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OBSERVATION

Familiarity Overrides Complexity in Rhythm Perception: A Cross-Cultural Comparison of American and Turkish Listeners

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Despite the ubiquity of dancing and synchronized movement to music, relatively few studies have examined cognitive representations of musical rhythm and meter among listeners from contrasting cultures. We aimed to disentangle the contributions of culture-general and culture-specific influences by examining American and Turkish listeners' detection of temporal disruptions (varying in size from 50–250 ms in duration) to three types of stimuli: simple rhythms found in both American and Turkish music, complex rhythms found only in Turkish music, and highly complex rhythms that are rare in all cultures. Americans were most accurate when detecting disruptions to the simple rhythm. However, they performed less accurately but comparably in both the complex and highly complex conditions. By contrast, Turkish participants performed accurately and indistinguishably in both simple and complex conditions. However, they performed less accurately in the unfamiliar, highly complex condition. Together, these experiments implicate a crucial role of culture-specific listening experience and acquired musical knowledge in rhythmic pattern perception.

Keywords: music, rhythm, perception, culture

Music is a universal phenomenon that carries profound social and emotional significance to human life. In order to sing, dance, and create music, listeners must rely on cognitive representations of musical structure that arise from a combination of culture-specific listening experiences and culture-general cognitive constraints. Although universal psychological principles and innate processes appear to govern musical experience across cultures (Balkwill & Thompson, 1999; Castellano, Krumhansl, & Bharucha, 1984; Fritz et al., 2009; Krumhansl et al., 2000; Morrison, Demorest, Aylward, Cramer, & Maravilla, 2003; Schellenberg, 1996), listeners undeniably perceive, remember, and respond emotionally to music in culture-specific ways (Ayari & McAdams, 2003; Balkwill & Thompson, 1999; Drake & El Heni, 2003; Eerola, Himberg, Toiviainen, & Louhivuori, 2006; Eerola, Louhivuori, & Lebaka, 2009; Krumhansl et al., 2000; Lynch, Eilers, Oller, Urbano, & Wilson, 1991; Morrison, Demorest, & Stambaugh, 2008; Nan, Knösche, Zysset, & Friederici, 2008). A comprehensive understanding of the cognitive architecture of music therefore depends on disentangling culture-general from culture-specific processes.

An essential human musical behavior is coordinated movement to music. Across cultures, music enables group dancing, singing, marching, and performing in synchrony (McNeill, 1995; Wallin, Merker, & Brown, 2000). Such behaviors depend on perception of both the *rhythm*, which is the patterning of event onsets and the resulting temporal intervals (such as *long-short-short*) as well as the *meter*, the regular underlying pulse containing alternating patterns of strong and weak beats. In Western music, meter is composed of multiple levels of periodic structure, with each level of *isochronous* (temporally equal) intervals multiplying or subdividing other isochronous levels by two or three (Lerdahl & Jackendoff, 1983; Trehub & Hannon, 2006). Because robust metrical representations arise when event onsets in the rhythm coincide with one or more pulse levels, the intended meter constrains the rhythmic patterning of interonset intervals. Thus, simple integer ratios such as 1:1 and 2:1 arise far more frequently in isochronous Western music than complex ratios such as 5:2 or 3:2 (Lerdahl & Jackendoff, 1983; London, 2004).

Numerous studies suggest that simple ratios are easier to perceive and produce than complex ratios across a wide range of tasks (Collier & Wright, 1995; Desain & Honing, 2003; Essens, 1986;

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Essens & Povel, 1985 Fraisse, 1982; Povel, 1981; Repp, London, & Keller, 2005; Sakai et al., 1999; Snyder, Hannon, Large, & Christiansen, 2006). A dominant explanation for these "universal" simple-ratio biases is that small integer ratios are readily reduced to hierarchically related units of time, whereas complex-ratio intervals must be encoded as a chain of unrelated values, placing increased cognitive load on the listener (Drake & Bertrand, 2001; Essens, 1986; Sakai, Hikosaka, & Nakamura, 2004).

