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## Conventional rhythms enhance infants' and adults' perception of musical patterns

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## ABSTRACT

Listeners may favour particular rhythms because of their degree of conformity to culture-specific expectations or because of perceptual constraints that are apparent early in development. In two experiments we examined adults' and 6-month-old infants' detection of subtle rhythmic and melodic changes to two sequences of tones, a conventional rhythm that musically untrained adults rated as rhythmically good and an unconventional rhythm that was rated as poor. Detection of the changes was above chance in all conditions, but adults and infants performed more accurately in the context of the conventional rhythm. Unlike adults, who benefited from rhythmic conventionality only when detecting rhythmic changes, infants benefited when detecting melodic as well as rhythmic changes. The findings point to infant and adult parallels for some aspects of rhythm processing and to integrated perception of rhythm and melody early in life.

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Music is characterized by considerable diversity across cultures, but that diversity is much “more restricted than the boundaries of the imaginable” (Nettl, 1983, p. 43). It is possible, indeed likely, that inherent perceptual constraints influence musical processing and memory. Music itself may be determined, at least in part, by such constraints, for example, by composers intuitively creating music that builds on universal principles of pattern perception (Terhardt, 1987). Obviously, culture-specific factors also contribute to music processing in experienced listeners (Hannon and Trehub, 2005a; Trainor and Trehub, 1992, 1994). In principle, such factors could exert some influence even prior to birth (DeCasper and Fifer, 1980; Kisilevsky et al., 2004). To date, however, there is no definitive evidence of prenatal influences on postnatal music perception.

Some musical pitch combinations, notably those involving *perfect consonances*—the octave (12 semitones), the perfect fifth, (7 semitones), and the perfect fourth (5 semitones)—are universal or near universal (Dowling and Harwood, 1986; Kilmer et al., 1976; Sachs, 1943). Adults prefer such consonant pitch combinations to dissonant pitch combinations. Consonant intervals are characterized by small-integer ratios between their component frequencies (2:1, 3:2, and 4:3 for the octave, perfect fifth, and perfect fourth, respectively) and dissonant intervals by large-integer ratios (Butler and Daston, 1968). In principle, adult preferences for consonance could arise from familiarity with consonant pitch combinations and cultural standards because consonance is ubiquitous in music. Familiarity is less adequate as an explanation for

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adult-like preferences in newborns whose parents are deaf and communicate by means of sign language (Masataka, 2006). Comparable preferences have been identified in 2-month-olds (Trainor et al., 2002), 4-month-olds (Zentner and Kagan, 1996), and 6-month-olds (Trainor and Heinmiller, 1998). In short, the available evidence is consistent with preferences for the consonance of simultaneous (harmonic) intervals arising from intrinsic properties of the human nervous system rather than familiarity or cultural learning. It is possible that experience and culture play a greater role in our preference for sequential (melodic) intervals.

Not only do adults and infants prefer consonant to dissonant patterns, but they also exhibit superior processing of consonant patterns. For example, adults have greater difficulty detecting subtle frequency changes in simultaneous or sequential combinations of pitches that are dissonant than in those that are consonant (Acker et al., 1995; Schellenberg and Trehub, 1994). Likewise, infants more readily detect changes in the context of consonant pitch patterns, simultaneous or sequential, than in the context of dissonant patterns (Schellenberg and Trehub, 1996). These findings are consistent with a link between aesthetic preferences and processing advantages. Moreover, infant and adult parallels are consistent with the notion that preferences and processing advantages for consonant pitch combinations are present at birth.

Aspects of temporal or rhythmic structure could also constrain music processing. Regular or temporally predictable rhythms are associated with preferences and processing advantages relative to irregular or less predictable rhythms. For example, adults readily differentiate isochronous rhythms (i.e., all temporal intervals of equal duration) from one another on the basis of tempo (i.e., speed), but their performance declines dramatically for rhythms comprised of randomly varied temporal intervals (Drake and Botte, 1993). In general, non-isochronous rhythms are perceived as regular if their component durations are related by simple ratios, such as 1:1 and 2:1 (Essens and Povel, 1985; Keller and Repp, 2005). When adults spontaneously produce rhythmic patterns, they generate durations related primarily by 1:1 and 2:1 ratios (Fraisse, 1982). In their reproductions of specific rhythmic patterns, they are considerably more accurate when the component durations are related by simple-integer ratios than by complex- or non-integer ratios (Essens and Povel, 1985; Essens, 1986; Sakai et al., 1999).

