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The Effects of cultural experience and subdivision on tapping to slow tempi

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THE EFFECTS OF CULTURAL EXPERIENCE AND SUBDIVISION

ON TAPPING TO SLOW TEMPI

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ABSTRACT

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Our ability to accurately synchronize with rhythmic patterns is constrained by two factors: temporal length and interval structure. By using strategies such as subdivision, we can improve synchronization accuracy at slow tempos, but our ability to utilize subdivisions is constrained by the nature of interval ratios contained in culture-specific subdivision types. Western music falls within a restricted temporal range and its metrical subdivisions contain simple ratios, but Indian music violates these constraints. The present study examines the effects of culture-specific experience on these constraints. American and Indian listeners were asked to perform synchronous tapping to a stimulus with a slow tempo which was accompanied by silence or by a rhythmic pattern that subdivided the inter-event interval into groups of two or three (simple), or alternating units of two and three (complex). On a subset of trials, the subdividing pattern switched halfway through the trial, from simple to simple, simple to complex, or complex to simple. Western listeners found complex patterns more challenging to reproduce, and exhibited a decrease in accuracy of synchronization whenever there was a switch away from a simple meter. By contrast, Indian listeners performed comparably across all subdivision patterns,

and exhibited a drop in accuracy whenever there was a switch. These results reflect the role of passive cultural exposure to our ability to synchronize with different metrical patterns, and have important implications for ability to form mental representations.

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CHAPTER 1

INTRODUCTION

Our ability to accurately perceive and produce temporal patterns is essential for most everyday tasks. Basic abilities such as understanding speech, recognizing tunes, dancing and tapping, turn taking in sports, and anticipating future events, are all dependent upon basic temporal processing.

Synchronized movement to music is evident in all cultures that have been studied. Anticipation, such as by tapping, dancing, or marching in time to music, is a fundamental aspect of experiencing the beat, which is inferred from the salient events in the pattern, and the tempo. Tempo can be determined either by the speed with which events unfold over time, or by the size of the temporal interval from each event onset to the following onset. This interval between onsets is defined as the inter-onset interval (IOI) (Palmer & Krumhansl, 1990; Povel & Essens, 1985). As a rich and complex stimulus, music is comprised of multiple events and IOIs, and tempo is therefore inherently subjective since the listener must infer a single salient beat – the tactus – which usually corresponds to the rate of synchronized behavior such as tapping (Cooper & Meyer, 1960, Lerdahl & Jackendoff, 1983, Clarke, 1999). The musical piece can be described in terms of its rhythm – the manner in which the durations within a sequence are organized, and the meter – an underlying pattern of weak and strong beats arising from hierarchical, nested levels of periodic structure.

According to one theoretical account, individual listeners infer the tactus and other metrical levels in accordance with their own preferred internal tempo.

Internal attentional oscillators attune to each level of the metrical hierarchy, directing attentional energy and enabling the listener to form expectations about important elements over a cycle of events (Drake, et al, 2000, Jones 1990). The oscillator associated with the tactus is known as the referent period. The process by which an oscillator aligns, or synchronizes, with each period is known as attunement.

Although synchronization to music is usually effortless and natural, a substantial body of literature suggests that our ability to accurately synchronize with rhythmic patterns is constrained by at least two factors. Firstly, if the rhythmic patterns fall outside of certain temporal range, that is, if they are too fast or too slow, then synchronization accuracy drops. Secondly, the intervals that comprise the rhythmic pattern need to be related by simple integer ratios.

One question of primary interest was whether these limitations arise from intrinsic constraints of the auditory system or from cultural exposure. Much of the research has been conducted on participants from Western cultures. Western music typically follows certain rules (Lerdahl & Jackendoff, 1983). Firstly, the beat level usually falls within an optimal temporal range between 200 and 1200 ms (van Noorden & Moelants, 1999). Secondly, the nested levels of periodic structure within Western meters are related by simple integer ratios such as 2:1 in a duple meter and 3:1 in a triple meter. Thus, much of Western classical and popular music complies with these two constraints, but it is not clear if the aforementioned constraints are the cause or the result of cultural conventions.

