

# Cross-cultural differences in meter perception

**Beste Kalender, Sandra E. Trehub & E. Glenn Schellenberg**

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**ORIGINAL ARTICLES**

**How reliable is the attentional blink? Examining the relationships within and between attentional blink tasks over time**  
G. Dale · K.M. Arnell 99

**Measuring the allocation of attention in the Stroop task: evidence from eye movement patterns**  
B. Oik 106

**Processing numerosity, length and duration in a three-dimensional Stroop-like task: towards a gradient of processing automaticity?**  
V. Dormal · M. Pesenti 116

**The impact of task rules on distracter processing: automatic categorization of irrelevant stimuli**  
R. Reisenauer · G. Dreisbach 128

**Setting sights higher: category-level attentional set modulates sustained inattention blindness**  
S.B. Most 139

**Cognitive control of feature bindings: evidence from children with autistic spectrum disorder**  
S. Zmigrod · L.M.J. de Sonneville · L.S. Colzato · H. Swaab · B. Hommel 147

**The effects of an unexpected spider stimulus on skin conductance responses and eye movements: an inattention blindness study**  
J. Wiener · A.B.M. Gerdes · P. Pauli 155

**The effect of distraction on face and voice recognition**  
S.V. Steyvers · G.J. Neil · J. Barlow · A. Dyson · C. Eaton-Brown · B. Barszars 167

**Overtraining and the use of feature and geometric cues for reorientation**  
B.R. Sturz · K.A. Gaskin · K.D. Bodily 176

**Detecting perturbations in polyrhythms: effects of complexity and attentional strategies**  
B.C. Fidali · E. Poudrier · B.H. Repp 183

**Cross-cultural differences in meter perception**  
B. Kalender · S.E. Trehub · E.G. Schellenberg 196

**Living on the edge: strategic and instructed slowing in the stop signal task**  
F. Sella · M. Bonato · S. Cutrini · C. Umiltà 204

**On costs and benefits of n-2 repetitions in task switching: towards a behavioural marker of cognitive inhibition**  
J.A. Grange · I. Juvina · G. Houghton 211

**Response-mode shifts during sequence learning of macaque monkeys**  
D. Rünger · F.G. Ashby · N. Picard · P.L. Strick 223

**Action video gaming and cognitive control: playing first person shooter games is associated with improvement in working memory but not action inhibition**  
L.S. Colzato · W.P.M. van den Wildenberg · S. Zmigrod · B. Hommel 234

**Effects of feature integration in a hands-crossed version of the Social Simon paradigm**  
R. Liepelt · D. Wenke · R. Fischer 240

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## Cross-cultural differences in meter perception

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**Abstract** We examined the influence of incidental exposure to varied metrical patterns from different musical cultures on the perception of complex metrical structures from an unfamiliar musical culture. Adults who were familiar with Western music only (i.e., simple meters) and those who also had limited familiarity with non-Western music were tested on their perception of metrical organization in unfamiliar (Turkish) music with simple and complex meters. Adults who were familiar with Western music detected meter-violating changes in Turkish music with simple meter but not in Turkish music with complex meter. Adults with some exposure to non-Western music that was unmetred or metrically complex detected meter-violating changes in Turkish music with both simple and complex meters, but they performed better on patterns with a simple meter. The implication is that familiarity with varied metrical structures, including those with a non-isochronous tactus, enhances sensitivity to the metrical organization of unfamiliar music.

### Introduction

Adults in all cultures clap their hands, tap their feet, sing, or dance in time to music. Such synchronous behavior would be impossible without implicit knowledge of the metrical structure of the music, specifically, its underlying

tactus or pulse, which is especially clear in most dance music. Such knowledge also enables listeners to sense that a note violates the prevailing metrical structure by occurring too early or too late (London, 2004). Speech, by contrast, has no highly predictable metrical patterns, except for some genres of poetry, which are considered hybrids of speech and music. Moreover, unlike simultaneous sound production in choral or instrumental ensembles, which is facilitated by the temporal predictability of the music, spoken conversations are sequential, involving turn-taking.