Rhythmic regularity may facilitate the processing of musical patterns by promoting future-oriented attending (Jones, 1976). According to Jones and her associates (Jones, 1976; Large and Jones, 1999), internal and periodic attending rhythms synchronize with external events, resulting in enhanced attention and processing at expected periodic temporal positions. Indeed, temporal interval discrimination is better when a target interval occurs at predictable than at unpredictable times in a sequence (Barnes and Jones, 2000). Similarly, memory for the temporal position of events is more accurate when the events occur at or near expected times than at unexpected times (Palmer and Krumhansl, 1990). In some circumstances, pitch changes are more readily detectable when they occur at expected than at unexpected temporal positions (Jones et al., 2002, 2006). In short, rhythmic regularity plays an important role in expectancy, which,

in turn, affects various aspects of music perception and memory.

Adults' preferences and enhanced processing for rhythmic regularity could stem from their long-term exposure to Western music, which tends to be characterized by regularity. As noted, however, inherent biases could also contribute to such enhancement. Research with infants, whose exposure to music is relatively limited, can help shed light on this issue. For isochronous auditory patterns, infants detect subtle tempo changes when tone sequences are presented at adults' optimal tempo range (600-msec inter-onset intervals) but not at much faster or slower rates (Baruch and Drake, 1997). They categorize non-isochronous sequences on the basis of rhythm rather than tempo, which indicates that, like adults, they focus primarily on the relative durations of tones as opposed to their absolute durations (Chang and Trehub, 1977; Demany et al., 1977; Lewkowicz, 2003; Trehub and Thorpe, 1989). Infants also infer the underlying beat, or metre, of simple rhythmic patterns (Hannon and Johnson, 2005; Phillips-Silver and Trainor, 2005). There is suggestive evidence, moreover, that they perceive sequences in duple metre (i.e., measures or units subdivided into two main beats, as in strong/weak) more efficiently than those in triple metre (i.e., measures subdivided into three main beats, as in strong/weak/weak) except when synchronized body movement accompanies the sequences (Bergeson and Trehub, 2006; Phillips-Silver and Trainor, 2005). Note that duple metre is considerably more common than triple metre in Western music, but both are characterized by regularity. In short, inherent biases are likely to influence the structure of music to some extent, but exposure to music is likely to intensify those biases in some cases and override them in others (Trehub et al., 1999).

Age-related changes in the processing of rhythms have provided some insight into culture-general and culture-specific aspects of rhythmic processing. For example, North American adults readily detect a small timing change that disrupts a conventional Western rhythm characterized by small-integer ratios, but they fail to detect a similar disruption in the context of a foreign rhythm with somewhat more complex ratios (Hannon and Trehub, 2005a). By contrast, North American 6-month-olds detect the rhythmic changes in both contexts, which implies that their processing of these rhythmic patterns is culture-general but adults' processing is culture-specific. By 12 months of age, however, infants exhibit more accurate processing of typical Western rhythms than non-Western rhythms (Hannon and Trehub, 2005b), which indicates culture-specific processing of some aspects of temporal structure after relatively limited exposure to music.

Despite adults' difficulty discerning temporal variations in foreign rhythms (Hannon and Trehub, 2005a, 2005b), there is no indication that they find these rhythms any less pleasing than familiar rhythms. We suggest that listeners tend to assimilate foreign rhythms to familiar rhythmic templates so that they seem neither odd nor unpleasant. In this regard, it is interesting that the complex rhythms of much American jazz do not detract from the appeal of this musical genre. The palatability of specific rhythms, whether in jazz or other musical genres, may not stem from rhythmic complexity per se but from the degree to which those rhythms can be assimilated to culturally familiar rhythmic and metrical templates.

At times, adults consider musical rhythms as good or bad, just as they rate melodies unfavourably because of unfamiliar or mistuned pitch intervals. Negative evaluations of rhythms could stem from listeners' inability to assimilate those rhythms to familiar rhythmic structures, which, in turn, could influence their processing of temporal and non-temporal details. The primary goal of the present research was to ascertain the impact of adults' aesthetic judgments of rhythmic patterns on the processing of those patterns by infants as well as adults. To this end, we tested adult and 6-month-old listeners on two rhythmic arrangements of the same melody, one of which was highly conventional, the other unconventional.

Rhythms in Western music are often evaluated in terms of formal principles or conformity to culture-specific conventions (e.g., containing no more than two or three different temporal intervals, with longer intervals being twice as long as shorter ones; evenly spaced beats; and a regular pattern of strong and weak beats such as STRONG-weak-strong-weak, or STRONG-weak-weak). For the present purposes, however, conventional and unconventional rhythms were defined solely by the "goodness" judgments of musically untrained adults. Interestingly, the conventional rhythm derived in this manner was not the most typical example of a Western rhythm with simple duration ratios, nor was the bad rhythm the one that deviated most from Western conventions.

