Peer Commentary on "Infants Perception of Musical Sequences: Implications for Language Acquisition" by Sandra Trehub

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The interesting notion put forth by Dr. Trehub in this article, namely that musical and linguistic processes may be inter-related in early infancy, leads me to ponder several questions. First, is it the case that attention to suprasegmental aspects of speech must occur at the cost of segmental processing. While Trehub does not explicitly state this, her idea that "the pitch contour is the utterance, with lexical or segmental content being optional" would suggest that she believes this is so. Since young infants have been shown to discriminate many segmental contrasts, however, and to ignore suprasegmental information in some contexts (for review see Kuhl, 1987), it would seem that they possess sufficient flexibility in their processing of linguistic information that simultaneous attention to both segmental and suprasegmental information would be possible. Furthermore, suprasegmental information may serve actually to focus the infant's attention on critical segmental aspects of the speech signal, thereby facilitating early language learning.

A second question that comes to mind based on the data presented in this article is why infants as young as 7 months show differences in response to lawful and unlawful melodies, although fine tuning of their ear to their native language is not evident until 10 to 12 months of age. If auditory experience is truly the determining factor in these two developmental acquisitions, this result is especially puzzling, since infants would likely receive much more linguistic than musical experience per se throughout this time period.

Finally, a third question that arises is whether these "intertwined" musical and linguistic processes should be considered as separate and distinct in infants, although, perhaps, similarly organized, or if these reflect the same underlying processes. In Trehub's discussion, it is not clear what her position is on this important question. If music and language perception reflect the same processes then one must explain somehow the research indicating a predominance of speech processing by the left hemisphere and of music processing by the right hemisphere. If one is to argue that these processes are separate although similarly organized, then one must explain why this is so and at such an early age. Clearly, as Trehub indicates in her thought-provoking and interesting review, "Many questions remain unanswered."

B.M.

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Dr. Trehub presents an overview of a systematic series of studies that probe some of the auditory perceptual abilities of human infants. These studies describe the sensitivity of the infant to melodic contours and to rhythm, and the infant's apparent perceptual grouping of temporal sequences of auditory events in an adult-like manner. Trehub points to the compatibility of these perceptual skills with the infant's sensitivity to the suprasegmental aspects of the speech signals in "motherese," and raises a number of intriguing questions. One of these concerns whether this perceptual ability forms the basis or the framework from which the infant explores the segmental components of auditory language. It is this question which I wish briefly and speculatively to address here.

There is preliminary evidence in adults that the perception of the phonetic and the prosodic elements of speech are mediated by different cerebral structures. Perhaps the strongest line of this evidence is the survival of either one, but not the other, following certain cerebral insults (compare: Blumstein & Cooper, 1974; Heilman et al., 1975; Saffran et al., 1976). There is also some evidence in normal adults supporting a similar argument in the case of music perception and speech perception per se (Gates & Bradshaw, 1977).

I have few defensible quibbles with the notion that a temporal correlation between the acoustic aspects of "motherese" and the mother's overt behavior might provide an attentional focus for the infant, and that such a focus might facilitate a developing perceptual elaboration of the segmental aspects

of the speech signal. Nevertheless, the processes mediating the discrimination of the short-term acoustic events that identify the phonetic composition of the speech signal are quite possibly separable from those underlying the discrimination of the (long-term) suprasegmental, "musical" patterns. Trehub in no way suggests that these are equivalent discriminators, but it is important for those of us concerned with developmental disorders that we remember the distinction between them. One seems to operate on events with a time frame in the ms to tens-of-ms range, while the other seems to operate on events spanning tens of hundreds of ms. If these functions are genuinely mediated by different brain regions, then the development of one could be quite independent of the other. Viewed in this admittedly tenuous light, the development of auditory temporal acuity and discrimination may not be the fine tuning of one (long-term) process to incorporate short-term events, but the development of two different perceptual skills. Trehub's studies clearly tap into the developing long-term auditory temporal processing capabilities of the infant, but this is not the same thing as probing the auditory perceptual capacities that underlie discrimination of the phonetic or short-term structure of speech sounds.

In this respect, it would be of considerable import to know how the developmental time course of short-term acoustic discriminations compares to that of the long-term ones. An answer to this question might address the issue of the relative rates of development of the left and right auditory hemispheres (Beaton, 1985; Bever, 1980), since there is some evidence in adults (Schwartz & Tallal, 1980) that a faster temporal processing capacity of the left hemisphere could in some way provide a seed for the development of language function on that side. By the same token, there is increasing evidence that some children with developmental dysphasias have both impaired auditory processing speeds and subtle pathologies of the left cerebral hemisphere (Jernigan et al., 1987). To the extent that the time frames of auditory processing might be different for the two cerebral hemispheres, it is possible that Trehub's studies have explored the developing right hemisphere more than the left.

D.P.P.

