Infants' Perception of Musical Sequences: Implications for Language Acquisition

Sandra E. Trehub
Department of Psychology
University of Toronto

Abstract

The present paper describes a program of studies directed at infants' perception of melodies or auditory sequences. When infants listen to melodies, they typically focus on the pitch configuration or contour, which is an adult-like strategy for processing unfamiliar melodies. In the case of lawful or good melodies, they encode and retain intervals, a strategy that adults use for processing familiar melodies. In the temporal domain, infants recognize a melody across changes in tempo (rate), just as they recognize it across changes in pitch. Moreover, they chunk or group the elements of auditory sequences on the basis of pitch, waveform or intensity, as is the case for adults. These pattern processing strategies have implications for infants' processing of speech in general and suprasegmental aspects of speech in particular. Finally, there are indications that parental speech to infants is intuitively tuned to infants' pattern perception abilities and attentional dispositions and that such tuning may facilitate language acquisition.

In recent years, my colleagues and I have been studying infants' perception of musical patterns. This might seem like a very specialized endeavour, with limited practical or theoretical significance, but music is found in every culture, just as language is. Moreover, there is no fundamental distinction between musical and non-musical sounds (Dowling & Harwood, 1986; Pantaleoni, 1985; Trehub, 1987). Strictly speaking, then, the concern is with *auditory sequences*, in contrast to the relatively simple sounds that have occupied researchers for decades (see Trehub, 1985).

The Test Procedure

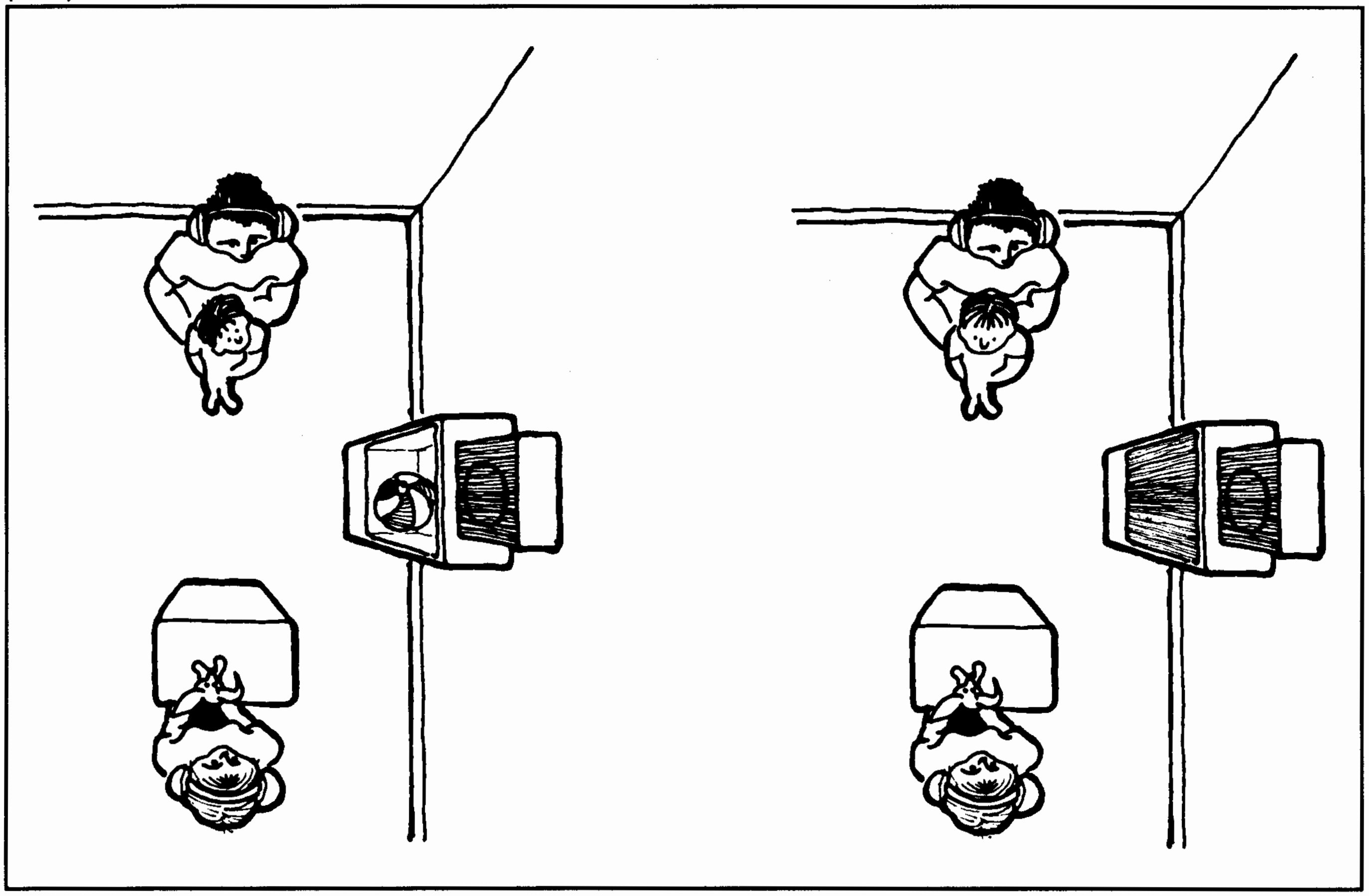
To study infants' perception of melodies or auditory sequences, we use a discrimination procedure derived from Visual Reinforcement Audiometry (Moore, Thompson, & Thompson, 1975) and known as Visually Reinforced Infant Speech Discrimination (VRISD, Eilers, Wilson, & Moore, 1977) or, simply, conditioned head-turning (HT, Kuhl, 1985). All testing is conducted in a sound-attenuating booth, the arrangement of which is illustrated schematically in Figure 1. Essentially, the procedure involves the presentation of a repeating melody over a loudspeaker to the infant's left side, with randomly occurring substitutions of an altered melody. (The left side is chosen simply to avoid the potential problem of rightward postural biases, which are characteristic of younger infants. See Harris & Fitzgerald, 1983). The tester, who faces the infant, and the parent, on whose lap the infant is sitting, wear headphones with masking patterns so that they remain unaware of the stimuli presented to the infant. The tester indicates, by means of a button press (linked to a computer), infant head turns of 45° or more to the loudspeaker. The computer monitors such turns, on the one hand, and the occurrence of melody changes, on the other, delivering visual reinforcement (i.e., activation of an animated toy for approximately 3 s) each time the infant turns within a specified time following a sound change (usually 3 or 4 s).

