

## Research Report

### ABSOLUTE PITCH AND TEMPO IN MOTHERS' SONGS TO INFANTS

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**Abstract**—We examined the relative stability of pitch, tempo, and rhythm in maternal speech and singing to prelinguistic infants. Mothers were recorded speaking and singing to their infants on two occasions separated by 1 week or more. The pitch level and tempo of identical utterances were highly variable across the 1-week period, but these features were virtually unchanged in song repetitions. Rhythmic patterning was largely maintained in speech, as in song. Mothers' accurate reproduction of their sung performances can be considered a form of absolute pitch and absolute tempo.

Caregivers are thought to use a distinct vocal register when singing or speaking to infants, a register that elicits heightened responsiveness from the infant audience (Fernald, 1992; Trehub & Trainor, 1998). According to Trainor, Austin, and Desjardins (2000), the illusion of distinctiveness arises from the emotionality of infant-directed speech, which contrasts with the muted emotional expressiveness of typical adult speech. When Trainor et al. (2000) compared infant- and adult-directed utterances that expressed love, surprise, and fear, they found similar pitch ranges, pitch contours, tempos, and rhythms for similar expressive intentions. These differences in emotional expressiveness might account for infants' reported preference for infant- over adult-directed vocalizations. Indeed, Singh and Morgan (2000) found that infants exhibited greater attention to utterances expressing positive affect than to those expressing neutral affect regardless of their infant- or adult-directedness.

The smooth pitch contours, heightened pitch, expanded pitch range, vowel elongation, and slow tempo of infant-directed utterances have led to their characterization as melodies (Fernald, 1992; Papoušek, Papoušek, & Symmes, 1991). Presumably, affective utterances to adults have comparable melodic qualities. The melodies of songs are constrained in some of the features that give emotional speech its musical quality (e.g., pitch contour, pitch range), but they are relatively unconstrained in other features such as pitch and tempo. For example, the identity of a song is retained across changes in overall pitch level (higher or lower) or tempo (faster or slower) provided the relations between component pitches (the tune) and durations (the rhythm) are preserved. Mothers use a higher pitch level and slower tempo than usual when talking to infants, and they do likewise when singing to infants (Bergeson & Trehub, 1999; Trainor, Clark, Huntley, & Adams, 1997; Trehub et al., 1997). Vocalizations with high pitch and slow tempo are typically associated with happiness or affection (Scherer, 1981).

Except for the 1 in 10,000 with absolute pitch (Takeuchi & Hulse, 1993), adults exhibit poor memory for isolated pitches (Deutsch, 1999), but surprisingly good memory for the pitch and tempo of

highly familiar songs. When adults sing well-known folk songs on different occasions, their repeated renditions deviate by about two semitones (Halpern, 1989). Similarly, when singing along with an imagined version of their favorite pop recording, they remain within two semitones of the canonical version (Levitin, 1994) and within about 8% in tempo (Levitin & Cook, 1996). It is unclear whether speech and song to infants have comparable stability because studies to date have focused on interindividual rather than intraindividual consistency.

In the present investigation, we examined the relative stability of pitch and tempo in maternal speech and singing to prelinguistic infants. Mothers were recorded while singing a song and talking to their 5- to 7-month-old infants. Approximately 1 week later, the mothers repeated the songs and a few of their verbal phrases during a similar interaction with their infants. On the one hand, the stereotypy of maternal speech and singing (Fernald, 1992; Trehub & Trainor, 1998) might be expected to promote intraindividual consistency equaling or exceeding that observed in informal adult singing (Halpern, 1989; Levitin, 1994; Levitin & Cook, 1996). On the other hand, the need for infant monitoring might reduce self-monitoring, leading to reduced vocal stability.

A secondary goal was to evaluate rhythmic stability in repeated maternal utterances across the 1-week period. Rhythm, which is central to song identity (Schulkind, 1999), plays a lesser role in everyday speech. Rubin (1995) claimed, however, that rhythm has critical aesthetic and mnemonic functions in oral traditions. It might also figure prominently in mothers' ritualized verbal interactions with infants.

## METHOD

### Participants

The mothers ( $N = 19$ ), who were recruited from the suburban community surrounding the campus of the University of Toronto, Mississauga, Canada, had infants ranging from 4 months 21 days to 7 months 19 days ( $M = 5$  months 10 days) at the time of their first visit.

