous to that constructed for the temporal pattern condition in the present study, could be created too for tonal pattern discriminaitons, although this was not done in the present study. For example, one could create tonal pattern discriminations which infants could perform based on detection of a change in the overall frequency contour of a pattern, rather than requiring that they necessarily keep specific detailed frequency information in auditory short-term memory, as was the case in the present study.

I would hypothesize that younger infants would be better able to perform discriminations of a rising vs a falling frequency contour for example, than discriminations of two rising frequency contours in which different frequency tones comprise the two rising patterns. The former involves a change in the overall spectral configuration of the pattern. Whereas, the latter necessitates attention to specific, detailed frequency information, and discrimination depends on the infant's ability to keep such information in auditory short-term memory. In support of these ideas, Chang and Trehub (1977) found that infants 5-months of age did not discriminate between a 6-tone pattern and the same pattern transposed, thus maintaining the same overall frequency contour configuration but comprising entirely new component tones. Infants did discriminate between the standard 6-tone pattern and a scrambled version of the transposed pattern, which presumably resulted in a change in the overall frequency contour.

In summary, what I am proposing is a hierarchically organized acquisition of auditory pattern discrimination skills in which infants are initially able to perform temporal and tonal pattern discriminations utilizing non-specific, <u>structural</u> information about the auditory pattern, and are subsequently capable of performing pattern discriminations based on <u>specific</u> detailed information about the auditory pattern. The present data set suggests that the transition from utilizing "configurational" information to utilizing "content specific" information in perception of auditory patterns involves age-related changes in auditory short-term memory, which serves to allow content specific information to be available over longer periods of time for comparison with the subsequently processed auditory pattern in older infants.

Storage of auditory information also plays an important role in speech perception, since it allows for processing time that is necessary for performing comparisons of one sound with another (e.g., in determining novelty vs familiarity of speech sounds). Furthermore, the developing infant must begin to recognize patterns of speech sounds in learning about and formulating expectations about the world (e.g., labels for primary caregivers, such as "Mommy"). In the field of infant speech perception there has been virtually no research performed investigating the role that auditory memory plays in infants' perception of speech. In part, this probably derives from the fact that the majority of this research has focused on examining phonemic perception of syllables presented in isolation, which is quite in contrast to the experience of perceiving running speech as it occurs in the natural environment. Investigators have not conceptualized speech perception by infants as a "pattern perception" process. Rather, they have perseverated in investigating infants' perception of content specific phonemic information. Since understanding infants perception of discrete phonemes provides little information about infants' perception of patterns of speech, it is important that we begin to explore infants' discrimination and recognition of multisyllabic targets in running speech. Working toward this end, Cowan and Morse (1982) have begun to examine 7-month-old infants' recognition of familiar syllables in trisyllabic sequences, in an effort to begin to understand infants' perception of patterns of speech sounds. Previously, Trehub (1973) had observed that infants could discriminate voicing differences of/b/ vs /p/ in bisyllabic contexts, but not in trisyllabic contexts (e.g., /atapa/ vs /ataba/), which suggests that auditory short-term memory may indeed constrain infants' perception of speech patterns in the natural environment.

The study of infants' perception of suprasegmental information, such as the prosodic aspects of speech, also could provide information relevant for the proposed theoretical speculations. If infants' abstract information about the overall structure of a pattern prior to their becoming skillful in discriminating content specific information in speech-sound patterns then infants, particularly at younger ages, might pay particular attention to the prosodic characteristics and regularities of speech in delimiting meaningful speech-sound patterns. In summary, perception of speech in the natural environment is a "pattern perception" problem that the developing infant must come to master. In so doing, the infant has available in the auditory signal both the content of speech (e.g., phonemes), as well as regularities in the structure of speech (e.g., stress and intonation patterns). Developing a thorough understanding of the developing infant's abilities to perceive speech-sound patterns will depend on our investigating infants' perception of the structure, as well as the content, of running speech.

Head Turns During Repetition 1 vs 2 of a Stimulus

Typically, when a conditioned head-turn procedure has been used to investigate infant auditory discrimination abilities infants have been expected to detect a stimulus change within about a 5 sec trial interval. In the present study a test trial consisted of two repetitions of a stimulus, allowing infants about a 10 sec interval for responding. Since several of the pattern changes were subtle ones, and in many cases the changes occurred toward the end of the pattern, it seemed important to allow infants the opportunity to hear the changed stimulus play twice. Pilot testing revealed that it was not uncommon for infants to alert and orient to the change during Repetition 1 and to complete their head turn during Repetition 2; this was particularly true for those changes that occurred toward the end of a pattern. In the present study infants at each age responded during Repetition 1 more often than during Repetition 2 of a stimulus. Moreover, the incidence of responding over test trial blocks to Repetition 1 of a stimulus did not vary, at either age, as a function of group, which indicates that at each age infants responded similarly for the frequency, tonal, and temporal pattern discriminations.

