Metrical Categories in Infancy and Adulthood

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Abstract

Adults tend to perceive and produce rhythmic structures with simple duration ratios and implied isochrony. If these biases result from long-term exposure to Western metrical structure, they should be evident in North American adults but not in infants. Adult similarity judgments were obtained for alterations of folk melodies that maintained or matched the original metrical structure, whether simple or complex, and for alterations that violated or mismatched the original metrical structure. Adults rated mismatching alterations as less similar than matching alterations, for simple meter patterns, but their ratings of matching and mismatching alterations did not differ for complex meter patterns. Infants, who were tested with a familiarization preference procedure, responded differentially to matching and mismatching alterations for complex as well as simple meter patterns. These findings imply that adult biases reflect long-term exposure to culture-specific metrical structure rather than intrinsic preference for simple meters.

Introduction

Complex auditory patterns such as speech and music confront listeners with rapidly changing information. Meter, which is common in music and some types of speech, provides hierarchical temporal structure that facilitates the organization of information, creating expectations about what events will follow and when they will occur. Metrical structure makes it possible for individuals to dance, sing, speak, clap, tap, and play instruments in synchrony with music and with each other.

It is generally assumed that meter is an internal representation of isochronous periodic structures at multiple levels, with faster levels being integer multiples of slower levels (Clarke, 1999; Drake, 1998; Povel & Essens, 1985; Povel, 1981). Several theorists maintain that incoming patterns of inter-onset intervals are assimilated to an internal periodic clock (Povel & Essens, 1985; Povel, 1981) or a system of oscillators (Large & Kolen, 1994). As a result, rhythmic patterns that are easily assimilated to such isochronous, periodic structures have greater coherence (Boltz & Jones, 1989; Povel & Essens, 1985).

The available evidence from adult production and perception of temporal patterns is consistent with this account of meter. When asked to tap spontaneously and rhythmically, adults produce a distribution of short and long inter-tap intervals that cluster around 1:1 and 2:1 ratios (Fraisse, 1978). Because adults have difficulty reproducing rhythms with complex duration ratios, they tend to stretch or shrink temporal intervals to fit 1:1 or 2:1 ratios (Deutsch, 1986; Povel, 1981). When asked to repeat an English phrase and align stressed syllables with tones at various temporal positions, the resulting pattern reflects a division of the inter-phrase interval into 1:2, 1:1, and 2:1 duration ratios, even though the target duration ratios vary along a continuum (Cummins & Port, 1998). These findings add support to the notion that adults assimilate complex duration ratios to simple-integer ratios in tapping and speech tasks.

Rhythm categorization studies provide evidence that durations are assimilated to simple ratios in perception as well as production. When music students are asked to categorize two intervals as either 2:1 or 1:1, they shift their categories according to metrical context, exhibiting a peak in discrimination at the category boundary (Clarke, 1987). Similarly, when required to indicate any category change while listening to a repeating set of two intervals that shift gradually from 1:1 to 2:1 ratios or vice versa, adults' judgments show a hysteresis-like effect which is consistent with perceptual categories for simple duration ratios (Large, 2000).

On the basis of the aforementioned findings as well as the prevalence of simple duration ratios in Western music, many scholars contend that basic cognitive biases constrain the organization of rhythmic patterns; specifically, "good" metrical structures will have temporal intervals at nested hierarchical levels that can be multiplied or subdivided by two or three (Clarke, 1999; Povel & Essens, 1985). These claims are at odds with the prevalence, in many cultures, of metrical structures that violate these assumptions about isochronous levels and simple ratios.

Much music from South Asia, Africa, the Middle East, and Eastern Europe is characterized by its "asymmetrical" temporal structure, in which the primary pulse level consists of alternating groups of short and long temporal intervals having a 2:3 ratio (Clayton, 2000; London, 1995). Such meters, which are often designated "complex," are common especially in the dance music of Bulgaria and Macedonia. Despite this temporal complexity, children and adults of all ages participate in dancing and singing to songs with complex meters (Singer, 1973). Have children and adults from these cultures overcome intrinsic perceptual biases to acquire culture-specific expertise? Alternatively, do the apparent biases for simple meters reflect long-term experience with temporal structures that are prevalent in Western music?

Because infants have limited experience with music, they provide unique opportunities for examining intrinsic biases for metrical structure. In principle, differences between infant and adult performance could reveal the extent to which the perception of meter is shaped by experience.