In contrast to previous studies of rhythmic regularity, which typically used monotone, random, or quasi-random pitch sequences (Barnes and Jones, 2000; Drake and Botte, 1993; Jones et al., 2002; Nakata and Mitani, 2005; Kidd et al., 1984), we used a highly conventional melodic pattern to ensure that the stimuli were processed musically. Of particular interest were the consequences of rhythmic conventionality or "goodness," as evaluated by adults, on the processing of melodic as well as rhythmic information. Although pitch processing is enhanced at expected temporal positions in an isochronous context (Jones et al., 2002), it is unclear whether pitch processing would be enhanced in the context of non-isochronous musical rhythms. Some scholars contend that melody and rhythm are independent dimensions of music that are processed separately and in parallel (Palmer and Krumhansl, 1987; Peretz and Coltheart, 2003; but see Boltz, 1998). Young children, however, are thought to process stimuli more holistically than older children and adults (Anvari et al., 2002; Bahrick and Lickliter, 2004; Overy et al., 2004).

## 1. Experiment 1

In the present experiment, we sought to determine whether conventional rhythmic arrangements of a melody, as judged by musically untrained adults, would enhance adults' detection of rhythmic and melodic changes relative to unconventional rhythmic arrangements of the same melody. Adults participated in a same-different task and judged whether the second of two 10-note melodies, which was always presented in transposition (i.e., shifted upward or downward in pitch level), was the same as or different from the first. The first, or

standard, melody was rhythmically conventional during half of the experimental blocks and rhythmically unconventional in the other half. The second, or comparison, melody differed from the standard by incorporating a rhythmic change in half of the trials and a melodic change in the other half.

The conventional and unconventional rhythms were selected in the following manner. First, a musicologist created 7 "appropriate" and 7 "inappropriate" rhythmic arrangements of a highly conventional (re Western music) 10-note sequence that had been used, with isochronous timing, in previous research with infants and adults (Trainor and Trehub, 1992, 1994). All rhythmic variations of this melody were presented in pairs to 41 musically untrained adults (from the same demographic background as participants in the test sample), who judged which rhythm was better from each pair of conventional variations and which rhythm was worse from each pair of unconventional variations. The most and least preferred variations, according to the nearly unanimous judgments of the 41 listeners in the pre-test, were designated "conventional" and "unconventional" for the purposes of the present study. These conventional and unconventional sequences are shown in Figs. 1 and 2. Both versions were identical in sequential melodic structure (i.e., same pitch sequence) and similar in duration, with average tone durations of 373 msec for the conventional version and 400 msec for the unconventional version. Because the melodic sequence was identical across conventional and unconventional versions, differences in performance between these versions could be attributed to rhythmic patterning. As can be seen in Figs. 1 and 2, the conventional pattern is metric, in contrast to the unconventional pattern, which is non-metric or metrically variable.

On the basis of previous research, we anticipated differences in the relative ease with which adults would detect the rhythmic and melodic changes. Both changes were implemented by alterations in a single note. The rhythmic change in the comparison pattern disrupted the original temporal arrangement by substituting a short-duration note for a long-duration note. By contrast, the melodic change maintained the pitch structure in the sense of preserving the pitch contour, key, and implied harmony of the original pattern, which was likely to create particular challenges for listeners with implicit knowledge of Western music (Trainor and Trehub, 1992, 1994).

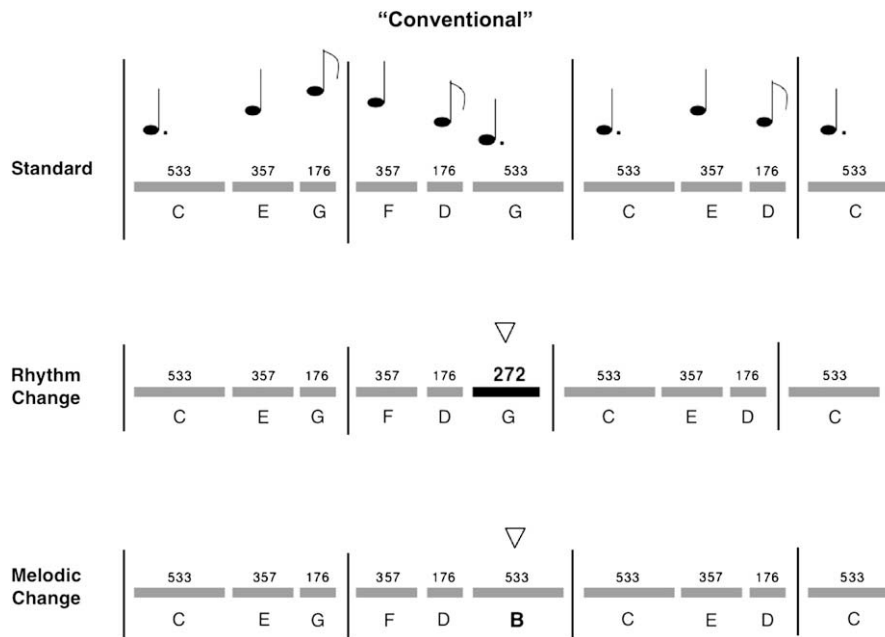
### 1.1. Method

#### 1.1.1. Participants

There were 24 adults (19 female, 5 male; ages 18–27 years) who participated in a same-different judgment task for course credit. An additional four participants completed the task but were not included in the analysis because they failed to perform adequately in a pre-testing practice block. Formal music training among participants ranged from 0 to 10 years ( $M = 2.4$ ).