Much music from the Balkan Peninsula, Asia, Africa, and Latin America uses rhythmic patterns that violate the constraints of Western music. Metrical structure in Bulgaria, for instance, is characterized by alternating groups of short and long intervals in 2:3 ratios. The extent to which such ratios pose a challenge to the listener depends on culture-specific musical exposure, and Western infants, who have minimal exposure to music of any culture, have less difficulty with complex rhythmic ratios than fully enculturated Western adults (Hannon & Trehub, 2005a, 2005b). Thus, cultural exposure may account for at least some of the constraints widely observed in the literature on temporal pattern perception and production.

The present study explores the role of cultural exposure as a means of more fully understanding the nature and underlying mechanisms of temporal processing. The study focuses on Indian listeners because Indian music violates both constraints of Western music: it frequently makes use of rhythms that fall outside of the optimal temporal range, and it often deviates from simple integer ratio intervals. Therefore, if our ability to accurately synchronize with music is shaped by cultural exposure and not by constraints, then unlike Western listeners, Indian listeners should not be constrained by rhythms that are too slow or composed of complex interval ratios.

The following sections review evidence that innate constraints limit human temporal processing, that musical training and cognitive strategies can overcome these constraints, and that culture can moderate theseconstraints.

CHAPTER 2

REVIEW OF RELATED RESEARCH

Constraints on Temporal Length

Tempo, or the speed at which events occur, appears to fundamentally constrain perception and production of auditory patterns. When a rhythm is too slow, it easily falls apart and fails to stay together as a cohesive pattern. In his classic work, Fraisse (1984) uses the concept of a psychological, or spacious present to describe this phenomenon. The psychological present describes the window within which events are held together as a perceptual unit. According to Fraisse, the psychological present has an upper limit of around 2 seconds, has no fixed duration and is merely based on what is perceived, and refers to one's capacity to compile sets of events or objects. Thus, according to Fraisse (1984) all of perception takes place within a 2- to 3-second window of time, which means that perception is constrained by the temporal length of stimuli.

In order to examine the notion of optimal temporal windows, laboratory tasks examine production and perception of different interval durations. Production tasks require the participants to synchronize taps with a series of iterated intervals having a fixed IOI. The intervals can be empty (defined by onset to onset) or filled (defined by onset and offset of sound or light continuous over the entire duration). Production tasks such as sensorimotor synchronization measure the asynchrony – the deviation of the produced tap relative to the actual time of the target. A negative asynchrony indicates an anticipatory error, i.e., a tap that precedes the target, whereas a positive asynchrony indicates a reactive error, i.e., a tap that follows the target. Other tasks, termed spontaneous production tasks, either require the participant to spontaneously tap without reference to a target stimulus, at a rate that is most comfortable to them (personal tempo), or at their slowest or fastest possible rate.

Production tasks become difficult if the intervals are longer than a few seconds. When participants are asked to tap as slowly as possible, the slowest tapping tempo in adults is around 2 seconds (Drake et al, 2000). More recent studies (Repp & Doggett, 2006) have found that although there seems to be a temporal rate limit of synchronization, there do not appear to be distinct landmarks in terms of the precise temporal length when this constraint arises. Similarly, when participants are asked to reproduce a range of intervals, they do this accurately from 400 ms to 3 seconds, but underestimation errors increase with interval durations larger than 3 seconds (Pöppel, 1971). Further, the production of intervals becomes increasingly variable with longer intervals. When participants attempt to produce a range of intervals ranging from 300 to 4800 ms, there is a narrow distribution of asynchronies at the fastest tapping rates, with a mean of 0, such that most taps are clustered around the actual tone onset. At the slower tapping rates, however, the distribution of asynchronies is broader (i.e. less precisely tuned), with an overall negative mean (Mates et al, 1994, Friberg & Sundberg, 1995).