At times, young infants outperform adults on speech and music perception tasks. For example, adults can discriminate phonetic contrasts in their native language, but they tend to have difficulty with some nonnative contrasts (Werker & Tees, 1999). Before 6 months of age, infants succeed in discriminating most contrasts in native and nonnative languages. In subsequent months, however, they display adult-like difficulty with nonnative contrasts (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Werker & Lalonde, 1988).

In the music domain, infants outperform adults on the detection of mistunings in unfamiliar musical scales (Lynch & Eilers, 1992; Lynch, Eilers, Oller, & Urbano, 1990; Trehub, Schellenberg, & Kamenetsky, 1999), and on the detection of pitch changes that preserve implied harmony (Trainor & Trehub, 1994). Such findings suggest perceptual reorganization that results from culture-specific experience. It is possible that infants begin life with flexible representations that are subsequently altered by processes of enculturation (Doupe & Kuhl; 1999; Schellenberg & Trehub, 1999).

If the perception of rhythmic patterns follows a similar developmental course, infants may perform equally well on patterns with simple or complex meter. If, however, intrinsic biases towards simple integer duration ratios are responsible for adults' ease of perceiving and producing patterns with simple meter, then infants and adults should experience greater difficulty with complex metrical structures than with simple metrical structures. In the present study, we compared infants' and adults' detection of changes in folk melodies with simple and complex meters.

Experiment 1: Adults

Adults' detection of changes in the metrical structure of unfamiliar folk melodies was assessed by means of a judgment task. After familiarization with multi-instrument performances of dance music, adults were tested with simpler versions of the same tune played on piano with drum accompaniment. The simplified versions contained alterations that maintained or violated the original metrical structure. We assessed the magnitude of perceived changes as a function of how consistent or inconsistent altered versions were with the meter of the original performance.

Method

Participants. There were 50 college students (35 female, 15 male, ages 18-25) who received course credit for their participation. Their musical experience ranged from 0-15 years (mean of 5.7 years formal training). Participants had lived exclusively in North America, except for three students who had lived in England, Russia, and the Dominican Republic for 6-10 years.

Familiarization stimuli. Four 8-measure excerpts were taken from traditional folk-dance melodies of Serbia, Macedonia, and Bulgaria (Geisler, 1989). Each excerpt was arranged as a MIDI performance with four Quicktime MIDI Instruments. The instrumentation consisted of a primary melodic instrument ("Acoustic Fretless Bass" or "Tango Accordian"), a secondary melodic instrument ("Flute"), an accompanying chordal instrument ("Acoustic Fretless Bass" or "Bright Acoustic Piano"), and a percussion instrument ("Melodic Tom" ,"Timpani", or "Kalimba"). Two of the excerpts were taken from dances in 4/4 meter (2 + 2 + 2 + 2), and two were in 7/8 meter (2 + 2 + 3 or 3 + 2 + 2). Both primary melodic instruments were used in each meter.

Most notes were of 250-ms duration (eighth notes), but several longer-duration notes occurred in the excerpts. The shortest note duration was 250 ms, and the longest was 1000 ms, both occurring in 4/4 and 7/8 meters. Dynamic accents were present in the primary and secondary melodic instruments as increases in MIDI velocity. The downbeat of the measure had a velocity of 127, the downbeats within the measure had a velocity of 120, and upbeats had a velocity of 90. Thus, ample cues to meter were provided in the familiarization stimuli. Cues were present in the drum accompaniment (at the beat level), the chordal accompaniment (whose bass notes articulated the beat level), dynamic accents, and structural features of the music, such as temporal and melodic accent.

Test stimuli. Test stimuli consisted of simplified and altered versions of the familiarization melodies. The timbres were simplified by the use of one melodic instrument ("Acoustic Grand Piano") and one drum accompaniment ("Woodblock"). For all stimuli, the drum accompaniment consisted of alternating patterns of long and short durations. For 4/4 and 7/8 stimuli, this accompaniment consisted of either a Long-Short-Short pattern or a Short-Short-Long pattern.

The test melodies were identical to the primary melody of the familiarization stimulus except for a *matching* or a *mismatching* alteration. For both matching and mismatching alterations, one note was added to each measure. For matching alterations, one inter-beat interval was subdivided into two, which decreased the duration of an existing quarter note to an eighth note and added an additional eighth note. Thus, the overall metrical structure was not disrupted by this alteration. For excerpts in 4/4 meter, the drum accompaniment consisted of a long duration of 1000 ms and short durations of 500 ms. For 7/8 excerpts, the drum accompaniment consisted of a long duration of 750 ms and short durations of 500 ms.