#### 1.1.2. Stimuli

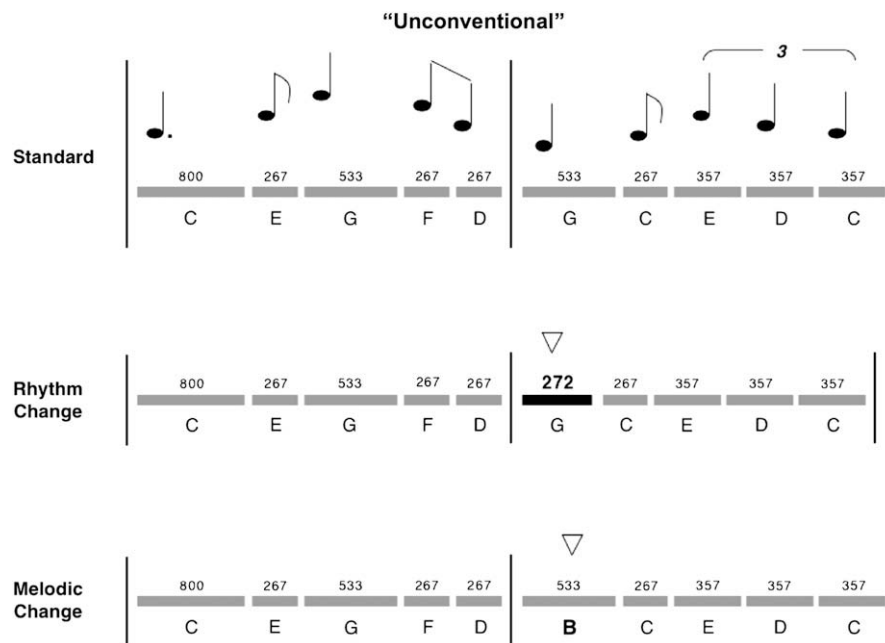
During each test trial, the conventional or unconventional standard sequence was followed by a comparison sequence featuring a rhythmic or melodic change (see Figs. 1 and 2) or



**Fig. 1 – The conventional rhythmic arrangement of the 10-note melodic sequence. The standard version is shown in music notation and graphical form, with the duration of each note indicated above each gray bar (in msec), and the pitch indicated beneath each gray bar (in the key of C in this example). The arrows identify the position of the melodic and rhythmic change. The rhythm change (a decrease of 261 msec in duration) is highlighted by a black bar (msec in bold), and the melodic change (a four-semitone change, from G to B in this example) is shown in bold.**

no change. For the rhythmic change, the duration of the fourth note in the sequence was reduced from 533 to 277 msec. For the melodic change, the pitch of the fourth note was altered by four semitones, preserving the contour, key, implied harmony and overall sense of the original melody. Rhythmic and melodic changes were identical across conventional and unconventional conditions.

All sequences were transposed to three unrelated keys: C major, E major, and A major. Standard and comparison sequences were always presented in contrasting keys to preclude the use of absolute pitch cues. Sequences were generated as Musical Instrument Digital Interface (MIDI) files and converted to sound (aif) using Quicktime's *ocarina* timbre, which approximates a pure tone (i.e., sine wave).



**Fig. 2 – The unconventional rhythmic arrangement of the 10-note melodic sequence, with the standard, rhythm change, and melodic change versions shown in music notation and graphic form.**

### 1.1.3. Apparatus and procedure

Participants were tested individually and presented with instructions and stimuli over headphones by means of PsyScope software (Cohen et al., 1993) on a Macintosh G4 computer. Each trial consisted of a standard sequence followed by a comparison sequence, with listeners judging whether the standard and comparison were the same or different. Before testing, adults were given a brief musical demonstration to illustrate that a melody can maintain its basic identity despite transpositions, or changes in the absolute pitch level. For example, the song “Happy Birthday” retains its identity when sung at a high or low pitch level. Participants were instructed to respond “different” only when they heard changes in the rhythm or melody and to respond “same” only when they heard changes in the overall pitch level (i.e., higher or lower).