### Stimuli and Apparatus

Digital audio recordings were made in a large IAC sound-attenuating booth by means of a SHURE 5155D microphone in the booth, which was linked to a Denon PMA-680R stereo amplifier and Radius 81/110 computer with SoundScope software (GW Instruments, Inc., Somerville, MA). Test sessions were videotaped to ensure that infants' mood was comparable across sessions (to preclude maternal vocal changes arising from infants' mood change).

### Procedure

Each mother was asked to sing a song that she typically sang to her infant and to talk to the infant in her usual style. The order of singing and speaking was counterbalanced across mothers. To reduce self-

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**Table 1.** Incidence of mothers' songs

Song title	Number of mothers
Twinkle, Twinkle, Little Star	2
The Barney Song	2
You Are My Sunshine	2
Blue Bird	1
Top of the Mountain	1
When You're Happy and You Know It	1
The Wheels on the Bus	1
Stretch and Grow	1
Michael, Row the Boat Ashore	1
Hush, Little Baby	1
Frère Jacques	1
Polka Dot Door	1

consciousness, we left each mother alone with her infant during the recording sessions. After each test session, observers documented the stereotyped speech phrases of the mother. During the second test session, which occurred a week or more after the first session, each mother sang the same song as in her first session and was also asked to repeat a few of the stereotyped phrases from her first visit (from a list provided) in the course of her verbal interaction. Because of computer storage limitations, audio recordings included the entire song but only the first minute of speech from each session.

## RESULTS

We focused on each mother's song and first repeated verbal phrase across the two sessions. Some participants were excluded because of poor recording quality ( $n = 3$ ) or failure to complete both sessions ( $n = 1$ ). Only 11 of the remaining 15 mothers repeated a verbal phrase across sessions despite being instructed to do so. Statistical comparisons between singing and speech across sessions were based on these 11 mothers, but comparisons of songs across sessions were based on all 15 mothers. The mothers' song selections are shown in Table 1, and their repeated verbal phrases are shown in Table 2.

When fundamental frequency (pitch) was measured instrumentally (SoundScope software), very soft or whisperlike productions did not yield reliable values. Because vocal pitch was still audible, two musically trained listeners were able to match the initial pitch of each verbal phrase to notes on an electric keyboard, rounding to the nearest quarter tone. They followed the same pitch-matching procedure for the initial and tonic pitches of songs. Interrater reliability of pitch estimates was 95%. Tonic pitch rather than initial pitch of songs was used in most analyses because the former is a more reliable index of musical pitch level. Because tonic pitch is undefinable in speech, the first pitch of each verbal phrase provided an index of pitch level. Two musically trained listeners used a metronome to match the average tempo (in beats per minute) of verbal phrases and songs (99% interrater reliability), with accented syllables of verbal phrases treated as beats. The rhythm of each verbal phrase was notated musically and poetically by the same musically trained listeners (100% interrater reliability). Poetic notation, which is considerably less precise than musical notation, involves the identification of strong and weak syllables.

Absolute differences, ignoring direction of difference, were used to estimate pitch and tempo variability in the sung and spoken renditions of individual mothers across sessions. Mothers' song repetitions differed by less than a semitone in pitch level ( $M = 0.82$ ,  $SD = 0.98$ ). By contrast, their speech repetitions differed by approximately five semitones ( $M = 4.96$ ,  $SD = 4.25$ ), with the difference between singing and speaking contexts being statistically significant,  $t(10) = 3.07$ ,  $p < .02$  (see Table 3). Tempo differences (in beats per minute) across sessions were significantly smaller for song repetitions ( $M = 3.64$ ,  $SD = 6.12$ ) than for speech repetitions ( $M = 22.82$ ,  $SD = 24.45$ ),  $t(10) = 2.44$ ,  $p < .05$  (see Table 3). Specifically, tempo deviated by 3.1% in singing contexts and by 20.2% in speaking contexts.<sup>1</sup>

The mean initial pitch (i.e., fundamental frequency estimate) of maternal utterances (i.e., musical pitch levels translated to frequencies) was 350.57 Hz ( $SD = 154.01$ ), and the mean tonic pitch of songs was 258.26 Hz ( $SD = 75.12$ ) for the first session. Pitch levels were comparable in the second session (speech: 325.84 Hz,  $SD = 116.64$ ; singing: 262.44 Hz,  $SD = 75.68$ ). Tempo did not differ across speaking and singing contexts in either session.