To ensure that infants understand and can perform the task, we require them to meet a training criterion of four successive correct responses to a substantial (i.e., discriminable) change in the auditory sequence. During the subsequent test phase, we present approximately 30 test trials, half of which incorporate more subtle changes in the melody, the other half involving no change, with the change and no-change trials occurring in random order. Spontaneous turning toward the toys may occur on 20-30% of trials so that the no-change or control trials are essential for interpreting performance on the change trials. If infants turn significantly more on change than on no-change trials (as determined by appropriate statistical tests), this indicates that they can detect the change in question. (For further procedural and statistical details, see Trehub, Bull, & Thorpe, 1984 & Thorpe, Trehub, Morrongiello, & Bull, 1988.)

Adult Music Perception

Research on music perception has revealed that adults' recognition of melodies does not depend on specific notes or exact pitch levels but rather on the *relations* among component notes. The key to tune recognition, in the case of *familiar melodies*, is the pattern of *intervals*, with intervals referring to the precise relations between adjacent notes (i.e., ratios or distance in semitones). This leads us to view transpositions,

Figure 1. Right panel: Infant looks directly ahead, ignoring the familiar repeating melody from the loudspeaker. Left panel: Infant turns when the melody changes, receiving visual reinforcement for a correct response. From Trehub & Thorpe (1989).



which have new notes but identical intervals, as equivalent to the original pattern (Attneave & Olson, 1971; Bartlett & Dowling, 1980) and, in some circumstances, indistinguishable from it.

Tune recognition, in the case of *unfamiliar melodies*, depends on configurational information about successive directional changes in pitch (i.e., ups and downs), which is known as melodic contour or, simply, *contour* (Dowling, 1978). The contour of a melody refers only to directional aspects of the pitch changes rather than the extent of such changes (Dowling & Harwood, 1986).

Infant Music Perception: Contour

From earlier research, we were aware that infants could distinguish between melodies (e.g., Chang & Trehub, 1977a) but the basis for their discrimination remained unclear. If infants were familiarized with a melody by means of repeated exposure, what would they remember of that melody? There were several possibilities. For example, they might recognize all of the notes of a very brief melody and, perhaps, the first two or three notes of a longer melody. On the other hand, they might recognize the global configuration or contour of the melody (i.e., adults' strategy with unfamiliar melodies) or its specific interval relations (i.e., adults' strategy with familiar melodies). In principle, infants' mental representation of the original melody should be evident from the kinds of changes that they are able to detect together with those that they fail to detect.

In one study (Trehub et al., 1984), we tested infants (8 to 10 months of age) for their discrimination of various changes to a six-tone melody, including *transpositions* (different notes, same intervals and contour), *contour-preserving* changes (different notes and intervals, same contour) and *contour-violating* changes (same component notes in different order, yielding different intervals and contour). From the perspective of adults, the transposed tunes would be most similar, and those with altered contour would be least similar to the original melody. In one condition, the standard or original repeating patterns were separated by 800 ms (i.e., a brief retention interval); in another, they were separated by 2.6 s (i.e., a longer retention interval). In fact, infants were able to detect all of the changes when the retention interval was brief, performing best, however, on the contour changes. With the longer retention interval, infants readily achieved the training criterion but they failed to respond to the transpositions or to the contour-preserving changes. This pattern of findings implies that they had encoded general contour information from the original melody and that precise pitch or interval information decayed rapidly. We subsequently found that infants (6 to 8 months of age) could detect contour changes even when only one note of a six-note melody had been changed (Trehub, Thorpe, & Morrongiello, 1985). As in the previous study, increases in the retention interval (i.e., time between familiarization and test melody) revealed the decay of pitch information.

In a further study (Trehub, Thorpe, & Morrongiello, 1987), we presented infants (9 to 11 months of age) with an even more challenging task. We reasoned that, if they indeed extracted contour information from a melody, then they should go beyond the discrimination of contour changes in the context of *fixed* repeating patterns (as in the aforementioned research) to discrimination in the context of *variable* melodies that shared a common contour. In other words, we were asking infants to differentiate a *set* of melodies from another set that differed in contour, with melodies within each set differing in their component notes but having the same contour. Infants were successful on this task, indicating that they could discriminate contrasting sets of melodies and also that they could *categorize* or group melodies on the basis of relational properties such as contour. In short, infants' representation of melodies seemed to have much in common with adults' representation of unfamiliar melodies, with contour playing a critical role in both cases.

Infant Music Perception: Intervals

It has long been clear that adults' detection of melodic changes is enhanced for melodies that conform to Western musical structure (Cohen, 1982; Cuddy, Cohen, & Mewhort, 1981), as is the case for children of school age (Zenatti, 1969). This is thought to be due to formal or informal exposure to the music of our culture, which leads to more stable mental representations of such melodies (Dowling & Harwood, 1986; Krumhansl, Bharucha, & Kessler, 1982). With infants, however, their relatively limited musical exposure would likely be insufficient to generate differential reactions to culturally typical and atypical tunes. On the other hand, Werker and her associates (Werker & Lalonde, 1988; Werker & Tees, 1983) found that some effects of specific language input on phonetic perception were evident in infants 10 to 13 months of age.