Participants were tested in each of four blocked conditions that required discrimination on the basis of (1) a rhythmic change to the conventional standard, (2) a rhythmic change to the unconventional standard, (3) a melodic change to the conventional standard, and (4) a melodic change to the unconventional standard. Adults initiated each trial by depressing the space bar on a computer keyboard. After hearing each pair of sequences, they pressed the “s” key to indicate judgments of “same” and the “d” key to indicate judgments of “different.” Visual feedback (correct or incorrect) was provided after each trial. The first 8-min block was preceded by six practice trials, in which changes in the comparison sequences were highlighted by a 5-dB increase in amplitude. Participants who did not respond accurately on four of the six practice trials were excluded from the study. Following practice trials, listeners were presented with blocks consisting of 10 same trials and 10 different trials, ordered randomly. Block order was counterbalanced across participants.

## 1.2. Results

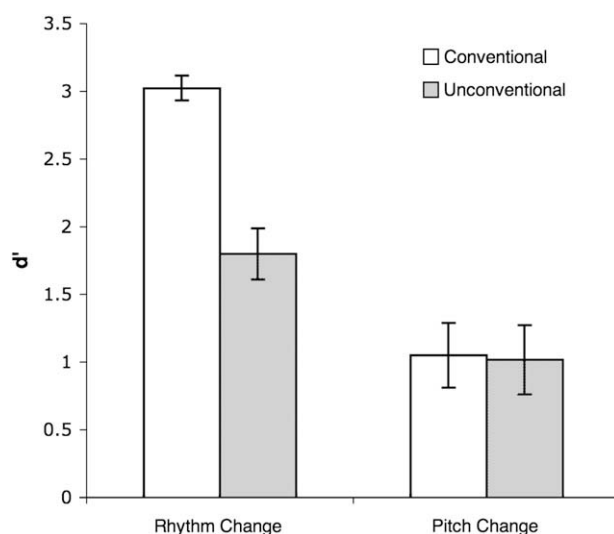
For each participant in each condition, discrimination ( $d'$ ) scores were calculated from proportions of hits (“different” responses on change trials) and false alarms (“different” responses on no-change trials) according to *yes/no* tables of signal detection theory (Green and Swets, 1966). Because perfect responding would generate infinite  $d'$  scores, proportions were calculated by adding .5 to the numerator (number of hits or false alarms) and 1 to the denominator (number of trials), which changes  $d'$  values slightly but maintains the original ranking of scores (Thorpe et al., 1988).

Performance exceeded chance levels ( $d' = 0$ ) in all four conditions,  $t(23) > 3.99$ ,  $p < .001$ , although accuracy varied across conditions. A two-way mixed-design analysis of variance (ANOVA), with rhythm type (good or bad) and change type (melodic or rhythmic) as within-subjects factors and years of musical training as a between-subjects covariate, revealed significant main effects of rhythm type,  $F(1,22) = 9.72$ ,  $MSE = 3.31$ ,  $p < .01$ , and change type,  $F(1,22) = 16.99$ ,  $MSE = 20.43$ ,  $p < .01$ , and a marginally significant interaction between change type and rhythm type,  $F(1,22) = 2.914$ ,  $MSE = 2.45$ ,  $p = .10$ . There were no other significant main effects or interactions.

Adults were better at detecting rhythm changes than melodic changes (see Fig. 3). Scores in the melodic-change condition were within the range of performance reported previously for isochronous versions of the same melody (Trainor and Trehub, 1992). Of greatest interest was the main effect of rhythm, which indicated that adults were better at detecting changes to the conventional rhythm than to the unconventional rhythm. The marginally significant interaction between rhythm type and change type reflected differential effects of the conventional rhythm on rhythmic and melodic discrimination. As can be seen in Fig. 3, the conventional rhythm facilitated the detection of rhythm changes but not melodic changes.

## 2. Experiment 2

Adults' enhanced processing for the conventional rhythms could arise from musical enculturation and learning (Hannon and Trehub, 2005a, 2005b; McFadden and Callaway, 1999). Alternatively, enhancement could stem from constraints on rhythmic pattern processing that are apparent early in development, much like the enhanced processing of consonant pitch combinations (Schellenberg and Trehub, 1996) and certain scale structures (Trehub et al., 1999). We addressed this issue by asking whether 6-month-old infants, who have had limited exposure to music, would perform more accurately in the context of rhythmic patterns that adults consider good than those considered poor. In previous research, North American 6-month-olds performed similarly on Western and non-Western rhythms, unlike North American 12-month-olds and adults, who performed better on the Western rhythms (Hannon and Trehub, 2005a, 2005b). These findings imply that listeners are initially unbiased in their processing of native and foreign rhythms but that sensitivity to the nuances of foreign rhythms declines after some period of exposure to culture-specific rhythms. We therefore expected adults'



**Fig. 3 – Adult  $d'$  scores in the melodic and rhythmic change conditions for “conventional” and “unconventional” rhythms (Experiment 2). Error bars represent standard errors.**

judgments of rhythmic goodness to have little consequence for 6-month-olds unless such judgments arise from temporal processing mechanisms that are common to infants and adults (e.g., Thorpe et al., 1988; Trehub and Thorpe, 1989).