Whereas musical rhythm reflects grouping, involving the relative inter-onset intervals (IOIs) of notes, meter is not available in the musical surface. Instead, it is inferred from periodic regularities in the music (Clarke, 1999). Evidence of meter perception very early in life attests to the importance of this dimension of auditory experience. For example, Western 6-month-old infants infer the metrical structure of auditory sequences (Hannon & Johnson, 2005), and they are sensitive to the metrical organization of Western and non-Western music (Hannon & Trehub, 2005a).

The metrical structure of Western music typically consists of an isochronous tactus with equidistant beats and IOIs related by simple ratios (1:1 and 2:1). Such simple metrical structures are present in the music of all cultures, but music in a number of geographical regions (e.g., Eastern Europe, Asia, Africa) also features complex meters in which the tactus is non-isochronous and IOIs are related by more complex ratios. Although such music may sound irregular or “jerky” to Western ears, listeners in those cultures perceive the tactus in the music, as reflected in their tapping or dancing.

French and Tunisian adults tap more accurately, more slowly (i.e., at higher hierarchical levels), and more flexibly (i.e., at different hierarchical levels) to familiar and

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unfamiliar pop songs from their own culture than to unfamiliar pop music that is similar in metrical structure but from a different culture (Drake & El Heni, 2003). In other words, the generalization of metrical knowledge from familiar to unfamiliar musical material is imperfect. Young children's tapping to music is also faster (i.e., closer to the musical surface), less accurate, and less flexible than that of older children and adults, reflecting poorer comprehension of metrical structure (Drake, Jones, & Baruch, 2000).

Culture-specific knowledge sometimes interferes with the perception of novel metrical categories. Unlike adults of Balkan origin, Western adults have difficulty detecting meter-violating changes in Balkan music with a complex meter, but they detect such changes in Balkan music with a simple meter (Hannon & Trehub, 2005a). By contrast, Western 6-month-olds detect meter-violating changes in Balkan music with a simple or complex meter (Hannon & Trehub, 2005a). By 12 months of age, Western infants are like their adult counterparts in failing to detect meter-violating changes in Balkan music with a complex meter, but they succeed after 2 weeks of daily (10-min) exposure to metrically complex Balkan music (Hannon & Trehub, 2005b). Comparable short-term exposure is insufficient to reverse Western adults' difficulty with complex meters.

The presumption is that long-term exposure to complex metrical structures accounts for the advantage of Balkan over Western adults (Hannon & Trehub, 2005a), but this advantage could also stem from familiarity with Balkan folk music and its specific meters. In other words, exposure to different musical cultures or genres may result in enhanced processing only for those specific cultures or genres. Note that children and adults exhibit better memory for novel musical pieces from their own culture than from a foreign culture (Demorest, Morrison, Beken, & Jungbluth, 2008). Comparable memory biases for Western or Indian music are evident for listeners with exclusive exposure to one but not both musical cultures (Wong, Roy, & Margulis, 2009).

We asked whether exposure to varied metrical structures from more than one culture facilitates the perception of complex meters from an unfamiliar musical culture. Traditional folk music from Turkey was selected because of its unfamiliarity to all participants and its use of simple and complex metrical patterns. Turkish folk music is monophonic (i.e., not polyphonic), consisting of a single melody line without harmony, often with multiple instruments (or voices) playing the same line in unison or in different octaves (Bartók, 1976). The melody is sometimes accompanied by a rhythm instrument to maintain the basic metrical structure. The scale structure is diatonic, with quartertones used on occasion in vocal music. In the present study, the Turkish music with complex meter featured 5-beat measures with 2 + 3 division (i.e., a non-isochronous tactus, see Fig. 1).

**Fig. 1** Sample stimuli in musical notation. *Dots* indicate the tactus or pulse at which listeners typically tap or clap to the music. Note that these pulses are isochronous in the familiarization stimulus for the simple meter but not for the complex meter. *Arrows* indicate the location of the extra note for test stimuli. (*FAM* familiarization stimulus, *MP* meter-preserving change, *MV* meter-violating change)

Western music was the dominant musical culture of all participants, but some participants occasionally heard music from a second musical culture that had complex as well as simple meters. Listeners who were familiar with two dissimilar musical cultures were considered *bimusical* (following Wong et al., 2009), but they were not “balanced” bimusicals because of their predominant experience with Western music. Familiarity with different musical systems may enhance the metrical processing of culturally unfamiliar musical materials, just as bilingualism enhances the acquisition of phonologically unfamiliar words (Kaushanskaya & Marian, 2009) and additional languages (Sanz, 2000). Bilingualism is also associated with processing advantages on tasks requiring the inhibition of salient but irrelevant information (Bialystok, Craik, & Luk, 2008).