Spontaneous Head Turns: Relevance for Learning the Task

The conditioned head-turn paradigm has become a useful and quite popular procedure for evaluating developmentally infant auditory discrimination abilities, but it may also be useful in providing information regarding developmental changes in infant attention and learning. Surprisingly, investigators that have utilized the procedure in evaluating infant auditory competencies have shown little interest in documenting the kinds of gradual changes in infants' behavior that might support their learning the task contingencies, or whether there are developmental changes in rate of acquisition of the conditioned response. The latter question would be best addressed in those investigations that have used a criterion of responding as prerequisite to beginning testing, and did not obtain evidence of developmental changes in the auditory discrimination ability under investigation.

For example, Trehub et al (1980) used a training to performance-criterion procedure and found that 12- and 18- month-old listeners did not differ in their threshold for hearing as a function of the frequency of the signal. Under these circumstances, age-related differences in infants' rate of acquisition during Training would most likely be indicative of developmental differences in attentional and/or learning processes, and would not be a result of age-related differences in discrimination abilities differentially affecting acquisition of the conditioned response. In the present investigation, examining the incidence of spontaneous head turns over the course of training yielded some clues as to the kinds of changes in infants' behavior that might have supported their learning the task.

Infants, particularly the 6-month-olds, showed an increase in the incidence of spontaneous head turns during Training. This behavior reflected their interest in observing the visual reinforcer, and created circumstances which probably aided them in learning the task. Performing many head turns that produced no observable effect probably made the conditions under which a head turn resulted in the visual reinforcer more salient for the infant to recognize. The decrease in spontaneous head turn that occurred between Training and Testing presumably reflected the infant's recognizing how to respond most efficiently in order to control the occurrence of the visual reinforcer.

Orienting Head Turns

Generally, 12-month-olds performed more orienting head turns than 6-month-olds, 34% vs 15%, respectively. Over the course of the test session infants at both ages habituated responding to the onset of the background pattern following an interblock silence interval, thus showing a reliable decrement in the incidence of orienting head turns over blocks. These results replicate those obtained with 5-month-olds in indicating infant habituation of orienting to sound onset with repeated presentations of the acoustic signal (Clifton, Morrongiello, and Dowd, Note 2). The results are consistent also with recent evidence indicating that a reinforcement head-turn procedure is more informative and successful than a non-reinforcement head turn procedure in assessing infant auditory discrimination performance (Trehub et al, 1981).

Suggestions for Future Research

The results of the present investigation did not reveal any developmental differences between 6- and 12- month-old infants in their ability to perform simple temporal pattern discriminations, drop-out frequency discriminations, or tonal pattern discriminations that did not impose stringent memory demands. Testing for these discrimination abilities in infants younger than 6-months of age might provide important information regarding the ontogenetic course of these discrimination capacities. In order to better understand the development of auditory perception it is important to know if the capacities to perform these three types of discriminations emerge simultaneously, at what ages these discrimination abilities first appear, and whether these discrimination abilities develop in a gradual or all-or-none fashion. To track developmental changes in processing the more subtle temporal patterns it would be important to test for these discrimination abilities in infants between the ages of 6- and 12- months, paying particular attention to whether there is a gradual or all-or-none onset of abilities.

The results also indicate that in investigations of the present type it may be important to utilize intervening silence intervals that are shorter than 2 sec duration, particularly if one is interested in testing infants 6-months of age or younger. In the present study, an intervening silence interval of 2 sec duration adversely affected 6-month-olds' frequency and tonal pattern perception performance. Apparently, auditory memory can play a signifcant role in infant auditory disdcrimination performance. In future research we should seek to delimit the auditory memory capacities infants' possess during the first year of life, paying particular attention to examine the role that auditory memory plays in infants' perception of speech-sound patterns. It would be interesting to determine, for example, whether 12-month-olds would display a similar pattern of responding reliably and at chance level for test patterns in the different conditions, relative to 6-month-olds' performance, if the interpattern interval was increased beyond 2 sec.

Lastly, it is important to extend the present research beyond the use of simple pure tones sounds, to more acoustically complex, naturally occurring sounds such as those heard in speech or music. Utilizing pure tones allows one to precisely specify stimulus parameters, but hearing in the natural environment demands sequential processing of sounds having complex frequency spectra and multidimensional cues that may interact in perception. It would be useful to utilize our knowledge of how infants' perceive and respond to simple pure tone signals to design experiments investigating infants' perception of naturally occurring complex auditory signals. A comparison of infant discrimination performance for speech and non-speech sounds, for example, might provide evidence as to whether the processing of speech is somehow special and distinct from the processing of non-speech sound, as some investigators have argued. An understanding of age-related changes in infant discrimination of musical, speech, and non-speech/musical sounds is essential if we are to develop a comprehensive theory of auditory perceptual development, and not just a description of the acquisition of specific discrimination skills. is to explain the development of general auditory competencies and not just the acquisition of specific discrimination skills.

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Note 1. Morrongiello, B.A., Kulig, J.W., & Clifton, R.K. Developmental changes in the perception of auditory temporal information. *Child Development*, under review.

Note 2. Clifton, R.K., Morrongiello, B.A., & Dowd, J.M. A developmental look at an auditory illusion: The precedence effect. In preparation.

