INFANTS' CATEGORIZATION OF MELODIC CONTOUR

Mark B. Ferland

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Department of Psychology
McGill University
Montreal

ISBN 0-315-38263-5

Abstract

Auditory categorization of nonspeech sequences was investigated in 10-month-old babies using a new paradigm. Study 1 established the usefulness of an operant-fixation preference technique for assessing auditory discrimination. Infants sat facing two identical visual displays, one on the right and the other on the left. Fixation of a display resulted in the presentation of a sound pattern from a loudspeaker located behind that display. During a familiarization phase, fixation of either display resulted in the same sequence; a pattern that alternated between two tones of a different frequency for half the infants and a pattern consisting of repetitions of a single tone for the other half. During a test, fixation of one display resulted in the alternating pattern while fixation of the other display resulted in the constant pattern. As expected, infants preferred to look at the display associated with the novel pattern thereby indicating discrimination of the two patterns. Study 2 used the procedure to test categorization of tonal patterns on the basis of melodic contour. Half of the infants were familiarized with a set of rising-contour patterns that differed in frequency range and wave form of their tones and the other half were familiarized with a similar set of falling-contour patterns. During a test, infants could listen to two new patterns; one had a rising contour and the other had a falling contour. Infants preferred the pattern with a novel contour, presumably because the familiar-contour pattern was perceived as one more instance of the

category of familiarization stimuli. To verify that infants in study 2 were performing on the basis of categorization, study 3 demonstrated that infants could discriminate between at least some of the same-contour sequences of study 2. It was argued that the operant-fixation preference paridigm offers certain advantages for future research on auditory categorization and the available evidence on categorization was discussed in relation to speech categorization.

Sommaire

Cette recherche concerna l' étude de la catégorisation auditive chez les nourrissons agés de dix mois dans le contexte d'une nouvelle méthodologie. La première étude a établi l'utilité de la procédure "operant-fixation preference technique" dans l'évaluation de la discrimination auditive. Les nourrissons furent assis en face de deux montages visuels identiques, l'un à gauche et l'autre à droite. Lorsque les bébés fixerent un montage, un son fut émit d'un haut-parleur situé derrière ce montage. Au cours de la période de familiarisation, la fixation de l'un ou l'autre des montages résulta à l'émission du même son. La moitié des enfants entendirent une séquence consistant de répétitions d'un son d'une seule fréquence alors que l'autre moitié entendirent une séquence consistant de sons alternants entre deux fréquences. Au cours d'un éssai subséquent, la séquence alternante fut présentée lorsque les nourrissons fixèrent l'un des montages alors que la séquence constante fut présentée lorsque les nourrissons fixèrent l'autre montage. Tel que prévu, les bébés préférèrent fixer le montage associé à la séquence qu'ils n'avaient pas entendue auparavant. La deuxième étude utilisa la technique pour déterminer si les nourrissons peuvent catégoriser des séquences auditives à partir de leur contours mélodiques. La moitié des bébés furent familiarisés avec un ensemble de séquences à contours levants qui se distingaient à base de leur étendue de fréquences et formes d'ondes. L'autre moitié des bébés furent familiarisés avec un ensemble de séquences similaires à contours tombants. Plus tard, pendant une épreuve, les bébés purent écouter deux nouvelles séquences; une à contour levant et l'autre à contour tombant. Les nourrissons préférèrent la séquence ayant le contour nouveau, probablement par ce que la séquence ayant le contour

nouveau, probablement par ce que la séquence ayant le contour familier fut percue simplement comme un autre exemplaire de la catégorie des séquences avec laquelle les bébés avaient déja été familiarisés. Afin de satisfaire une condition additionelle à la démonstration de catégorisation, la troisième étude démontra que les bébés pouvaient distinguer entre, au moins, quelque unes des séquences de la deuxième étude partageant le meme contour. On discuta des résultats en rélation à la recherche contemporaine sur la catégorisation du langage et puis, l'on proposa que la procédure "operant-fixation preference technique" aura de l'utilité pour de futures études sur la catégorisation auditive.

Acknowledgements

It is with great appreciation that I thank my supervisor, Dr. Morton Mendelson, for accepting me as his graduate student and providing an enriching experience for me during my studies. I benefited immensely not only from his extensive academic knowledge but also from his advice as a friend. He offered me every opportunity for personal growth and his door was always open. I am greatly indebted to him and have comparable respect and esteem for very few other individuals.

I would like to express my gratitude to my committee members, Dr. Barbara Sherwin and Dr. Mark Seidenberg, whose advice and insightful comments improved the research and the manuscript. I am grateful to Dr. Albert Bregman, who supervised my research while Dr. Mendelson was on sabbatical leave. Finally, I would like to thank Dr. Laura Petitto for her thorough reading of the final draft of the thesis.

A number of people participated in the day to day functioning of the infant laboratory. None deserve greater mention than my colleague and friend, Margaret Baratta who worked with me throughout the project. Her dedication and support, judgement, organizational skills, and sense of humor are only some of the reasons why I respect her immensely. It was a joy to work with her. I would also like to thank Jennifer Shellingford, and David Kaufman, for their participation in the research. Their ability to interact comfortably with families and effectively conduct experiments, contributed significantly to the smooth functioning of the laboratory and the overall success of the project.

I am grateful to the Natural Sciences and Engineering Research Council for funding the laboratory through a grant to Morton J. Mendelson. In addition, the Council supported me through a fellowship during the course of my studies. Their financial support relieved me of some of the monetary concerns associated with being a student.

Finally, I would like to thank my wife, Karen, and my parents for their love and support throughout my studies. My wife demonstrated unlimited amounts of patience during the preparation of the manuscript and was very helpful in the typing of text, tables, and appendices. My parents have always given me enormous encouragement and, from early on in life, the belief that I could accomplish the objectives I set out for myself.

TABLE OF CONTENTS

ABSTRACT i

SOMMAIRE iii

ACKNOWLEDGEMENTS v

LIST OF TABLES x

LIST OF FIGURES xi

LIST OF APPENDICES xii

INTRODUCTION 1

Defining Infant Categorization 2

Perceptual Constancy and Categorization 7

Methods for Studying Categorization 8

Training procedures 9

Habituation-dishabituation procedures 11

Novelty-preference paradigm 14

Infant Categorization of Auditory Signals 16

The Search for Natural Linguistic Categories 17

Auditory Perceptual Constancy 20

Categorization of Non-speech Auditory Signals 22

Outline of Thesis 24

STUDY 1 - A New Method for Evaluating Auditory Discrimination . . 26

Method 28

Subjects 28

Apparatus 28

Testing room 28

Control room 30

Stimuli 31
Procedure. 31
Results. 34
Discussion 38
STUDY 2 - Categorizing Sequences on the Basis of Melodic Contour 41
Method 44
Subjects. 44
Apparatus 45
Stimuli 45
Procedure 49
Results 51
Discussion 58
STUDY 3 - Discriminating Category Members 60
Part 1 - Discriminating Test and Familiarization Patterns . . . 61
Purpose 61
Method 61
Subjects 61
Apparatus. 61
Stimuli 61
Procedure. 63
Results. 63
Part 2 - Discriminating Familiarization Patterns on the Basis of Frequency Range 64
Purpose. 64

Method 66
Subjects 66
Apparatus 66
Stimuli 66
Procedure 66
Results 66
Part 3 – Discriminating Familiarization Patterns on the Basis of Wave Form 69
Purpose 69
Method 69
Subjects 69
Apparatus 70
Stimuli 70
Procedure 70
Results 70
Discussion 72
GENERAL DISCUSSION 73
Implications for Speech Categorization 73
Future Non-speech Auditory Categorization 74
Methodological Implications 78
Clinical Relevance 79
FOOTNOTES 81
REFERENCES 84
APPENDICES 98

List of Tables

Table 1 - The Relationship Between the Familiarization Pattern Received and the Amount of Looking During the First and Last 30 sec of Familiarization 36

Table 2 - The Relationship Between the Familiarization Patterns Received and the Amount of Looking During the First and Last 30 sec of Familiarization 53

Table 3 - The Relationship Between the First Test Pattern Heard and the Likelihood of Successfully Completing the Test 56

Table 4 - The Relationship Between the Familiarization Patterns Received and the Amount of Looking During the First and Last 30 sec of Familiarization 65

Table 5 - The Relationship Between the Familiarization Patterns Received and the Amount of Looking During the First and Last 30 sec of Familiarization 68

List of Figures

Figure 1 - Schematic illustration of the test chamber 29

Figure 2 - Temporal parameters of tonal patterns of study 1 . . . 32

Figure 3 - Temporal parameters of tonal patterns of study 2 . . . 46

Figure 4 - Rising melodic contour condition for study 2 47

Figure 5 - Falling melodic contour condition for study 2. 48

Figure 6 - Experimental design of study 2 50

Figure 7 - Duration of the last familiarization look and the first test look 57

Figure 8 - Sequence pairs tested for discrmination in part 1 62

Figure 9 - Sequence pairs tested for discrmination in part 2 67

Figure 10 - Sequence pairs tested for discrmination in part 3 71

List of Appendices

Appendix A - Consent Form 98

Appendix B - Demographic Information Questionnare 99

Appendix C - Demographic Information for Study 2 101

Developmental psychologists have recently turned their attention towards categorization behavior in infancy. Categorization is central to the development of flexible, economical information processing; it is involved in object identification and recognition and in the assimilation and organization of new knowledge (Bornstein, 1984; Bruner, Goodnow & Austin, 1956). Rudimentary categorization skills likely develop at an early age; otherwise the diversity of the environment would be overwhelming (Bruner et al., 1967).

Infant categorization refers to babies' ability to respond equivalently to discriminable stimuli on the basis of shared properties. Typically, studies on infant categorization consist of the following: After exposure to several discriminable stimuli that share common properties, babies tend to treat as familiar a **novel** stimulus that possesses the same common properties. For example, Fagan (1979) familiarized infants with several photographs of male faces. Subsequently, infants reacted to a **new** male face as familiar while they reacted to a female face as novel.

For the most part, categorization behavior has been demonstrated with visual stimuli (see Harris, 1983 for a review). Moreover, investigators have begun to study both the developmental course of visual categorization abilities during the first year of life (see Younger & Cohen, 1985) as well as the processes underlying categorization skills (Bomba & Siqueland, 1983; Sherman, 1985; Strauss, 1979). In contrast, there has been little research has been conducted on the categorization of auditory stimuli, and virtually all of the studies have dealt with speech signals (see Aslin, Pisoni & Jusczyk, 1983 for a review). Therefore, there is little information about infants' auditory categorization and its relationship to speech categorization. To begin to fill this gap, this thesis presents a new methodology for studying infant categorization and categorization of musical patterns.

This chapter presents a general introduction that first explores a working definition of infant categorization. Next, the relationship between categorization and a related phenomenon, perceptual constancy, is discussed. Then, various methods for studying infant categorization are examined. Finally, the chapter concludes with a review of the literature on infant auditory categorization, including work with speech and nonspeech signals.

Defining Infant Categorization

Categorization is the ability to treat discriminable stimuli as equivalent (Mervis & Rosch, 1981). It is a skill that is normally associated with adults or children, but not with infants. Indeed, categorization was traditionally believed to be very difficult for children younger than 5 to 7 years of age (see Gelman, 1978). However, even preschool children can categorize if the testing situation is appropriately adapted for youngsters (e.g., Markman, 1976; Rosch, Mervis & Gray, 1976). Moreover, researchers have recently developed new methods that seem to tap categorization skills in infants (Aslin et al., 1983; Harris, 1983; Olson & Sherman, 1983).

Thus, categorization abilities apparently extend over a wide age range beginning early in life. However, since testing procedures necessarily vary across age, it is not clear that category formation reflects similar cognitive processes across the life span. Consequently, the term categorization that is applied to infants may not be related to the same term found in the traditional literature on cognition.

Researchers have begun to speculate about the processes underlying infant categorization. Hypotheses vary considerably. Mervis and Rosch (1981) described infant categorization in terms of Flavell and Wellman's (1976) notion of "basic process." The term implies that infant categorization, unlike adult categorization, is an automatic, unconscious process. Similarly, Gibson (1979) believed that infants' detection of invariant (i.e., common) information across stimuli does not involve an intellectual act of forming an abstract concept. He believed that the perceptual system simply extracts the invariant information from the flowing stimulus array.

In contrast, some authors have argued that infant categorization requires abstraction (see Harris, 1983), or the intellectual act of forming a mental representation from a collection of physical objects. Intellectual abstraction is implicated by evidence that infant and adult categorization share certain processes. Adults calculate an average representation or **prototype** of the members of a category (Posner, 1969; Posner & Keele, 1968; Goldman & Homa, 1977). Similarly, infants apparently remember not only stimulus values that are actually present in all category members but rather, a prototype that does not necessarily correspond directly to any previously experienced stimulus Prototypes may correspond to the **mean** value of the dimension (Strauss, 1979). or the **modal** value (see Sherman, 1985).

For example, Strauss (1979) familiarized 10-month-olds with faces that differed along various dimensions such as the length of the nose and the distance between the eyes. During a subsequent test, infants treated a face containing the average value along the dimensions as more familiar than a face containing values that had actually been presented more frequently than the average. Similarly, Bomba and Siqueland (1983) exposed 3-month-old babies to various distortions of a prototypical geometric form. Subsequently, the newly presented prototypical form was perceived as more familiar than a previously presented distortion.

Although such experiments suggest that infants sometimes retain an abstract representation of category members, they do not demonstrate that conscious intellectual processes underlie infant categorization. Instead, the prototype effect may reflect constraints operating on unconscious perceptual and memory functions Further research is required to establish the role of active processes in prototype extraction.

Clearly, it is difficult to define infant categorization either on the basis of underlying processes or in relation to adult categorization. However, studies on infant categorization have several common characteristics that suggest an operational definition of the term. Babies are usually exposed to a series of stimuli that are similar along at least one dimension, but differ along at least one other dimension For example, infants might be familiarized with several stimuli (e.g., red square, red triangle, and red circle) from the category of red geometric forms. Next, categorization is tested by determining if babies respond to a new member of the familiar category (e.g, a red ellipse) similarly to the way they responded to the familiarization stimuli but respond to a member of a novel category (e.g., a blue ellipse) differently.

Within this paradigm, it is essential to demonstrate that the category members are not responded to equivalently simply because they are perceived as identical. Category members must be discriminable for infants within the testing situation (Olson & Sherman, 1983), and not simply discriminable for adults or distinguishable on the basis of a scale of measurement. Within-category discriminability has not always been verified in studies on infant categorization (e.g., Cornell, 1974; Kuhl, 1980, 1983) perhaps because researchers have assumed that category members are distinguishable. However, it is safer to actually test for within-category discrimination, especially in a new paradigm or if there is limited information about the stimulus dimensions being used.

Based on the operational definition, infant categorization here refers to the following set of behaviors. 1) After exposure to multiple stimuli with common properties, infants treat a novel stimulus possessing the properties as familiar, 2) babies discriminate among the stimuli sharing the common properties. A behavioral definition is adopted because of our limited understanding of the processes underlying infant categorization, especially infant auditory categorization However, such a position is not meant to imply that underlying processes are irrelevant; indeed, issues regarding processes will be addressed throughout the text.

In addition to the necessary criteria for demonstrating infant categorization, other conditions are also desirable. Both invariant features and differentiating features (i.e., features that vary across category members) should be specified (Olson & Sherman, 1983) Otherwise, it is difficult to know the basis for category formation. Indeed, studies in which invariant features cannot be specified may overestimate infants' categorization abilities. For example, Cohen and Strauss (1979) habituated infants to photographs of several female faces and found that infants did not dishabituate to a new female face. They concluded that babies formed a category for female faces and perceived the new face as a member of that category. However, the characteristics shared by the faces were not measured, so it cannot be determined whether babies' abstracted a category for female faces or abstracted a simple attribute shared by the photographs.

Specifying relevant features may help elucidate the various factors that influence infant categorization. Infants typically demonstrate categorization behavior after being exposed to a stimulus set that possesses invariant features. However, the probability of categorization is not similar for all stimulus sets; rather, categorization is influenced both by the nature of the perceiver and by the context (Mervis & Rosch, 1981; Rosch, 1978). Thus, the probability of categorization is increased if the invariant property is inherently salient and easily encodable, if within-category discriminability is reduced, or if between-category discriminability is enhanced. Consequently, the mere presence of an invariant property is not sufficient for eliciting categorization For example, 4-month-old infants categorized speech signals on the basis of vowel identity despite the presence of distracting pitch-contour information, but did not categorize the signals on the basis of pitch contour in the context of varying vowel identity (Kuhl & Miller, 1982). However, different results might have been obtained with more salient variation in pitch contour or with other changes to the stimuli.

In summary, infant categorization was defined in terms of infants' behavior because of our limited understanding of underlying processes. Also, the use of specifiable invariant and differentiating features was recommended to facilitate the understanding of babies' behavior. In the next section, categorization and a related phenomenon, perceptual constancy, are compared. Although categorization and perceptual constancy have traditionally been treated as distinct, justifications are given for considering auditory perceptual constancy in infancy as an example of infant auditory categorization.

Perceptual Constancy and Categorization

Categorization, the ability to treat discriminable stimuli as equivalent, often involves grouping **distinct** objects on the basis of common properties. Perceptual constancy refers to instances in which the visual perception of an object remains unchanged over transformations in rotation, in distance from the observer, or in color (Gibson, 1969) Nonetheless, perceptual constancy, which typically concerns a single object and only certain types of invariant and differentiating information, has been viewed as an instance of categorization. (see Bruner, Goodnow, Austin, 1956; see Bornstein 1984) In object constancy over rotation in space, for example, different perspectives of an object can be considered discriminable events that are members of a particular type of category called the object.