Examples of matching and mismatching changes are presented in musical notation in Figure 1 (simple meter) and in Figure 2 (complex meter). For mismatching alterations, an eighth-note was added without decreasing the duration of an adjacent quarter note. For drum accompaniments this resulted in long and short durations of 1125 ms and 500 ms in 4/4, and 1000 ms and 500 ms in 7/8. Thus, the mismatching change altered the metrical structure of the familiarization tune. For both matching and mismatching changes, the same note was added in the same location. The only difference was the effect of the alteration on the overall length of the measure.

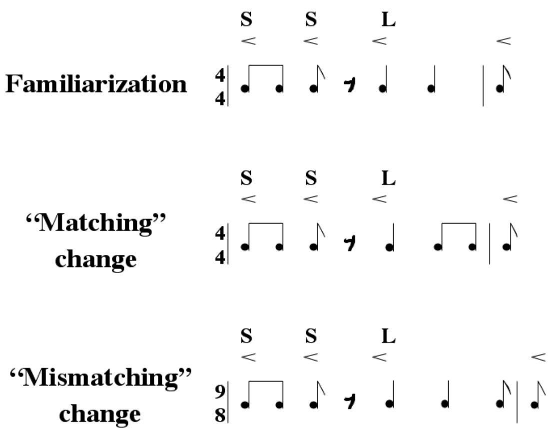

Figure 1: Sample alteration to simple meter pattern.

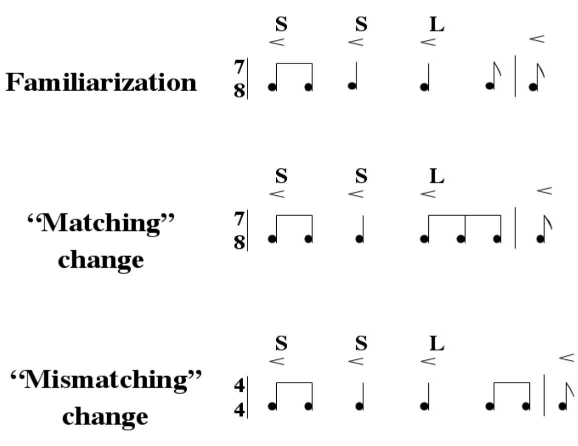

Figure 2: Sample alterations to complex meter pattern.

Procedure. Participants, who were tested in groups of 1-5, listened to the stimuli over headphones at individual computer stations. All musical excerpts and instructions were controlled by means of PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993). Trials were presented in blocks of one familiarization stimulus followed by corresponding test stimuli. Participants listened to the 2-minute familiarization performance, after which they judged how well each test stimulus matched the rhythmic structure of the familiarization stimulus (on a scale of 1 = very well to 6 = very poor). Each block was repeated three times, resulting in three sets of judgments for each stimulus. Order of blocks and test stimuli were counterbalanced across participants.

Results and Discussion

A three-way, repeated-measures, mixed-design ANOVA, with familiarization meter (simple vs. complex familiarization stimulus, within subjects), alteration type (matching vs. mismatching, within subjects) and years of musical training (between subjects), revealed a significant main effect of meter, F (1,38) = 374.6, p < .001, a significant main effect of alteration type F (1,38) = 396.9, p < .001, and a significant interaction between meter and alteration type, F (1,38) = 373.5, p < .001. There were no other significant interactions. Post-hoc Bonferroni paired t-tests revealed that the mismatching alteration was rated significantly higher (i.e., more dissimilar) than the matching alteration for the simple meter excerpts, $t(49)$ = 29.54, p < .001, but not for the complex meter excerpts, $t(49)$ = .056, p = .96 (see Figure 3).

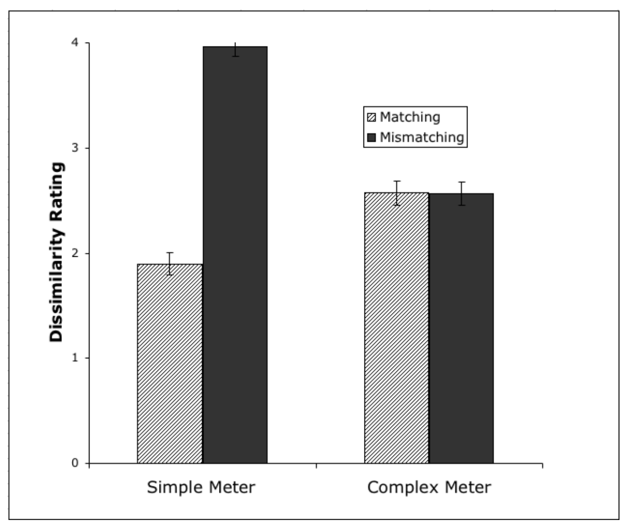

Figure 3: Mean dissimilarity ratings and standard errors for test stimuli in Experiment 1.