As can be seen in Table 2, the poetic rhythm of spoken phrases (i.e., syllables considered as strong or weak) was maintained for 9 mothers who accented the identical syllable across sessions. The 2 remaining mothers moved their accent to an adjacent word. Although the musical rhythm of spoken phrases was less stable across sessions than was the poetic rhythm, it was surprisingly consistent. For example, musical rhythm was maintained across sessions for 8 of 11 mothers, the difference involving a single rest or pause. (For 2 mothers, this change altered the rhythmic essence from straight to dotted rhythm.)<sup>2</sup> Infant-directed speech had more of a sense of "beat" or meter than is evident in typical adult-directed speech, but the metricality of infant-directed speech was nowhere near that of infant-directed singing. For maternal songs, rhythm was virtually identical across sessions. In view of the prescribed rhythms of songs, this finding is less impressive than is the stability of maternal speech rhythms.

## DISCUSSION

Mothers' vocal repetitions across a 1-week period revealed considerably greater consistency in singing than in speech. Specifically, mothers' song renditions deviated by less than a semitone in pitch level and by approximately 3% in tempo, with the modal response involving identical pitch and tempo. By contrast, repetitions of stereotyped verbal phrases differed by approximately five semitones in pitch level and 20% in tempo. The remarkable uniformity in the song renditions of individual mothers exceeds the reported uniformity of adults' renditions of familiar folk songs (Halpern, 1989) or of popular songs with canonical versions (Levitin, 1994; Levitin & Cook, 1996).

The present findings, along with other findings on song reproduction (Halpern, 1989; Levitin, 1994), are puzzling in light of adults' reportedly poor memory for pitch height (Deutsch, 1999). Parncutt and Levitin (2001) argued, however, that memory for the absolute pitch of tones—*tone-AP*—is poorer than is memory for the absolute pitch of familiar pieces or songs—*piece-AP*. Musical pieces offer contextual

1. Excerpts from mothers' repeated songs and verbal phrases can be heard on the Web at <http://www.utm.utoronto.ca/~w3trehub/>.

2. Rhythmic notations are available on the Web at <http://www.utm.utoronto.ca/~w3trehub/>.

**Table 2.** *Rhythmic accents in repeated verbal phrases*

Mother	Verbal phrase	
	Session 1	Session 2
1	What are you <b>doing</b> ?	What are you <b>doing</b> ?
2	Hi, <b>Sweetie</b> .	Hi, <b>Sweetie</b> .
3	What are you <b>doing</b> ?	What are you <b>doing</b> ?
4	And did you <b>see</b> the green frog?	And did <b>you</b> see the green frog?
5	Give him a <b>kiss</b> .	Give him a <b>kiss</b> .
6	What are you <b>doing</b> ?	What are you <b>doing</b> ?
7	Did you go in the <b>car</b> ?	Did you go in the <b>car</b> ?
8	Are you <b>gonna</b> roll over?	Are you gonna <b>roll</b> over?
9	Are you gonna tell me a <b>story</b> ?	Are you gonna tell me a <b>story</b> ?
10	Whatcha <b>doing</b> ?	Whatcha <b>doing</b> ?
11	He's nice and <b>soft</b> .	He's nice and <b>soft</b> .

*Note.* Primary accents (i.e., strong syllables) are in boldface.

cues that may facilitate the retrieval of performance details. Other factors that could account for mothers' retention of the vocal features of their songs are positive affect, which promotes stimulus elaboration and memory consolidation (Ashby, Isen, & Turken, 1999), and congruent mood across repeated performances, which also enhances memory (Eich & Macaulay, 2000). The assumption is that a mother's mood is similar (i.e., positive) on the various occasions when she sings to her infant, especially for repeated instances of the same song. Motor memory may be implicated as well because of mothers' tendency to sing a small set of nursery songs over and over again to their infants (Trehub et al., 1997). In so doing, they sing these songs considerably more often than other people sing their favorite pop or folk song. These memory-enhancing factors may operate jointly to yield highly stable musical performances from nonmusicians.