Infants apparently exhibit perceptual constancy of objects at an early age (see Bornstein 1984; Harris 1983), and discussions of infant categorization have referred to research on infant perceptual constancy (Bomba, 1984; Bornstein, 1984). Whether or not perceptual constancy and categorization across objects in infancy involve partially or entirely distinct processes remains unknown.

In the auditory modality, some experimenters have also described equivalence-making skills in infancy as perceptual constancy (Endman, 1985; Kuhl, 1980). Certain changes across auditory signals (e.g., variations in the intonation contour of a vowel) were seen as analogous to object transformations, so equating the stimuli was taken as an instance of perceptual constancy (Kuhl, 1980). However, since the notion of an "auditory object" is ambiguous, there appear to be no true distinguishing factors between studies on auditory perceptual constancy and studies on auditory categorization. Hence, in the present paper, studies on auditory perceptual constancy are reviewed and they are treated simply as research on auditory categorization.

Methods for Studying Categorization

So far, the discussion has focused on similarities across studies of infant categorization. However, experiments in this field have used a variety of different methods. The following review examines techniques that have been used to investigate categorization mainly of auditory signals, but also of visual signals when it is relevant to the research reported here.

To demonstrate categorization, infants must respond differentially to category and noncategory members. Identification procedures would be ideal, if they did not require infants to learn the difficult task of performing two distinct responses (Fodor, Garret & Brill, 1975; see Kuhl, 1983, for a discussion). Typically, experimenters have studied infant categorization with discrimination paradigms that fall into two main classes: reinforced training techniques and habituation-dishabituation procedures.

Training procedures. Visually reinforced head-turning techniques (Suzuki & Ogiba, 1961) have been used extensively to investigate speech categorization (Fodor, Garrett & Brill, 1975; Hillenbrand 1983; Holmberg, Morgan & Kuhl, 1977; Katz & Juscyzk, 1980; Kuhl, 1979,1983). Their basic premise is that babies will learn a behavior to see and hear the activation of a mechanical toy or a similar display.

Fodor, Garrett, and Brill (1975) investigated speech categorization in 4-month-old infants using a left-right reinforced head-turning procedure. Half the babies were tested for their ability to group syllables that shared phonetic information (same-phone syllables), while the other half were tested for their ability to group syllables that possessed a common acoustic cue (same-acoustic cue syllables). Babies sat facing two loudspeakers, one on the left and one on the right. Speech tokens from both categories of syllables were presented alternatively from one or the other of the loudspeakers. A visual reinforcer was activated at the sound source after each presentation of same-phone syllables for one group, and after each occurrence of same-acoustic cue syllables for the other. Anticipatory orienting to the visual reinforcer was taken as a measure of infants' ability to categorize speech tokens. Although phonetic-grouping babies demonstrated better anticipatory orienting, all infants performed poorly, perhaps because infants were too young to be trained in the procedure, or perhaps because two visual reinforcers were used (Kuhl 1983).

Kuhl (1979) developed a more commonly used training method. It combines visually-reinforced head-turning with a transfer of learning format. Infants are exposed to a repeating signal through a laterally positioned speaker. If they orient to the speaker when the signal changes, a mechanical toy is activated. In the first phase of training, infants are presented a background signal that consists of repetitions of one token of a particular category (e.g., /bi/) and they must orient when the background changes to repetitions of a token of another category (e.g., /di/). In the next phase, the background signal consists of repetitions of tokens that belong to the original training category but that differ along one or more irrelevant dimensions (e.g., /bo/, /bi/, /ba/, which are members of the category of syllables beginning with the phoneme /b/ that differ in vowel context). Infants must ignore changes within the background category, but must still orient to tokens from the second category.

Thus, recognition of a new category member is indicated by an orienting response, while recognition of a member of the familiar category is indicated by witholding the orienting response. The number of orienting responses is compared for test trials, in which the stimuli change, and designated control trials, in which they do not.

Kuhl's procedure has proven useful for studying speech categorization. Its primary advantage over other techniques is that infants do not habituate over many trials because of the visual reinforcer, so many data points can be obtained from each infant. Thus, it is possible to examine individual as well as group data.

The procedure, however, has some drawbacks for studying auditory categorization. First, it is difficult to obtain a reliable head-turning response with infants younger than 5 or 6 months old (Moore, Wilson & Thompson, 1977). Second, the method is actually a training procedure, inasmuch as the reinforcement contingencies specify the rules of categorization. Thus, it provides information mainly about infants' ability to learn speech categories and not necessarily about the dimensions along which infants most naturally categorize auditory signals.

Habituation-dishabituation procedures. Auditory categorization has also been studied with the high amplitude sucking (HAS) and operant fixation techniques. An infant is first habituated to a set of stimuli that share at least one common property defining the category. The infant is then presented a new stimulus from the familiar category or a stimulus from a novel category. Evidence for categorization is provided by generalized habituation to the new, familiar-category stimulus coupled with recovery from habituation to the novel-category stimulus. The discriminability of category members is tested by habituating babies to a single member of the familiar category and demonstrating recovery to other members of the category.

The invariant dimensions of the habituation stimuli specify the category, and infants presumably notice the common properties and habituate to the category as a whole. Members of the same category are treated similarly in the following sense: Just as there is little interest in the category members at the end of the habituation phase, there is little interest in a new member of the same category during the post-habituation test phase. In contrast, infants are expected to show recovery of interest to a member of a novel category.

The HAS technique (Siqueland & DeLucia, 1969) has been used to investigate categorization in very young infants (e.g., Juscyzk & Derrah, 1983; Kuhl & Miller, 1982). The infant learns that sucking strongly on a plastic nipple (i.e., high amplitude sucks) results in the presentation of an auditory stimulus. At first, the rate of high amplitude sucking increases as the infant learns the contingency, but then decreases over time as the novelty of the stimulus declines. Changing the auditory stimulus results in an increased rate of sucking, provided that the baby notices the change.

The HAS procedure can be used to study categorization behaviour. During habituation, sucking results in the presentation of multiple tokens from a category. During the test, half the infants receive a novel member of the familiar category, and the other half receive a member of a new category. Infants who receive the novel-category stimulus are expected to show an increase in their sucking rate, while those who receive with the familiar-category stimulus are not.

Although the HAS technique is effective, it requires rather elaborate equipment to monitor the response. Moreover, the procedure can be difficult to implement; baseline rates of sucking must be within a certain range to ensure that the infant's sucking can both increase as the contingency is learned and decrease as the novelty of the stimuli declines. Perhaps a more important drawback is that the procedure is only effective with pacifier-accommodating infants, thus excluding most babies older than 4 months of age.

The operant fixation habituation-dishabituation technique (Boyd, 1975), which has been used for some time to assess infants' auditory discrimination, has only recently been used to examine categorization (Miller, 1983; Washburn, 1984). An infant can learn that fixating a visual display results in the presentation of a sound. Furthermore, fixation of the visual display initially increases as the infant learns the contingency, but eventually decreases as the novelty of the sound declines. Changing the auditory signal results in a recovery of looking, provided that the baby notices the change.

Miller (1983) used this technique to study categorization of voices on the basis of gender by 2-and 6-month-old infants. During a familiarization phase, fixation of a display resulted in a sequence of six male voices or a sequence of six female voices. During a test phase, infants received either a set of new tokens of the familiar category, a set of tokens of a novel category, or the set of familiarization stimuli. Six-month-olds provided evidence of categorization: They did not show recovery for new tokens of the familiar-category, but did for tokens of a novel category.[1] Two-month-olds, in contrast, showed recovery for new tokens of the familiar category and for tokens of a novel category, indicating discrimination but not categorization of the stimuli.

Miller's study, along with a procedurally similar study by Washburn (1984), established the effectiveness of operant fixation techniques to test categorization. The operant fixation procedure offers a number of advantages. It requires only simple apparatus to measure the response, and there is no need to establish stringent baseline data. Moreover, categorization behaviour is evaluated without training. Finally, unlike the HAS and reinforced head-turning techniques, it can be used over a wide age range.

Novelty-preference paradigm. The novelty-preference technique has been used extensively to study infant visual categorization, but until the present research it has not been applied to auditory categorization. Infants are repeatedly presented several exemplars of a given category (e.g., a series of male faces) during a familiarization phase. Subsequently, two stimuli are presented in a preference test: a new familiar-category stimulus (e.g., a new male face) and a novel-category stimulus (e.g., a female face). Infants are expected to look at the novel-category stimulus more than at the new, familiar-category stimulus. To control for side preferences, each test stimulus can be presented to the child's left for half the test and to the right for the other half.

The procedure has been used to study categorization of faces both on the basis of identity independent of orientation (Cornell, 1974; Fagan, 1976) and on the basis of sex (Fagan, 1976, 1979). It has also been used to study categorization of geometric forms on the basis of shape (Bomba & Siqueland, 1983) and orientation (Bomba, 1984). Finally, the method has been used to test different models of how infants form a mental representation of a category (Bomba & Siqueland, 1983; Sherman, 1985; Strauss, 1979).

Habituation-dishabituation techniques and novelty-preference techniques have been thoroughly compared as tests of infant discrimination (Cohen & Gelber, 1975). In contrast, comparisons of the procedure for categorization research have generally focused on similarities of the techniques (Bomba and Siqueland, 1983; Olson & Sherman, 1983; Sherman, 1985). Categorization is indicated similarly in both procedures. Infants presumably lose interest in the category members during familiarization and continue to lack interest when a new member of the familiar category is presented.

Despite these similarities, there are important differences between the methodologies. During the test phase of habituation-dishabituation paradigms, stimuli of familiar and novel categories are generally presented to different groups of babies. Hence, the infant must make an absolute comparison of the test item and the familiarization stimuli. This is analogous to asking an adult if a single item does or does not belong to a previously experienced set. The experimenter then compares the absolute similarity judgements of babies presented a familiar-category stimulus with those presented a novel-category stimulus. In novelty-preference techniques, by contrast, both test stimuli are presented simultaneously, so the baby must make a relative similarity comparison. This is analogous to asking an adult which of two items least belongs to a previously presented set.

The distinction between procedures can also be exemplified by the discrepant findings one might obtain with each procedure. Infants in both groups of a between-subject procedure may dishabituate to test stimuli, but infants in a paired-comparison paradigm might nonetheless show a preference for one of them. Hence, categorization abilities might be considered absent in the between-subject procedure, but present in the paired-comparison method.

To summarize, a number of paradigms have been used to study categorization, each having its strengths and weaknesses. Differences in the phenomena tapped by, for example, training and non-training procedures, or by within-subject and between-subject designs, remain unclear. Future research using the variety of available techniques may elucidate these differences.

Infant Categorization of Auditory Signals

This section reviews studies of infant auditory categorization. It examines the work on perceptual constancy, the search for natural categories along which babies partition speech, and finally, the categorization of non-speech signals.

With two exceptions (Endman, 1985; Washburn, 1984), all studies on infant auditory categorization have used speech sounds (see Aslin et al., 1983), not simply because they are ecologically relevant, but also because of theoretical issues in the language development literature. Early on, investigators noted the considerable acoustic variability among the exemplars of particular phonetic categories. They sought to identify the invariant acoustic cues that specify such categories. Failing to do so, researchers suggested that specialized speech-processing mechanisms must underlie the comprehension of speech (Liberman, Cooper, Shankweiler & Studdert-Kennedy, 1967). Accordingly, experiments on infant categorization were undertaken to demonstrate that infants process speech signals differently from other auditory stimuli (Aslin et al., 1983). Two general types of categorization studies were conducted, each concerning different kinds of acoustic variation that are encountered across the speech tokens within common linguistic categories (Miller & Eimas, 1983).

The first type of acoustic variation reflects variable production of a particular segment in a given phonetic context by a single speaker. That is, the acoustic signal associated with a phoneme varies depending on its position in a word and the particular phonemes that precede and follow it. This variation has been studied in the context of experiments on "categorical perception" (for a review of this research see Pastore, 1981; Pisoni, 1978). However, the findings of infant categorical perception studies do not conform to one of the criteria of categorization used here, namely that category members be discriminable. Researchers have not firmly established that the grouping of stimuli in studies of categorical perception is not simply due to infants' inability to discriminate within-category stimuli[2] (Miller & Eimas, 1983).

The second source of acoustic variation specified by Miller and Eimas (1983) arises from changing the speaker, the speech rate, the intonation contour, the phonetic context, and the like. Categorization in the context of such variation has been investigated using acoustic tokens that have either been shown to be discriminable or are acoustically so different that they are presumed discriminable. Hence, this body of research is relevant to the present studies. Some studies searched for linguistic categories along which infants organize speech. Other research, on auditory perceptual constancy, concerned infants' ability to equate acoustically distinct speech tokens belonging to the same phonetic category.

<u>The search for natural linguistic categories</u> Developmental research has concerned itself with the way infants internally represent speech sounds, that is, investigators have sought the perceptual categories that babies may use to divide the speech stream (Aslin et al, 1983) Some have suggested that babies group speech signals into categories according to phonemes (Fodor, Garett & Brill, 1975; Holmberg, Morgan & Kuhl, 1977, Jusczyk & Derrah, 1983; Katz & Jusczyk, 1980). Others have argued that infants categorize speech at the sub-

phonetic level, at the level of phonetic features (Hillenbrand, 1983) (e.g., infants might group the phonemes /m/ and /n/ since they share a nasal feature).

As mentioned above, Fodor, Garrett and Brill (1975) used an anticipatory headturn response to examine 4-month-old babies' ability to form syllable groupings on the basis of phonetic and acoustic identity. The stimulus items consisted of different syllables, some of which were from the same phonetic category (e.g., /pa/ and /pi/) while others were from different phonetic categories (e.g., /pi/ and /ka/) that shared an important acoustic feature (i.e., frequency of the burst). Infants performed better for phonetic than acoustic groupings, suggesting that babies represent speech in terms of phonetic categories. However, the satisfactory levels of anticipatory behaviour were generally low, so the results should be interpreted cautiously.

Holmberg, Morgan, and Kuhl (1977) investigated phonetic categorization in 6-month-olds using Kuhl's head-turning procedure. Babies discriminated the fricative contrasts /f/vs./θ/and /s/vs./ʃ/ when vowel context (e.g., /fa/, /fi/, /fu/) and utterance position /fa/, /af/ were varied randomly. Hence, infants were able to categorize consonants despite the presence of distracting information

Katz and Jusczyk (1980) tested if 6-month-olds can categorize the stop consonants [b] and [d] across two and four different vowel contexts (e.g., /bi/, /bo/, /be/, /bʌ/) more easily than for an arbitrary grouping of the same stimuli (e.g., with two vowel contexts), infants performed above chance for a phonetic grouping of the syllables, but not for a nonphonetic grouping, which supports the phonetic categorization hypothesis. However, there was no evidence of phonetic categorization when four vowel contexts were used. Thus, infants' ability to categorize phonetically may be limited, or infants may have been taxed by the demands of the headturning paradigm, or both.

Jusczyk and Derrah (1983) used the HAS procedure to investigate phonetic categorization in 4-month-olds Based on studies of visual categorization (Bornstein, Kessen & Weiskopf, 1976, Cohen & Strauss, 1979), they hypothesized that familiarization to different instances of a particular phonetic category would result in less responding to a new instance of the same category than to a new instance of a different category. Using the HAS procedure, infants were first presented with a series of syllables /bi/, /bo/, /ba/, /be/ during a preshift phase and were that presented the same series plus /bu/ (i.e , a new instance of a familiar category) or /du/ (i.e , a stimulus from a new phonetic category). Infants in the two post-shift groups did not differ significantly, so the results failed to support a phonetic categorization hypothesis

Some investigators have hypothesized that infants categorize speech at the level of phonetic features Hillenbrand (1983) tested infants' ability to respond to syllable groupings organized on the basis of plosive (/b/, /d/ and /g/) versus nasal (/m/, /n/ and /ŋ/) features of the initial consonants Infants were initially trained to discriminate a change from stop consonant to a nasal consonant (e g , /ba/ vs /ma/) Subsequently, babies maintained this discrimination, even though other consonants were added to the categories (e g , /da/ and /ga/ vs /na/ and /ŋa/) Although these results suggest that infants can categorize speech tokens on the basis of phonetic features, babies' performance could have been based on the presence of a salient acoustic correlate, such as nasal resonance, rather than on an abstract phonetic feature (Aslin et al., 1983).

Auditory perceptual constancy. Some of the work on speech categorization has been conceptualized in terms of auditory perceptual constancy (Kuhl, 1979, 1980, 1983; Kuhl & Miller, 1982). Kuhl argued that much like the perceptual constancy of an object across transformations in space, the perception of a phone remains constant over acoustic transformations produced by particular syllabic contexts or by speakers. Just as we acknowledge the existence of real objects in the visual modality, Kuhl suggested that phonemes can be considered auditory objects, since they are eventually defined by sets of abstract prototypical acoustic cues (Kuhl, 1980,1983).

Kuhl's experiments concerned babies' ability to form auditory equivalence classes despite irrelevant variations in either pitch or speaker's voice. The method combines a visually reinforced head-turning procedure and a transfer of learning paradigm Infants are initially trained to discriminate between two single speech tokens that represent different phonetic categories. Next, they are tested for transfer of training to novel, discriminably different instances of the same phonetic categories.

Kuhl (1979) investigated 6-month-old infants' discrimination of two vowel categories, /a/ and /i/, when stimuli were varied across two irrelevant dimensions, pitch contour (rising and falling) and talker identity (male, female, and child). Babies maintained the discrimination between the /a/ and /i/ tokens despite variation across either dimension, which was taken as evidence of infants' ability for perceptual constancy of vowels.