A challenge to this explanation comes from cross-cultural and developmental research, which highlights the role of perceptual experience. Not all cultures have music with exclusively isochronous meters. Throughout South Asia, Africa, the Middle East, and Eastern Europe, nonisochronous, "complex" meters with 3:2 rhythmic ratios are common (Clayton, 2001; London, 1995; Pressing, 1983). Accordingly, individuals with culture-specific exposure to nonisochronous meters do not appear to exhibit a perceptual bias for simple-ratio rhythms (Hannon & Trehub, 2005a; Magill & Pressing, 1997; Ullal, Hannon, & Snyder, 2012). In one study, listeners were first presented a "reference" melody having either an isochronous meter with 2:1 rhythmic ratios or a nonisochronous meter with 3:2 ratios. Listeners then rated the similarity (relative to the reference melody) of subsequent variations that either disrupted or preserved the original rhythm and meter. Unlike Americans, who gave higher dissimilarity ratings to disrupted than nondisrupted variations *only* in the simple-ratio, isochronous condition, Balkan listeners—for whom isochronous and nonisochronous meters are both culturally familiar—correctly rated disrupted variations as less similar in both simple- and complex-ratio conditions (Hannon & Trehub, 2005a). Infant looking time studies with the same stimuli found that 6-month-old American infants exhibit a novelty preference for disrupted variations in both conditions, whereas 12-month-olds only did so in the isochronous, simple-ratio condition (Hannon & Trehub, 2005a, 2005b). These experiments provide compelling evidence that the observed difficulties in perceiving and producing complex-ratio rhythms may arise not from universal, innate constraints, but rather from learned expectations about Western meter and rhythm that are acquired during infancy.

The above conclusion is tempered by recent findings that even 5-month-olds, who perceive disruptions in either 2:1 or 3:2 ratio contexts, fail to perceive disruptions of a highly complex, 7:4 ratio (Hannon, Soley, & Levine, 2011). Ratio complexity therefore *does* appear to constrain rhythm perception even among the youngest, least experienced listeners. This hints at the possibility that even among adult listeners for whom nonisochronous meters are familiar, we might expect to find subtle influences of ratio complexity and isochrony on rhythm perception. Unfortunately, limitations in the above studies leave such critical questions unanswered.

First, previously used tasks and stimuli were not ideal for uncovering nuanced effects of ratio complexity on rhythm perception. Disruptions were large (200–250 ms), and they occurred every measure, or cycle, of the stimulus. If detection was trivially easy for Balkan adults in both conditions, this would obscure potential advantages for simple-ratio over complex-ratio rhythms. Likewise, infant looking time procedures are not ideal for demonstrating differential performance across conditions—such paradigms reveal whether or not infants discriminate two stimuli, but they say nothing about how well stimuli are discriminated (McMurray & Aslin, 2004). Requiring adult listeners to detect smaller, more subtle disruptions would be a straightforward way of revealing potential performance asymmetries even among listeners for whom nonisochronous meters are familiar. Such an outcome would support the hypothesis that complex ratios are intrinsically challenging and thus require specific strategies (Large, 2008).

An additional limitation of prior adult work (Hannon & Trehub, 2005a) arises from the use of similarity ratings; perceptual discrimination was never directly measured. While differences in similarity ratings for two test stimuli imply discrimination, the absence of such differences does not necessarily imply a lack of discrimination. In fact, because participants never directly compared variations to each other, it is possible that they rated test stimuli not according to similarity but rather their conformity to familiar metrical structures. It is therefore important to verify that similarity ratings obtained in prior work with American listeners reflect a genuine lack of perceptual discrimination in the case of unfamiliar, complex-ratio rhythmic structures.

Finally, although developmental findings (Hannon et al., 2011) suggest that unfamiliar, highly complex ratios are challenging even to very young listeners who lack culture-specific metrical knowledge, it is still possible that prolonged exposure to nonisochronous music gives rise to a greater general tolerance for rhythmic irregularity among adults. To address this question it would be necessary to compare how accurately adult Balkan listeners perceive culturally familiar and unfamiliar complex-ratio rhythms.

The present experiment investigated the extent to which rhythm perception is influenced by universal, culture-general constraints on temporal processing, or by conformity to acquired, culture-specific cognitive representations of meter. We replicated, extended, and improved upon prior work by directly measuring discrimination among listeners from North America and Turkey. The latter group was chosen because traditional music in Turkey contains both isochronous and nonisochronous meters (Bates, 2010). Listeners decided whether pairs of melodies were the same or different. When pairs differed, the comparison melody contained a rhythmic disruption ranging from 50 to 250 ms. Parallel to prior work (Hannon et al., 2011), discrimination was compared across three metrical conditions: (1) isochronous, simple meter with a 2:1 rhythmic ratio, (2) nonisochronous, complex meter pattern with a 3:2 ratio, or (3) nonisochronous, highly complex meter with a 7:4 ratio. If rhythm processing is influenced by universal constraints, we expected performance of both groups to vary by ratio complexity. By contrast, if culture-specific metrical representations drive rhythm perception, discrimination should be predicted by culture-specific familiarity and not complexity.