We tested infants (9 to 11 months of age) and preschool children (4 to 6 years of age) for their detection of a single semitone change in one position of a *lawful* or *unlawful* melody, defined in terms of Western musical conventions (Trehub, Cohen, Thorpe, & Morrongiello, 1986). The lawful tune was a prototypical Western melody with the following notes: C-E-G-E-C, all belonging to a single Western scale or key. The unlawful melody was similar in its contour (rising-falling) and composition of notes (all but one were identical) but had one incorrect note in terms of Western scales (C-E-G$^{\#}$-E-C). For adult listeners, the lawful melody would be relatively easy to remember and reproduce but this would not be the case for the unlawful melody. Because we were evaluating the perception of subtle interval changes (one semitone) as opposed to salient contour changes, we presented fixed repetitions of the standard pattern (i.e., an easier task), as in Trehub et al. (1984). We found that preschool children were more successful at detecting semitone changes in the context of the lawful melody, presumably doing so on the basis of their incidental exposure to Western music. In contrast to the preschool participants, infants performed equivalently and successfully in both contexts, indicating that such structural aspects of a melody might be irrelevant to their ability to process and retain melodic information. In any case, infants' ability to discriminate semitone changes in any position of a five-tone melody was impressive and confirmed, moreover, that they could discriminate, in a melodic context, the smallest interval change relevant to Western music, namely the semitone (a 5.9% frequency change).

In a replication and extension of the study (Cohen, Thorpe, & Trehub, 1987), we presented infants (7 to 11 months of age) with the same lawful and unlawful melodies in the context of transpositions. In the previous study (Trehub et al., 1986), the provision of exact repetitions would have allowed infants and children to solve the task if they noticed the one novel pitch in the contrasting melody. With all standard and contrasting melodies presented in transposition (i.e., repetitions had new pitches), they could solve the task only by discriminating the interval change. Under these more demanding conditions, infants surprised us by discriminating the semitone change in the context of the lawful melody but not the unlawful melody.

To confirm that this effect was not limited to the specific melodies used, we executed a further study in which infants (7 to 10 months of age) were presented with one of three sets of five-note melodies in transposition (Trehub & Thorpe, 1988). All three patterns had similar contour (rise-fall) and overall pitch range but each had five different notes instead of the three different notes (e.g., C-E-G-E-C) in the melodies of Cohen et al. (1987). Only one melody could be considered lawful because all of its notes were consistent with a single key or scale (i.e., a diatonic melody, B-D-G-E-C). In fact, it sounded rather pleasant to Western adult listeners. The second melody could be considered unlawful by virtue of its notes not belonging to any single scale (i.e., a nondiatonic melody, C-F$^{\#}$-B-F-C$^{\#}$) and the presence of two *dissonant* intervals (C-F$^{\#}$; B-F). It sounded terrible, to say the least. The third melody incorporated frequency values that were inconsistent with a chromatic or semitone scale (i.e., it could not be played on a conventional Western instrument) and also had two intervals smaller than one semitone. This one sounded unusual rather than unpleasant. If infants could not resolve the subtle pitch differences in these very small intervals, then they would hear repeated notes and, consequently, a simpler melody than the others. The outcome was in line with our earlier findings. Infants discriminated the semitone change only in the context of the musically lawful or diatonic melody.

One can only speculate on the nature of the apparent performance-enhancing properties of lawful melodies. In each of these studies, the lawful melody not only had notes drawn from a legitimate Western scale but also incorporated the notes of the *major triad*, which occupies a privileged position in music theory and is regarded as the prototype of tonal structure (Schenker, 1906/1954). Nevertheless, it is not known to have any cross-cultural significance in music (Dowling & Harwood, 1986). However, the component notes of the major triad exemplify simpler ratio relations than do the notes of the unlawful melody (see Cohen et al., 1987) although the relation between ratio simplicity, on the one hand, and discriminability or memorability, on the other, remains unclear. Finally, enhancement for the notes of the major triad could be attributable to exposure to these ratios in naturally occurring sounds (Terhardt, 1974) or to pitch processing mechanisms that are sensitive to periodicity (Creel, Boomsliter, & Powers, 1970).

An alternative account is to posit an effect of early experience emanating from unsystematic exposure to parental music-making (e.g., singing) or listening (e.g., radio, television, stereo). Indeed, major triads occur very frequently in Western art music (Roberts, 1982) and even more frequently in nursery songs (Cohen et al., 1987). However, many parents who visit our laboratory report that they rarely sing or play music in their infant's presence, but the accuracy of such reports is open to question. If music listening experience is the relevant factor, then its impact would be evident earlier than the reported phonetic experience effects (Werker & Lalonde, 1988; Werker & Tees, 1984). Recall that infants as young as 7 months showed performance enhancement for lawful melodies whereas the youngest infants showing differential performance for phonetic segments of native and non-native languages were 10 months of age. If there is any perceptual reorganization for music in the second half-year of life, as is presumed to be the case for speech (Burnham, 1986; Werker, 1989; Werker & Tees, 1984), its details remain to be determined. In fact, we are currently engaged in research designed to uncover the developmental course of these abilities.

Another possibility is that prototypical Western melodies exhibit *good form* in a more general sense, in line with the thinking of Gestalt psychologists (Koffka, 1935) and information-processing theorists (Garner, 1974). If this is the case, then *good form* is equally likely to characterize the prototypical melodies of other cultures which, although very different from ours, would nevertheless incorporate structural features that facilitate their encoding and retention. In analogous fashion, the syntactic structures of various languages differ substantially but none is more legitimate than another. Indeed, there would be an even greater premium on *good form* in cultures with an oral music tradition, where melodies are likely to involve greater disparity from one presentation to another (Sloboda, 1985). One way to assess the contribution of musical acculturation would be to compare infants' performance on culturally-typical and culturally-atypical melodies, where the latter melodies are typical of a foreign culture. No evidence of this kind is currently available.