Similar studies with 6-month-olds demonstrated perceptual constancy of consonants (/s/ vs. /ʃ/ and /f/ vs. /θ/) (Hillenbrand, 1983; Kuhl, 1980) and of other vowels (/a/, /ɔ/) (Kuhl, 1983) across variations in speaker identity. Using the HAS procedure, Kuhl and Miller (1982) also demonstrate perceptual constancy of vowels (/a/, /i/) in 1-to 4-month-old infants. Thus infants have quite a broad capacity for perceptual constancy of speech signals, a capacity that is at least partly developed soon after birth.

To summarize, the research conceptualized in terms of perceptual constancy suggests that young infants can group speech tokens according to phonetic categories despite variations in pitch and speakers. The search for innate categories along which infants partition speech has been less fruitful. Results suggest categorization at the phonetic (Fodor, Garrett & Brill, 1975; Holmberg, Morgan & Kuhl, 1977; Katz & Jusckyk, 1980) and sub-phonetic levels (Hillenbrand, 1983). However, conclusions are difficult to draw because positive evidence was partial in certain circumstances (e.g., Katz & Jusczyk, 1980) and subject to alternative interpretations in other instances (e.g., Hillenbrand, 1983)

In general, a number of factors make the interpretation of speech categorization research difficult. Among the factors is the frequent inability to define the invariant acoustic information that underlies infants' categorization[3] Typically, it is simply assumed that a phonetic category is, as yet, defined by an unknown set of abstract configurational properties (see Kuhl, 1980). Since the basis for categorization is unknown, it is difficult to draw conclusions. For example, categorization studies have sought to compare infants' ability to group speech signals according to linguistic versus acoustic dimensions (e.g., Fodor et al., 1975). However, it is doubtful whether superior linguistic categorization in a particular study could ever be taken as evidence of a general phenomenon. The experimental stimuli may simply incorporate richer information for linguistic categorization than acoustic categorization. Hence, specification of the information underlying linguistic categorization is required.

Categorization of Non-speech Auditory Signals

Only two studies have demonstrated true categorization of non-speech signals by infants.[4] Washburn (1984) examined the development of infants' ability to perceive a category of rhythmic patterns. Four-and 7-month-old babies were tested using a habituation of fixation procedure. There were two categories of rhythms [2-1 patterns (● ● ●) and 1-2 patterns (● ● ●)], each with several exemplars that differed in tempo. During the habituation phase, infants in a category condition received either three sequences of the 2-1 category or three sequences of the 1-2 category, while infants in a control condition received just one 1-2 or one 2-1 pattern. During a test phase, all infants were presented four sequences: the familiar rhythm at a familiar tempo (a familiar category member), the familiar rhythm at a novel tempo (a novel instance of the familiar category), a novel rhythm with a familiar tempo, and finally, a novel rhythm with a novel tempo.

At both ages, babies in the control condition dishabituated to a change in rhythm or to a change in tempo, thereby indicating their sensitivity to both these auditory dimensions. In the category condition, 7-month- olds showed the expected pattern of results. They did not show recovery to a new member of the familiar category (a familiar rhythm with a novel tempo), but did recover to a member of a novel category (i.e., a new rhythm). In contrast, 4-month-old infants showed recovery not only to an instance of a novel category, but also to a novel member of the familiar category. Thus, both groups discriminated rhythm and tempo information, but only the older group categorized the sequences on the basis of rhythm.

Endman (1985), using Kuhl's (1979) proceudure, investigated perceptual constancy of two harmonic structures in 7- and 8-month-old babies. In the training phase, babies were taught the harmonic structure contrast. Subsequently, infants were tested for their ability to maintain the harmonic structure discrimination across variation along one of three dimensions: intensity, duration, or fundamental frequency. A fourth condition was included to rule out the possibililty that infants performed simply by memorizing which exemplars belonged to a particular harmonic structure category. This condition tested babies' ability to form arbitrary groupings from exemplars that did not all share the same harmonic structure.

Infants were able to categorize signals according to harmonic structures, despite variations along the other dimensions. In contrast, exemplars could not be categorized on the basis of arbitrary groupings. In a second study, Endman demonstrated that babies were also able to maintain intensity, duration, and fundamental frequency discriminations across variations in harmonic structure.

The dearth of research on the categorization of nonspeech signals is surprising. Such studies could examine the processes underlying early auditory categorization. Moreover, investigations of nonspeech categorization might also elucidate findings for the language development literature. Thus, several studies were undertaken here to examine babies' ability to categorize auditory sequences.

<u>Outline of Thesis</u>

The studies used synthetic nonspeech tonal sequences, which enabled the specification of differentiating and invariant information across category members. At the same time the stimuli were selected to resemble those used for speech categorization research. As mentioned above, speech categorization studies typically require infants to categorize stimuli that do not share any simple invariant acoustic cues. Similarly, the present research concerned infants' ability to equate sequences that do not share any simple acoustic information, but rather share a more abstract characteristic, frequency contour (e.g., a 100Hz tone followed by a 150 Hz tone represents a rising frequency contour).

Sequences with the same contours differed in frequency range and absolute frequency of the tones, but possessed similar frequency relationships between tones. For example, the sequences 100 Hz-150 Hz and 2000Hz-3500 Hz have the same rising contour. They share relational information rather than any specific acoustic information. Thus, category formation on the basis of frequency contour is a more abstract form of categorization than categorization on the basis of a single acoustic cue. The abstraction of frequency contour requires an appreciation of the complete pattern over time, and equating patterns on the basis of contour information cannot be done simply by matching tonal frequency values in two patterns.

Study 1, described in the following section, evaluated the suitability of a new technique for examining auditory functions in infancy. In studies 2 and 3, the method was an effective non-training procedure to demonstrate auditory categorization in 10-month-old babies. In particular, the studies tested babies' ability to categorize auditory patterns on the basis of melodic contour.

Study 1

A New Method for Evaluating Auditory Discrimination

To measure infant auditory discrimination, an operant-fixation technique was combined with a novelty-preference test similar to that used in studies of infant vision.[5] Operant fixation procedures in between-subject designs are effective for assessing auditory discrimination in 3- to 7- month-olds (Demany, 1982; Demany & Armand, 1984; Demany, Goodman & Haith, 1982; Demany, McKenzie, & Vurpillot, 1977; Washburn & Cohen, 1984). Babies are presented a single visual target, and sound is presented contingent on fixation of the target. All infants are typically habituated to the same stimulus, and, after habituation, different groups of infants receive different test stimuli. Conclusions are based on between-group differences in infants' responses to the test sounds.

Bundy and Columbo (1981) conducted the only study of infant audition using an operant-fixation preference technique. They tested 4-month-old infants for a natural preference between two sounds, white noise and a female voice. Infants were seated facing two identical lit patterns. Fixation of one display resulted in the presentation of a female voice, while fixation of the other display resulted in white noise. Half the infants received a voice-left/noise-right condition, while the other half received the opposite contingency. A comparison of the total time fixating each display revealed that infants preferred the voice.

Thus, a fixation preference procedure can measure auditory selectivity for strikingly different sounds in young infants. The present study extended Bundy and Columbo's (1981) findings in the following ways: First, the procedure was adopted to test auditory discrimination rather than natural preferences; the new procedure incorporated both a familiarization phase and two test periods similar to those in visual novelty-preference studies. Second, the procedure was used to test a finer auditory discrimination than that tested by Bundy and Colombo. Finally, the present study evaluated the effectivenes of the technique with infants as old as 11 months of age.

The utility of the procedure was tested with a frequency discrimination, since it is well established that babies are sensitive to frequency information. Young infants discriminate frequency changes in pure tones, viz., 200 Hz vs. 500 Hz (Wormith, Pankhurst & Moffit, 1975) and 1100 Hz vs. 1900 Hz (Berg, 1972; Leavitt, Brown, Morse & Graham, 1976). Indeed, frequency difference limens in 5- to 8-month-old infants are almost as small as adult values (Olsho, Schoon, Sakai, Turpin & Sperduto, 1982b). Moreover, babies are sensitive to frequency information in patterns. They can discriminate between auditory sequences that either differ in the frequency values of their tones (e.g., Chang & Trehub, 1977a; Kinney & Kagan, 1976) or differ in the order of their tonal components (e.g., Demany, 1982; McCall & Melson, 1970; Melson & McCall, 1970).

The present study tested babies' discrimination of two sequences. One pattern consisted of an identical repeating tone; the other pattern alternated between two tones that differed in frequency. Infants were first familiarized with one of the sequences and then tested for a preference between the two patterns. It was expected that following familiarization, infants would prefer the novel test pattern.

Method

Subjects

Twenty-four full-term infants (13 males and 11 females) served as subjects; they were between 44 and 48 weeks of age (mean age: 46 weeks). The infants were recruited by first sending a letter to parents whose names were found in newspaper birth announcements and in hospital lists. The letter was followed up with a phone call. Eleven additional infants were seen in the laboratory, but they did not provide data due to distress (n = 6), procedural or equipment problems (n = 4), or because they did not sufficiently sample both test stimuli (n = 1).

Apparatus

The equipment included a camera (Panasonic WV-1350A) with an infra-red lens (Canon TV Zoom lens), two loudspeakers (Boston Acoustic A40), two tapedecks (Hitachi D-E11), one stereo amplifier (Hitachi HA-2800), a videotaperecorder (Sony-matic AV-3650), a television monitor (Sony CVM-131), a pocket computer (Radio Shack TRS-800), a Tandy headphone radio, and a sychronizer. Two adjacent rooms were used: the infants were tested in one room and the experimenters operated the video, audio, and computer equipment in the other (see Figure 1).

Testing room. The testing room included two visual displays mounted 42.5 cm apart from centre to centre on a table 73.5 cm from the ground. Each visual display was a lit hexagonal form with a perimeter of 15.3 cm, constructed by inserting transparent plastic markers into a pegboard placed in front of a 25-watt

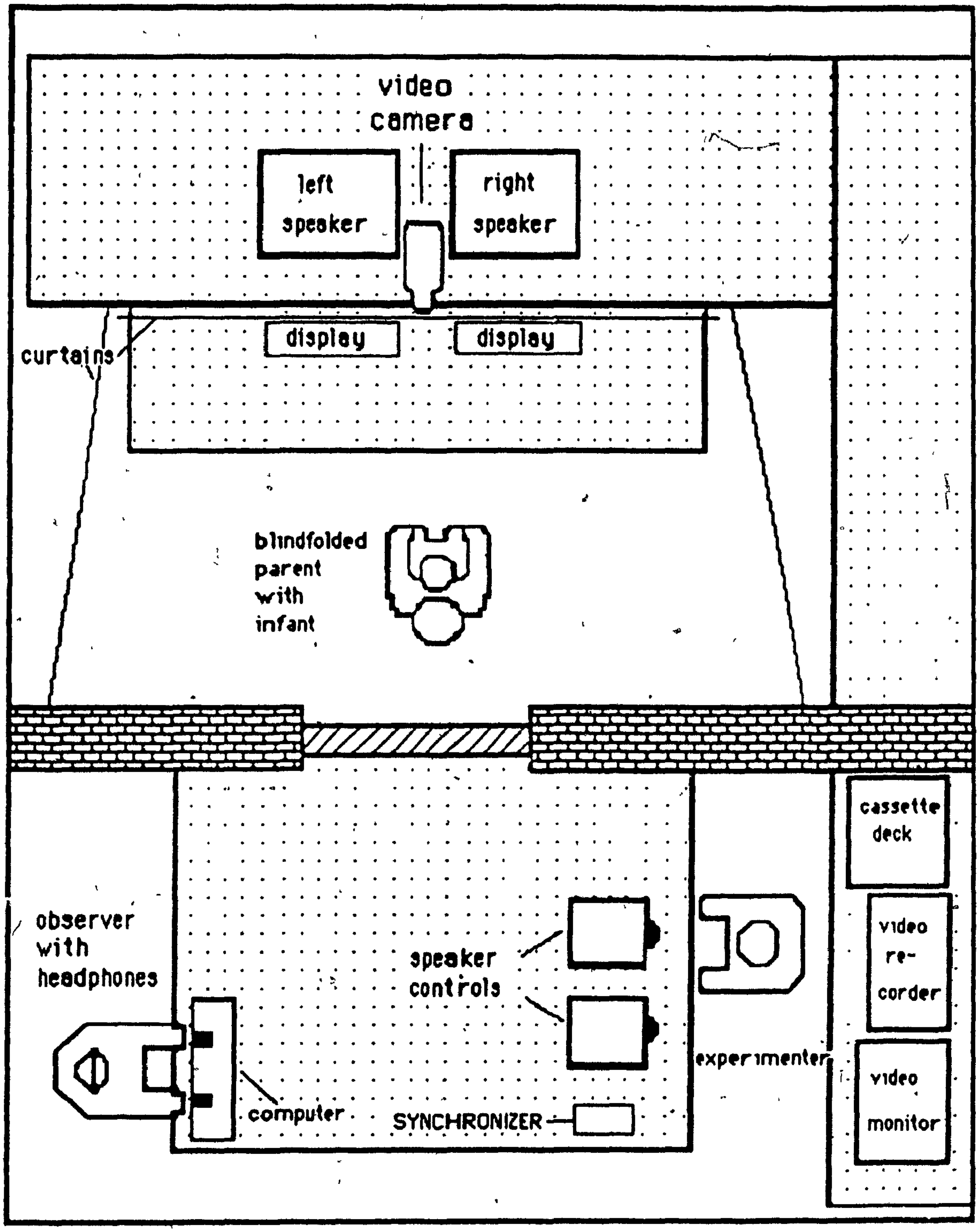


Figure 1 Schematic illustration of the test chamber.

white bulb. Infants faced both displays at a distance of approximately 65 cm. Behind the displays was a large, dark blue screen, at the top of which were mounted two red lamps that dimly lit the room. A camera, hidden behind the screen and located midway between the two displays, videotaped the baby's face through an observation hole. Also hidden by the screen were two loudspeakers, one located behind each display.

Control room. A videorecorder in the operator's room displayed the image of the infant's face on a television monitor. A pocket computer mounted in a wooden frame was used to record the infant's total fixation times during successive 10-sec periods of observation (see Haith & Bertenthal, 1979 for a discussion of this technique). Two Plexiglas levers were fixed to the wooden frame and extended over the keyboard of the computer. Depressing a lever simultaneously closed switches controlling both a timer in the computer and the loudspeaker-tape deck circuit. One lever activated the left loudspeaker, while the other activated the right speaker. The synchronizer monitored the output of the tape decks via the headphone jacks. The synchronizer prevented a clicking sound associated with the sudden onset or offset of an auditory signal: If one of the levers was depressed during a signal, the presentation of the sequence was delayed until a silent interval was encountered in the pattern; similarly, if a lever was released during a signal, the cessation of sound was delayed until a silent interval. An additional switch controlled the illumination of the visual displays and two other switches determined which of the two tape decks supplied sound to a particular speaker.

Stimuli

The stimuli were synthesized digitally on a PDP-11/34 computer, using the Mitsyn software package (Henke, 1975). Stimuli were output on two channels of the computer's digital to analog converter and recorded on 4-track, 2-channel audiotapes (Realistic, Hi-Bias) with an Hitachi D-E11 tape deck.

Two auditory patterns were used (see Figure 2). Each consisted of a series of 200-msec pure tones with 20-msec exponentially ramped rise and fall times. All inter-tone intervals were 200 msec. In one pattern, all the tones were 1100 Hz (constant pattern). In the other pattern, the tones alternated between 1100 and 1900 Hz (alternating pattern). The two frequencies were chosen because they are discriminable by infants (Berg, 1972; Leavitt, Brown, Morse & Graham, 1976). The ambient sound pressure level in the room was 50 -55 dBA. All patterns were presented at mean peak intensities of 65 dBA, as measured at the position of the infant's head.

The auditory patterns were recorded on one channel of the audiotapes, while a sequence of 100-Hz pure tones was recorded on the other channel to control the functioning of the synchronizer. The 100-Hz pure tones began 10 msec before, and ended 10 msec after, each of the simulus tones.