Increased cognitive load may be associated with longer intervals, suggesting that listeners use cognitive strategies such as counting or subdividing to overcome the difficulty of producing long intervals. For instance, when participants are asked to perform word memory tasks simultaneously with tapping tasks, this should prevent counting or subdivision. In such a situation, reactive errors predominate beyond IOIs of 1800 ms , with more than half of the taps (60%) reactive at 6000 ms. In particular, performing a word memory task increases the frequency of reactive taps at the longer IOIs (Miyake et al, 2004). This suggests that at smaller IOIs (faster tempos) between 450 and 1800 ms, the cognitive resource requirement is not great, whereas at longer IOIs additional resources are required, probably to implement strategies such as counting and subdividing. Performing a distractor task thus diverts attention, reducing the cognitive resources available for use in performing the tapping task.

Several perceptual tasks can be used to measure the increased cognitive resources needed to process longer IOIs. Perceptual tasks typically measure our ability to detect temporal deviations, such as lengthening (one interval is lengthened or shortened), displacement (one event is earlier or later than expected), or tempo change (length of an interval is increased or decreased). Such tasks either require the subject to detect the change or to discriminate whether two stimuli are similar or different. Given that slower tempos require greater attentional requirements, it makes sense that there would be different neural mechanisms for processing and integrating slow versus fast tempos (Pöppel , 1997, 2003; Toma et al, 2002, Giraud et al, 2000). During a temporal discrimination task in which participants are asked to attend to the duration of a target stimulus and compare it to the duration of a previously presented standard, fMRI reveals that separate areas of the brain respond to intervals longer than 3 seconds. The longer interval (3 seconds) preferentially activates the inferior parietal cortex – which is involved with tasks that require explicit attention – and the posterior cingulate, a region thought to be involved in spatial orientation and memory. Activation of these areas may reflect the increased attentional requirements associated with longer intervals (Lewis & Miall, 2003). Thus, studies of brain activity are consistent with production tasks in revealing that long intervals are difficult for listeners and require additional cognitive resources and attention.

The increased cognitive load in processing longer intervals is often reduced by employing cognitive strategies such as counting and subdivision. Subdivision appears to be an important way that listeners reduce the processing load of long intervals and overcome tempo constraints. Subdividing allows listeners to segment information into smaller, more manageable parts (Grondin, 2001). The role of subdivision is clear from studies examining explicit counting--when presented with a temporal discrimination task over standard durations of 0.8 seconds and 1.6 seconds, participants only find explicit counting helpful at the slower intervals (1.6 second intervals), with no benefit conferred on the faster intervals (0.8 second intervals).

Similar to explicit counting, antiphase tapping (essentially tapping “off beat”) seems to improve synchronization to slow tempos, presumably because it doubles the perceived tempo through subdivision. When participants were asked to tap in-phase and anti-phase over a range of tempi, mean asynchronies revealed that anti-phase tapping was more stable than in-phase tapping at slower tempi for IOIs greater than 600 ms (Semjen et al, 1992).

Consistent with counting evidence, if a longer interval is filled with intervening sounds this improves discrimination. When intervals are filled with continuous sound or “noise bursts” of computer generated tones between the onset and offsets of long intervals this provides the listener with more structure within the interval duration than with empty intervals, which only had onsets and offsets. This makes the discrimination of filled intervals more accurate than empty intervals (Rammsayer & Lima, 1991). This perhaps also explains why filled intervals, much like subdivisions (duple, triple, quadruple), aid in synchronization tapping, tempo judgment, perception, and reproduction tasks (Repp, 2008).

In summary, when presented with slow tempos that fall outside of the range of optimal temporal processing, listeners use strategies such as subdivision to overcome that constraint. An interesting possibility is that through greater exposure to slow tempos, such as in cultures with very slow music, listeners might develop specific strategies to improve their ability to make predictions and synchronize with music.

Constraints on Interval Structure

Rhythm perception and production are constrained by the nature of the interval ratios that make up a rhythm. Music does not typically consist of metronomic, isochronous sequences as described above, but rather of complex rhythmic patterns containing a combination of long and short durations. The accuracy with which listeners perceive and produce rhythmic patterns composed of intervals varying in length (such as long and short intervals) is powerfully influenced by the ratios that describe adjacent intervals within a rhythm.