Like the adults in Experiment 1, infants in the present experiment were required to detect rhythmic and melodic changes to the conventional and unconventional rhythmic patterns. Unlike adults, however, infants lack implicit knowledge of key and implied harmony, as reflected in the equal ease with which they detect melodic changes that preserve the key and implied harmony of a tone sequence and those that disrupt those elements (Trainor and Trehub, 1992). Thus, infants were expected to perform as well on the melodic changes as on the rhythmic changes. Moreover, if infants exhibited processing advantages for the conventional rhythm, such advantages were anticipated for melodic as well as rhythmic changes.

## 2.1. Method

### 2.1.1. Participants

There were 60 healthy, full-term infants between 6 and 7 months of age ( $M = 6.4$  months; 35 female, 25 male). Each infant was assigned to one of four conditions: standard melody with conventional or unconventional rhythm paired with comparison melody with rhythmic or melodic change. An additional 36 infants were tested but excluded from the final sample because of fussing ( $n = 9$ ), failing to meet the training criterion ( $n = 18$ ), inattentiveness ( $n = 2$ ), or parental interference ( $n = 7$ ).

### 2.1.2. Stimuli

Sequences were identical to those used in Section 2, except that tones were generated on-line rather than being pre-recorded (see Section 2.1.3).

### 2.1.3. Apparatus and procedure

Infants were tested individually in a double-walled, sound-attenuating booth (Industrial Acoustics Co.). Each infant was seated on a parent's lap in a corner of the booth, facing the experimenter. Located 45° to the infants' left was a single loudspeaker (Avant 2AX) and Plexiglas box housing four mechanical toys and lights. An Elitegroup Computer Systems (ECS) microcomputer controlled the audio equipment and mechanical toys and recorded the experimenter's button presses through a custom-built interface. Pure tones were generated on-line by two Hewlett-Packard 3325A synthesizer-function generators, attenuated by two Med Associates attenuators, switched on and off by two Med Associates rise-fall switches, and amplified by a Marantz-1070 amplifier.

Infants were tested by means of a go/no-go conditioned head-turn procedure. The standard sequence in each condition repeated in transposition (i.e., different pitch levels) throughout the entire test session, with 1600 msec between presentations. Transpositions were selected in a "random-walk" pattern, with presentations always at a higher or lower pitch level than the previous presentation.

A correct response to a melodic or rhythmic change in the repeating background sequence was to turn to the loudspeaker within 3 sec of the change. The experimenter, who sat

facing the infant, wore headphones with masking stimuli so that she was unable to hear the stimuli presented to infants. She used hand-held toys to attract the infant's attention, and initiated trials via a button press when the infant was quiet and facing directly ahead. When the experimenter called for a test trial, the computer presented either a change or no-change (i.e., control) trial. On change trials, the standard background sequence was replaced by a comparison sequence that incorporated a rhythmic or melodic change. On no-change trials, the unchanged standard sequence was repeated in transposition. A variable number of standard background sequences (minimum of two) intervened between test trials, whether change or no-change. The experimenter recorded any responses (i.e., turns to the loudspeaker) by pressing a button. If infants responded correctly to a change trial (i.e., turning to the loudspeaker within 3 sec after the onset of the changed event), reinforcement was provided automatically in the form of illumination and activation of a mechanical toy for 4 sec. If infants turned on no-change trials, the computer recorded the response but did not deliver reinforcement.

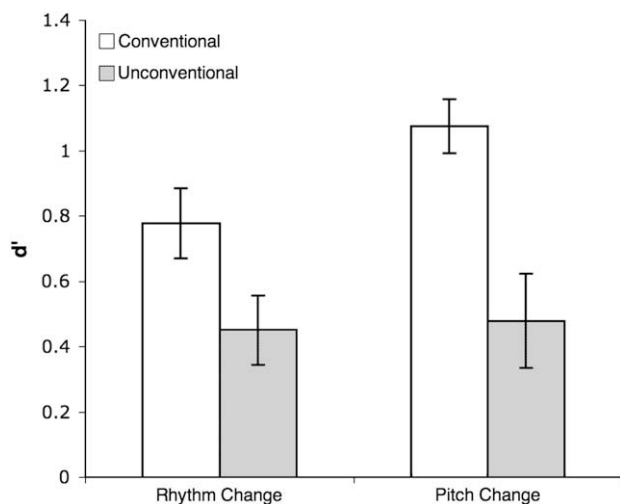
The test phase was always preceded by a training phase. The training phase, which consisted only of change trials, familiarized infants with the procedure. During the first two trials of the training phase, the contingency between the altered pattern and the reward was demonstrated by presenting the reward immediately after the altered pattern, which invariably elicited a turn toward the activated mechanical toy. On subsequent trials, the reward was contingent upon correct responses. Failure to respond to a change led to a 5-dB increase in the intensity of the subsequent altered pattern, and correct responding led to a decrease in intensity until change and background patterns and comparison patterns were of equal intensity. Infants had to meet a training criterion of four successive correct trials at equal amplitude before proceeding to the test phase. If infants failed to meet the training criterion within 20 trials, the session was terminated.