Procedure

Parents were first asked to read and sign a consent form that reassured them regarding the safety of the procedure and briefly described the nature of the study (see Appendix A). Next, one of the parents was seated in front of the displays and instructed to hold the child on his/her lap without hindering the infant's head movements and without talking To reduce the likelihood that the

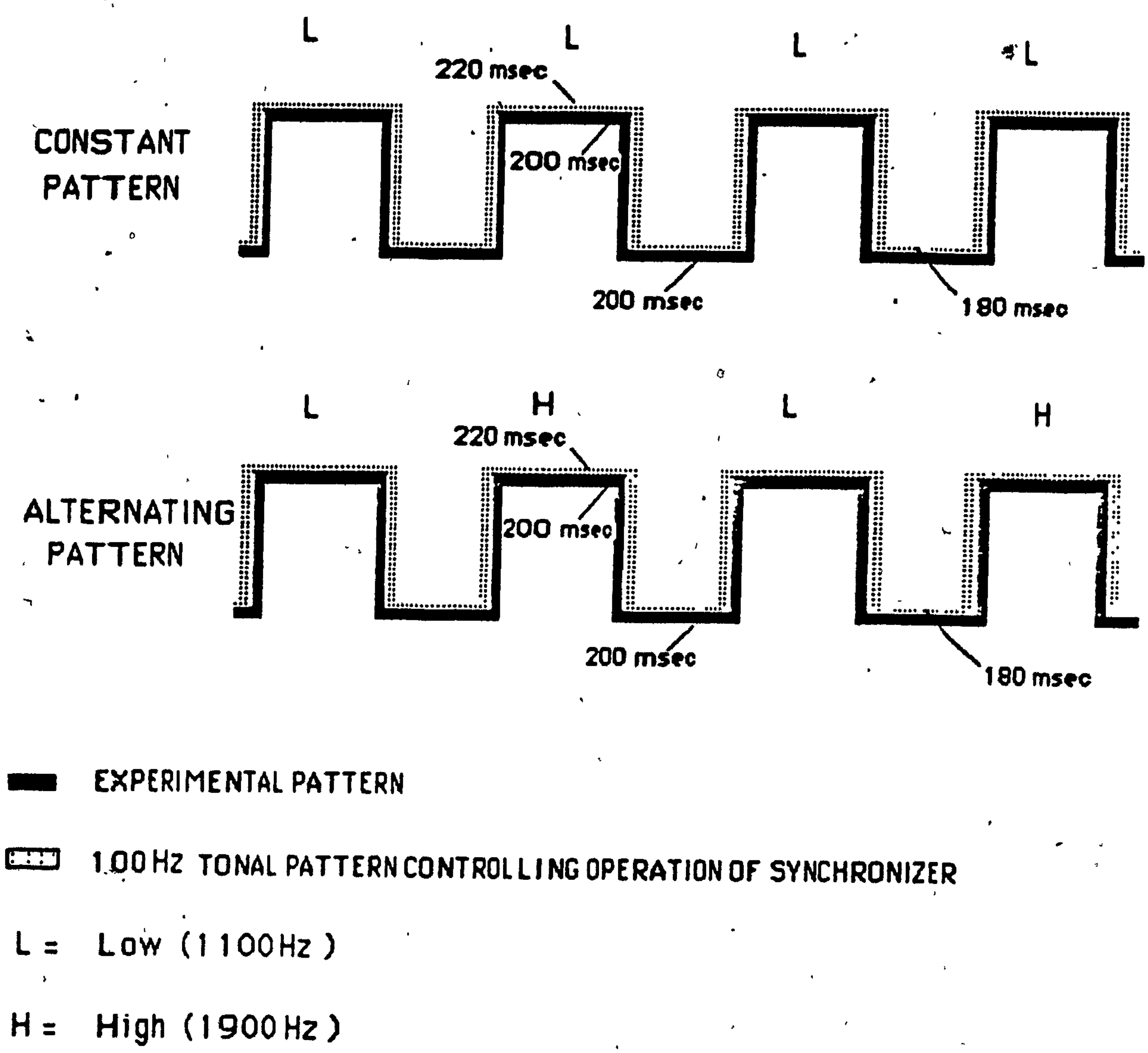


Figure 2. Temporal parameters of tonal patterns of study I.

parent would influence the child's behavior, he/she was asked to wear a blindfold, and the purpose of the study was not revealed until testing was completed

The infant faced the two identical visual displays, one on the left and one on the right. An observer, unaware of the experimental conditions, monitored the infant's visual activity on the video monitor. The observer listened to music through headphones which prevented her from hearing the experimental stimuli and ensured that she remained naive to the experimental conditions Whenever the baby fixated one of displays, the observer pressed the lever that presented a sound pattern through the speaker behind that display An assistant controlled the lighting of the visual displays, the synchronizer, and two relays that determined which of the two tape decks supplied sound to each of the loudspeakers.

The procedure included a familiarization and a test phase The familiarization phase began when the observer signalled the assistant to illuminate the visual displays. During familiarization, fixation of either display resulted in the presentation of one of the repeating sequences, the constant pattern for half the infants and the alternating pattern for the other half When the pattern had been presented for a cumulative period of 60 sec, the computer emitted a 3.2-sec tone that indicated the end of familiarization. During this interval, the assistant signalled the observer not to judge the infant's fixations and made the necessary adjustments in the audio equipment to start the test phase.

The 40-sec test was divided into two 20-sec periods The first test period began when the signal tone stopped, at which time the assistant signalled the observer to resume judging fixations At the end of the first test period, the 3.2-

sec tone was emitted again, during which time adjustments were made to the equipment. The second test period followed.

During one of the test periods, fixation of the right display resulted in the familiar pattern, whereas fixation of the left display resulted in the novel pattern. For the other test period, the left-right position of the sequences was reversed. Hence, the familiar pattern was presented on the left for half the test phase and on the right for the other half, with the order of familiar-left and familiar-right counterbalanced across subjects.

After the test, the observer, who was still naive to the experimental conditions, determined if the infant had been sufficiently calm and alert to provide scorable data. Next, the fixation data were retrieved from the computer's memory and considered acceptable if the child sampled each test pattern for at least 1 5 sec during the test. Finally, parents were asked for some demographic information concerning themselves and their child (Appendix B) and they were informed regarding the purpose of the study.

Results

An initial analysis tested if infants in the two familiarization groups took similar amounts of time to accumulate 60 sec of viewing time. The basic datum was the number of 10-sec blocks to reach the familiarization criterion. A one-way analysis of variance (ANOVA) was conducted with Familiarization Pattern (constant and alternating) as a between-subject factor.[6] Although infants who received with the constant pattern took somewhat longer to accumulate 60 sec of fixation time than infants who received the alternating pattern (13.6 vs. 11.4 10-sec blocks), the groups did not differ significantly, $F(1, 22) = 2.90$, $p > .05$.

An analysis was undertaken to determine if infants' interest in the stimuli declined over the course of the familiarization phase (see Table 1). The dependant variable of interest was amount of looking. A 2 x 2 ANOVA was conducted with Block (the first 30 sec of familiarization and the last 30 sec) as a within-subject factor and with Familiarization Pattern (alternating and constant) as a between-subject variable. The analysis yielded a significant main effect for Block, $F(1,22) = 9.35$, $p < .05$, but the interaction was not significant, $F(1,22) = .14$, $p > .05$. Hence, the mean duration of looking declined from the first to the last 30-sec block similarly for both familiarization groups.

The primary analysis determined if, as expected, infants fixated the display associated with the novel pattern more than they fixated the display associated with the familiar pattern. The dependent variable of interest was the proportion of time spent fixating the display associated with the novel pattern ($prop_{nov}$). It was calculated as $prop_{nov} = [\, t_{nov} / (t_{nov} + t_{fam}) \,]$ where t_{nov} was the total time an infant fixated the display associated with the novel sequence and t_{fam} was the total time the infant fixated the display associated with the familiar sequence[7]

The mean $prop_{nov}$ value was calculated across all subjects and compared to .50, the proportion expected by chance. The obtained value, .61, was significantly greater than .50, $t(23) = 3.67$, $p < .05$, 1-tailed. Thus, babies fixated the display associated with the novel sequence more than the display associated with the familiar pattern.

Table 1

<u>The Relationship Between the Familiarization Pattern Received and the Amount of Looking During the First and Last 30 sec of Familiarization.</u>

Familiarization Pattern	First 30 sec	Last 30 sec
Constant	20.6	3.6
Alternating	23.1	2.8
M	21.9	3.2

Although the experimental design was counterbalanced, an analysis was conducted to verify that the preference for the novel sequence was not artifactually due to a natural preference for one of the patterns. The $prop_{nov}$ data were subjected to a one-way ANOVA with Familiarization Pattern (alternating and constant) as the between-subject factor. The analysis yielded a marginally significant effect of familiarization pattern, $F(1,22) = 3.41$, $p < .08$. Infants in the constant-pattern group looked at the display associated with the novel pattern more than infants in the alternating-pattern group (.66 vs. .56). That is, babies looked somewhat more at the display associated with the novel pattern if it was alternating rather than constant.

An additional analysis was necessary to ensure that the preference for the novel test pattern across conditions was not attributable solely to infants' natural preferences. The proportion of looking time attending to the alternating pattern ($prop_{alt}$) was computed as follows: $prop_{alt} = t_{alt} / (t_{alt} + t_{con})$, where t_{alt} was the total time an infant fixated the display associated with the alternating pattern, and t_{con} was the total time an infant fixated the display associated with the constant pattern. A one-way ANOVA with Familarization Pattern (alternating and constant) as a between-subject factor yielded a significant result, $F(1,22) = 5.53$, $p < .05$. Infants fixated the display associated with the alternating pattern significantly more during the test when they had been familiarized with the constant pattern than when they had received the alternating pattern (.60 vs. .44). That is, infants' preference for the novel test pattern was not attributable to a natural preference for the alternating pattern.

Discussion

Study 1 established the utility of a novelty-preference fixation procedure for testing infant auditory discrimination. Moreover, the experiment demonstrated that an infant-controlled preference technique is suitable for testing a finer auditory discrimination than the one originally examined by Bundy and Colombo (1981). Finally, although operant fixation procedures have generally been used with young babies, this study demonstrated that the procedure can be used with infants as old as 11 months of age.

When the present research was underway, Colombo and Bundy (1983) developed a similar novelty-preference technique for testing auditory discrimination in 4-month-olds. Just as in the present technique, infants were familiarized with a pattern and then, during a test, fixation of one display resulted in a novel pattern, while fixation of the other display resulted in the familiar pattern. However, there is an important difference between their procedure and the one reported here. In the Colombo-Bundy procedure, presentation of the familiarization stimuli was not contingent upon infants' fixations, whereas, here, infants' were presented the familiarization stimuli only if they fixated the displays.

Colombo and Bundy's (1983) familiarization procedure may be advantageous for testing young infants, since it requires shorter performance. However, there are possible drawbacks to their approach: First, at the onset of the test, infants have not learned the contingency between fixation of the displays and the presentation of sounds. Consequently, comparison of the two test stimuli may be delayed, so novelty preferences may not be obtained with familiarization stimuli that are remembered only briefly.

Second, infants see the visual displays for the first time at the onset of the test, so they probably process and compare them. Indeed, infants shift gazes back and forth between two displays, especially if they are similar (Ruff, 1975). Initial visual processing may disrupt auditory processing, thereby introducing error into the results.

Finally, in the Colombo-Bundy procedure, it is not possible to evaluate babies' initial interest in the familiarization stimuli or the decline in interest over time. Experimenters do not always necessarily know how many stimulus presentations are necessary to ensure familiarization; so, an actual measure of familiarization may be useful.

Despite the differences between the two paradigms, the consistent findings indicate that a novelty-preference fixation technique is suitable over a wider age range than other procedures. The HAS procedure is not suitable for infants older than 4 months, while reinforced head-turning techniques do not work with infants younger than 5 or 6 months. Thus, novelty-preference techniques of the type used here can probably play a role in future studies that compare auditory functions of different age groups and age comparisons will not be confounded with procedural differences (Washburn, 1984).

The method developed here is not only useful for developmental studies, it is also suitable for addressing questions on infant auditory categorization. A novelty-preference paradigm has the advantage of incorporating within-subject comparisons and, unlike the reinforced head-turning procedure, enables the evaluation of categorization in the absence of training. Hence, Study 2 investigated categorization in 10-month-old infants using the methodology developed in study 1.

Study 2

Categorizing Sequences on the Basis of Melodic Contour

Using the novelty-preference method, study 2 examined the ability to categorize auditory sequences in 10- to 11-month-old infants. Specifically, the study tested categorization of sequences on the basis of melodic contour in the context of two varying dimensions, the frequency range[8] and the wave form[9] of the tones. One objective of this study was to examine infants' ability to form categories on the basis of invariant information that is more abstract than simple acoustic features. The abstraction of melodic contour requires a sensitivity to the frequency relations between tones across time. Equating frequency relations cannot be done by simply matching frequency values of tones across sequences. Rather, the frequency relations must be encoded in a more abstract form, independent of the particular frequency values. Before describing study 2, it is worth reviewing the relevant research on infants' perception of melodic contour.

There is considerable evidence that infants are sensitive to the contour information of auditory signals. Babies can distinguish between speech tokens that have different frequency contours[10] (Kuhl & Miller, 1982) and they prefer to listen to sounds that have expanded frequency contours (Fernald, 1981; Fernald & Kuhl, 1981). Two studies have also demonstrated that infants are sensitive to melodic contour (Chang & Trehub, 1977a; Trehub, Bull & Thorpe, 1984).

Using a cardiac habituation-dishabituation procedure, Chang and Trehub (1977) habituated 5-month-old infants to a single six-tone pattern and then shifted either to a musical transposition of the standard pattern or to a control pattern that consisted of the transposed pattern in scrambled order. Dishabituation, as measured by cardiac deceleration, was indicated by the control group, but not by the group exposed to the transposition. The authors concluded that infants' performance was based on the common melodic contour of the standard and transposed patterns. Strictly speaking, the authors demonstrated discrimination of melodic contour, and obtained no evidence of discrimination of a transposition.

Recently, Trehub, Bull, and Thorpe (1984) tested perception of melodic contour in 8- to 11-month-old infants using a reinforced head-turning procedure. In two studies, infants were first exposed to a six-tone "standard" melody and then tested for discrimination of the following types of transformations of the standard melody: 1) a transposition, in which the frequency ratio of successive tones remained intact, but the absolute frequency of individual tones was changed; 2) a contour-preserving condition in which the contour remained intact, despite changes in absolute frequencies and frequency ratios; 3) an octave-change/contour-preserving condition in which several tones were displaced to the same note in another octave, thereby altering the absolute frequencies and frequency ratios, but retaining the original contour; 4) an octave-change/contour-violating condition in which several tones were displaced, thereby altering the absolute frequencies, the frequency ratios, and the contour.

Initially, the standard pattern was repeatedly presented from a laterally positioned sound source. Next, infants received one of the transformations of the standard pattern, and a visual reinforcer was activated if they oriented toward the sound source when the pattern was changed. Infants were required to learn to consistently turn toward the sound source when a transformation was presented, but withhold the response when no change in the standard pattern occurred. Successful performance was taken as evidence of the discriminability of the standard pattern from transformations.

In the first study, infants discriminated all transformations from the standard contour. In the second study, a distraction sequence was inserted between repetitions of the standard melody as well as between the standard and transformed melodies. Infants failed to discriminate transpositions as well as contour preserving patterns in which the absolute frequencies and frequency ratios were changed. In contrast, they discriminated transformations involving changes of contour with note name and frequency preserved Infants also discriminated between sequences whose tones were from different octaves, suggesting that babies are sensitive to overall frequency range of the patterns.

The two experiments support a number of conclusions First, under ideal circumstances, babies are sensitive to changes in melodic contour, frequency range, the absolute frequency of tones, and the frequency intervals between successive tones. However, under distraction conditions, infants attend to and remember the melodic contour and frequency range, but are less likely to remember information about absolute frequency or frequency ratio. Thus, it may be that melodic contour and frequency range are inherently more salient and/ or resistant to memory decay than other dimensions in the presence. Alternatively, the particular values and differences selected for melodic contour and frequency range may have been more salient than those selected for absolute frequency and frequency ratio.

Hence, previous evidence indicates that infants perceive melodic contour. The present study extended these findings by investigating babies' ability to equate distinct sequences that shared a common contour. The sequences differed strikingly along two, rather than one dimension; frequency range and wave form of the tones.

Infants were initially familiarized either with a set of rising melodic-contour sequences or with a similar set of falling melodic-contour sequences. Within each set, sequences differed from each other in frequency range and wave form. Next, during a preference test, the subjects were presented two novel patterns with a new frequency range and a new wave form; one of the patterns had a rising contour and the other had a falling contour. That is, one of the test patterns was a new member of the familiarization category while the other test pattern was a member of a novel category Even though both test stimuli were actually new, it was expected that infants would prefer the sequence from the novel category over the sequence from the familiar category.

Method

Subjects

Twenty-four full-term infants (11 boys and 13 girls) between 44 and 48 weeks of age (mean age: 46 weeks) participated in study 2. Infants were recruited in the same manner as in study 1. An additional 24 infants were seen in the laboratory, but they did not provide data due to distress (N= 12), procedural difficulties (N = 7), or a failure to sample both test patterns (N = 5). Additional demographic information regarding the infants that provided acceptable data is presented in Appendix C.

Apparatus

The equipment used was the same as for study 1.

Stimuli

The sequences were synthesized in the same manner as the stimuli in study 1. They consisted of five tones spanning one octave, arranged in either an ascending or descending pattern. The tones were 150 msec, with 20- msec exponentially ramped rise and fall times (see Figure 3). All intertone intervals were 50 msec. As in study 1, a 100-Hz tonal sequence controlled the functioning of the synchronizer.