For identical and iterated intervals, such as those found in many repetitive behaviors like walking, running, chewing, etc, the pattern is isochronous (Janata & Grafton, 2003). Other rhythmic patterns may consist of long and short intervals having primarily 2:1 ratios that give rise to a subjective experience of multiple isochronous metrical levels, which is typical of isochronous meters. By contrast, when patterns contain long and short intervals having more complex ratios such as 3:2, the tactus is not usually perceived as isochronous and the meter is therefore non-isochronous (Fraisse, 1982).

Numerous studies with Western listeners reveal that patterns with ratios of 1:1 (isochronous) or 2:1 are preferred, and that participants are most accurate in the production and perception of these ratios. For example, when asked to spontaneously produce rhythmic patterns, participants either produce perfectly isochronous sequences (i.e., 1:1) or rhythmic sequences with long and short intervals having a 2:1 ratio (Fraisse, 1978). Despite being encouraged to produce irregular spontaneous patterns, listeners tend to produce 2:1 or 1:1 ratios (Fraise, 1982). Participants have difficulty accurately reproducing specific rhythmic patterns composed of complex integer ratios. For example, when participants are asked to reproduce patterns composed of short and long intervals having varying ratios, the simple ratios (such as 1:1 and 2:1) are reproduced accurately, whereas more complex ratios are seemingly assimilated to 1:1 and 2:1 ratios (Povel, 1981, Essens & Povel, 1985, Essens, 1986).

Functional MRI (fMRI) evidence further supports the notion of the integer ratio constraints. Qualitative differences are observed in the brain activity depending on whether the participants are producing patterns containing simple or complex ratios (Sakai et. al.,1999). When participants are scanned prior to reproducing rhythmic patterns composed of intervals of three different durations having simple (1:2:3 or 1:2:4 ratios) or complex (1:2.5:3.5) ratios, separate brain areas are active for complex versus simple ratio patterns; the simple ratios activate left premotor and parietal areas, and complex ratio rhythms activate right prefrontal, premotor, and parietal areas. The increased prefrontal activation could result from the increased role of memory required to process complex ratio patterns. Likewise, reproduction accuracy is more variable for the complex than simple patterns. Interestingly, participants who drift towards simple ratios when reproducing complex ratios also exhibit brain responses resembling those seen during simple ratio trials.

To summarize, the above findings suggest that tempo and integer-ratio simplicity might be important constraints on perception and production of rhythmic patterns. However, a remaining question is whether such constraints arise from innate limitations of the auditory system or from learned representations. If musical training and culture-specific exposure affect performance in such tasks, learned representations may be implicated.

From Culture-General to Culture-Specific

Temporal Length

Very slow tempos tend to be difficult without strategies such as subdividing or counting, described above. In addition, individual factors such as age and music training may affect the extent to which slow tempos are optimal or suboptimal. As described above, each individual has a rate of optimal event processing or an internal referent period that generally falls within the range of 300-1000 ms. Because music is composed of complex sequences organized into multiple hierarchical metrical levels, it is generally assumed that listeners focus their attention on the metrical levels closest to their referent period. According to dynamic attending theory (Jones, 1990, Large & Jones, 1999), once listeners choose a referent level, they can then direct attention to other hierarchical levels in the musical piece, by a process called focal attending, whereby listeners can attend to faster rates (analytical attending) or to slower rates (future-oriented attending), relative to the referent level.

Our ability to perform focal attending can be shaped by factors such as music training and age. For instance, musicians spontaneously synchronize at lower hierarchical levels (i.e., slower referent levels) and have access to more hierarchical levels (greater focal attending) than non-musicians (Drake et al, 2000). This could arise because musical training explicitly focuses attention on the metric structure. In particular, music training allows listeners to acquire strategies such as subdivision and counting (Grondin, 2001) to accomplish very slow timing. This enhances the complexity of their mental representations and increases the number of hierarchical levels available to them.