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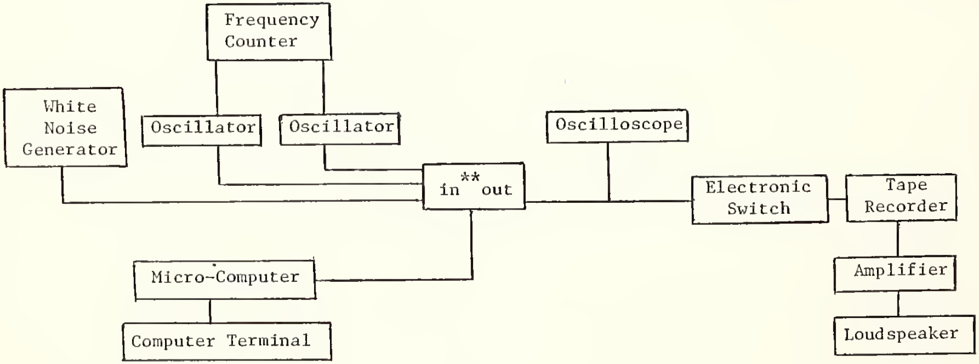
APPENDIX 1

METHODOLOGICAL CONSIDERATIONS

Fig. 25. Implementation Block Diagram of the Electrical and Computer Engineering Laboratory Equipment Used in Stimulus Preparation.

FIGURE 25



**Custom-built computer-interface box

Fig. 26. Implementation Block Diagram of the Equipment Room Adjacent to the Testing Room.

FIGURE 26

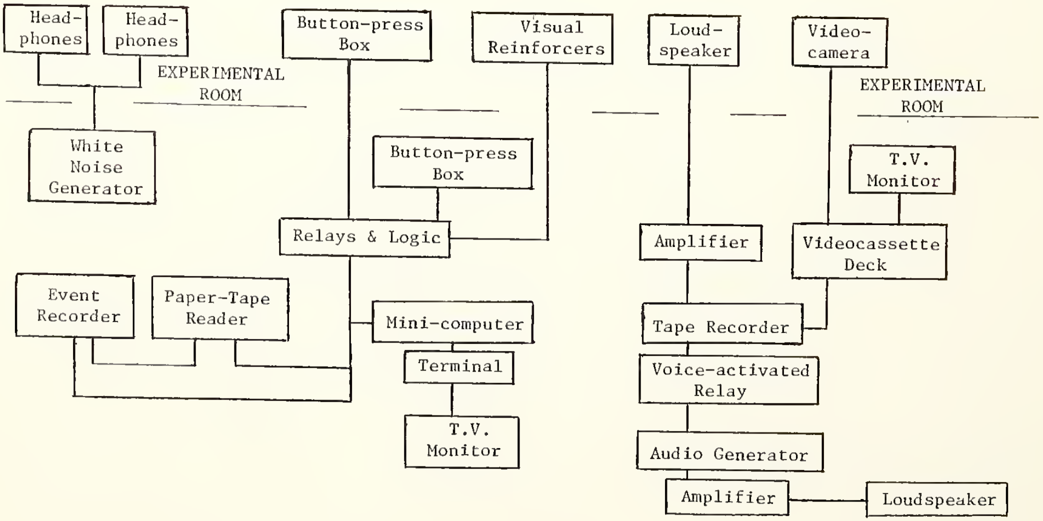

Head-phones
Head-phones
EXPERIMENTAL ROOM
White Noise Generator
Button-press Box
Button-press Box
Relays & Logic
Visual Reinforcers
Event Recorder
Paper-Tape Reader
Mini-computer
Terminal
T.V. Monitor
Loud-speaker
Amplifier
Tape Recorder
Voice-activated Relay
Audio Generator
Amplifier
Loudspeaker
Video-camera
EXPERIMENTAL ROOM
T.V. Monitor
Videocassette Deck

TABLE 5

SEQUENCE OF TEST PATTERNS WITHIN EACH BLOCK

BLOCK SEQUENCE LABEL [1]	TRIAL NUMBER WITHIN A BLOCK: [2] 1	2	3	4	5
AA	A	B	C	D	E
BB	B	C	D	E	A
CC	C	D	E	A	B
DD	D	E	A	B	C
EE	E	A	B	C	D

[1] Blocks are labelled according to which test pattern occurs first

[2] Each letter designates a test pattern (see Table 1)

TABLE 6

SEQUENCE OF BLOCKS WITHIN EACH SESSION AND NUMBER OF SUBJECTS RECEIVING EACH SEQUENCE FROM THE RIGHT AND LEFT LOUDSPEAKER

SEQUENCE OF TEST BLOCKS: 1	2	3	4	5	LOUDSPEAKER: LEFT	RIGHT	TOTAL NUMBER OF SUBJECTS
AA	BB	CC	DD	EE	1	1	2
BB	CC	DD	EE	AA	1	1	2
CC	DD	EE	AA	BB	1	1	2
DD	EE	AA	BB	CC	1	1	2
EE	AA	BB	CC	DD	1	1	2

TABLE 7

SEQUENCE OF BLOCKS ON AN AUDIO TAPE, SEQUENCE OF BLOCKS WITHIN EACH SESSION, AND NUMBER OF SUBJECTS RECEIVING EACH BLOCK SEQUENCE DURING TESTING