The familiarization stimuli are presented in Figures 4 and 5 There were two sets of six different auditory sequences One set included three rising patterns (Figure 4), with two versions of each, that differed in the wave form of their tones. One wave form (W_1) consisted of equal intensity weightings (33, 33, and .33) on the first, second, and third harmonics, while the other (W_2) consisted of tones with approximately equal intensity weightings (30, .35, and 35) on the first, sixth, and eighth harmonics The other set of familiarization stimuli (Figure 5) was identical to the six rising patterns except that the temporal order of the tones was reversed to yield six falling patterns The test stimuli (Figures 4 and 5) consisted of two new patterns that were identical to each other, except one had

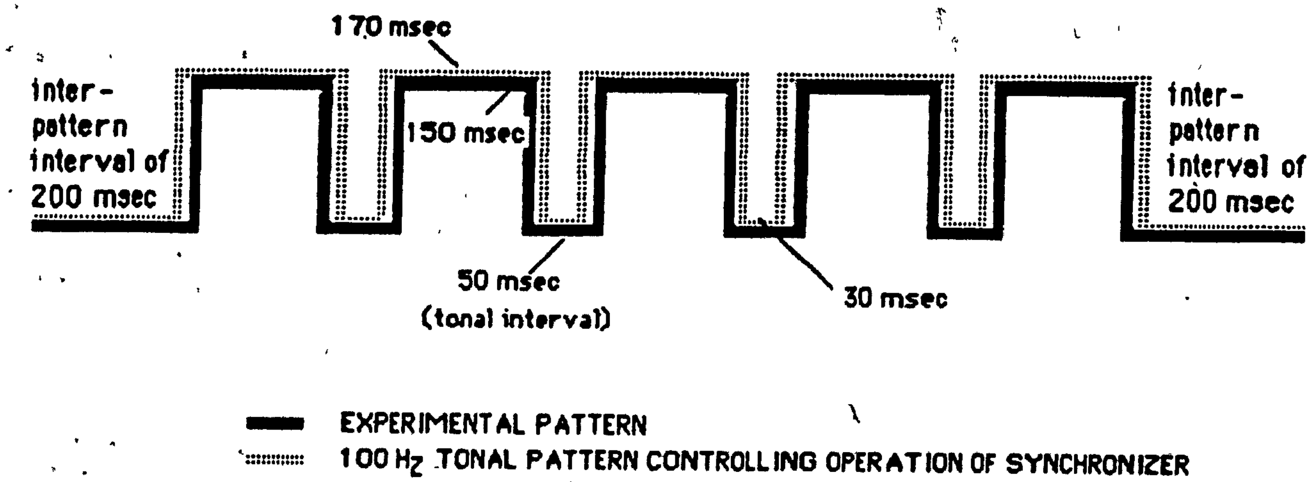


Figure 3. Temporal parameters of tonal patterns of study 2.

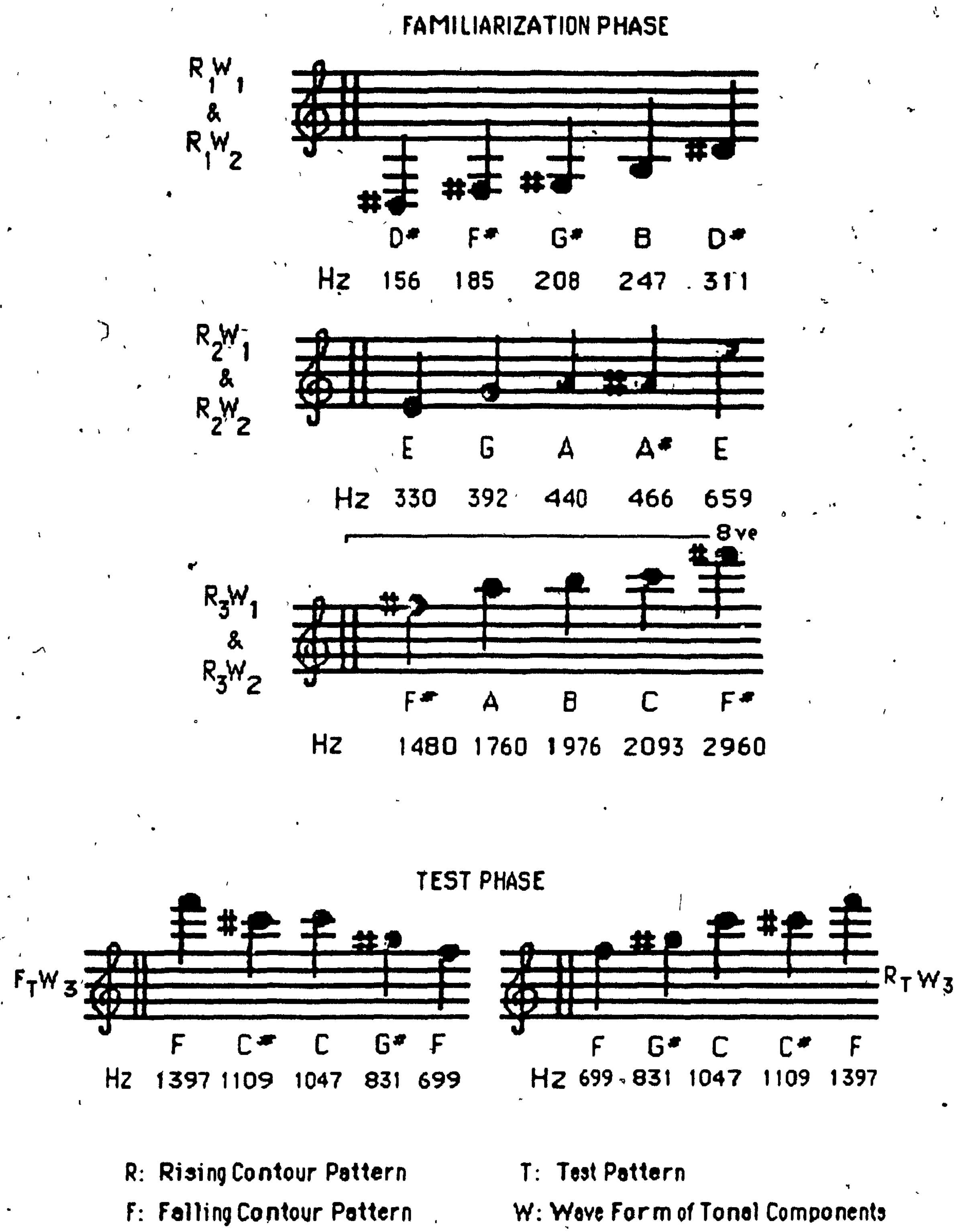


Figure 4. Rising melodic contour condition for study 2.

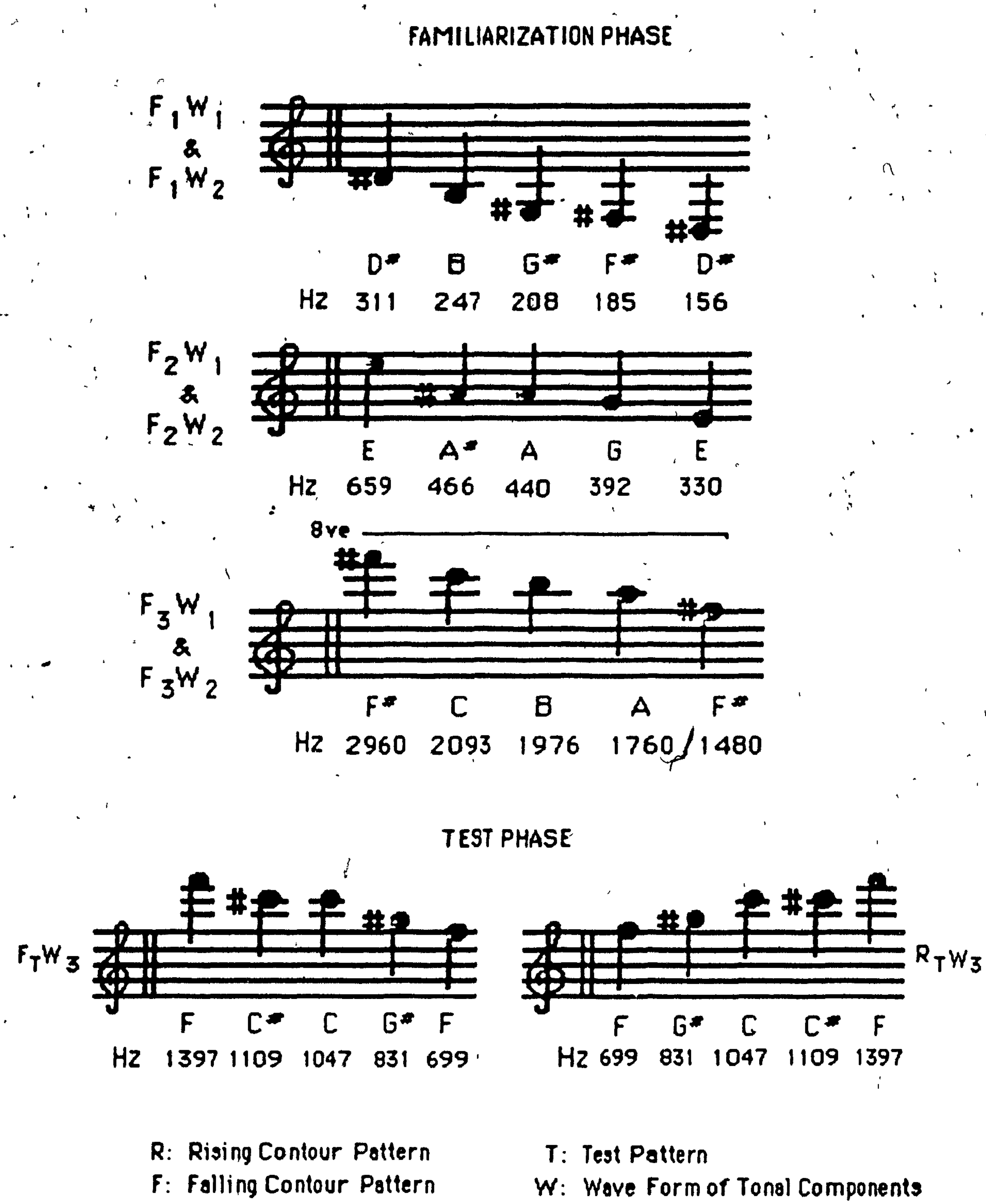


Figure 5. Falling melodic contour condition for study 2.

a rising contour and the other a falling contour. The tones of the test patterns were sine waves (W3) (i.e., they had intensity weightings only with the first harmonic).

The ambient sound pressure level in the room was 50-55 dBA. The intensity level of familiarization stimuli was set at 65 dBA at the position of the baby's head according to a calibration tone recorded at the beginning of each audiotape. The calibration tone consisted of a pure tone with a frequency level corresponding to the average frequency of all notes of the familiarization patterns. The test patterns were presented at mean peak intensities of 65 dBA.

Procedure

The procedure was similar to study 1. The experimental design is represented in Figure 6. During the familiarization phase, fixation of either display resulted in a randomly ordered presentation of the six rising-contour sequences for half the infants and the set of six falling-contour sequences for the other half. Familiarization continued until an infant's total fixation time in a 30-sec period had declined by below 50% of the fixation time during the first 30 sec of familiarization A subject-specific criterion was adopted because it was unclear how much time infants required to process the varying familiarization sequences. As in study 1, the test phase consisted of two 20-sec periods, but there was a 48-sec pause between the familiarization phase and the first test period and between the first and second test periods

During the test periods, fixation of one display resulted in the presentation of the rising-contour test sequence, while fixaton of the other display resulted in the presentation of the falling-contour test sequence Each test pattern was

CONDITION	FAMILIARIZATION	TEST
RISING MELODIC CONTOURS	... R_1W_1, R_2W_1, R_3W_2, R_1W_2, R_2W_2, R_3W_1 ...	R_TW_3 <u>vs</u> F_TW_3
FALLING MELODIC CONTOURS	... F_1W_1, F_2W_1, F_3W_2, F_1W_2, F_2W_2, F_3W_1 ...	R_TW_3 <u>vs</u> F_TW_3

<u>Figure 6.</u> Experimental design of study 2.

presented on the left for one test period and on the right for the other test period, with the order of rising-left and rising-right counterbalanced across subjects.

The criteria for including an infant's data were similar to those used in study 1. First, the observer, who was unaware of the experimental condition, determined if the baby had been sufficiently calm and alert to provide scorable data. Next, the fixation data were retrieved from the computer's memory and considered acceptable if the infant had sampled both test patterns for at least 1.5 sec during the test period.

Results

Initially an analysis was conducted to determine if the amount of looking during familiarization was influenced by the familiarization condition. A one-way ANOVA was conducted with Familiarization Condition (i.e., rising or falling) as a between-subject factor. The analysis yielded no significant difference between the familiarization looking time in the rising condition (90.5 sec) and the falling condition (101.9 sec).

The use of a relative criterion of habituation ensured that data were obtained only from subjects who habituated to the familiarization stimuli. However, an analysis was conducted to determine if initial looking and the decline of looking was influenced by the familiarization condition. The dependent variable was amount of looking during a 30-sec block. A 2 x 2 ANOVA was conducted with Block (the first 30 sec of familiarization and the last 30 sec) as a within-subject factor and with Familiarization Condition (rising and falling) as a between-subject variable. The analysis yielded a significant main effect of Block, $F(1,22)$

= 622.38, $p < .05$. Neither the main effect of Familiarization Condition, $F(1,22) = .49$, $p > .05$, nor the Block X Familiarization Condition interaction, $F(1,22) = .07$, $p > .05$, were significant. The data are presented in Table 2. As expected, infants looked less during the last 30-sec block of familiarization than during the first 30-sec block. Moreover, virtually identical patterns of looking were obtained for the two familiarization groups.

The primary analysis determined if infants fixated the display associated with the novel-contour pattern more than the display associated with the familiar-contour pattern. The measure of primary interest was the proportion of test time spent fixating the display associated with the novel-contour pattern [i.e., $prop_{nov} = [\, t_{nov} / (t_{nov} + t_{fam})]$]. The mean $prop_{nov}$ was calculated across all subjects and compared to .50, the proportion expected by chance. The obtained value .58, was significantly greater than .50, $t(23) = 2.31$, $p < .025$, 1-tailed. Thus, infants fixated the display associated with the novel-contour pattern more than the display associated with familiar-contour pattern.

Secondary analyses were conducted on the $prop_{nov}$ data separately for each familiarization group. The rising-contour familiarization group preferred the falling contour test sequence ($M = .61$) significantly more than chance, $t(11) = 2.75$ $p < .05$, 1-tailed. The falling-contour familiarization group preferred the rising-contour test ($M = .54$) sequence, but the preference was not statistically significant, $t(11) = 1.00$, $p > .05$, 1-tailed. However, the two groups did not differ in their preference for the novel-contour test, $F(1,22) = .92$, $p > .05$.

Although the experimental design was counterbalanced, an additional analysis was conducted to verify that the overall group preference for the novel

Table 2

The Relationship Between the Familiarization Patterns Received and the Amount of Looking During the First and Last 30 sec of Familiarization.

Familiarization Condition	First 30 sec	Last 30 sec
Rising-contour	21.3	8.6
Falling-contour	20.1	8.5
M	20.7	8.5

contour was not artifactually due to a natural preference for the falling-contour test pattern. The proportion of looking time spent attending to the falling-contour pattern ($prop_{fal}$) was computed as follows: $prop_{fal} = t_{fal} / (t_{fal} + t_{ris})$, where t_{fal} was the total time an infant fixated the display associated with the falling-contour seque[illegible], and t_{ris} was the time the infant fixated the display associated with the rising-contour sequence. The $prop_{fal}$ data were subjected to a one-way ANOVA with Familiarization Condition as the between-subject factor. Infants preferred the falling-contour test pattern significantly more after having been familiarized with the rising-contour sequences (M = .61) than after being exposed to the falling-contour sequences (M = .46), F (1,22) = 4.69, $p < .05$. Thus, the demonstrated preference for the novel-contour test pattern was not attributable to a natural preference for the falling-contour test sequence.

The analysis so far examined infants' relative interest in the familiar- and novel-category test patterns. It was also worthwhile to examine infants' absolute interest in each test pattern independent of their interest in the other pattern. Therefore, additional analyses were conducted to compare infants who happened to hear the familiar-contour sequence for their first look of the test with those who happened to hear the novel-contour sequence.

The data from all subjects who performed adequately until the end of the first test look were included in this comparison, i.e., data from 23 of the original 24 subjects[11] plus data from an additional 10 subjects. The additional 10 subjects were selected by a naive observer who viewed the videotapes of the first test period and chose only babies who were calm and alert beyond the end of the first test look.

A preliminary analysis determined if the first test pattern heard by an infant (novel-contour or the familiar-contour) influenced the likelihood that the infant would successfully complete the test phase. Table 3 shows the relationship between the first test pattern heard (novel vs. familiar) and completing the test. A Chi square test revealed a significant relationship between the two variables, (χ^2 (1, N = 33) = 4.46, p<.05). Infants who first heard the novel-contour pattern were more likely to complete the test successfully than those who first heard the familiar-contour test pattern. Infants who first sampled the familiar-contour test sequence experienced more distress or disinterest, presumably because they did not perceive the continuing procedure as novel.

A more direct measure of infants' relative interest in the two test patterns was obtained. Post-habituation recovery of interest was compared for the group of infants who first sampled the same-contour test pattern and the group who first sampled the novel-contour pattern. A naive observer reviewed the videotapes for the group of 33 infants who performed adequately until the end of the first test look. She scored the duration of the last familiarization fixation and the duration of the first test look.

The data (Figure 7) were subjected to a 2 X 2 ANOVA with Look (last familiarization and first test) as a within-subject factor and with Test Pattern (Familiar-contour and Novel-contour) as a between-subject variable. The analysis revealed a main effect of Look, $F(1,31) = 7.42$, $p<.05$, and no significant interaction. However, planned comparisons indicated that infants who first heard the novel-contour pattern demonstrated post-habituation recovery of interest, while infants who heard the familiar-contour pattern did not. For infants who

Table 3

The Relationship Between the First Test Pattern Heard and the Likelihood of Successfully Completing the Test.