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In this enjoyable paper Trehub reviews a series of experiments which have been conducted in her lab examining infant perception of various aspects of musical structure. She then relates these studies to speech perception and language acquisition, and raises a number of interesting questions. Foremost among these is the question she poses on the last page: "Why is music present in all human cultures and what is its biological significance?" That is, what is the functional value of the impressive musical processing abilities of the young infant? She then follows this with the provocative suggestion that perhaps musical perception is, or at least involves, the most fundamental aspects of auditory processing mechanisms.

Although all the experiments reviewed in this paper have been conducted with impeccable attention to experimental design and stimulus preparation, perhaps the most impressive aspect of this work is the simultaneous investigation of many different levels of perceptual organization. In the series of experiments examining the perception of both melodic and rhythmical structure, Trehub tests perception of units at various levels of complexity. For example, in the series of experiments examining contour perception, it was shown that at brief intervals infants could detect all changes in stimuli, including changes in individual notes, although they showed a processing advantage for contour changes over individual note changes. At longer retention intervals, information regarding specific pitch and contour was lost, and infants only recognized sequences that preserved the precise melody (even in a transposed key). Finally, when tested in an even more difficult procedure, the infants showed an ability to categorize entire sets of melodies according to contour shape. Similar findings were reported with respect to perception of rhythm and temporal patterning.

The power and importance of this sort of work is that it presents a complete picture of infant abilities. This is in contrast to much of the work in infant speech perception where researchers argue about the most fundamental level of representation (is it the phone or the syllable or the word). Trehub recognizes that many levels of representation are available to

the infant just as they are to the adult, and focuses her experiments on investigating the ways in which the infant imposes organization on the variability he/she can perceive. I would argue that many of the disagreements in the infant speech perception field could be resolved if, like Trehub, other researchers similarly acknowledged that infants might be capable of multiple levels of representation.

The series of experiments examining perception of musical sequences which either conform to or violate Western scales is also of interest, but perhaps not yet complete. In this series of experiments, Trehub presents data which indicates that by as young as 7-months, infants show a processing advantage for musical sequences which conform to a Western diatonic scale. As Trehub notes however, in the experiments to date, typical Western structure and "good form" are confounded. Thus it is unknown whether infants of 7 months of age have already developed a sensitivity to familiar structure, or whether they are simply showing a preference for auditory stimuli that correspond to "good form" in a Gestalt sense. As Trehub suggests, the only way to disambiguate this question is to compare infants' perception of Western and non-Western stimuli, both of which either correspond to or violate principles of good form.

Supposing such experiments were conducted and the results still indicated that by 7-months of age infants do show an effect of listening experience on music perception - that is, that even when "good form" was controlled, Western infants preferred Western over non-Western music. Although such an effect would predate that which has been shown for the reorganization in phonetic perception which is apparent by around 10-12 months (Werker & Tees, 1984; Werker & Lalonde, 1988), it would be consistent with some of the more recent work indicating that the more global aspects of speech perception might show an effect of experience at an earlier age. Specifically, in a recent series of experiments, Jusczyk (1989) showed that infants as young as 4 months can discriminate clause boundaries in both native and non-native languages, but by 6-months show only a sensitivity to native language clause boundaries. In related work, it was shown that by 9-months (but not before) infants seem to show a sensitivity to phrase boundaries (Hirsh-Pasek, Kemler-Nelson, Jusczyk, Wright Cassidy, Druss, & Kennedy, 1989), and by 11-months may be able to abstract words from the speech stream (Jusczyk, 1989). Although no cross-language comparisons were run on the perception of phrases and words, this series of experiments does suggest that experience may first tune the more global aspects of speech perception, and only later have an impact at the phonetic level. Consistent with this is some recent work by Mehler and colleagues in which it was shown that infants as young as 4 days of age show a preference for native over non-native selections of continuous speech (Mehler, Jusczyk, Lambertz, Halsted, Bertoncini, & Amiel-Tison, 1988).

In future work, it would be interesting to investigate the age at which experience affects different aspects of music perception. On the basis of the work reviewed above with respect to speech perception, one might speculate that the most global aspects of music perception would also show the earliest influences of specific listening experience. One might also speculate that it is those very aspects that are held constant, or presented most consistently in infant-directed musical interaction - that is, when singing lullabies or nursery rhymes.

To return to Trehub's original question: "Why is music present in all human cultures, and what is its biological significance?" Convincing evidence is presented that infants can process music in a very sophisticated fashion. Given this, and given the musical nature of infant-directed talk, it does seem likely that music provides an initial route into language acquisition. As well, music might play an important role in affective development. In this respect, it would be of interest to measure infants' affective responses to "good" and "bad" musical forms. Many other possibilities exist that could be explored - music as a soother, music to facilitate group cohesion and cooperation to name a few. But it is also important to consider the many ways in which music might reflect rather than form a culture. For example, with respect to language, it is possible that the prosody of a specific language might influence the musical structure - both the scale and the tempo - that is dominant in that culture. These, and many other exciting possibilities follow directly from Trehub's work.