BLOCK SEQUENCE ON THE AUDIO TAPE:									TOTAL NUMBER OF SUBJECTS RECEIVING BLOCK SEQUENCE
1	2	3	4	5	6	7	8	9	
CC	DD	EE	AA	BB	CC	DD	EE	AA	
└	─	─	─	┘					2
	└	─	─	─	┘				2
		└	─	─	─	┘			2
			└	─	─	─	┘		2
				└	─	─	─	┘	2

TABLE 8

NUMBER OF MALES (M) AND FEMALES (F) RECEIVING EACH BLOCK SEQUENCE FROM THE RIGHT AND LEFT LOUDSPEAKER[1]

	LEFT LOUDSPEAKER:					RIGHT LOUDSPEAKER:					TOTAL	
CONDITION	AA	BB	CC	DD	EE	AA	BB	CC	DD	EE	MALES	FEMALES
FREQUENCY-1	F	M	M	F	F	M	F	F	M	M	5	5
FREQUENCY-2	M	M	M	F	F	F	F	F	M	M	5	5
PATTERN-1	M	F	F	M	M	F	M	M	F	F	5	5
PATTERN-2	M	M	F	F	F	F	F	M	M	M	5	5
TEMPORAL	F	F	M	M	M	M	M	F	F	F	5	5

[1] For 12-month-olds the assignment of males and females to conditions was the direct opposite of that shown here for the 6-month-olds.

TABLE 9

NUMBER OF CHANGE AND NO CHANGE CONTROL TRIALS FOR EACH BLOCK OF TRAINING AND TESTING

PHASE	BLOCK NUMBER	NUMBER OF: CHANGE TRIALS	NO CHANGE CONTROL TRIALS
TRAINING	1	4	0
	2	4	0
	TOTAL	8	0
TESTING	1	4	1
	2	4	1
	3	4	1
	4	4	1
	5	4	1
	TOTAL	20	5

TABLE 10

RELIABILITY COEFFICIENTS FOR THE BEHAVIORS SCORED FROM THE VIDEORECORDS

BEHAVIOR	RELIABILITY COEFFICIENT
RESPONDING TO REPETITION 1 vs 2	.985
SPONTANEOUS HEAD TURNS	.99
ORIENTING HEAD TURNS	1.00
ELIMINATION OF TEST TRIALS DUE TO:	
FUSSY STATE	1.00
IMPROPER HEAD ORIENTATION AT TRIAL ONSET	1.00

APPENDIX 2

BONFERRONI T-TEST VALUES:

RESPONDING ON CHANGE vs NO CHANGE CONTROL TRIALS AT EACH AGE

TABLE 11

BONFERRONI T-TEST VALUES FOR EACH GROUP OF 6-MONTH-OLDS FOR NO CHANGE CONTROL (NCC) vs EACH TYPE OF CHANGE TRIALS (TP-A, TP-B, TP-C, TP-D)

	CONTRASTS:			
GROUP	NCC vs TP-A	NCC vs TP-B	NCC vs TP-C	NCC vs TP-D
FREQUENCY-1	28.17	21.00	19.36	7.65
FREQUENCY-2	13.50	13.04	15.24	3.08
PATTERN-1	19.90	4.75	2.81*	1.98*
PATTERN-2	11.21	16.71	4.04	1.65*
TEMPORAL	12.32	12.89	3.41*	2.50*

Note 1: All contrasts, with the <u>exception</u> of those designated by an *, are significant at $P < .05$

TABLE 12

BONFERRONI T-TEST VALUES FOR EACH GROUP OF 12-MONTH-OLDS FOR NO CHANGE CONTROL (NCC) vs EACH TYPE OF CHANGE TRIALS (TP-A, TP-B, TP-C, TP-D)

	CONTRASTS:			
GROUP	NCC vs TP-A	NCC vs TP-B	NCC vs TP-C	NCC vs TP-D
FREQUENCY-1	12.33	15.71	12.24	14.21
FREQUENCY-2	12.89	9.16	12.83	9.00
PATTERN-1	11.44	9.00	10.00	14.21
PATTERN-2	9.82	8.43	10.88	15.19
TEMPORAL	10.59	9.39	8.57	7.00

Note 1: All contrasts, with the exception of those designated by an *, are significant at $P < .05$

APPENDIX 3

RESPONDING ON CHANGE TRIALS: STATISTICAL RESULTS

TABLE 13

ANALYSIS OF VARIANCE OF RESPONDING ON CHANGE TRIALS OVER BLOCKS AS A FUNCTION OF AGE AND GROUP

SOURCE	DF	MEAN SQUARE	F	PROBABILITY
AGE	1, 90	7.54238	230.96	.0000
GROUP	4, 90	.43147	13.21	.0000
BLOCKS	4, 360	.16660	7.08	.0000
AGE x GROUP	4, 90	.26220	8.03	.0000
BLOCK x GROUP	16, 360	.06416	2.73	.0004

Note 1: The design of the analysis was an Age(2) x Group(5) x Block(5) RM-ANOVA

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

TABLE 14

T-TEST RESULTS COMPARING THE PROPORTION OF RESPONDING ON CHANGE TRIALS IN EACH CONDITION AS A FUNCTION OF AGE

CONDITION	AGE (MONTHS): 6	12	T-VALUE
FREQUENCY-1	.81	.95	4.48
FREQUENCY-2	.73	.90	3.82
PATTERN-1	.49	.90	10.14
PATTERN-2	.64	.91	7.12
TEMPORAL	.685	.92	8.25

Note 1: Each age contrast was significant at $P < .05$

Fig. 27. Proportion of Responding on Change Trials Over Blocks as a Function of Condition Averaged Over Age.