		Test Session	
		Complete	Incomplete
First Test Pattern Heard	Novel Contour	16	3
	Familiar Contour	7	7

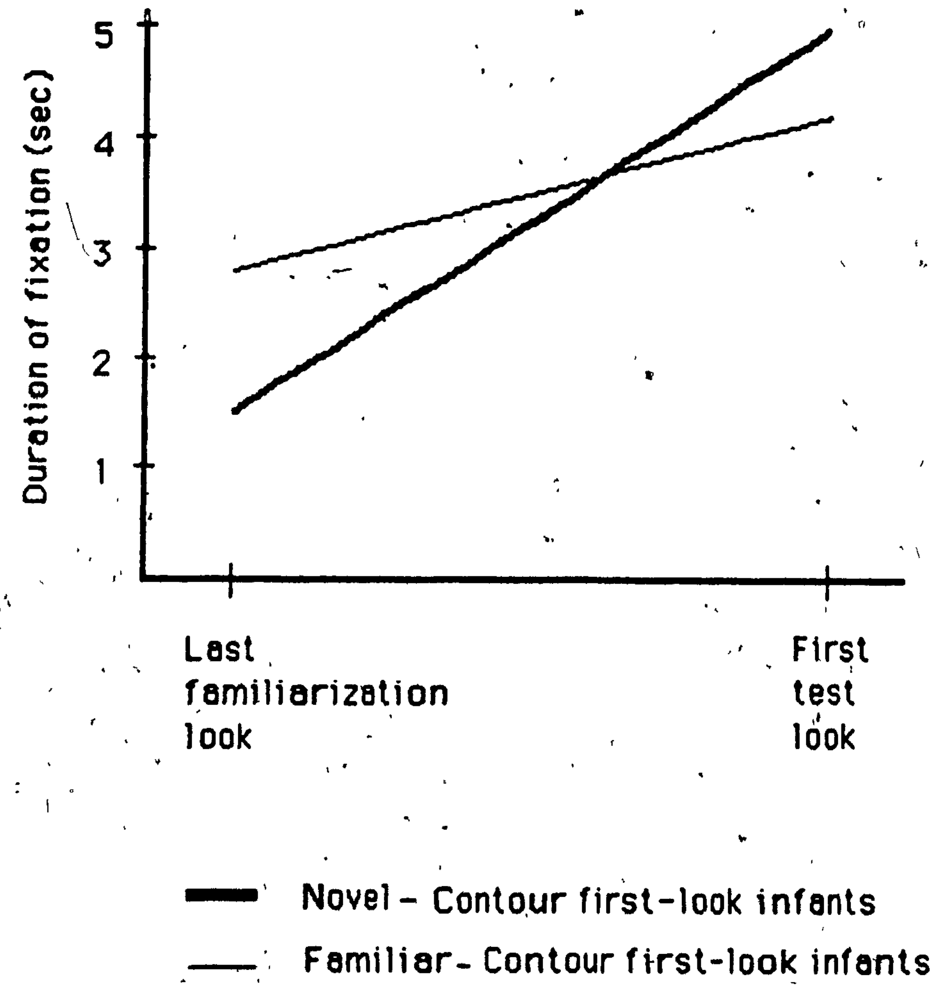


Figure 7. Duration of the last familiarization look and the first test look.

first sampled the novel-contour test pattern, the first test look was significantly longer than the last familiarization look, $t(18) = 2.94$, $p < .01$, two-tailed. In contrast, for infants who first sampled the familiar-contour test pattern, the first test look did not differ significantly from the last familiarization look, $t(13) = 1.09$, $p > .05$, two-tailed.

Discusssion

Study 2 established the suitability of a fixation preference technique for evaluating auditory categorization in infancy. Unlike other methods, the preference technique assesses categorization on the basis of a relative similarity judgement, and the experimental design incorporates within-subject comparisons In addition, categorization can be measured on the basis of an absolute similarity judgement by conducting a between-subject analysis of babies' first test look

The technique differs from the reinforced head-turning paradigm which is commonly use to study infant auditory categorization in an other important way Babies in the head-turning procedure are taught to attend to a perceptual property that is invariant across stimuli and to treat different stimuli as similar. The procedure may actually train infants to categorize stimuli that they would not naturally consider as equivalent (Aislin et al, 1983). In contrast, infants in the fixation procedures are simply presented stimuli that share invariant information and are allowed to abstract that information on their own Thus, the fixation techniques may be better suited to evaluate infants' natural tendencies to categorize certain stimuli.

More important than its methodological contribution, Study 2 established that infants can categorize melodies as equivalent on the basis of contour information. Both relatively and absolutely, infants were interested in a sequence from a novel category and were uninterested in a new sequence from a familiar category. Hence, babies abstracted contour information across very distinct patterns and then treated a markedly different same-contour test pattern as equivalent on the basis of the invariant relational information that is more abstract than simple acoustic features.

According to the operational definition used here, categorization requires not only an equivalence response, but also a demonstration that category members are discriminable. Since infants can make fine frequency discriminations, they probably discriminated among the considerably distinct patterns used in study 2. However, elements of the procedure may have prevented discrimination. Therefore, study 3 directly addressed this issue. Since little is known regarding infants' sensitivity to the wave form of tones, study 3 also tested babies' ability to discriminate between patterns on the basis of this dimension.

Study 3

Discriminating Category Members

Study 2 demonstrated that infants can treat same-contour sequences as equivalent even though their tones differ in frequency range and wave form. To fulfill the operational definition of categorization, however, the discriminability of category members should be demonstrated, rather than assumed. If infants can discriminate among the familiarization patterns, babies in study 2 would have had to abstract the contour information despite noticeable irrelevant information. If infants can discriminate between the familiarization patterns and the same-contour test pattern, then infants in study 2 treated the same-contour test pattern as equivalent to the familiarization stimuli despite noticeable differences

Most often, evidence from other experiments is not sufficient to establish the discriminability of category members. First, stimuli are often constructed from combinations of features that vary across studies. Second, discriminability should be established using a paradigm as similar as possible to the categorization paradigm (Olson & Sherman, 1983). Different paradigms make different demands on infants, so babies might discriminate category members in one situation, but not in another Moreover, the incentive for discriminatory responses varies across techniques; for example, babies are more likely to show discrimination in a reinforced head-turning procedure than in an habituation procedure (Trehub, Schneider & Bull, 1981).

Study 3 included three types of discrimination tests. The first part determined if infants can discriminate between the familiarization patterns and the same-contour test pattern of study 2. The second part tested if infants can discriminate among the same-contour familiarization sequences of study 2 that differed only in frequency range. Finally, the third part tested for discrimination among the familiarization patterns differing solely on the basis of the wave form of the tones.

Part 1

Discriminating Test and Familiarization Patterns

Purpose

Part 1 evaluated infants' ability to discriminate between the familiarization sequences and the same-contour test sequences of study 2.

Method

Subjects. Sixteen full-term babies (9 boys and 7 girls) participated as subjects, they were between 44 and 48 weeks of age (mean age 46 weeks). Nine additional infants were seen in the laboratory, but they did not provide data due to distress (N = 3), technical and procedural difficulties (N = 4), and failure to sample both test patterns (N = 2).

Apparatus. The equipment used was the same as for study 1.

Stimuli. The stimuli consisted of sequences previously used in study 2. There was a pair of rising contour sequences (R_3W_1 and R_tW_3) and a pair of falling contour sequences (F_3W_1 and F_tW_3) (see Figure 8). The sequences within a pair differed both in the frequency range and in the wave form of their tones. The ambient sound pressure level in the room was 50-55 dBA. All patterns were

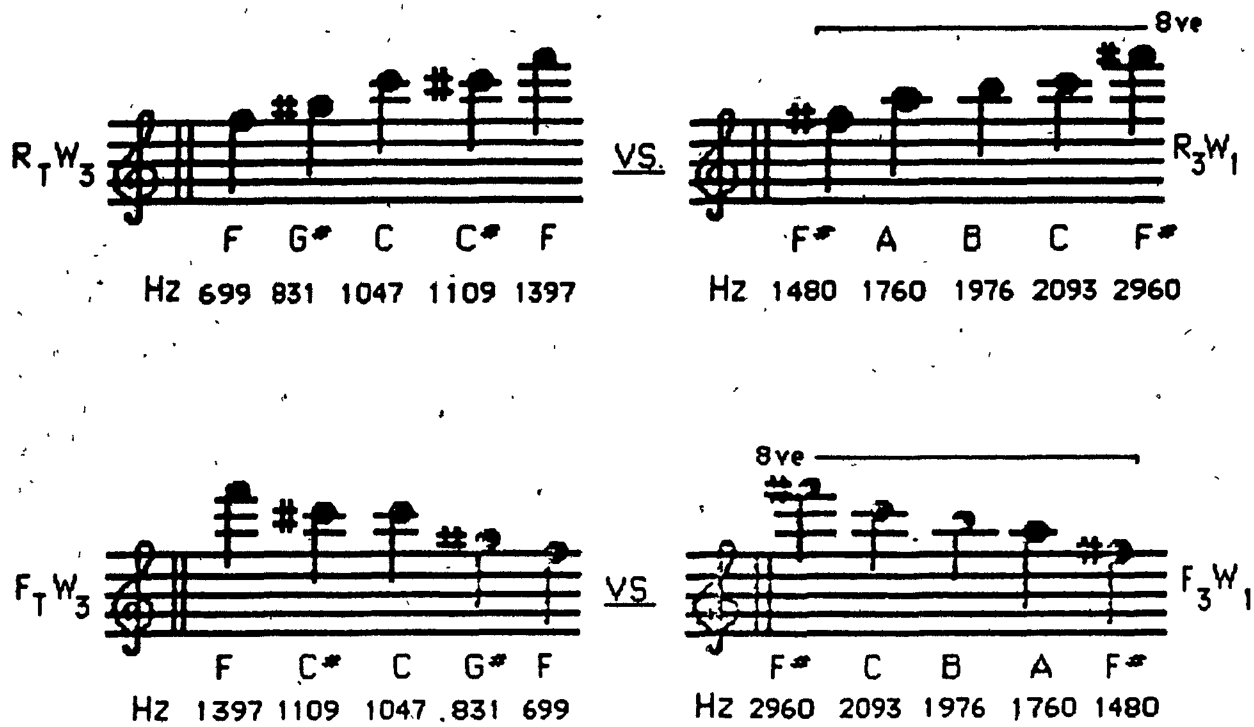


Figure 8. Sequence pairs tested for discrimination in part 1.

presented at mean peak frequencies of 65 dBA at the location of the infant's head.

Procedure. Half the infants were required to discriminate between the pair of rising-contour patterns and the other half between the pair of falling-contour patterns. Otherwise, the procedure was similar to that of study 2. During familiarization, fixation of either display resulted in the repeated presentation of one sequence of a pair. Familiarization continued until one of two criteria were met: Either the infant's total fixation time in a 30-sec period declined to 50% of the fixation time during the first 30 sec, or 120 sec of familiarization had elapsed. A maximum duration of familiarization was used because some infants in study 2 did not reach the habituation criterion even when their distress suggested disinterest in the stimuli Limiting the familiarization period was expected to reduce the attrition rate.

During the test phase, fixation of one of the displays was associated with the presentation of the familiarization pattern and fixation of the other display resulted in the second pattern from the pair The test phase again consisted of two 20-sec periods in which the left-right order of the test stimuli were reversed

Results

The first dependent variable of interest was the total fixation time during familiarization A one-way ANOVA with Familiarization Condition (rising and falling-contour) as a between-subject factor did not yield a significant effect, $F(1,14) = .56$, $p > .05$.

An analysis was undertaken to determine if infants' interest in the stimuli declined over the course of the familiarization phase (see Table 4). The dependent variable of interest was amount of looking during 30-sec blocks. A two-way ANOVA was conducted with Block (the first 30 sec of familiarization and the last 30 sec) as a within-subject factor and Familiarization Condition (rising and falling) as a between-subject variable; the analysis yielded a significant main effect of Block, $F(1,22) = 27.48$, $p < .05$, but the interaction was not significant, $F(1,22) = .39$, $p > .05$. As expected, the mean duration of looking across the familiarization groups declined from the first to the last 30-sec block of familiarization and similar patterns of looking were observed for both familiarization groups.

The measure of primary interest was the proportion of time spent fixating the display associated with the novel sequence (i.e., $prop_{nov} = [t_{nov} / (t_{nov} + t_{fam})]$). The mean $prop_{nov}$, calculated across all subjects was .60, a preference significantly greater than chance, $t(15) = 2.5$, $p < .05$, 1-tailed. Moreover, the mean $prop_{nov}$ values did not differ for the falling- and rising-contour groups, $F(1,14) = .161$, $p > .05$ (.59 vs. .62).

Part 2

Discriminating Familiarization Patterns on the Basis of Frequency Information

Purpose

Part 2 evaluated infants' ability to discriminate between a familiarization sequences on the basis of frequency range.

Table 4

The Relationship Between the Familiarization Patterns Received and the Amount of Looking During the First and Last 30 sec of Familiarization.

Familiarization Condition	First 30 sec	Last 30 sec
Rising-contour	21.4	5.0
Falling-contour	20.1	3.9
M	20.7	4.4

Method

Subjects. Sixteen full-term babies (7 boys and 9 girls) participated as subjects; they were between 44 and 48 weeks of age. (mean age: 46 weeks). Seven additional infants were seen in the laboratory, but they did not provide data due to distress (N = 3), technical and procedural difficulties (N = 3), or a failure to sample both test patterns (N = 1).

Apparatus. The equipment used was the same as for study 1.

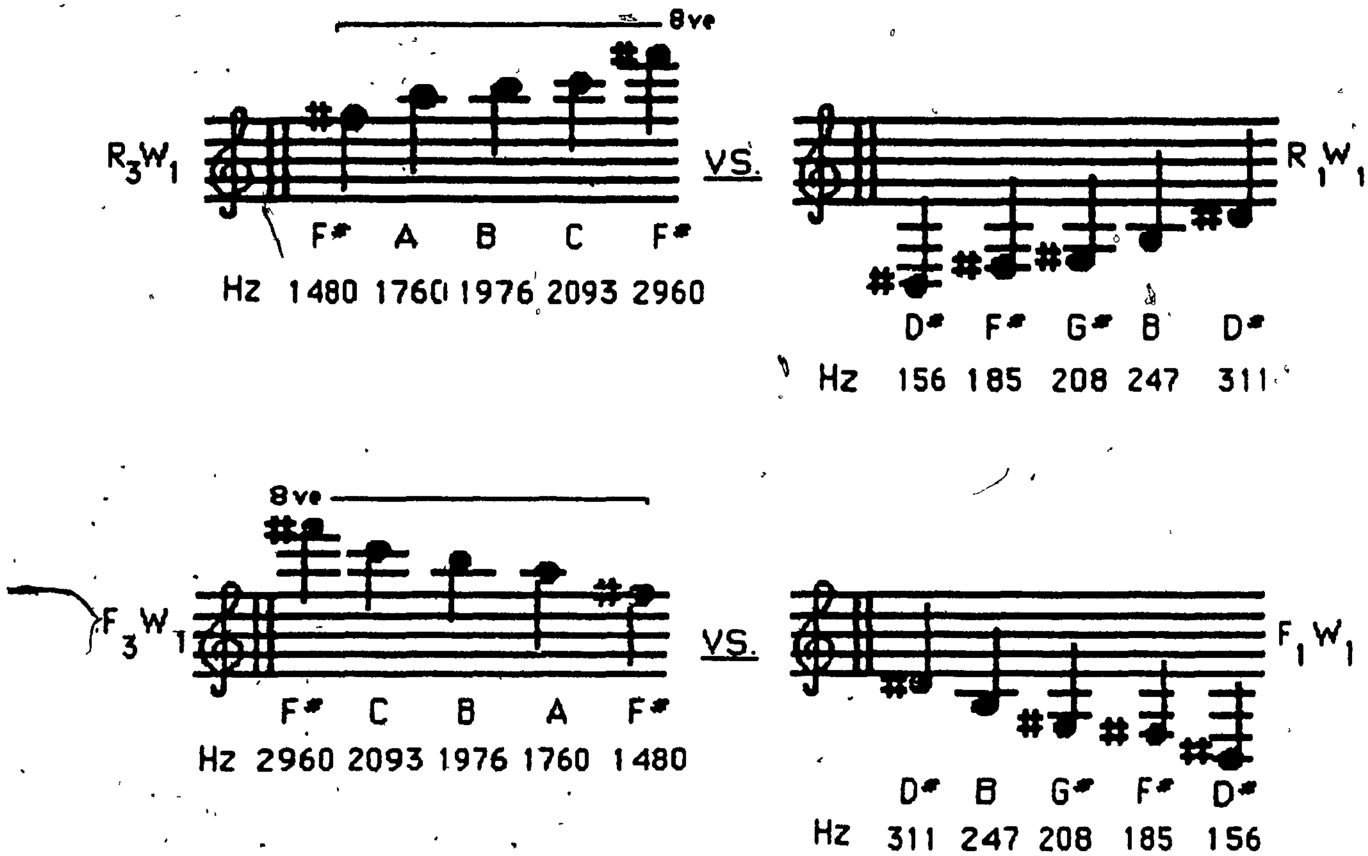
Stimuli. The stimuli consisted of sequences previously used in study 2. These were two rising contour sequence (R_3W_1 and R_1W_1) and a pair of falling contour sequences (F_3W_1 and F_1W_1) (see Figure 9). The two sequences in each pair differed only in frequency range. The ambient sound pressure level in the room was 50-55 dBA. All patterns were presented at mean peak frequencies of 65 dBA at the location of the infant's head.

Procedure. The procedure was identical to part 1. Infants were required to discriminate between the two rising-contour patterns or between two falling-contour patterns.

Results

The first dependent variable of interest was the total fixation time during familiarization. A one-way ANOVA[12] with Familiarization Pattern (rising and falling-contour) as a between-subject factor yielded no significant effects, $F(1,14) = 2.12$, $p > .05$.

An analysis was undertaken to determine if infants' interest in the stimuli declined over the course of the familiarization phase (see Table 5). The dependent variable of interest was amount of looking during 30-sec blocks. A 2x2 ANOVA



<u>Figure 9</u> Sequence pairs tested for discrimination in part 2.

Table 5

The Relationship Between the Familiarization Patterns Received and the Amount of Looking During the First and Last 30 sec of Familiarization.