In any case, evidence of enhanced processing in the context of certain lawful melodies necessitates some revision of the view that infants are simply contour processors. Although it is generally the case that infants extract the contour and not the intervals of melodies presented in difficult contexts (e.g., transposed), this is not always the case. As we have seen, when a melody is composed of notes that are *central* to the Western tonal system, exemplifying diatonic structure in general or major triadic structure in particular, infants seem to be capable of encoding and retaining interval information, even in the context of transpositions. Thus, for reasons that are as yet unclear, infants' representation of prototypical Western tonal melodies is similar to adults' representation of *familiar* melodies.

Infant Perception: Temporal Patterning

Just as the contour of an auditory sequence and sometimes its intervals can confer a specific melodic identity, so the rhythmic patterning of a melody may confer a distinct temporal identity. In earlier research (Chang & Trehub, 1977b), we had established that 5-month-old infants could discriminate between six-tone patterns with identical tones but contrasting temporal arrangements of these tones (2,4 vs. 4,2 grouping) but the generality and extent of infants' temporal processing abilities remained unclear. To evaluate this question, we tested infants for their discrimination of sets of three-tone patterns of 2, 1 (XX X) or 1, 2 (X XX) form as well as sets of four-tone patterns characterized by 2, 2 (XX XX) or 3, 1 (XXX X) form (Trehub & Thorpe, 1989). Their task was to respond only to changes in rhythmic patterning, ignoring numerous other changes. For both the three- and four-tone patterns, there were 5 tempos or rates of presentation combined with 5 frequency values, yielding 25 different sequences in each set. Infants succeeded in discriminating contrasting temporal structure in the sets of three- and four-tone patterns, indicating that they could conserve the rhythm or temporal patterning of auditory sequences across changes in tempo and frequency.

Finally, there are indications that infants group the component sounds of auditory sequences much as adults do. Characteristically, adults chunk or group the elements of auditory sequences on the basis of duration, pitch or intensity information. In fact, this grouping tendency often leads adult listeners to group sounds that are uniform in all respects (Fraisse, 1982) just as it leads them to hear non-existent pauses between words. Fortunately, such temporal grouping (e.g., the 3, 4 grouping of telephone numbers) enhances our memory for auditory sequences (Huttenlocher & Burke, 1976) and our perception of speech (Bailey, 1983; Martin, 1972) and is thought to be critical to our understanding of music (Lerdahl & Jackendoff, 1983).

We attempted to ascertain whether infants exhibit grouping processes that are comparable to those of adults. To do so, we constructed patterns with three tones of one pitch, waveform or intensity followed by three tones of contrasting pitch, waveform or intensity (XXXOOO), with all tones and intertone intervals of equal duration (Thorpe & Trehub, 1989; Thorpe et al., 1988). The general idea was to have simple patterns with unambiguous structure. Infants' task was to discriminate a contrasting pattern created by lengthening the intertone interval following the third tone (XXX OOO, *between-group*) or following the fourth tone (XXXO OO, *within-group*). If infants grouped the original (equally-spaced) pattern into two groups of three tones, then the contrasting pattern with the extended *between-group* interval would be consistent with the original structure (3,3) and, consequently, somewhat difficult to detect. By contrast, the pattern with an extended *within-group* interval of equivalent magnitude would incorporate an altered structure (4,2) and, as a result, should be more readily detectable. In fact, infants exhibited superior detection for extended *within-* compared to *between-group* increments, indicating that they had, indeed, grouped the original sequence in the characteristic adult manner. In short, infants not only grouped the patterns appropriately but also imposed temporal or rhythmic patterning on sequences with equally spaced notes.

Musical Aspects of Infant-Directed Speech

These adult-like melodic and temporal processing strategies have implications for infants' perception of speech, for relational processing is predominant in speech, as it is in music. Although relational perception is relevant to segmental and suprasegmental aspects of speech, it is in the suprasegmental domain that the parallels to the present research are most striking (Trehub, 1989). Moreover, suprasegmental or music-like aspects of speech are particularly salient in the prelinguistic period, when they seem to have processing priority over segmental aspects (Crystal, 1973; Lewis, 1951). For example, in listening to their mother's speech, infants attend principally to its fundamental frequency configuration (Fernald & Kuhl, 1987), just as they attend principally to the contour of musical pattern. Moreover, they prefer infant-directed speech to adult-directed speech (Fernald, 1985; Werker & McLeod, 1989) and the former is likely to induce vocalization (Stevenson, VerHoeve, Roach, & Leavitt, 1986), positive affect (Mayer & Tronick, 1985; Werker & McLeod, 1989) and imitation of maternal intonation contours (Lieberman, Ryalls, & Robson, 1982, cited in Lieberman, 1984; Papoušek & Papoušek, 1981).

There are indications that caretakers, who obviously lack *explicit* knowledge of infants' perceptual capabilities, nevertheless exhibit *tacit* knowledge of such skills, delivering stimulation that is finely tuned to infants' perceptual abilities and attentional dispositions. Indeed, the most distinctive characteristic of infant-directed speech (often termed *motherese* or *baby talk*) is its prosody, particularly its increased pitch, extended pitch range, rhythmicity, slow tempo and simple, repeated pitch contours (Fernald, 1984, 1985; Fernald & Kuhl, 1987, Fernald & Simon, 1984; M. Papoušek & Papoušek, 1981). These pitch contours of infant-directed speech bear little relation to those of adult-directed speech and are typically unidirectional (rising, falling) or bell-shaped (rise-fall or fall-rise), the same contours being presented repeatedly with altered segmental content (Fernald, 1984; M. Papoušek, Papoušek, & Harris, 1986). It is quite likely, then, that for infant-directed speech, the pitch contour *is* the utterance, with lexical or segmental content being optional (Trehub, 1989). In Fernald's (1989) words, "the melody is the message." Moreover, the rhythmicity of infant-directed speech (Beebe, Feldstein, Jaffe, Mays, Alson, 1985; Fernald & Simon, 1985) is also in marked contrast to adult speech, where rhythmicity is typically limited to ritual or pathological contexts (Jaffe, Anderson, & Stern, 1979).