Adults exhibited an asymmetry in their perception of rhythmic patterns. They readily detected alterations that disrupted simple-duration ratios and underlying isochronous structure, but they did not differentiate similar structure-violating from structure-preserving alterations in the context of complex metrical structures. Alterations of complex meter excerpts resulted in simpler ratios, which parallels observed biases in the production of rhythmic patterns (Deutsch, 1986; Povel, 1981; Cummins & Port, 1998). For this reason, perhaps, mismatching alterations were indistinguishable from matching alterations of complex meter stimuli.

Experiment 2a: Infants and Simple Meter

We investigated infants' perception of the simple meter stimuli of Experiment 1 by means of a familiarization preference procedure.

Participants. Participants were 32 healthy, full-term infants 6.5 to 7.6 months (*M* = 7.0 months, *SD* = 0.27) whose families volunteered in response to letters distributed in the community surrounding the University of Toronto at Mississauga campus. An additional 14 infants were excluded from the final sample because of fussing (n = 11), sleeping (n = 1), or technical failure (n = 2).

Familiarization and Test stimuli. We used the two sets of simple meter familiarization and test stimuli as in Experiment 1. Stimuli were prepared as Quicktime movies, accompanied by a dynamic but non-rhythmic visual excerpt, taken from Attenborough (1991).

Apparatus. A 350-MHz MacIntosh G4 computer, two 17-in color monitors, and a loudspeaker were used to present visual and auditory stimuli and collect infant fixation times toward each monitor. The two monitors were positioned side by side, approximately 3 ft apart. The experimenter viewed the infant through a small hole in a partition separating the infant from the experimenter and the control equipment. Infant fixation was also visible from the monitor of a video camera that recorded infant looking behavior for subsequent verification of looking times. The computer controlled trial duration, recorded looking-time judgments, and presented all stimuli as Quicktime movies. The experimenter and mother wore headsets playing music to mask the auditory stimuli presented to infants.

Procedure. We tested infants by means of a familiarization preference procedure. Infants sat on their parents' lap in a dimly lit testing room. The two monitors were approximately 4.5 ft in front and to the right and left of the seated infants. The observer monitored infant looking times by pressing one of two buttons on the computer, each corresponding to one monitor. Infants were first presented with 2 min of the familiarization stimulus, consisting of four repetitions of the stimulus presented on alternate monitors. Trials were preceded by a flashing red stimulus to orient the infant's attention. When the infant looked at the appropriate monitor, familiarization trials began and continued for 30 s. After four familiarization trials, test stimuli were presented six times each, with the matching and mismatching test stimuli alternating between monitors. Test trials were terminated when the infant looked away for more than 2 s or when 60 s had elapsed.

Each infant was randomly assigned to one of the two familiarization excerpts in simple meter. Order of the first monitor in familiarization phase, first monitor in test phase, and test stimuli were counterbalanced.

Results and Discussion

Looking times were analyzed for differential attention to matching and mismatching alterations. A paired *t*-test revealed a significant difference between looking times to matching and mismatching alterations, $t(31) = 2.63$, $p = .013$ (see Figure 4). Greater looking time to the mismatching alterations can be interpreted as a novelty preference, which implies that infants perceived mismatching alterations as less similar to the familiarization stimulus than matching alterations. In other words, infants exhibit adult-like response patterns for simple meter stimuli. They notice structure-violating alterations to the metrical pattern more readily than structure-preserving alterations.

Experiment 2b: Infants and Complex Meter

A separate group of infants was tested with the complex meter patterns from Experiment 1 and the procedure from Experiment 2a.

Participants. Participants were 18 healthy, full-term infants 6.5 to 7.6 months (*M* = 7.1 months, *SD* = 0.34), who were recruited as in Experiment 2a. An additional 4 infants were excluded from the final sample because of fussiness.

Stimuli and Procedure. The complex meter familiarization and test stimuli from Experiment 1 were used. The apparatus and procedure were identical to those of Experiment 2a.