FIGURE 27

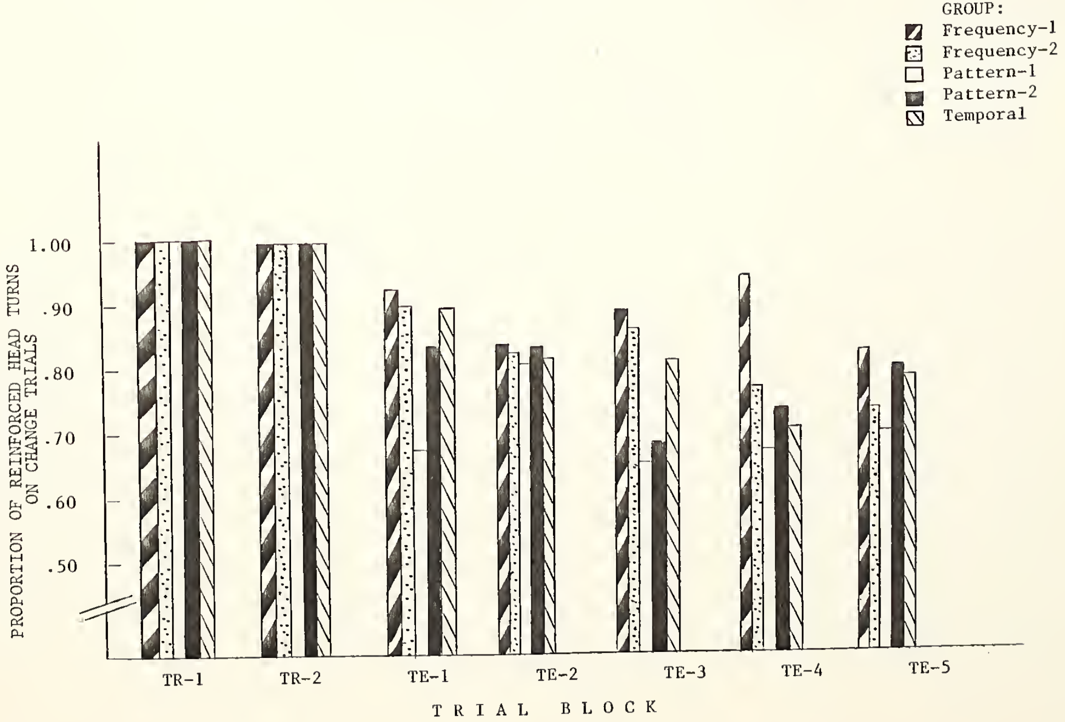

GROUP:
▨ Frequency-1
⬚ Frequency-2
☐ Pattern-1
■ Pattern-2
▧ Temporal
PROPORTION OF REINFORCED HEAD TURNS ON CHANGE TRIALS
1.00
.90
.80
.70
.60
.50
TR-1
TR-2
TE-1
TE-2
TE-3
TE-4
TE-5
TRIAL BLOCK

TABLE 15

ANALYSIS OF VARIANCE OF RESPONDING ON CHANGE TRIALS OVER BLOCKS AS A FUNCTION OF CONDITION

CONTRAST	SOURCE	DF	MEAN SQUARE	F	PROBABILITY
FREQUENCY-1 vs					
PATTERN-2	BLOCK x GROUP	4, 152	.08758	3.63	.0074
TEMPORAL	BLOCK x GROUP	4, 152	.06931	2.68	.0336
FREQUENCY-2 vs					
PATTERN-1	BLOCK x GROUP	4, 152	.09171	4.18	.0031
	x Linear	1, 38	.08732	4.39	.0430
PATTERN-2	BLOCK x GROUP	4, 152	.08241	3.47	.0096
PATTERN-1 vs					
TEMPORAL	BLOCK x GROUP	4, 152	.07741	3.24	.0138

Note 1: The design of each analysis was a Group(5) x Block(5) RM-ANOVA

Note 2: Only those interactions and linear and quadratic trends significant at $P < .05$ are listed

TABLE 16

NEWMAN-KEULS ANALYSIS OF 6-MONTH-OLDS' RESPONDING ON CHANGE TRIALS AS A FUNCTION OF CONDITION

MEAN PROPORTION OF RESPONDING ON CHANGE TRIALS FOR EACH CONDITION:				
PATTERN-1	PATTERN-2	TEMPORAL	FREQUENCY-2	FREQUENCY-1
.50	.64	.68	.73	.81
———				
	———	———	———	
			———	———