Method

Participants

Participants were 75 U.S. (42 female; M_{age} = 21.3, age range: 18–60) and 75 Turkish (40 female; M_{age} = 21.3, age range: 19–28) university students with normal hearing who received course credit for participating in the experiment. Formal music training ranged from 0 to 16 years (M = 1.66) among American participants, and from 0 to 15 years (M = 2.53) among Turkish participants.[1] The majority of participants had lived in their country of residence since birth, but some were born (N = 14 American, N = 3 Turkish) or had lived (N = 15 American, N = 11 Turkish) in other countries. It is important to note that no American participants had visited Turkey or the Balkan Peninsula and none reported being familiar with music from that region. Each participant was randomly assigned to participate in the simple, complex, or highly complex conditions (N = 25 per condition per group). Additional participants (3 American, 3 Turkish) were run but excluded from the final sample for not following instructions (i.e., giving the same response on every trial, n = 4), equipment failure (n = 1), or experimenter error (n = 1).

Materials

All stimuli were derived from one Bulgarian folk melody (Geisler, 1989), used across the simple, complex, and highly complex conditions (see Figure 1). The four-measure melody was accompanied by a long-short-short drum pattern, with each drumbeat corresponding to a strong metrical position. Across conditions the long interval was 756 ms. The short interval was 378 ms, 504 ms, and 432 ms for the simple, complex, and highly complex conditions. This gave rise to long-to-short interval ratios of 2:1, 3:2, and 7:4 and time signatures of 4/4 (isochronous, typical of Western and Balkan music), 7/8 (nonisochronous, typical of Balkan music), and 15/8 (nonisochronous, rare in Western *and* Balkan music), respectively (see Figure 2).

Four standard stimuli per condition were created using a MIDI sequencer (MOTU Digital Performer 5) and recorded to AIFF format using Quicktime 7 MIDI instruments for the melodic (vibraphone) and drum (rim shot) components (30-ms vibraphone and 0-ms drum rise times). The basic melody was transposed to four different pitch levels (349 Hz, 392 Hz, 440 Hz, and 493 Hz) in each condition. On no-change trials, comparison and standard stimuli were identical but differed in pitch level. On change trials, comparison stimuli were temporally disrupted by adding 50, 100, 150, 200, or 250 ms of silence to the end of every 756-ms long interval using sound editing software (Sound Studio). Thus the absolute duration of the long interval and the disruptions were held constant across conditions.

Apparatus and Procedure

Participants were tested individually at a Mac Mini computer and presented with instructions and stimuli over headphones using Psyscope software (Cohen, MacWhinney, Flatt, & Provost, 1993).

Figure 1. One folk melody, adapted from Geisler (1989), was used in all conditions by adjusting the ratio between long and short intervals of melody and accompanying drum pattern (indicated by black dots, with "L" marking long intervals and "S" marking short intervals). In this example the melody is in the key of G (392 Hz) and the accompanying drum pattern is consistent with a simple isochronous (2:1) meter.

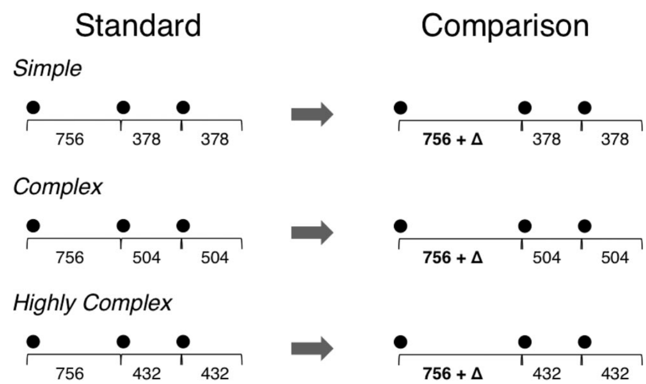

Figure 2. To left are durations (in ms) of long and short intervals of the drum pattern (back dots) in simple, complex, and highly complex conditions. The duration of the long interval remains constant across conditions (756 ms), but the short interval durations vary and thus form long-to-short ratios of varying complexity. Comparison trials are depicted on the right, where Δ represents the duration increase of the long interval, which can range from 0 to 250 ms.