When musicians and nonmusicians are asked to synchronize their taps with tone sequences ranging in tempo from 1000 to 3500 ms, nonmusicians show much larger anticipatory errors and higher variability than musicians (Repp & Doggett, 2006). Overall, musicians demonstrate higher levels of accuracy, as shown by their tendency to tap closer to the target tone, whereas nonmusicians consistently underestimate the IOI duration, as evidenced by early taps. This ability of musicians to synchronize more accurately than nonmusicians at longer intervals indicates that music training facilitates the development of strategies that enable musicians to overcome the constraint of slow tempos.

Age also shapes focal attending. Referent period and the referent level slow with age, as shown by spontaneous tapping tasks (Drake, et al, 2000a). Young children under the age of 4 synchronize more easily with a fast rate than a slow rate (Provasi & Bobin-Begue, 2003). On the other hand, older adults exhibit slower spontaneous tapping rates than do younger adults (Vanneste, 2001). Moreover, focal attending appears to increase with age. Such age-related changes could be due to maturation or learning. Interestingly, 6-year-old musicians perform in synchronization tasks like 8-year-old nonmusicians, indicating that musical training may serve to accelerate normal development of focal attending (Drake et al, 2000). More recent studies, however, show that although spontaneous motor tempo (SMT) shifts from 300 ms in young children to nearly 700 ms for adults over 75, the range of event rates that individuals can track widens during childhood and then narrows again in later life, exhibiting a quadratic profile (McAuley, et al, 2006).

Cross-cultural comparisons of Tunisian and French listeners suggest that synchronization at higher metrical levels (i.e. slower tempos) is more likely to occur when participants tap to the music of their own culture and synchronization at lower levels (i.e. faster tempos) predominates when they tap to the music of an unfamiliar culture (Drake, 2007). Thus, focal attending and the referent level may change as a function of acquired knowledge. Such knowledge could be driven by enculturation, a process by which structures are learned through everyday experiences, such as passively listening to music, singing, or dancing. Since we are constantly exposed to music (even before birth), we may gradually develop a culture-specific representation of the regularities in our culture's music that subsequently guides perception.

Interval Structure

Like nonmusicians, musicians have difficulty successfully producing rhythmic patterns having complex ratios, especially when attempting to generalize a learned rhythm to a new tempo. For example, although musicians often play pieces at faster and slower tempos in practice, they are only able to rescale rhythmic patterns at slower tempos when rhythms are composed of simple intervals ratios (Collier and Wright, 1995). When asked to rescale tempos having highly complex ratios (such as 3:4), musicians fail even with extended practice, and are only able to rescale the simplest of the complex ratios like 3:2.

Musical rhythms from North America and Western Europe contain predominantly simple-integer ratios and thus conform to proposed processing constraints on rhythm perception and production. However, rhythms from cultures in South Asia, Africa, the Middle East, and Eastern Europe violate assumptions about simple integer ratios (Clayton, 2000; London, 1995; Merriam, 1981). Ratios in music from these cultures, although complex, do not show a lack of participation in dancing, singing, and music making on the part of adults and children of all ages within these cultures (Rice, 1994).

Extensive exposure to Western rhythmic structures may give rise to powerful categorization processes that dominate performance. When presented with rhythmic variations in Western (simple-integer ratio) and Balkan (complex-integer ratio) meters, Western adults easily detect disruptions to Western meter, but have trouble detecting comparable disruptions to Balkan meters. However, Bulgarian and Macedonian adults show no such asymmetry, and can detect disruption in either meter with equivalent ease, presumably because of their life-long exposure to both simple and complex meters (Hannon & Trehub, 2005a). Similar to the performance by Bulgarian adults, 6-month-old Western infants treat disrupted variations as more novel than non-disrupted alterations in both Western and Bulgarian contexts when tested using a familiarization-preference procedure. Similarly, 6 to 8 month old infants who have extensive exposure to duple meters through music classes show a preference for duple meters over triple meters, whereas infants who have not had the same exposure show no such preference (Gerry et al, 2009). This implies that exposure to certain musical patterns through music classes can accelerate the development of culture-specific metrical perception. These results suggest that culture-specific fine-tuning causes a shift in performance from culture-general (ability to perform equally well over cultures) to culture-specific (differential ease of performance for one's own culture over another) by adulthood.