At occasional family or community gatherings, the bimusic participants heard Indian music (North Indian in some cases, South Indian in others), which differs from Western and Turkish music in its pitch structure and temporal patterning (Clayton, 2000; Jairazbhoy, 1995). Traditional Indian music includes considerable rhythmic and melodic improvisation, with one performer commonly maintaining the basic metrical structure in the background

(Jairazbhoy, 1995). Such music also involves numerous complex meters, which are particularly difficult for Western listeners in the absence of special training or experience (Clayton, 2000). Indian melodic frameworks for composition and improvisation, or *ragas*, often begin with a non-metrical section, and metrical improvisation and modulation are common in the metered sections. Moreover, vocal music, which occupies a central role in India, is often non-metrical (Gosvami, 1961).

Indian classical music has over 100 different metrical cycles, or *talas*, most of which feature 5, 6, 7, 8, 10, 12, 14, and 16 beats divided into sub-units of various sizes, either symmetrically or asymmetrically (Clayton, 2000; Jairazbhoy, 1995). For example, a 14-beat cycle can be subdivided as 5 + 5 + 4 (*Dhamar*), 2 + 4 + 4 + 4 (*Ada Chautal*), or 3 + 4 + 3 + 4 (*Chanchar*). According to Montfort (1985), 1 of the 10 most common *talas* in North Indian (Hindustani) classical music has a meter resembling 5/8 (*Jhaptal*, with 10 beats divided 2 + 3 + 2 + 3), but Indian musicians consider *talas* to be fundamentally different from Western meters. South Indian music has different *talas* (Sambamurthy, 1968). Although Indian instrumental music predominates in Western concert halls, vocal music predominates in India and in the Indian diaspora, and the characteristically sensual performances of vocal music are often unmetered or metrically variable. Indian film (Bollywood) music, which is popular in India and abroad, typically uses Western metrical structure.

Because musically untrained individuals are generally unfamiliar with the term *meter*, often characterizing meter as rhythm, we asked participants to rate the rhythmic similarity or difference between standard and comparison patterns. To familiarize listeners with the judgment task, which involved focusing on the metrical structure, we provided a training phase with a highly familiar melody (*Twinkle, Twinkle Little Star*), which featured a standard version and melodic alterations that preserved or violated the original metrical structure. In the test phase, listeners rated multi-instrument samples with noticeable melodic changes that were consistent or inconsistent with the original metrical structure. Participants' unfamiliarity with Turkish music and the need to focus on metrical organization in the context of salient melodic changes were expected to make the task challenging for all listeners.

If monomusical Western listeners "regularized" the music with unfamiliar metrical structure by assimilating it into a familiar, simple-meter framework, they might fail to differentiate meter-preserving from meter-violating alterations. By contrast, listeners who had some familiarity with non-metrical or metrically complex music might not expect unfamiliar music to be metrically simple or isochronous. Despite their limited experience with music having a non-isochronous tactus, bimusical listeners were expected to

perform better than monomusical Western listeners on such music. Nevertheless, bimusical listeners' predominant experience with Western music was expected to result in more efficient processing for metrically simple than metrically complex music.

The need to focus on metrical structure in the context of salient but irrelevant melodic changes capitalizes on selective or controlled attention, which could favor bilingual listeners or those with music training (Bialystok & DePape, 2009; Strait, Kraus, Parbery-Clark, & Ashley, 2010). Although musicians perform better than non-musicians when required to respond to pitch level (high or low) in the context of conflicting verbal content (the words "high" or "low"), bilinguals exhibit no advantage over monolinguals (Bialystok & DePape, 2009). Nevertheless, we investigated the possibility of metrical processing advantages for bilingual participants beyond those conferred by bimusical status.