## 2.2. Results

Proportions of hits (head turns during change trials) and false alarms (head turns during no-change trials) were converted to  $d'$  scores for each infant. Infants detected changes at above-chance levels in all four conditions,  $t(14) > 3.33$ ,  $p < .01$ . A two-way analysis of variance (ANOVA) with change type (melodic or rhythmic) and rhythm type (good or bad) revealed a significant main effect of rhythm type,  $F(1,56) = 18.483$ ,  $MSE = 3.47$ ,  $p < .001$ . There were no other main effects or interactions. As shown in Fig. 4, infants detected pitch and rhythm changes more readily in the context of the conventional rhythm than in the unconventional rhythm. There was no interaction between change type and rhythm type, which implies that the conventional rhythm provided comparable facilitation for the detection of both rhythmic and melodic changes.

## 3. Discussion

The principal goal of the present research was to ascertain whether conventional rhythms, specifically, those judged



**Fig. 4 – Infant  $d'$  scores in the melodic and rhythmic change conditions for “conventional” and “unconventional” rhythms (Experiment 3). Error bars represent standard errors.**

“good” by naïve adults, facilitate adults’ and infants’ perception of rhythmic and melodic changes in musical contexts. Accordingly, adults and 6-month-olds were required to detect rhythmic and melodic changes in the context of a conventional, or metric, and unconventional, or non-metric, rhythm. We reasoned that if adults displayed processing advantages for the conventional rhythm but infants did not, that would implicate culture-specific factors. By contrast, processing advantages for infants as well as adults would implicate intrinsic temporal constraints that are apparent early in life.

Adults in Experiment 1 more readily detected disruptions to conventional rhythmic sequences than those to unconventional rhythmic sequences. This finding extends previous evidence of enhanced processing for sequences with regular (i.e., more conventional) as opposed to irregular (i.e., less conventional) timing (Jones et al., 2002). It also parallels adults’ enhanced processing of consonant pitch combinations relative to dissonant pitch combinations (Acker et al., 1995; Schellenberg and Trehub, 1994). It differs, however, in being the first demonstration that adults’ rhythmic preferences, as indicated by judgments of “good” and “bad,” predict infants’ and adults’ relative ease of detecting timing changes in musical sequences. Although different groups of adults were tested on the preference task, the uniformity of the preference and the similar background of participants (i.e., students at the same university) make it highly likely that the same preferences would be evident in both groups. Because we did not evaluate the basis for adults’ rhythmic preferences, it remains for future research to ascertain the specific aspects of rhythmic structure that underlie preference and discriminability.

Rhythmic conventionality affected adults’ detection of rhythmic disruptions but not melodic disruptions, which is consistent with claims of separate processing of melody and rhythm (Palmer and Krumhansl, 1987; Peretz and Coltheart, 2003; Peretz and Kolinsky, 1993). Although there is suggestive evidence that temporal regularity enhances the detection of pitch as well timing changes (Jones et al., 2002, 2006), such

evidence has been limited to pitch sequences that are unmusical rather than conventionally melodic, as in the present investigation. It is possible, then, that the processing of melodic and rhythmic cues is more independent for musical materials with greater ecological validity. In short, the timing regularity of the conventional patterns, which should have facilitated anticipatory attending (Large and Jones, 1999), did not result in enhanced perception of rhythmically expected tones over unexpected tones in the present task.

Differential effects of rhythmic organization on adults’ detection of rhythmic and melodic changes could also stem from their difficulty in detecting a melodic change that preserved the implied harmony. It remains to be determined whether rhythmic conventionality, as defined here, would enhance the detectability of melodic changes that disrupt the implied harmony or key (Trainor and Trehub, 1994) or those that occur at positions with explicit temporal accents (Boltz, 1998).