There are suggestions, moreover, that specific contours are linked to distinctive caretaking contexts, so that rising and bell-shaped contours tend to be used for capturing or holding infants' attention, falling contours for soothing, and variable contours for heightening positive affect (M. Papoušek & Papoušek, 1981; Stern, Spieker, & MacKain, 1982). Thus, the *contentless* pitch contours (M. Papoušek, 1987) and gliding, elongated vowels (Fernald & Simon, 1984; H. Papoušek & Papoušek, 1987) of infant-directed speech can be considered meaningful utterances. There are comparable context-dependent variations in tempo and rhythm, with increasing tempo used to engage the infant's attention, decreasing tempo to promote sleep, and slow rhythmic stimulation to maintain the infant's attention (Koester, 1987).

This fine-tuning of infant-directed speech is hardly unique to our culture, having been observed in a wide range of language groups including German, Kwara'ae and Mandarin (Fernald & Simon, 1984; Grieser & Kuhl, 1988; Watson-

Gegeo & Gegeo, 1986). Moreover, such speech adjustments are not confined to experienced mothers, being used, as well, by primiparous mothers (Fernald & Simon, 1984), fathers (H. Papoušek & Papoušek, 1984) strangers (Rheingold & Adams, 1980), and even preschool children (Anderson, 1986; Shatz & Gelman, 1973). There are indications that such musical speech originates in positive feelings of nurturance on the part of caretakers. For example, certain aspects of infant-directed speech, notably the expanded pitch contours, are absent or attenuated in the speech of depressed mothers (Bettes, 1988). As we have seen, moreover, infants seem to comprehend these nurturing messages, as reflected in their own heightened affect (Werker & McLeod, 1989).

There are those who view the special quality of infant-directed speech as part of a repertoire of intuitive parenting behaviours that promote the cognitive and social growth of infants (H. Papoušek & Papoušek, 1987; M. Papoušek & Papoušek, 1981). Such speech, by virtue of its potential for optimizing infant state and encouraging visual contact, is viewed as a favourable medium for promoting a wide range of skills. Parents are not consciously providing instruction but rather they are predisposed to share their knowledge, on the one hand, and their infants are receptive to such exposure, on the other (H. Papoušek & Papoušek, 1987). The fruits of these so-called *tutorials* can be seen in the pitch contours produced by young infants (Delack & Fowlow, 1978), the association of happy and sad sounding voices with appropriate facial expressions (Walker, 1982) and the emergence of prosodic aspects of language well before the first words (Boysson-Bardies, Sagart, & Durand, 1984). The suggestion, then, is that musical properties of infant-directed speech provide a favourable context for early language acquisition. The infant begins by attending to the melodies and rhythms of a loving caretaker's speech, subsequently delving into these musical *frames* to explore the words and phrases.

Concluding Considerations

The research reviewed on infants' perception of auditory sequences would seem to indicate that infants are predisposed to use a global processing strategy, extracting the pitch configuration (i.e., contour) and rhythmic structure of such sequences. Such strategies facilitate the retention of auditory information and are qualitatively similar, although less efficient quantitatively, in comparison to the strategies used by adults when they listen to unfamiliar or atonal melodies. When the melodies are structured in particular ways, infants go beyond this global strategy to process finer melodic details such as intervals, an approach that characterizes adults' processing of familiar melodies. Are these melodies *familiar* to infants in some sense or are they simply well matched to the properties of their auditory system? The answer to this question must await future research.

Infants' music processing skills and biases may provide them with a congenial as well as informationally rich path to the acquisition of language. Their responsiveness to the pitch contours of infant-directed speech from the earliest days of life (Mehler et al., 1988) could encourage caretakers to talk to their infants and to do so in prosodically appropriate ways, providing a multitude of potential cues for language learning (Broen, 1972; Garnica, 1977; Morgan, Meier, & Newport, 1987). Many researchers have noted the high incidence of questions directed to prelinguistic infants who cannot answer them (see Snow & Ferguson, 1977). These questions, with their rising pitch contours, may serve the function of arousing infants and maintaining their attention. Prosodic forms may serve specifically linguistic as well as attentional functions, delineating important linguistic units or boundaries. For example, prelinguistic infants are sensitive to the prosodic markers of clauses, phrases and words (Hirsh-Pasek et al., 1987; Jusczyk, 1989; Kemler Nelson, 1989; Kemler Nelson, Hirsh-Pasek, Jusczyk, & Wright Cassidy, 1989), which are highlighted in infant-directed speech. Perhaps pitch contours and rhythmic patterns are the initial units of analysis in running speech, with syllables and phonemes relegated to a later role in linguistic segmentation. To a considerable extent, then, musical and linguistic processes appear to be intertwined in the early months of age.