## Methods

### Participants

Participants were 56 students at a Canadian university (38 women, 18 men) who were of Indian ( $n = 21$ ), Chinese ( $n = 16$ ), North American ( $n = 17$ ), and Arabic ( $n = 2$ ) descent. Over half ( $n = 36$ ) spoke one or more languages in addition to English, including Arabic, Bengali, Burmese, Cantonese, French, German, Hindi, Konkani, Korean, Malay, Mandarin, Punjabi, Tagalog, Telugu, Twi, Urdu, and Vietnamese. Four additional participants were excluded because of their inability to distinguish meter-violating from meter-preserving changes in the training phase. Participants of Indian and Arabic origin had occasional exposure to traditional Indian music, usually at weddings or community gatherings. All had daily or near-daily exposure to Western music. Participants of Chinese origin reported exposure to Western music only.

We designated 23 participants as bimusical because of their exposure to two divergent musical systems (Western and Indian) and 33 participants as monomusical because of their exposure to a single (Western) musical system. No participant was familiar with Turkish music or had formal training in non-Western music. On average, participants had 2.6 years of Western music lessons ( $SD = 3.4$ ) but the distribution was positively skewed. Duration of lessons did not differ between monomusical ( $M = 3.0$  years) and bimusical participants ( $M = 2.0$  years),  $p > 0.2$ . The odds of speaking more than one language, however, were more than four times greater among bimusical than among monomusical participants,  $\chi^2(1, N = 56) = 5.71$ ,  $p = 0.017$  (odds ratio 4.47).



## Apparatus

Testing took place in a double-walled sound-attenuating booth with stimuli played over high-quality loudspeakers. Participants used a touch-sensitive monitor for responding. A computer outside the booth with customized software controlled stimulus presentation and response recording.

## Stimuli

The stimuli were MIDI versions of four traditional Turkish folk songs created with Finale 2009 software. Two songs were in a simple meter (2/4), with each measure subdivided into two groups of two notes, such that the tactus was isochronous. Two other songs were in a complex meter (5/8) with a non-isochronous tactus. Each measure was subdivided into groups of two and three.

Stimuli in the familiarization period were 2 min in duration, featuring 8–11 repetitions of the introductory instrumental portion of the target song. Test stimuli were 16 measures long, or 20–23 s in duration. The stimuli, which featured seven melodic instruments—pan flute, bagpipe, banjo, dulcimer, ocarina, agogo, and shakuhachi (not all played simultaneously)—and a taiko drum, were designed to match, as closely as possible, the timbre and overall texture of the original Turkish recordings on which they were based. The most common notes were 8th notes but the excerpts also contained 16th notes, quarter notes, and dotted-quarter notes. The duration of an 8th note was 250, 300, or 333 ms, depending on the number of 16th notes in each piece (i.e., a song with more 16th notes required a slower tempo to sound natural). The simple meters had more 16th notes than the complex meters (i.e., greater note density), and therefore fewer note onsets that corresponded to beats (strong or weak). Although this difference should make our test of an advantage for simple meters more conservative than it would be otherwise, it was irrelevant to tests of group differences. The use of two drum pitches (high and low) highlighted the metrical structure. IOIs of the drum accompaniment consisted of long–short–short patterns (2 beats [beat = 8th note], 1 beat, 1 beat; low–high–high) for simple-meter excerpts, and long–short–short–short patterns (low–low–high–high) for complex-meter excerpts, which were repeated in every measure.

For each familiarization melody, two test stimuli were created by adding an 8th note to the end of each measure, the additional note having the same pitch as the previous note. For the meter-preserving version, the duration of notes at the two earlier metrical positions (i.e., last two 8th note beats of the original) was halved. In the meter-violating version, the note addition increased the overall duration of each measure. The meter-violating change to

simple-meter excerpts resulted in a complex meter (5/8, one group of three 8th notes, one group of two 8th notes), which changed the tactus from isochronous to non-isochronous. The meter-violating change to complex-meter excerpts resulted in a simple meter (6/8, two groups of three 8th notes), which changed the tactus from non-isochronous to isochronous. When the tactus changed, the drum patterns changed accordingly. In both cases, the first drumbeat was three beats in duration rather than two.