Note 1: Those groups mutually underlined do not significantly differ from one another. Conversely, those groups that do not share an underline are significantly different from one another

TABLE 17

ANALYSIS OF VARIANCE OF EACH GROUP OF 6-MONTH-OLDS' RESPONDING AS A FUNCTION OF TYPE OF TEST PATTERN

CONDITION	SOURCE	DF	MEAN SQUARE	F	PROBABILITY
FREQUENCY-1	CHANGE PATTERN	3, 27	.37217	21.51	.0000
FREQUENCY-2	CHANGE PATTERN	3, 27	.68540	18.94	.0000
PATTERN-1	CHANGE PATTERN	3, 27	1.16590	39.70	.0000
PATTERN-2	CHANGE PATTERN	3, 27	1.08425	33.85	.0000
TEMPORAL	CHANCE PATTERN	3,27	.90467	34.48	.0000

Note 1: The design of each analysis was a change pattern(4) RM-ANOVA

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

TABLE 18

BONFERRONI T-TEST RESULTS COMPARING THE PROPORTION OF RESPONDING ON CHANGE TRIALS IN EACH GROUP OF 6-MONTH-OLDS AS A FUNCTION OF TYPE OF TEST PATTERN

	CONTRASTS OF TEST PATTERNS:					
CONDITION	TP-A vs TP-B	TP-A vs TP-C	TP-A vs TP-D	TP-B vs TP-C	TP-B vs TP-D	TP-C vs TP-D
FREQUENCY-1	2.45	.45	5.26*	1.26	4.68*	6.71*
FREQUENCY-2	1.86	1.79	6.02*	.40	5.23*	4.77*
PATTERN-1	6.29*	9.68*	12.32*	1.32	3.06	2.08
PATTERN-2	0.00	6.92*	7.26*	6.92*	5.84*	1.49
TEMPORAL	.39	6.48*	7.14*	8.25*	6.33*	.51

Note 1: Only those contrasts designated with an * are significant at $P < .05$

TABLE 19

ANALYSIS OF VARIANCE OF RESPONDING ON CHANCE TRIALS FOR EACH CONDITION AS A FUNCTION OF ACE AND TYPE OF TEST PATTERN

CONDITION	SOURCE	DF	MEAN SQUARE	F	PROBABILITY
FREQUENCY-1	AGE	1, 18	.37813	19.83	.0003
	CHANGE PATTERN	3, 54	.18688	12.97	.0000
	ACE x CHANGE PATTERN	3, 54	.19804	13.75	.0000
FREQUENCY-2	ACE	1, 18	.57800	18.85	.0004
	CHANGE PATTERN	3, 54	.34121	12.12	.0000
	AGE x CHANCE PATTERN	3, 54	.34692	12.32	.0000
PATTERN-1	AGE	1, 18	3.32113	103.18	.0000
	CHANGE PATTERN	3, 54	.57683	24.57	.0000
	AGE x CHANGE PATTERN	3, 54	.62313	26.54	.0000
PATTERN-2	AGE	1, 18	1.44453	50.34	.0000
	CHANGE PATTERN	3, 54	.55836	22.28	.0000
	AGE x CHANCE PATTERN	3,54	.54161	21.61	.0000
TEMPORAL	AGE	1, 18	1.14003	68.05	.0000
	CHANCE PATTERN	3, 54	.47361	22.21	.0000
	AGE x CHANGE PATTERN	3, 54	.43228	20.27	.0000

Note 1: The design of each analysis was an Age(2) x Change Pattern(4) RM-ANOVA

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

TABLE 20

T-TEST RESULTS COMPARING THE PROPORTION OF RESPONDING BY 6- AND 12-MONTH-OLDS AS A FUNCTION OF TYPE OF TEST PATTERN FOR EACH CONDITION

CONDITION	TEST PATTERN	AGE (MONTHS): 6	12	T-VALUE
FREQUENCY-1	A	.94	.96	.49
	B	.86	.895	.63
	C	.915	.975	1.15
	D	.525	.96	6.15*
FREQUENCY-2	A	.78	.895	1.75
	B	.88	.92	.64
	C	.91	.88	.42
	D	.345	.90	5.64*
PATTERN-1	A	.98	.915	1.61
	B	.455	.82	3.67*
	C	.325	.90	7.67*
	D	.205	.96	12.94*
PATTERN-2	A	.92	.955	.65
	B	.92	.86	.98
	C	.41	.915	6.65*
	D	.30	.895	6.51*
TEMPORAL	A	.935	.94	.11
	B	.955	.92	.65
	C	.445	.915	7.31*
	D	.405	.92	6.12*

Note 1: Age contrasts designated with an * are significant at $P < .05$

APPENDIX 4

RESPONDING TO REPETITION 1 vs 2 OF A STIMULUS: STATISTICAL RESULTS

TABLE 21

ANALYSIS OF VARIANCE OF RESPONDING TO REPETITION 1 vs 2 OF A TEST STIMULUS OVER BLOCKS AS A FUNCTION OF AGE AND GROUP

SOURCE	DF	MEAN SQUARE	F	PROBABILITY
GROUP	4, 90	.88343	5.77	.0004
BLOCK	4, 360	.18777	2.78	.0269
AGE x GROUP x BLOCK	16, 360	.13197	1.95	.0155

Note 1: The design of the analysis was an Age(2) x Group(5) x Blocks(5) RM-ANOVA

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

Fig. 28. Proportion of Responding to Repetition 1 vs 2 of the Test Stimulus Over Blocks as a Function of Condition for 6-Month-Olds.