On each trial, a standard stimulus preceded a comparison stimulus, and subjects responded "same" or "different" (by pressing "s" or "d"). There were 32 trials: 12 no-change trials (3 per pitch level) and 20 change trials (5 disruptions × 4 pitch levels). Trials were randomly ordered for each participant. To ensure participants understood the task, prior to the experiment they were given five practice trials with 350-ms disruptions and explicit feedback. After the experiment each participant completed a questionnaire assessing language, music, and hearing background.

Results

For each participant and change size, discrimination (d') scores were calculated from proportions of hits ("different" responses on change trials) and false alarms ("different" responses on no-change trials). We applied a log-linear correction to avoid infinite d' scores, 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, Trehub, Morrongiello, & Bull, 1988; Trehub & Hannon, 2009). Because the experiment used a roving design (i.e., stimuli varied from trial to trial), d' scores were calculated assuming a differencing strategy (MacMillan & Creelman, 2005). Because we were primarily interested in the relative pattern of performance across conditions, results for each nationality are presented separately.

American Participants

Discrimination scores (d') were submitted to a 3 × 5 (Condition [simple, complex, highly complex], between-subjects × Change Size [50, 100, 150, 200, 250 ms], within-subjects) mixed-design ANOVA. This revealed main effects of Condition, $F(2, 72) = 7.439$, $p < .01$, and Change Size, $F(4, 72) = 49.346$, $p < .001$.

[1] Amount of formal music training (in years) did not differ across conditions for either American or Turkish participants, $Fs < 1$.

There was no interaction between Condition and Change Size, $F(2, 72) = 1.004$, $p = .43$. Fisher's least significant difference comparisons confirmed higher scores in simple than complex ($p = .002$) or highly complex conditions ($p = .001$), but no difference between complex and highly complex conditions ($p = .71$). As shown in Figure 3, discrimination increased as a function of change size, and was above chance for disruptions of 100 ms or larger across conditions (see Figure 4). Regardless of change size, Americans in the simple condition showed the highest accuracy, whereas performance was lower and generally indistinguishable across complex and highly complex conditions.

Turkish Participants

A 3 × 5 (Condition [simple, complex, highly complex], between-subjects × Change Size [50, 100, 150, 200, 250 ms], within-subjects) mixed-design ANOVA revealed main effects of Condition, $F(2, 72) = 4.178$, $p < .05$, and Change Size, $F(4, 72) = 35.539$, $p < .001$, and no interaction between Condition and Change Size, $F(2, 72) = 1.659$, $p = .11$. Like Americans, Turkish participants were more sensitive to the change as it increased in size, and discrimination was above chance for disruptions 150 ms or larger across conditions (see Figure 4). Fisher's LSD comparisons indicated that scores in the highly complex condition were significantly lower than in the simple ($p < .01$), and complex conditions (marginally, $p = .056$), but indistinguishable across simple and complex conditions ($p = .362$). While there was a trend toward a simple-meter bias in the 50ms and 250ms conditions, post hoc univariate ANOVAs yielded no significant effects of condition at these disruptions sizes, $Fs(2, 72) < 2.720$, $ps > .15$.

Discussion

The pattern of results provides strong evidence that familiarity—and not ratio complexity—is the most important factor influencing rhythm perception among American and Turkish listeners. If culture-general constraints on ratio complexity were driving performance, we should have observed (1) an advantage for the complex over the highly complex pattern among Americans and (2) an advantage for the simple over the complex pattern among Turkish listeners. Instead, American listeners were equally poor at discriminating both unfamiliar rhythmic patterns, presumably because neither pattern conforms to Western metrical structures. Likewise, Turkish listeners were as good at detecting disruptions in the context of simple or complex meter, both of which are familiar in their culture.

The present experiments replicate and extend prior work in three important ways. First, by using a direct measure of perceptual discrimination, we were able to confirm that similarity ratings obtained in prior research (Hannon & Trehub, 2005a) do reflect genuine perceptual differences in processing of simple- versus complex-ratio rhythms. Replication not only establishes the robustness of prior findings, but it also demonstrates the validity of using similarity measures in research with infants and children (Hannon, 2010). Second, by using a range of disruption sizes, we were able to probe discrimination performance at various difficulty levels and thus maximize our chances of observing simple-ratio biases among Turkish listeners. Because Turkish listeners were at chance in the most difficult condition, we can now rule out alternative explanations based on ceiling effects. Third, we can unambiguously reject the hypothesis that exposure to nonisochro-