Some years ago, the discovery that infants perceived certain speech sounds in a categorical manner (Eimas, Siqueland, Jusczyk, & Vigorito, 1971) shook the academic realms of psychology and linguistics. The implication was that infants were pre-wired with specialized mechanisms for perceiving phonetic aspects of speech, or that they perceived speech-like stimuli in the so-called *speech mode* (Eimas et al., 1971). Subsequent evidence of categorical perception of speech by chinchillas (Kuhl & Miller, 1975) and monkeys (Kuhl & Padden, 1982) called into question the *special* or *phonetic* nature of infants' perceptual processing mechanisms, and the issue still remains unresolved. This should serve as a cautionary note to those eager to advance the claim that infants perceive auditory sequences in a *musical mode*. Nevertheless, it is of considerable interest that research with various non-human species, including primates, reveals that relational processing in the pitch domain may well be a uniquely human disposition (D'Amato, 1988). For example, although songbirds can learn to discriminate between rising and falling pitch sequences (with great difficulty), they do so by remembering the exact pitch level of one or more tones (Hulse & Cynx, 1986). By contrast, infants are relational processors *par excellence*. Thus, they readily differentiate rising from falling pitch sequences even when exact pitch cues are unavailable (Thorpe, 1986), and are inclined to forget the exact pitches, in any case.

Many questions remain unanswered or unsubstantiated. Why is music present in all human cultures and what is its biological significance? More important for our present purposes, what is the function of the precocious musical processing skills that are evident in the early months of life? It is possible, although admittedly speculative, that musical processing involves auditory mechanisms that are very general, mechanisms that guide the infant's gradual entry into linguistic and other domains, and that optimize the attentional and affective factors that support skill acquisition.

Acknowledgements

The preparation of this paper was assisted by financial support from The Natural Sciences and Engineering Research Council of Canada and The University of Toronto. Send reprint requests to Sandra E. Trehub, Centre for Research in Human Development, University of Toronto, Erindale Campus, Mississauga, Ontario, Canada L5L 1C6.

Address all correspondence to:
Sandra E. Trehub, Ph.D.
Centre for Research in Human Development
University of Toronto, Erindale Campus
Mississauga, Ontario, Canada L5L 1C6

References

Anderson, E. S. (1986). The acquisition of register variation by Anglo-American children. In B. B. Schieffelin & E. Ochs (Eds.), *Language socialization across cultures* (pp. 153-166). Cambridge: Cambridge University Press.

Attneave, F., & Olson, R. K. (1971). Pitch as a medium: A new approach to psychophysical scaling. *American Journal of Psychology, 84*, 147-166.

Bailey, P. J. (1983). Hearing for speech: The information transmitted in normal and impaired speech. In M. E. Lutman & M. P. Haggard (Eds.), *Hearing science and hearing disorders* (pp. 1-34). London: Academic Press.

Bartlett, J. C., & Dowling, W. J. (1980). Recognition of transposed melodies: A key-distance effect in developmental perspective. *Journal of Experimental Psychology: Human Perception and Performance, 6*, 501-515.

Beebe, B., Feldstein, S., Jaffe, J., Mays, K., & Alson, D. (1985). Interpersonal timing: The application of an adult dialogue model to mother-infant vocal and kinesic interactions. In T. M. Field & N. A. Fox (Eds.), *Social perception in infants* (pp. 217-247). Norwood, NJ: Ablex.

Bettes, B. A. (1988). Maternal depression and motherese: Temporal and intonational features. *Child Development, 59*, 1089-1096.

Boysson-Bardies, B., deSagart, L., & Durand, C. (1984). Discernible differences in the babbling of infants according to target language. *Journal of Child Language, 11*, 1-15.

Broen, P. (1972). The verbal environment of the language learning child. *American Speech and Hearing Association Monographs, 17.*

Burnham, D. K. (1986). Developmental loss of speech perception: Exposure to and experience with a first languge. *Applied Psycholinguistics, 7*, 207-240.

Chang, H. W., & Trehub, S. E. (1977a). Auditory processing of relational information by young infants. *Journal of Experimental Child Psychology, 24*, 324-331.

Chang, H. W., & Trehub, S. E. (1977b). Infants' perception of temporal grouping in auditory patterns. *Child Development, 48*, 1666-1670.

Cohen, A. J. (1982). Exploring the sensitivity to structure in music. *Canadian University Music Review, 3*, 15-30.

Cohen, A. J., Thorpe, L. A., & Trehub, S. E. (1987). Infants' perception of musical relations in short transposed tone sequences. *Canadian Journal of Psychology, 41*, 33-47.

Creel, W., Boomsliter, P. C., & Powers, S. R. (1970). Sensations of tone as perceptual forms. *Psychological Review, 77*, 534-545.

Crystal, D. (1973). Non-segmental phonology in language acquisition: A review of the issues. *Lingua, 32*, 1-45.

Cuddy, L. L., Cohen, A. J., & Mewhort, D. J. K. (1981). Perception of structure in short melodic sequences. *Journal of Experimental Psychology: Human Perception and Performance, 7*, 869-883.

D'Amato, M. R. (1988). A search for tonal pattern perception in cebus monkeys: Why monkeys can't hum a tune. *Music Perception, 5*, 453-480.

Delack, J. B., & Fowlow, P. J. (1978). The ontogenesis of differential vocalization: Development of prosodic contrastivity during the first year of life. In N. Waterson & C. Snow (Eds.), *The development of communication* (pp. 93-110). Chichester: Wiley.

Dowling, W. J. (1978). Scale and contour: Two components of a theory of memory for melodies. *Psychological Review, 85*, 341-354.

Dowling, W. J., & Harwood, D. L. (1986). *Music cognition.* Orlando, FL: Academic Press.

Eilers, R. E., Wilson, W. R., & Moore, J. M. (1977). Developmental changes in speech discrimination in infants. *Journal of Speech and Hearing Research, 20*, 766-780.

Eimas, P.D., Siqueland, E. R., Jusczyk, P. & Vigorito, J. (1971). Speech perception in infants. *Science, 171*, 303-306.

Fernald, A. (1984). The perceptual and affective salience of mothers' speech to infants. In L. Feagans, C. Garvey, & R. Golinkoff (Eds.), *The origins and growth of communication* (pp. 5-29). Norwood, NJ: Ablex.