Results and Discussion

Looking times on test trials were analyzed for differential responsiveness to alteration type. A paired *t*-test on average looking times revealed a significant difference between looking times to matching and mismatching alterations, $t(17) = 2.59$, $p < .05$ (see Figure 4).

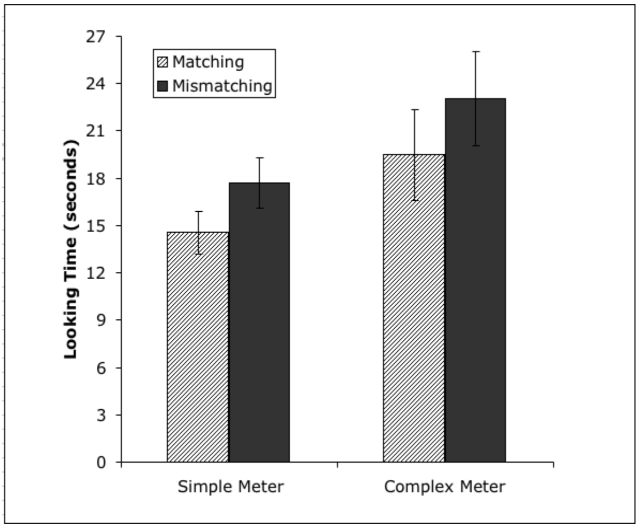

Figure 4: Mean looking times for infants in Experiments 2a and 2b.

The pattern of looking behavior in the present experiment was similar to that in Experiment 2a. Infants looked significantly longer during mismatching trials than during matching trials, which implies that they perceived the mismatching stimuli as novel. In contrast to adults, who differentiated mismatching from matching changes only in the context of simple meter excerpts, infants differentiated the two types of changes in the context of complex as well as simple meters.

General Discussion

Infants outperformed adults in detecting temporal alterations of musical stimuli. These findings suggest that adult biases in perceiving and producing temporal patterns arise from extended exposure to simple metrical structures in music.

Another interpretation of the present findings is that temporal processing is fundamentally different in infancy and adulthood. For example, infants may process temporal patterns in a serial manner, without the hierarchical and anticipatory aspects of metrical representation in adults (Drake, Jones, & Baruch, 2000). It is possible, however, that metrical representations are fundamental to the organization of auditory-temporal input. Moreover, greater flexibility in that organization may be possible early in life, before listeners become attuned to typical input in their environment.

Several lines of evidence are consistent with the possibility of rich metrical representations in infancy. Infants have a number of prerequisite skills for perceiving meter, including the detection of subtle changes in duration (Morrongiello & Trehub, 1987) and tempo (Baruch & Drake, 1997), the detection of miniscule gaps in tones (Trehub, Schneider, & Henderson, 1995), the discrimination of isochronous from nonisochronous tone patterns (Demany, McKenzie, & Vurpillot, 1977), and the generalization of melodies on the basis of rhythmic structure (Trehub & Thorpe, 1989). Infants can also discriminate musical excerpts on the basis of rhythm changes (Chang & Trehub, 1977) and on the basis of the subtle performance cues that result from metrical structure, such as intensity and inter-onset interval changes (Palmer, Jungers, & Jusczyk, 2001). These cues are also correlated with metrical position in infant-directed singing (Trainor, Clark, Huntley, & Adams, 1997). Infants' ability to detect small timing changes depends on the strength of implied metrical structure (Bergeson, 2000). Finally, 7-month-old infants can categorize unique rhythms on the basis of implied metrical structure (Hannon & Johnson, 2002). It is likely, then, that infants' performance in the present experiment resulted from the kind of metrical processing that underlies adult performance.

Our findings imply that adult biases in temporal pattern processing result from category learning processes that occur in the course of musical enculturation, and not necessarily just from intrinsic preference for patterns with simple temporal structure. Implicit knowledge of musically relevant categories is critical for the appreciation of music. For example, listeners must discern the metrical structure of a piece in the face of temporal fluctuations that reflect the performer's expressive intentions (Large & Palmer, 2002). Such category learning is also relevant to speech processing. For example, listeners must recognize words and meaningful prosodic changes in the context of enormous variability across utterance and speakers (Doupe & Kuhl, 1999).

Infant perceptual abilities may undergo subsequent reorganization as young listeners discover which distinctions are meaningful and which are not. Our findings provide the first example of such reorganization in the perception of temporal patterns.

Acknowledgments

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