Figure 1 provides musical notation for one familiarization stimulus with each meter and the corresponding meter-preserving and meter-violating versions. A longer portion of the stimuli from Fig. 1, including drum beats, is available in Online Resource 1. Audio examples of familiarization (i.e., original) and test stimuli (i.e., meter-preserving and meter-violating versions) for patterns with simple and complex meters are also available online (Online Resources 2–7). To increase the range of difference from familiarization to test stimuli, two additional test stimuli were used as foils: an abbreviated no-change version of the familiarization stimulus (i.e., identical except for fewer repetitions) and a version with a relatively obvious change that involved the addition of one 8th note at the beginning and end of each measure (changing 2/4 to 6/8 and 5/8 to 7/8).

## Procedure

Participants were tested individually. Two practice trials were designed to ensure that listeners could focus on the metrical structure of a familiar tune in the context of melodic changes. Participants listened to a synthesized piano version of *Twinkle, Twinkle, Little Star* with drum accompaniment followed by meter-preserving and meter-violating versions created by adding an extra note, as described for the test stimuli. They were told to attend to the rhythm and the drums. As in the subsequent test phase, they were required to rate how different the rhythm of each test stimulus sounded from the original rhythm on a 7-point scale ranging from 1 (same as original) to 7 (very different from original). Participants could achieve error-free performance by ignoring the melodic patterns and listening for changes in the drumming patterns, which occurred only in the meter-violating condition, but this strategy was not suggested to participants.

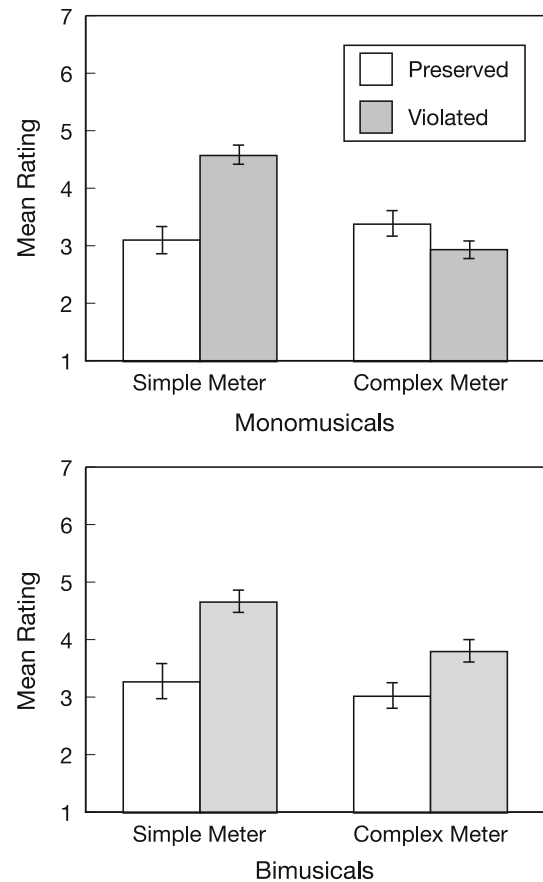
Participants who rated the meter-violating version of *Twinkle* as more discrepant from the original than the meter-preserving version proceeded to the test phase. Stimuli in the test phase were presented in four blocks corresponding to the four different songs (two with a simple meter, two with a complex meter), with order of

blocks randomized. In each block, one of the four familiarization stimuli was presented for 2 min followed by the four test stimuli in random order: meter-preserving alteration, meter-violating alteration, and two foils (i.e., no change and obvious change). Following each test stimulus, participants rated how different its rhythm sounded from the original rhythm.