Fernald, A. (1985). Four-month-old infants prefer to listen to Motherese. *Infant Behavior and Development, 8*, 181-195.

Fernald, A. (1989, April). *The universal language: Meaningful melodies in mothers' speech to infants.* Paper presented to meetings of the Society for Research in Child Development, Kansas City, MO.

Fernald, A. & Kuhl, P. K. (1987). Acoustic determinants of infant preference for Motherese. *Infant Behavior and Development, 10*, 279-293.

Fernald, A., & Simon, T. (1984). Expanded intonation contours in mothers' speech to newborns. *Developmental Psychology, 20*, 104-113.

Fraisse, P. (1982). Rhythm and tempo. In D. Deutsch (Ed.), *The psychology of music* (pp. 149-180). New York: Academic Press.

Garner, W. R. (1974). *The processing of information and structure.* Hillsdale, NJ: Erlbaum

Garnica, O. K. (1977). Some prosodic and paralinguistic features of speech to young children. In C. E. Snow & C. A. Ferguson (Eds.), *Talking to children* (pp. 66-88). Cambridge: Cambridge University Press.

Grieser, D. L., & Kuhl, P. K. (1988). Maternal speech to infants in a tonal language: Support for universal prosodic features in motherese. *Developmental Psychology, 44*, 14-20.

Harris, L. J., & Fitzgerald, H. E. (1983). Postural orientation in human infants: Changes from birth to three months. In G. Young, S. J. Segalowitz, C. M. Corter, & S. E. Trehub (Eds.), *Manual specialization and the developing brain* (pp. 285-305). New York: Academic Press.

Hirsh-Pasek, K., Kemler Nelson, D. G., Jusczyk, P. W., Wright Cassidy, K., Druss, B., & Kennedy, L. (1987). Clauses are perceptual units for young infants. *Cognition, 26*, 269-286.

Hulse, S. H., & Cynx, J. (1986). Interval and contour in serial pitch perception by a passerine bird, the European starling (*Sturnus vulgaris*). *Journal of Comparative Psychology, 100*, 215-228.

Huttenlocher, J., & Burke, D. (1976). Why does memory span increase with age? *Cognitive Psychology, 8*, 1-31.

Jaffe, J., Anderson, S., & Stern, D. (1979). Conversational rhythms. In D. Aronson & R. Rieber (Eds.), *Psycholinguistic research.* Hillsdale, NJ: Erlbaum.

Jusczyk, P. W. (1989, April). *Perception of cues to clausal units in native and non-native languages.* Paper presented at the Society for Research in Child Development. Kansas City, MO.

Kemler Nelson, D. G. (1989, April). *Developmental trends in infants' sensitivity to prosodic cues correlated with linguistic units.* Paper presented at meetings of the Society for Research in Child Development, Kansas City, MO.

Kemler Nelson, D. G., Hirsh-Pasek, K., Jusczyk, P. W., & Wright Cassidy, K. (1989). How the prosodic cues in motherese might assist language learning. *Journal of Child Language, 16*, 55-68.

Koester, L. S. (1987, April). *Multimodal repetitive stimulation in parent-infant interactions: A look at micro-rhythms.* Paper presented at meetings of the Society for Research in Child Development, Baltimore.

Koffka, K. (1935). *Principles of gestalt psychology.* New York: Harcourt, Brace, & Co.

Krumhansl, C., Bharucha, J., & Kessler, E. (1982). Perceived harmonic structure of chords in three related musical keys. *Journal of Experimental Psychology: Human Perception and Performance, 8*, 24-36.

Kuhl, P. K. (1985). Categorization of speech by infants. In J. Mehler & R. Fox (Eds.), *Neonate cognition: Beyond the blooming, buzzing confusion* (pp. 231-262). Hillsdale, NJ: Erlbaum.

Kuhl, P. K., & Miller, J. D. (1975). Speech perception by the chinchilla: Voiced-voiceless distinction in alveolar plosive consonants. *Science, 190*, 69-72.

Kuhl, P. K., & Padden, D. M. (1982). Enhanced discriminability at the phonetic boundaries for the voicing feature in macaques. *Perception & Psychophysics, 32*, 542-550.

Lerdahl, F., & Jackendoff, R. (1983). *A generative theory of tonal music.* Cambridge, MA: MIT Press.

Lewis, M. M. (1951). *Infant speech.* London: Routledge & Kegan Paul.

Lieberman, P. (1984). *The biology and evolution of language.* Cambridge, MA: Harvard University Press.

Martin, J. G. (1972). Rhythmic (hierarchical) versus serial structure in speech and other behavior. *Psychological Review, 79*, 487-509.

Mayer, N. K., & Tronick, E. Z. (1985). Mothers' turn-giving signals and infant turn-taking in mother-infant interaction. In T. M. Field & N. A. Fox (Eds.), *Social perception in infants* (pp. 199-216). Norwood, NJ: Ablex.

Mehler, J., Jusczyk, P. W., Lambertz, G., Halstead, N., Bertoncini, J., & Amiel-Tison, C. (1988). A precursor of language acquisition in young infants. *Cognition, 29*, 143-178.

Moore, J. M., Thompson, G., & Thompson, M. (1975). Auditory localization of infants as a function of reinforcement conditions. *Journal of Speech and Hearing Disorders, 40*, 229-234.

Morgan, J. L., Meier, R. P., & Newport, E. L. (1987). Structural packaging in the input to language learning: Contributions of prosodic and morphological marking of phrases to the acquisition of language. *Cognitive Psychology, 19*, 498-550.

Pantaleoni, H. (1985). *On the nature of music.* Oneonta, NY: Welkin Books.