Familiarization Condition	First 30 sec	Last 30 sec
Rising-contour	20.6	6.9
Falling-contour	21.0	1.6
M	20.8	4.2

was conducted with Block (the first 30 sec of familiarization and the last 30 sec) as a within-subject factor and Familiarization Condition (rising and falling) as a between-subject variable. The analysis yielded a significant main effect of Block, $F(1,22) = 52.00$, $p < .05$, and a significant interaction, $F(1,22) = 20.55$, $p < .05$. The interaction effect results from less looking in the falling-contour group than in the rising-contour group during the last 30 sec of familiarization. Nevertheless, the mean duration of looking across the familiarization groups declined from the first to the last 30-sec block of familiarization (20.8 vs. 4.2 sec).

The measure of primary interest was the proportion of time spent fixating the display associated with the novel sequence (i.e., $prop_{nov} = [t_{nov} / (t_{nov} + t_{fam})]$). The mean $prop_{nov}$ calculated across all subjects was .58, a preference significantly greater than chance, $t(15) = 2.91$, $p < .05$, 1-tailed. The mean $prop_{nov}$ values computed for the rising-contour condition ($M = .61$) and the falling-contour condition ($M = .54$) did not differ significantly, $F(1,14) = 2$, $p > .05$.

Part 3

Discriminating Familiarization Patterns on the Basis of Wave Form

Purpose

Part 3 of the experiment tested if infants can discriminate between familiarization sequences from study 2 that differed only in the wave form of their tones.

Method

Subjects. Thirty-two full-term babies (16 boys and 16 girls) served as subjects; they were between 44 and 48 weeks of age (mean age: 46 weeks). Twenty-one additional babies participated in the study but did not yield satisfactory data because of distress (N=14) or technical and procedural difficulties (N=7).

Apparatus. The equipment used was the same as for experiment 1.

Stimuli. The stimuli were previously used in study 2. There was a pair of rising-contour patterns (R_2W_1 and R_2W_2) and a pair of falling-contour patterns (F_2W_2 and F_2W_1) (see Figure 10). The two sequences in each pair differed in the wave form of their tones. The ambient sound pressure level in the room was 50-55 dBA. All sequences were presented at mean peak frequencies of 65 dBA at the location of the baby's head.

Procedure. Part 3 of the experiment used a natural preference[13] technique to test if infants can discriminate between sequences that differed only in the wave form of their tones. Infants received two natural preference test periods, each lasting 30 sec Half of the babies were exposed to the pair of rising-contour patterns while the other half received the falling-contour sequences During the tests, fixation of one of the displays resulted in the presentation of a W_1 sequence while fixation of the other display resulted in a W_2 sequence To control for side preferences, the W_1 sequence was associated with the right diplay for one of the test periods and with the left display for the other test period

Results

The dependent variable of interest was the proportion of time spent fixating the display associated with the W_2 pattern, calculated as follows $prop_{w2}$ =

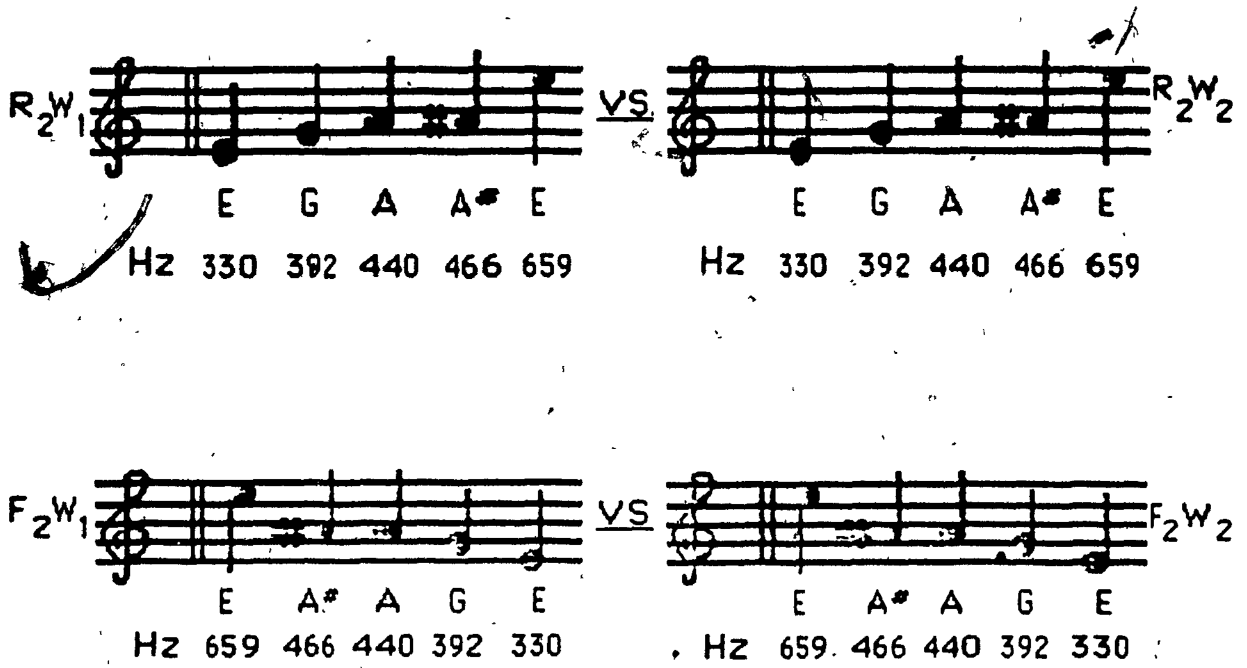


Figure 10. Sequence pairs tested for discrimination in part 3.

$t_{w2}/(t_{w2} + t_{w1})$ where t_{w2} was the total time an infant fixated the display associated with the W_2 pattern and t_{w1} was the time the infant fixated the display associated with the W_1 pattern. A preliminary examination of the data revealed a significant difference, $F(15,15) = 2.47$, $p < .10$ in the variances between conditions (rising- and falling-contour patterns), so the data were subjected to an arcsin square root transformation. A one-way ANOVA indicated no significant effect due to contour. The mean transformed $prop_{w2}$ data were virtually identical for the two contour groups ($M_{rising} = .82$, $M_{falling} = .85$). Hence, the mean $prop_{w2}$ value was calculated across all subjects, the obtained value ($M=.83$) was significantly greater than the value expected by chance, .785, $t(31)=2.71$, $p<.05$, 2-tailed. The results indicate that infants were able to discriminate between same-contour familiarization sequences from study 2 that differed only in wave form.

Discussion

Study 3 demonstrated that infants can discriminate between the same-contour familiarization patterns of study 2 either on the basis of frequency range or wave form of the tonal components. The findings suggest that infants in study 2 were indeed sensitive to these two distracting auditory dimensions and, nevertheless, abstracted melodic contour information. Study 3 also established that babies can discriminate between the same-contour test pattern and at least some of the familiarization patterns. Therefore, the combined findings of studies 2 and 3 satisfy the criteria for demonstrating categorization. That is, infants in study 2 treated same-contour patterns as equivalent, even though the same-contour patterns are discriminable from each other.

General Discussion

In the research presented here, 10-month-old infants treated discriminable auditory patterns equivalently on the basis of a common melodic contour. Thus, even without training, infants can categorize very distinct nonspeech signals The findings highlight the significance of contour information for infants, babies are not only sensitive to the contour of sound patterns, but spontaneously organize auditory signals on the basis of this dimension.

The important contribution of the studies is the demonstration that infants can categorize nonspeech signals on the basis of invariant information that is more abstract than a simple acoustic feature. In study 2, test patterns and familiarization sequences with the same contour could only be equated on the basis of relational information Infants must have processed the sequences globally to abstract the melodic contour, and must have compared the sequences at a level higher than that of tonal frequencies to recognize contour equivalence Thus, preverbal infants can apparently access contour information in an abstracted form that is analogous to a description of "increasing" and "decreasing"

Implications for Future Studies on Speech Categorization

The present studies demonstrate that musical patterns can be categorized on the basis of an abstract dimension (i e, contour) that is also relevant in the identification of speech signals The task requirements point to the role of a sophisticated mechanism for equating same-contour patterns, although the nature of this mechanism remains unknown It could be argued that the melodic contour of the patterns mimicked the contour of speech so that special speech processing mechanisms were "fooled" into operation (see Kuhl 1985, for a discussion). However, such an arguement is rather weak, since the musical patterns used can hardly be described as analogs of speech Hence, the findings implicate a relatively complex mechanism underlying the categorization of nonspeech signals, a mechanism that probably originated to process a variety of auditory signals rather than to process speech, per se.

The evidence seems to indicate that objectives of studies on infant speech categorization should be refocused. Traditionally, researchers have been concerned simply with demonstrating that infants can categorize signals that share no known acoustic cues (i.e , on the basis of abstract information) (e.g., Kuhl, 1980; Katz & Jusczyk, 1980). Such demonstrations in infancy were taken as evidence of the existence of a special speech processing mechanism (see Fodor et al., 1975) Future research must demonstrate which processes underlying speech categorization are different from processes underlying similar types of categorization of nonspeech stimuli Indeed, categorization may involve some processes common to all stimuli as well as processes that are stimulus-specific.

Future Studies on Non-Speech Auditory Categorization

The present studies only begin to address questions regarding infants' ability to categorize nonspeech signals It remains to be seen if infants can categorize sounds on the basis of other dimensions or on the basis of combinations of dimensions. Also, studies on non-speech categorization may expand our understanding of why certain experimental situations lead to categorization behaviour in infants. Researchers have begun to study mechanisms underlying infant visual categorization in the light of adult models of category formation (Olson & Sherman, 1983, Sherman, 1985), but substantial work remains to be done. Moreover, processes underlying auditory categorization may not be identical to those of visual categorization

Several important questions already arise regarding processes underlying auditory categorization. It is worthwhile considering these in the context of the present studies

The first question concerns the nature of the information that is retained by infants who are familiarized with several discriminable auditory stimuli that possess some common properties. In accord with adult prototype theories of categorization (Posner, 1969, Posner & Keele, 1968), infant visual categorization studies suggest that babies initially retain both specific information about category members as well as a generalized representation of the category However, member-specific information is forgotten more rapidly than category-level information (Bomba & Siqueland, 1983, Sherman, 1985)

It is not known if auditory categorization follows the same principles In study 2, it is unclear to what extent infants retained information specific to particular familiarization sequences (e g., frequency values) versus information about the category as a whole (e.g , contour information) Moreover, at least two types of category-level information may have been retained Infants may have retained a same-contour pattern with frequency range and wave form characterisitcs that approach an average of all the familiarization stimuli Alternatively, they may have retained contour information stored to specify "increasing" and "decreasing" independent of frequency and waveform values

The relative role of sequence-specific and category-level information could be addressed with methods used to test "prototype" theories of categorization. For example, let us assume that infants were familiarized with the set of rising-contour patterns of study 2. If infants retain sequence-specific information, they should subsequently prefer a novel rising-contour pattern (i.e., one with a new frequency range and wave form) over one of the familiar rising-contour patterns. Alternatively, if infants retain only a prototype, they should prefer a rising contour test pattern that is distinct from the prototype over a rising-contour pattern that is similar to it. Of course, infants may also retain the contour information in a form independent of other auditory dimensions. If this were so, they should not demonstrate a preference for some rising-contour patterns over others, but should demonstrate a preference for a novel-contour pattern over a rising-contour pattern.

A second question about infant auditory categorization regards the relative contribution of passive and active processes. That is, the question concerns whether or not categorization responses in infancy involve any conscious processes on the part of babies. The issue is addressed by comparing the present research with the work by Trehub and her colleagues on melodic contour. Trehub et al. (1984) demonstrated that infants normally discriminate between a standard pattern and a contour-preserving transformation that differs in absolute tonal frequencies and frequency ratios. However, if a distracting sequence is inserted between repetitions of the experimental stimuli, infants do not discriminate between the standard pattern and the transformation. The distracting sequences may prevent the encoding of absolute frequency and frequency ratio values of the standard melody that is necessary for discrimination. Hence, distinct same-contour patterns were probably rendered non-discriminable by the disruption of memory functions, a passive process

In study 2 of the present research, the evidence suggests that test patterns and familiarization sequences with the same contour were treated equivalently. Such behavior was interpreted as evidence of categorization. Whether or not the processes underlying the "equivalence" response resembled those proposed to operate in Trehub's study remains an empirical question. The sequential presentation of distinct familiarization patterns may have prevented the encoding of frequency range and wave form information That is, each sequence may have acted as a distracting pattern for the other patterns Hence, one explanation of categorization behavior could involve the disruption of memory functions

However, other processes may also have been operating For example, a mechanism must be proposed to explain infants' apparent ability to extract an abstract representation of a contour category by being exposed to several members Moreover, babies who are exposed to a variable stimulus array such as the familiarization stimuli of study 2, may **actively** search for invariant information that facilitates the perceptual organization of the array and ignore varying information

Currently, infant visual categorization is being compared to several adult models of categorization (Strauss, 1979, Bomba & Siqueland 1983, Sherman 1985). The results of infant studies are predicted by certain models, but these are complex and imply the role of active processes It is not clear, therefore, to what extent the processes underlying infant studies merely mimic those proposed by the adult models. Hence, investigating the relative role of active and passive processes in infant categorization is important.

Training procedures such as the one used by Kuhl might be most useful for investigating infants' use of active processes in categorization. For example, one could test if infants can change their focus of attention to different aspects of a variable stimulus array (e.g., focus on a certain type of invariant information over another, focus on the differentiating information rather than invariant information) according to the reinforcement contingencies. The ability to shift focus of attention would point towards the role of conscious processing strategies.

Methodological Implications

The experiments undertaken here have established the suitability of a novelty-preference fixation procedure for testing infants' ability to categorize auditory patterns Perhaps future research will determine that the technique is also useful for conducting speech categorization studies

The present method is especially appealing for evaluating infants' ability to form categories without training. Non-training procedures seem more appropriate for tapping natural tendencies that infants might have for organizing stimuli along particular dimensions.

The present findings with 10-month-olds along with Colombo and Bundy's (1983) success using a similar procedure with 4-month-old infants together indicate that the novelty-preference fixation technique is effective across a wide age range. Thus, the method should permit a direct comparison of categorization skills in infants of different ages Of course, the differences between the present procedure and Colombo and Bundy's should first be investigated. In particular, the implications of presenting familiarization stimuli either contingently or noncontingently upon visual fixation of the displays should be examined. The advantages of making stimulus presentation contingent upon visual fixation were mentioned earlier, but it remains to be seen whether young infants could adapt to this procedure.

The method used here also enables the study of infant categorization both on the basis of relative and absolute similarity judgments. Novelty-preference scores were used as an indication of categorization based on a relative similarity judgment. That is, novelty-preference scores were an indication of infants' interest in a new member of a familiar category in relation to its interest in a member of a novel category In contrast, the analysis of babies' first-test look is a measure of categorization based on an absolute similarity judgment. First-look data assesses infants' interest in each test pattern relative to the familiarization sequence, but independently of each other. The present research yielded concordant results using both types of measures suggesting that infants' disinterest in the new familiar-contour test pattern was not due solely to the overwhelming interest in the novel-contour pattern

Clinical Relevance

As with most basic research, it is difficult to predict how studies on infant categorization might eventually have clinical relevance Certainly, any research that contributes to a better understanding of auditory perception and language skills in infancy may help in the development of assessment and treatment tools for related disabilities. Furthermore, categorization paradigms may be useful for assessing mental abilities. There has been increasing interest in the use of non-psychometric instruments to evaluate infants (see Bornstein, 1985). For example, infants' performance within habituation procedures have been shown to predict future scores on intelligence tests (e.g., Bornstein & Ruddy, 1984; Lewis, Goldberg & Campbell, 1969; Miller, Spiridigliozzi, Ryan, Callan & McLaughlin, 1980), and clinical populations perform differently from normal infants in such paradigms (Barnet, Ohlrich & Shanks, 1971; Cohen, 1981). To date, such measures as rate of habituation, amount of habituation, and discriminatory skills have been of interest. It is possible, however, that tests of categorization will prove to be superior indicators of cognitive functioning early in life.

Footnotes

[1] Categorization of voices on the basis of gender has also been successfully studied using Kuhl's training procedure (Miller, Younger, & Morse 1982).

[2] It is worth recalling that the working definition of categorization is "treating discriminable stimuli equivalently." Hence, if two stimuli are treated equivalently because they cannot be distinguished (i.e., because they are perceived as identical rather than similar), this would not constitute an instance of categorization.

[3] In fact, researchers have often preferred to study phonetic categories that have not as yet been defined in terms of stable acoustic properties Categorization of such stimuli is taken as an example of the more impressive ability to group speech signals according to abstract properties rather than simply on the basis of acoustic cues (Kuhl, 1983; Katz & Jusczyk, 1980).

[4] Several experiments have shown categorical perception of non-speech stimuli in infants (Jusczyk, Pisoni, Walley & Murray, 1980; Jusczyk, Rosner, Cutting, Foard & Smith, 1977) but, as mentioned, it is questionable whether this phenomenon should be considered categorization.