FIGURE 28

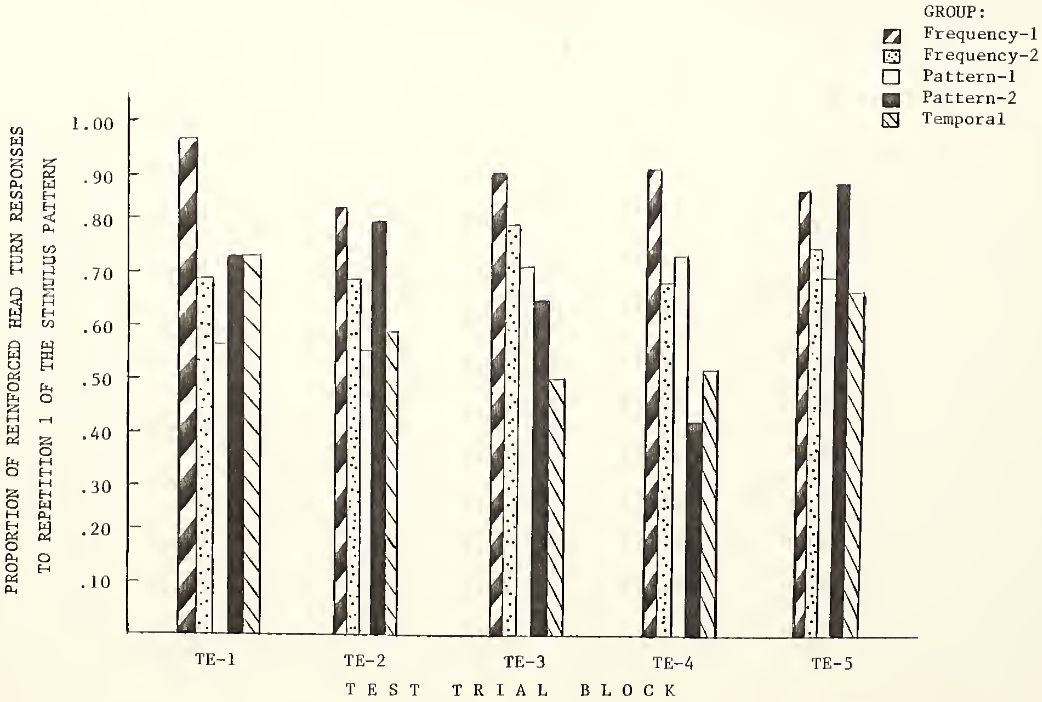
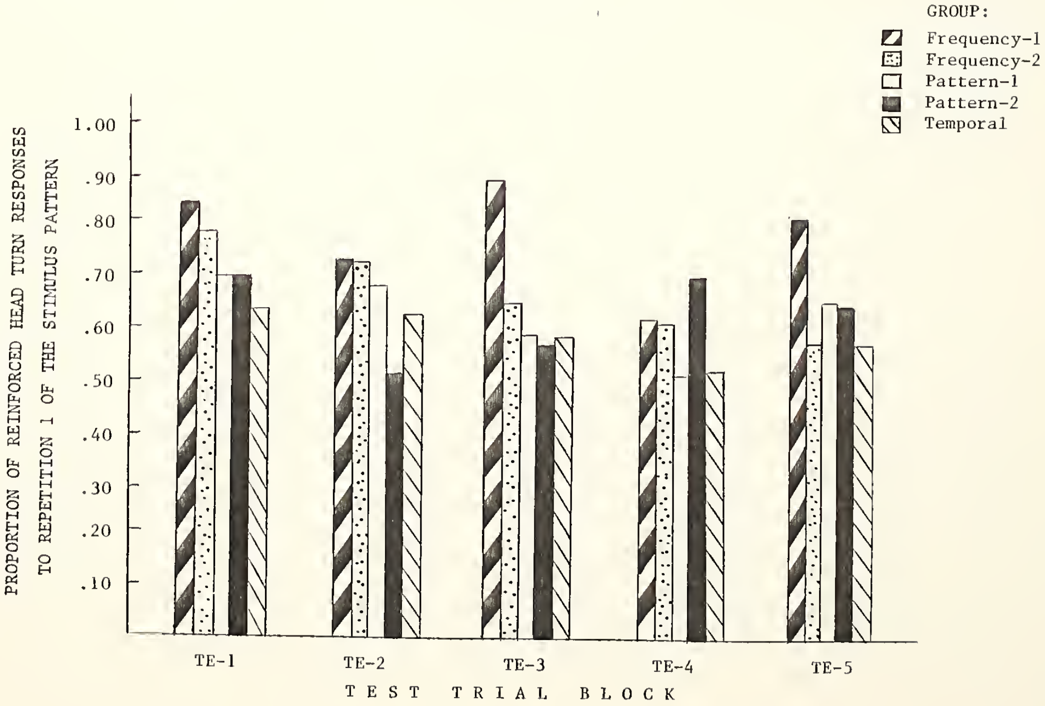

GROUP:
Frequency-1
Frequency-2
Pattern-1
Pattern-2
Temporal
PROPORTION OF REINFORCED HEAD TURN RESPONSES
TO REPETITION 1 OF THE STIMULUS PATTERN
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
TE-1
TE-2
TE-3
TE-4
TE-5
TEST TRIAL BLOCK

Fig. 29. Proportion of Responding to Repetition 1 vs 2 of the Test Stimulus Over Blocks as a Function of Condition for 12-Month-Olds.