Papoušek, H., & Papoušek, M. (1984). Learning and cognition in the everyday life of human infants. *Advances in the Study of Behavior, 14*, 127-163.

Papoušek, H., & Papoušek, M. (1987). Intuitive parenting: A dialectic counterpart to the infant's integrative competence. In. J. Osofsky (Ed.), *Handbook of infant development*, 2nd ed. (pp. 669-720). New York: Wiley.

Papoušek, M. (1987, April). *Models and messages in the melodies of maternal speech in tonal and nontonal languages.* Paper presented at meetings of the Society for Research in Child Development, Baltimore.

Papoušek, M., & Papoušek, H. (1981). Musical elements in the infant's vocalization: Their significance for communication, cognition, and creativity. In L. P. Lipsitt (Ed.), *Advances in infancy research*, Vol. I (pp. 163-224). Norwood, NJ: Ablex.

Papoušek, M., Papoušek, H. & Harris, B. J. (1986). The emergence of play in parent-infant interactions. In D. Gorlitz & J. F. Wohlwill (Eds.), *Curiosity, imagination, and play: On the development of spontaneous cognitive and motivational processes* (pp. 214-246). Hillsdale, NJ: Erlbaum.

Rheingold, H., & Adams, J. L. (1980). The significance of speech to newborns. *Developmental Psychology, 16*, 397-403.

Roberts, L. A. (1982). *Perceived structure of four elementary chords: The effects of musical training, key and inversions.* Unpublished master's thesis. Rutgers University, New Brunswick, NJ.

Schenker, H. (1906/1954). *Harmony* (O. Jones, Ed., & E. M. Borgese, Trans.). Cambridge: MIT Press. (Original published 1906.)

Shatz, M., & Gelman, R. (1973). The development of communication skills: Modifications in the speech of young children as a function of listener. *Monographs of The Society for Research in Child Development*, Serial no. 152, *38*, No. 5.

Sloboda, J. A. (1985). *The musical mind: The cognitive psychology of music*. Oxford: Clarendon Press.

Snow, C. E., & Ferguson, C. A. (Eds.). (1977). *Talking to children*. Cambridge: Cambridge University Press.

Stern, D. N., Spieker, S., & MacKain, K. (1982). Intonation contours as signals in maternal speech to prelinguistic infants. *Developmental Psychology, 18*, 727-735.

Stevenson, M. B., VerHoeve, J. N., Roach, M. A. & Leavitt, L. A. (1986). The beginning of conversation: Early patterns of mother-infant vocal responsiveness. *Infant Behavior and Development, 9*, 423-440.

Terhardt, E. (1974). Pitch, consonance, and harmony. *Journal of the Acoustical Society of America, 55*, 1061-1069.

Thorpe, L. A. (1986, April). *Infants categorize rising and falling pitch*. Paper presented at meetings of the International Conference on Infant Studies, Los Angeles.

Thorpe, L. A., & Trehub, S. E. (1989). Duration illusion and auditory grouping in infancy. *Developmental Psychology, 25*, 122-127.

Thorpe, L. A., Trehub, S. E., Morrongiello, B. A., & Bull, D. (1988). Perceptual grouping by infants and preschool children. *Developmental Psychology, 24*, 484-491.

Trehub, S. E. (1985). Auditory pattern perception in infancy. In S. E. Trehub & B. A. Schneider (Eds.), *Auditory development in infancy* (pp. 183-195). New York: Plenum Press.

Trehub, S. E. (1987). Infants' perception of musical patterns. *Perception & Psychophysics, 44*, 635-641.

Trehub, S. E. (1989). The perception of musical patterns by human infants: The provision of similar patterns by their parents. In W. C. Stebbins & M. Berkley (Eds.), *Comparative perception, Vol. 1*. New York: Wiley-Interscience.

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., Cohen, A. J., Thorpe, L. A., & Morrongiello, B. A. (1986). Development of the perception of musical relations: Semitone and diatonic structure. *Journal of Experimental Child Psychology: Human Perception and Performance, 12*, 295-301.

Trehub, S. E., & Thorpe, L. A. (1988, April). Infants' perception of *good* and *bad* music. Paper presented at the International Conference on Infant Studies, Washington, D.C.

Trehub, S. E., & Thorpe, L. A. (1989). Infants' perception of rhythm: Categorization of auditory sequences by temporal structure. *Canadian Journal of Psychology, 43*, 217-229.

Trehub, S. E., Thorpe, L. A., & Morrongiello, B. A. (1985). Infants' perception of melodies: Changes in a single tone. *Infant Behavior and Development, 8*, 213-223.

Trehub, S. E., Thorpe, L. A., & Morrongiello, B. A. (1987). Organizational processes in infants' perception of auditory patterns. *Child Development, 58*, 741-749.

Walker, A. S. (1982). Intermodal perception of expressive behaviors by human infants. *Journal of Experimental Child Psychology, 33*, 514-535.

Watson-Gegeo, K. A., & Gegeo, D. W. (1986). Calling out and repeating routines in Kwara'ae children's language socialization. In B. B. Schieffelin & E. Ochs (Eds.), *Language socialization across cultures* (pp. 17-50). Cambridge: Cambridge University Press.

Werker, J. F. (1989). Becoming a native listener. *American Scientist, 77*, 54-59.

Werker, J. F., & Lalonde, C. E. (1988). Cross-language speech perception: Initial capabilities and developmental change. *Developmental Psychology, 24*, 672-683.

Werker, J. F., & McLeod, P. J. (1989). Infant preference for both male and female infant-directed talk: A developmental study of attentional and affective responsiveness. *Canadian Journal of Psychology, 43*, 230-246.

Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development, 7*, 49-63.

Zenatti, A. (1969). *Le développement génétique de la perception musicale* [The development of musical perception]. Paris: Centre National de la Recherche Scientifique.