[5] After this research was undertaken, Colombo and Bundy (1983) developed a version of a similar paradigm that is appropriate for use with infants between 1 and 4 months of age. Their paradigm will be addressed more fully in the discussion of this study

[6] Fisher tests of the homogeneity of variance were conducted prior to undertaking ANOVA's in studies 1,2, and 3. Unless otherwise noted, these tests

yielded insignificant findings ($p > .10$). Also, in each case, preliminary ANOVA's were conducted with Sex as a between-subject factor Unless otherwise noted, no significant effects due to Sex or interactions with Sex were obtained Hence, the analyses were recomputed without Sex as a factor and there computed analyses are reported here

[7] Since virtually all the $prop_{nov}$ values were within the range of 20 to .80 for studies 1,2, and 3, it was not necessary to transform these values

[8] Both the absolute frequency values of the tones and the frequency ratios of successive tones were varied across sequences

[9] The wave form of a tone refers to the intensity weightings of the various harmonics levels of the tone

[10] It is important to distinguish between the terms frequency and pitch Frequency refers to the repetition rate (i e , the number of periods per second) of the wave form of a sound In contrast, pitch is a subjective quality that cannot be measured directly. It is the attribute of auditory sensation that enables sounds to be ordered on a musical scale (American Standards Association, 1960) For pure tones, the pitch value corresponds to the frequency of the tones, but for periodic complex tones, it generally corresponds to the fundamental frequency For research with infants, the term frequency contour may be more appropriate than pitch contour, because there is no evidence that babies perceive pitch (see Bundy, Colombo & Singer, 1982) Hence, the term melodic contour used here refers to frequency contour rather than pitch contour The term melodic contour is used rather than frequency contour, simply to indicate that the present

research concerns the frequency contour of melodies rather than other auditory signals

[11] The data of one of the 24 original subjects could not be used since the videotapes of this subject was accidently erased

[12] The original analysis that also included Sex as a between-subject factor yielded an unexplainable significant interaction of Familiarization Condition X Sex.

[13] A test for a natural, rather than a novelty, preference was used in part 3 for the following reasons Previous studies indicated how difficult it is to obtain acceptable data from an infant in two consecutive familiarization procedures A shorter natural preference procedure was expected to be less taxing on infants Piloting suggested that babies naturally prefer sequences possessing the wave form with weightings on the higher harmonics (i.e., W_2). Thus, the technique seemed appropriate to demonstrate discrimination of sequences on the basis of wave form

[14] Pearson product moment correlations were conducted to determine if infants' performance during the test phase was related to demographic variables. No significant results were obtained

References

American Standard Association (1960). Acoustical Terminology Sl. 1-1960, American Standards Association, New York

Aslin, R. N, Pisoni, D B, & Jusczyk, P W (1983) Auditory development and speech percepton in infancy In P. H Mussen (Ed), Handbook of child psychology. Vol II. Infancy and developmental psychobiology. New York. Wiley.

Barnet, A B, Ohlrich, E S, & Shanks, B L. (1971) EEG evoked responses to repetitive auditory stimulation in normal and Down's syndrome infants Developmental Medicine and Child Neurology, 13, 321-329

Berg, W. K (1972) Habituation and dishabituation of cardiac responses in 4-month-old alert infants Journal of Experimental Child Psychology, 14, 92-107

Bomba, P C (1984) The development of orientation categories between 2 and 4 months of age Journal of Experimental Child Psychology, 37, 609-636.

Bomba, P. C., & Siqueland, E. R. (1983). The nature and structure of infant form categories. Journal of Experimental Child Psychology, 35, 294-328

Bornstein, M. H. (1984). A descriptive taxonomy of psychological categories used by infants In C Sophian (Ed.), Origins of cognitive skills. Hillsdale, NJ: Erlbaum

Bornstein, M H (1985) Habituation of attention as a measure of visual information processing in human infants Summary, systematization, and synthesis In G Gottlieb & N A Krasnegor (Eds), Development of audition and vision during the first year of postnatal life: A methodological overview. Norwood, NJ ABLEX

Bornstein, M H , Kessen, W., & Weiskopf, S. (1976) Color vision and hue categorization in young human infants Journal of Experimental Psychology. Human Perception and Performance, 2, 115-129

Bornstein, M. H., & Ruddy, M (1984) Infant attention and maternal stimulation: Prediction of cognitive and linguistic development in singletons and twins In H Bouma & D Bouwhuis (Eds.), Attention and performance X. Hillsdale, NJ Erlbaum

Boyd, E. F. (1975). Visual fixation and voice discrimination in 2 month-old infants In F. D Horowitz (Ed.) Visual attention, auditory stimulation, and language in young infants Monographs of the Society for Research in Child Development, 39 (5-6, Serial no 158), 63-77

Bruner, J S , Goodnow, J. J., & Austin, J G. (1956). A study of thinking. New York Wiley

Bruner, J S , Olver, R. R., Greenfield, P. M , et al. (1967) Studies in cognitive growth, New York: Wiley.

Bundy, R. S , Columbo, J , & Singer, J (1982) Pitch perception in young infants Developmental Psychology, 18, 10-14

Chang, H , & Trehub, S E (1977) Auditory processing of relational information Journal of Experimental Child Psychology, 24, 324-331

Cohen, L B (1981). Examination of habituation as a measure of aberrant infant development. In S L Freedman & M Sigman (Eds), Preterm birth and psychological development. New York Academic Press

Cohen, L B , & Gelber, E R (1975) Infant visual memory In L.B Cohen and P Salapatek (Eds), Infant perception. From sensation to cognition (Vol. 1). New York Wiley

Cohen, L. B., & Strauss, M. S. (1979). Concept acquisition in the human infant. Child Development, 50, 419-424.

Colombo, J., & Bundy, R. S (1981). A method for the measurement of infant auditory selectivity. Infant Behavior and Development, 4, 219-233.

Colombo, J., & Bundy, R. S (1983). Infant response to auditory familiarity and novelty. Infant Behavior and Development, 6, 305-311.

Cornell, E (1974) Infants' discrimination of photographs of faces following redundant presentations. Journal of Experimental Child Psychology, 18, 98-106

Demany, L (1982) Auditory stream segregation in infancy. Infant Behavior and Development, 5, 215-226

Demany, L., & Armand, F (1984). The perceptual reality of tone chroma in early infancy. Journal of the Acoustical Society of America, 76, 57-66.

Demany, L., Goodman, G. S., & Haith, M. M. (1982, March) Infants' perception of rhythmic invariants in melodic tone sequences. Paper presented at the Third International Conference on Infant Studies, Austin, Texas

Demany, L., McKenzie, B., & Vurpillot, E. (1977). Rhythm perception in early infancy Nature, 266, 718-719

Endman, M. (1985) Perceptual constancy for auditory stimuli in infancy, unpublished doctoral dissertation, University of Toronto, Toronto, Ont

Fagan, J F III (1976) Infants' recognition of invariant features of faces. Child Development, 47, 627-638.

Fagan, J F III (1979) The origins of facial pattern recognition In M. H. Bornstein & W Kessen (Eds.), Psychological development from infancy. Image to intention Hillsdale, NJ Erlbaum Associates

Fernald, A (1981, April) Four-month-olds prefer to listen to 'motherese' Paper presented at the meeting of the Society for Research in Child Development, Boston, MA

Fernald, A., & Kuhl, P K (1981, April) Fundamental frequency as an acoustic determinant of infant preference for motherese Paper presented at the meeting of the Society for Research in Child Development, Boston, MA

Flavell, J.H., & Wellman, H.M., (1976). Metamemory. In R.V. Kail., Jr., J.W. Hagen, (Eds.), Perspectives on the development of memory and cognition Hillsdale, N.J. : Erlbaum.

Fodor, J. A., Garrett, M F. & Brill, S L. (1975) Pi ka pu The perception of speech sounds by prelinguistic infants Perception and Psychophysics, 18, 74-78

Gelman, R. (1978). Cognitive development Annual Review of Psychology, 29, 297-332.

Gibson, E J (1969) Principles of perceptual learning and development NY Appleton-Century-Crofts

Gibson, J. J (1979) The ecological approach to visual perception Boston Houghton-Mifflin

Goldman, D, & Homa, D (1977) Integrative and metric properties of abstracted information as a function of category discriminability, instance variability, and experience Journal of Experimental Psychology: Human Learning and Memory, 3, 375-385.

Haith, M. M., & Bertenthal, B. (1979). Programmable calculator as timer, storer, and decision maker in psychology experiments. Behavior Research Methods and Instrumentation, 11, 349-354

Harris, P. L. (1983). Infant cognition. In P. H. Mussen (Eds.), Handbook of child psychology, Vol. II: Infancy and developmental psychology. New York: Wiley.

Henke, W. L. (1975). Mitsyn: An interactive dialogue language for tone signal processing. MIT Research Laboratory of Electronics. Cambridge, MA

Hillenbrand, J. M. (1983). Perceptual organization of speech sounds by infants. Journal of Speech and Hearing Research, 26, 268-282

Holmberg, T. L., Morgan, K. A., & Kuhl, P. K. (1977). Speech perception in early infancy: Discrimination of the fricative consonants. Journal of the Acoustical Society of America, 62, Supplement 1, S99(A)

Jusczyk, P. W., & Derrah, C. (1983). A study of phonetic categorization in 2-month-olds. In Aslin, R. N., Pisoni, D. B., & Jusczyk, P. W. (1983). Auditory development and speech percepton in infancy. In P. H. Mussen (Ed.), Handbook of child psychology, Vol II: Infancy and developmental psychobiology. New York: Wiley

Jusczyk, P W., Pisoni, D. B , Walley, A., & Murray, J. (1980) Discrimination of relative onset time of two-component tones by infants Journal of the Acoustical Society of America, 67, 262-270.

Jusczyk, P. W , Rosner, B S , Cutting, J. E , Foard, F , & Smith, L. B. (1977). Categorical perception fo non-speech sounds by two-month-old infants Perception and Psychophysics, 21, 50-54.

Katz, J , & Jusczyk, P W (1980) Do six-month-olds have perceptual constancy for phonetic segments? Paper presented at the International Conference on Infant Studies, New Haven, CT.

Kinney, D K , & Kagan, J. (1976) Infant attention to auditory discrepancy Child Development, 47, 155-164

Kuhl, P K (1979) Speech perception in early infancy Perceptual constancy for spectrally dissimilar vowel categories Journal of the Acoustical Society of America, 66, 1668-1679

Kuhl, P K (1980) Perceptual constancy for speech sound categories in early infancy In G H Yeni-Komshian, J F Kavanaugh, & C A Ferguson (Eds), Child Phonology, Vol. 2: Perception. NY. Academic Press.

Kuhl, P. K. (1983). Perception of auditory equivalence classes for speech by infants Infant Behavior and Development, 6, 263-285.

Kuhl, P K, (1985) Categorization of speech by infants In J Mehler & R. Fox (Eds), Infant cognition Beyond the blooming, buzzing confusion. Hillsdale, NJ Erlbaum

Kuhl, P. K, & Miller, J D (1982) Discrimination of auditory target dimensions in the presence or absence of variation in a second dimension by infants Perception and Psychophysics, 31, 279-292.

Leavitt, L A, Brown, J W, Morse, P A., & Graham, F K (1976) Cardiac orienting and auditory discrimination in 6-week-old infants Developmental Psychology, 12, 514-523

Lewis, M, Goldberg, S, & Campbell, H A, (1969) A developmental study of learning within the first three years of life Response decrement to a redundant signal. Monographs of the Society for Research in Child Development, 34 (9, Serial No 133)

Liberman, A M, Cooper, F S, Shankweiler, D P, & Studdert-Kennedy, M (1967) Perception of the speech code Psychological Review, 74, 431-461

Markham, E. M., & Siebert, J. (1976). Classes and collections: Internal organization and resulting holistic properties. Cognitive Psychology, 8, 561-577.

McCall, R. B., & Melson, W. H. (1970). Amount of short-term familiarization and the response to auditory discrepencies. Child Development, 41, 861-869.

Melson, W. H., & McCall, R. B. (1970). Attentional responses of five-month girls to discrepant auditory stimuli. Child Development, 41, 1159-1171.

Mervis, C. B., & Rosch, E. (1981) Categorization of natural objects. Annual Review of Psychology, 32, 89-115

Miller, C. L. (1983) Developmental changes in male/female voice classification by infants. Infant Behavior and Development, 6, 313-330.

Miller, C. L., Younger, B. A., & Morse, P. A. (1982) Categorization of male and female voices in infancy. Infant Behavior and Development, 5, 143-159

Miller, D., Spiridiliozzi, G., Ryan, E. B., Callan, M. P., & McLaughlin, J. E. (1980) Habituation and cognitive performance relationship between measures at 4 years and earlier assessments International Journal of Behavioral Development, 3, 131-146

Miller, J. L., & Eimas, P. D (1983). Studies on the categorization of speech by infants Cognition, 13, 135-165.

Moore, J M, Wilson, W R, & Thompson, G (1977). Visual reinforcement of head-turn responses in infants under 12 months of age. Journal of Speech and Hearing Disorders, 42, 328-334.

Olsho, L. W, Schoon, C, Sakai, R., Turpin, R., & Sperduto, V. (1982). Auditory frequency discrimination in infancy Developmental Psychology, 18, 721-726.

Olson, G.M., & Sherman, T (1983) Attention, learning, and memory in infants. In P H Mussen (Ed), Handbook of child psychology, Vol II: Infancy and developmental psychobiology. NY Wiley

Pastore, R E (1981) Possible psychoacoustic factors in speech perception. In P D Eimas & J L. Miller (Eds), Perspectives on the study of speech. Hillsdale, NJ: Erlbaum.

Pisoni, D. B (1978). Speech perception. In W K. Estes (Ed.), Handbook of learning and cognitive processes, Vol. 6. Hillsdale, NJ. Erlbaum.

Posner, M.I (1969). Abstraction and the process of recognition. In G. H. Bower & J T. Spence (Eds), The psychology of learning and motivation. NY: Academic Press.

Posner, M I & Keele, S. W (1968). On the genesis of abstract ideas. Journal of Experimental Psychology, 77, 353-363.

Rosch, E (1978) Principles of categorization In E Rosch & B Lloyd (Eds), Cognition and Categorization, 27-48. Hillsdale, NJ: Erlbaum.

Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyes-Braem, P. (1976). Basic objects in natural categories. Cognitive Psychology, 8, 382-439.

Ruff, H. A. (1975). The function of shifting fixation in the visual perception in infants. Child Development, 46, 857-865.

Sherman, T. (1985). Categorization skills in infants. Child Development, 56, 1561-1573.

Siqueland, E. R., & DeLucia, C. A. (1969). Visual reinforcement of non-nutritive sucking in human infants Science, 165, 1144-1146

Strauss, M (1979). Abstraction of prototypical information in adults and 10-month-old infants Journal of Experimental Psychology. Human Learning and Memory, 5, 618-632

Suzuki, T., & Ogiba, Y (1961) Conditioned orientation reflex audiometry Archives of Otolaryngology, 74, 192-198.

Trehub, S. E, Bull, D, & Thorpe, L A (1984) Infants' perception of melodies: The role of melodic contour Child Development, 55, 821-830

Trehub, S E., Schneider, B., & Bull, D (1981). Effect of reinforcement on infants' performance in an auditory detection task. Developmental Psychology, 17, 872-877

Washburn, K. J (1984, April) Development of Categorization of Rhythmic Patterns in Infancy Presented at the International Conference on Infant Studies. New York, NY.

Washburn, K.J., & Cohen L.B., (1984, April) Infant Perception of Rhythmic Form. Presented at the International Conference on Infant Studies. New York, NY.

Wormith, S. J., Pankhurst, D., & Moffitt, A. R. (1975). Frequency discrimination by young infants. Child Development, 46, 272-275.

Younger, B A , & Cohen, L. B. (1985). How infants form categories. In G. Bower (Ed) The psychology of learning and motivation. Advances in research and theory (Vol 19, pp. 211-247). NY Academic Press.

Appendix A

Consent Form

McGill University

Psychology Department

CONSENT

I agree to allow my baby ______________________ to be observed in the study of infant perception at McGill's Psychology Department. I understand the following:

1) The purpose of the study is to find out how babies learn about sounds.
2) Sounds and visual displays will be presented to my baby.
3) My baby will be observed with a video camera throughout the procedure.
4) The procedure has been designed with my baby's safety in mind.
5) I will hold my baby during the observation.
6) I can ask to stop the observation at any time.
7) The results of the experiment will be sent to me when they are available.

Witness: ______________________ Signed: ______________________

Date: ______________________

Appendix B

Demographic Information

Subject #: __________ Date of Birth : __________ Today's date: __________

The following information would be helpful to us for analysing the results of our study. Your answers will be held in the strictest of confidence.

1. At birth my baby's weight was: ______________

   length was: ______________

2. My baby's due date was: ________________

3. Were there any complications in the delivery? __________

   If yes, please describe - (for example, did the mother have a Caesarian? etc.)

4. Does the baby have any brothers or sisters? ____________

	brother/sister	date of birth
1.		
2.		
3.		

5. Age of Parents: Mother - ______________

   Father - ______________

6. Parents' occupations: Mother - ______________________

   Father - ______________________

7. Total number of years of parents' education: Mother - ____________

   Father - ____________

8. Are there any hearing problems in your extended family? ______________

If so what kind ? ____

9. Has your baby had any hearing problems or infections? ________ If yes,

how many? ________ and when did they occur? ______________________

10. How is your baby's health today? ______________________________

Appendix C

Demographic Information for Study 2[14]

Category	Mean	SD	Minimum	Maximum
Birth Weight (gm)	3314.1	436.6	2636.5	4054.0
Length at Birth (cm)	51.6	2.8	48.3	58.4
Difference between due date and date of birth (days)	-6.1	10.8	-24	10
Placement in family	1.5	0.7	1	3
Age				
Mother	30.6	4.7	24	39
Father	33.3	7.5	25	61
Blishen and McRobert's Socioeconomic Index	53.8	16.6	27	75
Years of schooling				
Mother	15.7	3.4	11	21
Father	15.0	3.5	11	21