What are the potential implications of maternal song stability for infant listeners? Pitch memory is thought to be more accurate in early childhood than it is subsequently (Takeuchi & Hulse, 1993). Saffran and Griepentrog (2001) claimed that infants, unlike adults, preferentially track absolute over relative pitch patterns when they listen to sound sequences. If Saffran and Griepentrog are correct, then mothers' use of consistent pitch levels and tempos would be well matched to infants' listening preferences. Consistent pitch, tempo, and tunes should facilitate infants' recognition of the words of songs, just as stability in pitch, tempo, and intonation enhances adults' recognition of utterance content (Balch & Lewis, 1996; Church & Schacter, 1994). Stable, individualized performances could also provide a basis for maternal voice recognition. That situation would be analogous to numerous examples in the animal kingdom of stereotyped emotive vocalizations being individually distinctive and recognizable (Marler, 2000).

Mothers' infant-directed speech was higher pitched than was their infant-directed singing, a situation that reverses the usual relation between adults' speech and singing (i.e., higher-pitched singing than speech). This situation results from mothers raising their usual pitch level by about a semitone when singing to infants (Bergeson & Trehub, 1999; Trehub et al., 1997) and by three to four semitones when talking to infants (Fernald & Simon, 1984). The factors responsible for the reversed pitch level of speech and songs across infant- and non-infant-directed contexts are unclear. Untrained singers may have less flexibility in their singing range than in their speaking range. Dif-

ferent caregiving goals may also be implicated. Maternal singing is effective in maintaining infants' attention (Trehub & Nakata, 2000; Trehub & Trainor, 1998), but maternal speech has attention-getting as well as attention-holding goals (Fernald, 1992). High pitch, in particular, may be the feature responsible for capturing infants' attention (Colombo, Frick, Ryther, Coldren, & Mitchell, 1995). In short, the variability of caregivers' speech may arise, in large measure, from its multiple functions.

Caregivers' speech, although more variable than their singing, is less variable in some respects than is speech directed to adults. Maternal speech rhythms were relatively consistent from one week to the next despite pronounced variability in pitch and tempo. It is surprising, then, that speech rhythms—the most stable feature of mothers' repeated utterances—have received so little attention to date. Rhythm, which is critical for the recognition of familiar songs (Schulkind, 1999), may play a comparable anchoring role in infant-directed speech. From the earliest days of life, infants are sensitive to the rhyth-

**Table 3.** *Differences in absolute pitch and tempo for mothers' infant-directed speech and singing across sessions*

Mother	Pitch (in semitones)		Tempo (in beats per minute)	
	Speech	Singing	Speech	Singing
1	4.0	1.0	16	0
2	6.0	0.0	32	4
3	5.0	1.0	6	0
4	3.0	2.0	32	6
5	4.0	0.0	88	0
6	4.5	0.0	0	0
7	5.5	0.0	4	12
8	16.0	0.0	16	0
9	6.5	3.0	18	18
10	0.0	0.0	8	0
11	0.0	1.0	31	0

mic properties of speech. They differentiate languages on the basis of dissimilar rhythmic properties, and they confuse languages with similar rhythmic properties (Nazzi, Bertoncini, & Mehler, 1998). By 5 months of age, infants recognize specific rhythmic patterns from their native language (Nazzi, Jusczyk, & Johnson, 2000). By 7 months, they favor bisyllabic words with conventional, or trochaic (strong-weak), stress patterns over those with less conventional, or iambic (weak-strong), stress patterns (Jusczyk, Houston, & Newsome, 1999). Over the next few years of development, the improvised musical phrases that accompany children's play routines are stable in rhythm and meter but variable in melody (Kartomi, 1991).

In summary, the present study revealed remarkable stability in the pitch and tempo of mothers' repetitions of songs to infants. Caregivers' near-perfect reproduction of these features can be considered a form of absolute pitch and absolute tempo, even though it may be restricted to their own sung performances. Mothers' speech repetitions were highly variable in pitch level and tempo but relatively stable in rhythm. Consistency in the vocal character of maternal songs makes them suitable vehicles for soothing infants, for promoting social bonds, and, perhaps, for directing attention to particular words. Variability in maternal utterances may enhance their appropriateness for attention-getting or mildly arousing purposes. An important task for future research is to specify other aspects of intraindividual stability in maternal vocal productions and their consequences for infant listeners.

**Acknowledgments**—This research was supported by the Natural Sciences and Engineering Research Council of Canada.

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(RECEIVED 6/24/00; REVISION ACCEPTED 3/20/01)