FIGURE 29


GROUP:
▨ Frequency-1
⬚ Frequency-2
☐ Pattern-1
■ Pattern-2
▧ Temporal
PROPORTION OF REINFORCED HEAD TURN RESPONSES
TO REPETITION 1 OF THE STIMULUS PATTERN
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
TE-1
TE-2
TE-3
TE-4
TE-5
TEST TRIAL BLOCK

APPENDIX 5

SPONTANEOUS HEAD TURNS: STATISTICAL RESULTS

TABLE 22

ANALYSIS OF VARIANCE OF SPONTANEOUS HEAD TURNS OVER BLOCKS AS A FUNCTION OF AGE AND GROUPS

SOURCE	DF	MEAN SQUARE	F	PROBABILITY
AGE	1, 90	.19422	33.03	.0000
GROUP	4, 90	.01481	2.52	.0467
BLOCK	6, 540	.47386	252.85	.0000
BLOCK x AGE	6, 540	.06164	32.89	.0000
AGE x GROUP x BLOCK	24, 540	.00406	2.17	.0012

Note 1: The design of the analysis was an Age(2) x Group(5) x Block(7) RM-ANOVA

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

TABLE 23

ANALYSIS OF VARIANCE OF SPONTANEOUS HEAD TURNS OVER BLOCKS AS A FUNCTION OF AGE FOR EACH CONDITION

CONDITION	SOURCE	DF	MEAN SQUARE	F	PROBABILITY
FREQUENCY-1	BLOCK x AGE	6, 108	.01364	5.20	.0001
	x LINEAR	1, 18	.05853	10.89	.0040
	x QUADRATIC	1, 18	.01600	7.48	.0136
FREQUENCY-2	BLOCK x AGE	6, 108	.01733	11.14	.0000
	x QUADRATIC	1, 18	.02211	27.51	.0002
PATTERN-1	BLOCK x AGE	6, 108	.00985	5.23	.0001
	x LINEAR	1, 18	.03640	7.72	.0124
	x QUADRATIC	1, 18	.01765	9.54	.0063
PATTERN-2	BLOCK x AGE	6, 108	.00602	3.20	.0063
	x QUADRATIC	1, 18	.00862	5.63	.0290
TEMPORAL	BLOCK x AGE	6, 108	.01305	21.72	.0000
	x LINEAR	1, 18	.11572	51.05	.0000
	x QUADRATIC	1, 18	.05658	29.45	.0000

Note 1: The design of each analysis was an Age(2) x Blocks(7) RM-ANOVA

Note 2: Only those interactions and linear and quadratic trends significant at $P < .05$ are listed

TABLE 24

ANALYSIS OF VARIANCE OF SPONTANEOUS HEAD TURNS OVER BLOCKS AS A FUNCTION OF CONDITION FOR 12-MONTH-OLDS

CONTRAST	SOURCE	DF	MEAN SQUARE	F	PROBABILITY
FREQUENCY-2 vs TEMPORAL	BLOCK x GROUP	6, 108	.00993	6.67	.0000
	x LINEAR	1, 18	.03348	13.13	.0019
	x QUADRATIC	1, 18	.00837	5.12	.0362
PATTERN-1 vs TEMPORAL	BLOCK x GROUP	6, 108	.00697	3.42	.0039
	x LINEAR	1, 18	.02647	5.67	.0286
PATTERN-2 vs TEMPORAL	BLOCK x GROUP	6, 108	.00848	4.19	.0008
	x LINEAR	1, 18	.02936	5.34	.0329
	x QUADRATIC	1, 18	.01497	6.67	.0188

Note 1: The design of each analysis was a Group(2) x Block(7) RM-ANOVA

Note 2: Only those interactions and linear and quadratic trends significant at $P < .05$ are listed

APPENDIX 6

ORIENTING HEAD TURNS: STATISTICAL RESULTS

TABLE 25

ANALYSIS OF VARIANCE OF ORIENTING HEAD TURNS OVER BLOCKS AS A FUNCTION OF AGE AND GROUP

SOURCE	DF	MEAN SQUARE	F	PROBABILITY
AGE	1, 90	6.41286	15.99	.0001
BLOCK	6, 540	1.11571	8.46	.0000
BLOCK x AGE	6, 540	.39286	2.98	.0072
x LINEAR	1, 90	1.50893	8.29	.0050

Note 1: The design of the analysis was an Age(2) x Group(5) x Block(7) RM-ANOVA

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