J.F.W.

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Reply to Morrongiello, Phillips and Werker

The commentators raise a number of provocative questions for which I offer the following comments.

1. Is the lawful melody effect a genuine effect of experience?

Morrongiello questions the appearance of music experience effects as early as 7 months of age, when comparable phonetic experience effects are only apparent by 10-12 months of age. She finds this especially puzzling in view of the richness of language listening experience and the relative poverty of musical experience in early life. Werker answers this question, in part, citing recent evidence of early experiential effects on infants' perception of phrase and clause boundaries and the dramatic finding of native language preferences in neonates. Werker suggests, moreover, that early experience effects in music, as in speech, are likely to appear, first, in the global aspects or macrostructure of musical events (e.g., contour, rhythm) and, considerably later, in the microstructure of such events.

Let me add, however, that it is as yet premature to attribute the *lawful melody effect* to musical exposure. An alternative possibility is that *lawful* melodies from any culture have properties, as yet undefined, that facilitate their encoding and retention. To resolve this issue, I am currently conferring with a number of ethnomusicologists in order to identify candidate melodies that are simple and well structured (with reference to a foreign musical culture) but totally unfamiliar to Western infants (or adults, for that matter). Even if experience proves to be relevant, it is unlikely that the amount of such experience will be the key factor. Rather, it is reasonable to expect innately driven facilitation for certain kinds of learning. Otherwise, prelinguistic infants might exhibit processing priority for certain vegetative and environmental sounds (e.g., ventilation noise) with which they have extensive experience.

2. Are there common processes underlying speech and music or are these processes separate from the very beginning?

Morrongiello and Phillips raise this question, noting the well publicized research on differential processing of speech and musical elements by the cerebral hemispheres. Phillips also advances the intriguing notion that these cerebral structures may subserve distinct perceptual functions such as the processing of short-term acoustic events (e.g., segmental), on the one hand, and the processing of long-term events (e.g., suprasegmental), on the other, with the latter having developmental priority over the former.

Surely there is no simple answer to this question. Although the processing of musical and speech stimuli may be distinct for mature listeners, there is no necessity for this to be the case for immature listeners. Moreover, the hemispheric dominance that is so clearly evident for speech is much less clear for music (Marin, 1982; Zatorre, 1984). For example, melody recognition is affected by left as well as right temporal lobectomy (Zatorre, 1985), and there are claims that musical rhythm and speech prosody are controlled by the left hemisphere (Borchgrevink, 1982). It would appear that melodic perception is not limited to the pattern processing mechanisms of the right hemisphere but also involves bilaterally represented mechanisms for storing and retrieving auditory information (Zatorre, 1985).

Roederer (1982) suggests one reason why music and language may have common ontogenetic roots, notably an innate motivation for exercising the language processing network, even with biologically irrelevant sounds. "A crying baby being pacified by the song of the mother may be following dictates of its limbic system to pay attention to simple sounds as a training in speech perception" (Roederer, 1982, p. 42).

3. Does music play an important role in emotional development?

Werker suggests that the biological significance and universality of music may be related to its possible role in affective development. Indeed, the universality of music is often attributed to its ability to communicate emotion (Marin, 1982) and to stimulate emotion (Dowling & Harwood, 1986). Nevertheless, cross-cultural similarities in the musical expression of emotion remain undefined.

Speech prosody, another vehicle for expressing emotion, is not as conventionalized as typically believed, displaying interesting similarities across cultures (Frick, 1985). For example, arousal is associated with increased pitch and pitch range, two features that are prominent in infant-directed speech. Moreover, high pitch is associated with happiness (Frick, 1985), as it is in music (Trehub, Cohen, & Guerriero, 1986).

Finally, there are further claims that communicative intent (e.g., approval, comfort, prohibition) is transparent in the prosody of infant-directed speech (Fernald, in press); perhaps emotional tone is equally transparent. Werker and McLeod's (1989) recent finding of enhanced positive affect in infants exposed to infant-directed as opposed to adult-directed speech is consistent with this view. A parallel finding in relation to infant-directed music (e.g., lullabies) would provide support

for the compelling notion of common emotional roots for music and language.

4. Is the processing of suprasegmental information achieved at the expense of segmental information?

Whereas my answer is clearly in the affirmative on this issue, Morrongiello's is in the negative. Her position is that infants can deploy their attention simultaneously to both levels of analysis and that they are sufficiently flexible to ignore one class of features or the other, depending upon the specific demands of the situation. In my view, there is a critical distinction between what infants *can* do and what they actually do when the alternatives are unconstrained. There is no doubt that infants can discriminate a wide range of segmental features, as demonstrated in numerous studies with single-syllable stimuli (for a review see Kuhl, 1987), but my contention is that they are inclined to ignore such information in the everyday context of running speech. Instead, they attend to speech melody or prosody.

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