Adults’ rhythmic preferences and their consequences for music processing could arise from the relative familiarity of the rhythmic or metrical structures (e.g., Hannon and Trehub, 2005a) or from factors that affect inexperienced as well as experienced listeners (e.g., simplicity, consistency). The fact that 6-month-old infants in Experiment 2 showed enhanced detection of changes in the context of the conventional rhythm implies that little or no experience is implicated in these processing biases. Comparable processing biases are presumed to account for infants’ processing of consonant and dissonant pitch combinations (Masataka, 2006; Schellenberg and Trehub, 1996; Trainor et al., 2002; Zentner and Kagan, 1996), aspects of scale structure (Lynch et al., 1990; Trehub et al., 1999), temporal grouping (Thorpe et al., 1988), and metrical organization (Bergeson and Trehub, 2006; Hannon and Trehub, 2005a). In fact, Bergeson and Trehub (2006) argue not only for processing dispositions that favour metric frameworks but also for those that favour duple metre, in particular.

In contrast to the adult findings, the conventional rhythm facilitated infants’ detection of melodic as well as rhythmic changes. Joint facilitation of this nature could implicate integrated processing of melody and rhythm in early life (Anvari et al., 2002; Overy et al., 2004). Experiential factors that alter the salience of pitch changes may also be implicated. For example, infants detect pitch changes that disrupt the key of a melody as readily as those that preserve it (Trainor and Trehub, 1992), in contrast to 5-year-olds, who detect pitch changes more readily when they disrupt the key than when they preserve it, and to 7-year-olds and adults, who detect pitch changes more readily when they disrupt the key or harmonic structure than when they preserve either (Trainor and Trehub, 1994). In other words, exposure to Western music generates incremental changes in the representation of key structure and harmony, which would make some melodic changes more salient and others less salient (e.g., those that alter vs those that preserve culture-specific pitch structures).

The factors that led adults to identify one of the rhythms in the present study as good and the other as poor remain unclear. In general, simple duration ratios such as 1:1 and 2:1 are associated with enhanced processing and memory (Essens and Povel, 1985; Essens, 1986; Fraisse, 1982; Sakai et al., 1999). In this study, however, both rhythms included ratios that were more complex than 2:1, for example, 3:2 between notes 1

and 2 and between notes 7 and 8 of the conventional rhythm and 7:5 between notes 7 and 8 of the unconventional rhythm. In principle, the greater ratio complexity and metrical variability of the unconventional rhythm, with its four component durations (compared to three for the good rhythm), could have contributed to its perception as less coherent and, therefore, to the observed processing difficulties for adults and infants.

Note, however, that the so-called “unconventional” rhythms were unconventional with reference to any known musical culture, unlike unconventional rhythms that are simply foreign or unfamiliar. Further insight into the role of ratio complexity could be obtained by exploring evaluative judgments and their processing consequences for rhythms incorporating a wider range of duration ratios. Lower-level auditory constraints, such as the relative size of the target inter-onset interval (Monahan and Hirsh, 1990), may also contribute to performance. Future studies could control for such factors by embedding the target interval in rhythms with an identical immediate context (i.e., identical neighbouring inter-onset intervals) but contrasting metrical context. If listeners are able to extract an underlying pulse more readily from the conventional rhythm than from the unconventional rhythm, they should benefit from temporal expectancies in one case but not the other (Jones, 1976; Large and Jones, 1999). Adults’ relative ease of tapping to the preferred and non-preferred rhythms from the present study could shed light on this issue.

Adult–infant differences in the present study provide some insight into culture-specific factors and learning. Specifically, differential consequences of the conventional rhythm on melodic processing in adults and 6-month-olds are consistent with long-term musical exposure leading to more independent processing of rhythm and melody, decreased salience of the target pitch change, or both. Culture-specific factors also account for North American adults’ inability to detect changes in foreign metrical patterns that are detectable by North American 6-month-olds (Hannon and Trehub, 2005a) and for the greater ease of acquiring sensitivity to foreign rhythms by 12-month-olds than by adults (Hannon and Trehub, 2005b). In short, sensitivity to rhythmic and melodic changes in music is predictable, in part, from the rhythmic preferences of musically untrained adults and, in part, from musical exposure, reflecting the joint contributions of culture-general and culture-specific factors.

By demonstrating similarities in adults’ and 6-month-olds’ perception of conventional and unconventional rhythmic patterns, we highlight culture-general aspects of rhythmic processing. Our contention is that judgments of rhythmic goodness in the present study were based, in part, on rhythmic processing constraints that remain to be identified. It is likely that such constraints, including those on metre, have influenced the nature of musical rhythms across cultures. We are not suggesting that all adult preferences are grounded in inherent perceptual constraints. Undoubtedly, many preferences and processing biases arise from culture-specific factors and listeners’ history of musical exposure, which make some patterns seem familiar and others unfamiliar or unconventional in terms of their musical prosody (Palmer and Hutchins, 2006). We contend, however, that aesthetic preferences and ease of processing depend, in part, on mechanisms that are operational early in life, if not at birth.

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