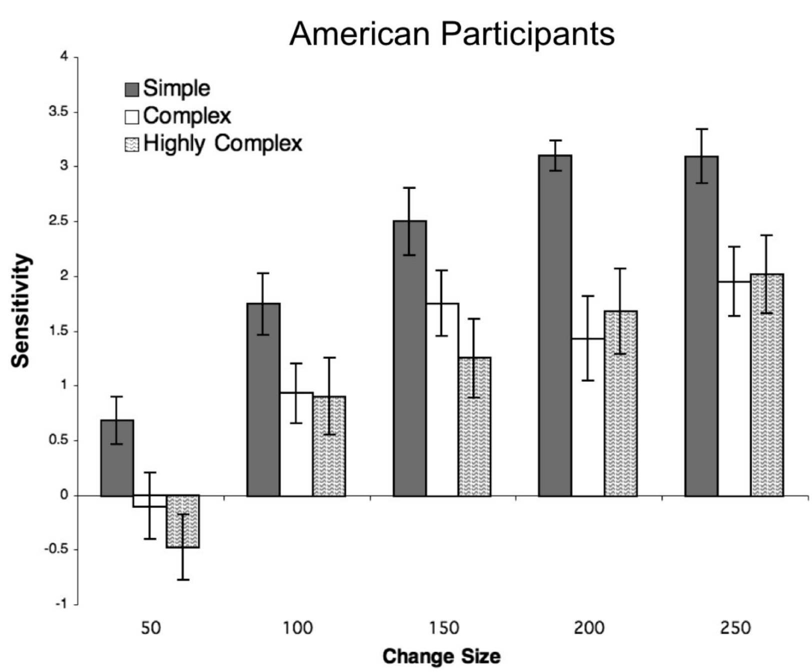

Figure 3. From Experiment 1, American participants' discrimination scores (d') across conditions for each change size (50, 100, 150, 200, 250 ms increases in the length of the 756-ms long interval of the drum pattern). Error bars represent standard error.

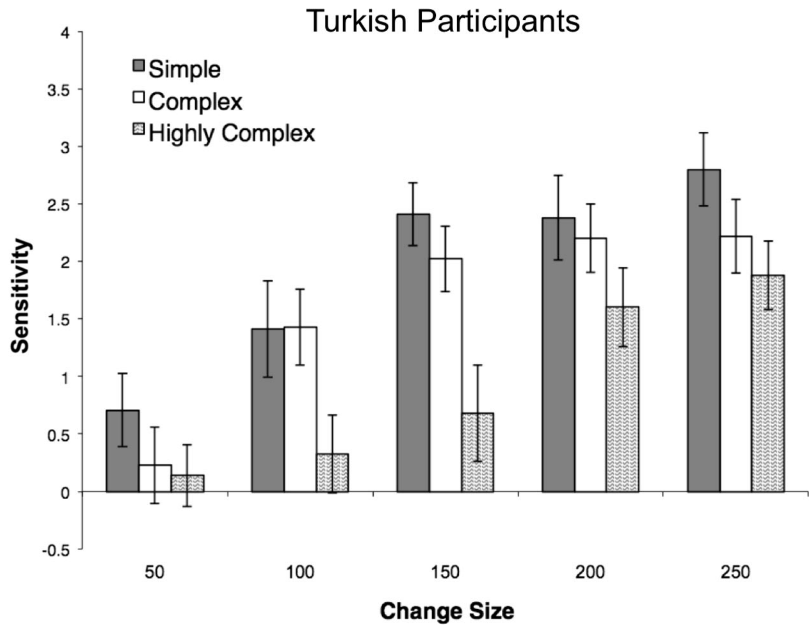

Figure 4. Data from Experiment 2, Turkish participants' discrimination scores (d') across conditions for each change size (50, 100, 150, 200, 250 ms increases in the length of the 756-ms long interval of the drum pattern). Error bars represent standard error.

nous meters gives rise to greater tolerance for rhythmic complexity, because the highly complex condition was more difficult for Turkish listeners.

The present findings provide novel empirical support for the notion that acquired, culture-specific cognitive representations of musical meter play a crucial role in temporal pattern perception, and they challenge alleged universal constraints of ratio simplicity and isochrony (Drake & Bertrand, 2001; Hannon & Trainor, 2007). If future models, theories, and empirical work attempt to account for the cross-cultural variation presented here and elsewhere, this may advance our understanding of the nature and origins of musical perception and cognition. More broadly, our results underscore the importance of considering cultural environment in the examination of any psychological domain.

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