## Results

For each participant, ratings were averaged across the two songs with a simple meter and the two with a complex meter, resulting in eight scores, one for each of the four conditions (meter-preserving, meter-violating, and the two foils) in both meters (simple and complex). A preliminary analysis examined scores on the two foils (i.e., no change and obvious change) to verify that participants understood the instructions and responded systematically. A three-way mixed-design Analysis of Variance (ANOVA) with one between-subjects factor (culture: monomusical or bimusical) and two repeated measures (meter: simple or complex; change: no change or obvious change) revealed a very robust effect of change,  $F(1, 54) = 335.35$ ,  $p < 0.001$ , partial  $\eta^2 = 0.86$ . Higher difference ratings for the obvious change ( $M = 4.8$ ) compared to no change ( $M = 1.9$ ) confirmed task comprehension and appropriate use of the scale. There was also a main effect of meter,  $F(1, 54) = 5.80$ ,  $p = 0.019$ , partial  $\eta^2 = 0.10$ , which was qualified by a two-way interaction between change and meter,  $F(1, 54) = 39.50$ ,  $p < 0.001$ , partial  $\eta^2 = 0.42$ . The difference between ratings in the no-change and obvious-change conditions was highly significant in both cases,  $ps < 0.001$ , but larger for the simple meter ( $M = 1.7$  and  $M = 5.3$ , respectively),  $F(1, 54) = 326.82$ ,  $p < 0.001$ , partial  $\eta^2 = 0.86$ , than for the complex meter ( $M = 2.1$  and  $M = 4.4$ , respectively),  $F(1, 54) = 153.12$ ,  $p < 0.001$ , partial  $\eta^2 = 0.74$ . Alternative analyses indicated that ratings in the no-change condition were higher (more different) for the complex than the simple meter,  $F(1, 54) = 6.90$ ,  $p = 0.011$ , partial  $\eta^2 = 0.11$ , whereas ratings in the obvious-change condition were higher (more different) for the simple than the complex meter,  $F(1, 54) = 32.32$ ,  $p < 0.001$ , partial  $\eta^2 = 0.37$ . In other words, listeners exhibited a processing advantage for the simple meters even with a relatively obvious metrical violation, but there was no main effect and no interactions involving musical culture,  $F_s < 1$ .

Subsequent analyses focused on the meter-preserving and meter-violating changes of interest. Scores for bimusical and monomusical participants on simple and complex metrical patterns are illustrated in Fig. 2. A three-way mixed-design ANOVA with culture (bimusical or monomusical) as a between-subjects factor and meter (simple or



**Fig. 2** Mean difference ratings for monomusical and bimusical listeners as a function of meter (simple or complex) and whether the change preserved or violated the meter. Error bars are standard errors

complex) and change (meter-preserving or meter-violating) as repeated measures revealed a significant three-way interaction,  $F(1, 54) = 5.89$ ,  $p = 0.019$ , partial  $\eta^2 = 0.10$ . As shown in Fig. 2, the difference between the meter-preserving and meter-violating conditions was in the expected direction in all instances except for monomusical participants tested with complex meters. Follow-up analyses explored these observations by considering the monomusical and bimusical groups separately.

For the monomusical group, the two-way interaction between meter and change was significant,  $F(1, 32) = 22.97$ ,  $p < 0.001$ , partial  $\eta^2 = 0.42$ . These participants provided higher difference ratings for the meter-violating ( $M = 4.6$ ) than for the meter-preserving ( $M = 3.1$ ) change in the simple-meter condition,  $F(1, 32) = 31.36$ ,  $p < 0.001$ , partial  $\eta^2 = 0.49$ , but slightly higher ratings for the meter-preserving ( $M = 3.4$ ) than for the meter-violating ( $M = 2.9$ ) change in the complex-meter condition,  $F(1, 32) = 3.78$ ,  $p = 0.061$ , partial  $\eta^2 = 0.11$ . For the bimusical group, the two-way interaction between meter and change was also significant,  $F(1, 22) = 5.01$ ,  $p = 0.036$ , partial

$\eta^2 = 0.19$ , but much smaller in magnitude than it was for monomusicals. Indeed, the bimusical group provided higher ratings for the meter-violating than for the meter-preserving change in both the simple-meter ( $M_s = 4.6$  vs. 3.3),  $F(1, 22) = 19.80$ ,  $p < 0.001$ , partial  $\eta^2 = 0.47$ , and the complex-meter ( $M_s = 3.8$  vs. 3.0) conditions,  $F(1, 22) = 6.90$ ,  $p = 0.015$ , partial  $\eta^2 = 0.24$ , with the interaction indicating that the difference was larger for simple than for complex meters.