The above findings indicate that supposed constraints might not be inherent to human auditory processing, but rather acquired through exposure to a specific musical culture and the development of culture-specific metrical representations. Thus, Western music, which contains primarily simple integer ratios such as 1:1, 2:1 and 3:1, might lead us to specialize in only those ratios.

From research on Western listeners, metrical patterns composed of simple integer ratios appear to be more easily perceived and reproduced than those composed of complex integer ratios, even for highly trained musicians. However, the role of culture seems to be extremely important, with musical exposure altering the nature of the constraints.

Thus, both of the supposed constraints seem to be susceptible to modification: via music training or cognitive strategies in the case of tempo constraints and via cultural exposure in the case complex ratios. Given that Indian music violates both these constraints, it provides an interesting means of examining the role of culture in basic temporal processing constraints.

An Overview of Rhythm and Tempo in Indian Music

Temporal Length in Indian Music

Talas, or cyclically repeating time measures, help organize rhythm in Indian music. Indian music theory historically places great emphasis on the accurate and unambiguous measurement of time (Clayton, 2000). Matras are the individual beats that make up a tala. There are seven recognized tempos or layas, Ati vilambit (very slow), Vilambit (slow), Madhya vilambit (medium slow), Madhya laya (medium or natural tempo), Madhya drut (medium fast), Drut (fast), Ati drut (very fast). By convention Madhya laya tends to be played at one beat/second. Vilambit corresponds to half of this rate (2 seconds between consecutive beats). Ati vilambit corresponds to half of vilambit (4 seconds between consecutive beats). These terms describe the duration between two beats, but because the tala is composed of a cycle of beats, its duration is much longer, usually around 10 seconds (Naimpalli, 2005).

Since a 3-second IOI duration has been reported to be too slow for accurate motor production, it makes sense that such slow tempos should give rise to decreased synchronization accuracy (mean distance of tap from beat) and precision (variability of tap position relative to the beat). However, if individuals spend a lifetime tapping to music composed of such slow tempos, it is possible Indian adults might learn to subdivide long intervals according to the temporal organization of their culture's music, which would help them synchronize with slow tempos.

Interval Structure in Indian Music

Indian rhythms often consist of beat levels that defy Western conventions of isochrony at multiple metrical levels. For instance, the commonly heard jhaptal is composed of 10 beats in a 2+3+2+3 pattern with a distinct short-long-short-long beat pattern. Clayton (2000) suggests that such metrical construction may be related to other phenomena prevalent in the culture, such as speech prosody in languages like Hindi and Sanskrit, and to dance rhythms where long beats correspond to “heavy” dance steps. Thus, like Eastern European, Middle Eastern, and African, Indian music defies Western conventions of metrical isochrony and simple interval ratios (London, 2004).

The current study examined the role of cultural exposure on accurate synchronization with temporal patterns that contain complex-integer ratios and extremely slow tempos. As discussed above, Indian music violates both tempo and ratio constraints presumed to influence human temporal processing independent of experience. Comparison of listeners from North America and India provides a unique opportunity to examine whether or not exposure to Indian music allows listeners to overcome proposed constraints. A strong possibility is that listeners’ difficulties with slow tempos and complex ratios are shaped primarily by cultural context, and are not innate but rather acquired. Therefore, Indian adults, who are accustomed to complex-integer ratios and slow tempos through exposure to Indian music might not be limited by the temporal and ratio constraints that are seen among Western adults.