A separate mixed-design ANOVA examining performance in the complex-meter condition, with group as a between-subjects variable and change as a repeated measure, revealed a robust two-way interaction between group and change,  $F(1, 54) = 10.80$ ,  $p = 0.002$ , partial  $\eta^2 = 0.17$ . The groups provided similar ratings in the meter-preserving condition,  $p > 0.2$ , but the bimusical group provided much higher ratings than the monomusical group in the meter-violating condition,  $F(1, 54) = 13.68$ ,  $p < 0.001$ ,  $\eta^2 = 0.20$ . In short, only listeners with exposure to non-Western metrical structures detected meter-violating changes in complex metrical patterns from an unfamiliar musical culture.

To examine effects of music training and bilingualism on performance, we calculated difference scores (meter-violating minus meter-preserving) separately for the simple- and complex-meter conditions. Higher scores indicated greater sensitivity to the meter-violating changes. Music lessons were uncorrelated with performance in either condition,  $p_s > 0.6$ . By contrast, participants who spoke more than one language performed better ( $M = 0.3$ ,  $SD = 1.6$ ) than monolingual participants ( $M = -0.5$ ,  $SD = 1.2$ ) on stimuli with a complex meter,  $t(54) = 2.01$ ,  $p = 0.049$ ,  $\eta^2 = 0.07$ , but not on those with a simple meter,  $p > 0.09$ .

Because bimusical listeners were more likely than their monolingual counterparts to speak more than one language, we examined whether the advantage for bimusical listeners with complex meters would remain evident when bilingual (or multilingual) status was held constant. A general linear model with two predictor variables (musical culture and language background) revealed a significant effect of musical culture,  $F(1, 53) = 7.61$ ,  $p = 0.008$ ,  $\eta^2 = 0.13$ , but no effect of language background,  $p > 0.2$ . In other words, participants' status as bimusical or monomusical influenced performance with complex meters when language status was held constant, but language status had a negligible effect on performance when musical culture was held constant. The advantage for bimusical listeners remained evident when training in Western music was included as a third predictor variable in the model,  $F(1, 52) = 8.28$ ,  $p = 0.006$ ,  $\eta^2 = 0.14$ , and neither language status nor music training made a significant contribution,  $p_s > 0.2$ .

## Discussion

We asked whether familiarity with music from more than one musical culture, or bimusicality, facilitates the perception or memory of complex metrical patterns from an unfamiliar musical culture. Adults who listened exclusively to Western music, with its typically simple metrical structures, detected metrical changes in Turkish music only when the music had a simple meter. By contrast, adults who also listened occasionally to foreign (Indian) music with a non-isochronous tactus detected metrical changes in Turkish music with complex as well as simple meter. We did not establish definitively that the performance differences arose from differences in the perception of complex metrical structures as opposed to their retention. In principle, however, greater difficulty at encoding would lead to poorer retention.

The findings extend the work of Hannon and Trehub (2005a), who reported that previous exposure to Balkan music, with its simple and complex meters, enhanced perception of novel Balkan music with a complex meter. Unlike Balkan bimusical adults, who performed comparably on simple and complex metrical patterns from a familiar musical culture, bimusical and monomusical adults in the present study performed better on simple than on complex metrical patterns from an unfamiliar musical culture. The Balkan listeners were familiar with the musical culture and with the complex meters on which they were tested. By contrast, the present bimusical listeners had no familiarity with Turkish music, modest familiarity with Indian music, and little likelihood of being familiar with the 5/8 meter used in the present study. They had occasional and unsystematic exposure to Indian music, much of it vocal in folk or semi-classical style, which is often un-metered or metrically variable (Clayton, 2000). For them, music with a non-isochronous tactus would not be as unexpected as it was for monomusical listeners.

Of course, it is impossible to claim that bimusical listeners never heard any music with 5/8 meter, but it is equally impossible to claim that monomusical listeners never heard any Western jazz or art music with a non-isochronous tactus. For example, Lalo Schifrin's theme music for the TV show *Mission Impossible* has a 5/4 time signature with a long–long–short–short tactus (3:3:2:2 ratio), and Dave Brubeck's *Take Five* has a 5/4 time signature with a long–short tactus (3:2). Thus, a more reasonable claim is that bimusical listeners had considerably more exposure to music with a non-isochronous tactus than did their monomusical counterparts. Interestingly, when U2 members Adam Clayton and Larry Mullen re-recorded the *Mission Impossible* theme for the movie version, they retained the 5/4 time signature of the original for only the first eight measures, changing it subsequently to 4/4 to make the recording danceable for typical Western listeners.



In principle, the metrical processing advantage of bimusical individuals could stem from general factors associated with implicit knowledge of two musical cultures, but the advantage was not general. Instead, it was limited to performance on the complex metrical patterns. Incidental exposure to a variety of meters or to non-metrical music may facilitate the processing of novel metrical patterns in unfamiliar musical contexts. By contrast, exposure that is limited largely to simple metrical patterns within a single musical culture seems to interfere with the processing of complex metrical patterns from a foreign musical culture.

Bilingualism, or exposure to two languages, has been associated with advantages on a variety of auditory or language processing tasks (Bialystok et al., 2008), including the acquisition of a third language (Sanz, 2000). Although the bilingual or multilingual listeners in the present study performed better on complex meters than did their monolingual counterparts, this effect was not evident when the musical culture of participants (monomusical or bimusical) was held constant. In other words, bilingualism made no independent contribution to metrical processing.

The present findings have parallels in language processing. Adults apply native-language segmentation strategies to foreign-language input, which is helpful when both languages are rhythmically or metrically similar, as in French and Korean (Kim, Davis, & Cutler, 2008), but counterproductive when the languages are rhythmically distinct, as in French and English (Cutler, Mehler, Norris, & Seguí, 1986). The presumption, in the present study, is that monomusical listeners' use of Western metrical processing strategies led to anomalous judgments in the context of Turkish music with a complex meter, in line with Western listeners' anomalous judgments in the context of Balkan music with a complex meter (Hannon & Trehub, 2005b). When the metrical organization of music seems unfamiliar or opaque, listeners may default to surface features such as sustained notes and discernible rhythmic patterns.

Most bimusical participants in the present study had immigrant parents or were immigrants themselves, which makes it likely that they were exposed to non-Western music in early childhood. It remains to be determined whether there are differential consequences of early versus late exposure to a musical culture, as there are for exposure to a second language (Flege, 2002). Multimodal aspects of experience with complex meters may also affect the performance advantage of bimusical individuals. Because of the metrical complexity of traditional Indian compositions, one performer in an ensemble commonly highlights the underlying metrical structure for the soloist by clapping or slapping his thigh on accented beats and waving his hand on unaccented beats, with that role rotating among performers (Jairazbhoy, 1995). Adults of Balkan origin in Hannon and Trehub (2005a) may have had comparable

multimodal advantages because of the use of Balkan folk-dance music.

Obviously, awareness of the meter facilitates movement to music. Conversely, movement draws attention to the meter of the unfolding music and influences pulse-finding and metrical interpretations (Su & Pöppel, 2011). For example, moving while listening to music influences infants and adults' encoding and retention of ambiguous metrical patterns (Phillips-Silver & Trainor, 2005, 2007). Prior experience of moving to complex meters, with their non-isochronous tactus, may have induced some bimusical participants to move (e.g., foot tapping) or generate movement imagery as they listened to the Turkish music. Perhaps the performance of Western listeners could be enhanced if they tapped or clapped while listening to unfamiliar music with complex metrical structure.

If listeners had simply ignored the melodic information and attended exclusively to the drumming patterns, they could have achieved errorless performance, but neither the bimusical nor monomusical listeners did so. In fact, the relatively modest performance of all listeners implies that melody is processed relatively automatically, sometimes at the expense of metrical processing, just as written words are processed relatively automatically at the expense of rapid color identification on Stroop tasks (MacLeod, 1991).

In summary, exposure to varied metrical structures from more than one musical culture, especially to music with a non-isochronous tactus, was associated with enhanced sensitivity to foreign music with a non-isochronous tactus. Within-culture facilitation may also be possible. Western jazz musicians or aficionados, who have regular exposure to complex meters, may have comparable processing advantages for Western avant-garde music or even for non-Western music featuring complex meters. Another question of interest is whether exposure to varied metrical patterns at different developmental periods has differential consequences for the parsing of unfamiliar music and the processing of its pitch and metrical patterns.

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