The current study measured how listeners from contrasting cultural backgrounds synchronize their tapping to long intervals that fall outside of an optimal temporal range. In addition, the experiments investigate the extent to which listeners benefit from the presence of intervening subdivisions that do or do not contain simple-integer ratios. Western adults, whose musical exposure is generally limited to metrical intervals between 200 and 1200 ms and simple-integer rhythmic ratios, should experience difficulty synchronizing to intervals of 3000 ms without subdivisions. Relative to their performance for such long unfilled intervals, Western listeners should benefit from the presence of subdivisions that conform to Western, simple-integer ratio patterns. If, however, rhythmic and metrical processing capacities are shaped by cultural factors, then Indian listeners with exposure to slow tempos and complex metrical structures should outperform Western listeners in their synchronization to long intervals in the absence of subdivisions, and they should benefit from subdivisions containing either simple-integer or complex-integer ratios.

CHAPTER 3

METHODOLOGY

Study Overview

Listeners were asked to synchronize their taps with a cycle of 3 seconds in duration. Given the evidence reviewed above, in the absence of subdivisions such a task should be inherently challenging, although culture-specific experience with slow tempos might lead to greater synchronization accuracy among Indian listeners than among Western listeners. In addition to synchronizing their tapping to unfilled 3-s intervals, listeners also synchronized to subdivided 3-s intervals (filled trials). On filled trials, 3-second intervals contained 12 equally spaced events with intensity accents that promote simple- or complex-integer ratio metrical patterns. Participants were told to ignore the subdivisions, but the presence of subdivisions was nevertheless expected to enhance synchronization accuracy, at least when subdivisions conform to simple-integer ratios. A question of interest was whether or not Indian listeners would benefit from simple-integer ratio subdivisions as well as from complex-integer ratio subdivisions. Thus, comparison of tapping during unfilled and filled intervals having various types of subdivision was expected to reveal potential benefits of subdivision and constraints on the nature of such subdivisions (e.g. composed of simple and complex-integer ratios).

On a subset of filled trials, the subdivision pattern was suddenly switched halfway through the trial. The cost of switching between various meters was expected to reveal the strength of the metrical representation prior to the switch.

It has been well documented that stronger representations are more useful than weaker representations when the representations can be used. However, in situations where the representation needs to be reorganized and discarded, a stronger representation is more resistant to change. This phenomenon has been used to study various concepts, such as the Implicit Association Task (Greenwald, et al, 2003) and the cued spatial orientation task (Posner, 1980). In all these tasks, the strength of representation is studied by administering tasks that require the participant to disengage the representation.

With unfilled, filled baseline, and filled switch trials, the present design allowed us to address the extent to which cultural experience affects two temporal processing constraints: tempo and ratio simplicity. If tempo constraints are influenced by culture, Indian listeners should perform better than American listeners on unfilled trials. Additionally, if simple-meter and complex-meter subdivisions both improve the synchronization accuracy of Indian listeners relative to unfilled trials, whereas Americans only benefit from simple subdivisions, this would implicate an important influence of culture. Finally, the strength of the underlying representations of simple- vs. complex-meter subdivisions (and associated metrical hierarchies) was investigated by looking at the effects on accuracy of a sudden switch in the accompanying subdivision pattern, assuming the a greater cost of switching would reflect stronger representations of the metrical structure perceived prior to the switch. Overall, our results were expected to illuminate basic questions about the nature of human temporal processing constraints - whether such constraints are readily modified by cultural experience.

Participants

Indian listeners were recruited from Bangalore, India and American listeners were recruited from Las Vegas, NV (USA). Indian listeners were invited via word-of-mouth from a university (Karnataka Chitrakala Parishat) to volunteer their participation. American listeners were invited from the Department of Psychology at University of Nevada, Las Vegas, to participate for course credit in Psychology classes. None of the participants claimed to have hearing problems. Information on music training was gathered in the background questionnaire.

Demographics

Fifty-one participants were recruited for each group. For the Indian participants (18 male, 33 female), the mean age was 22.6 years. The average number of years of music training was 4.7 years (range: 0 years – 15 years). For the American participants (14 male, 35 female, 2 undisclosed), the mean age was 23.2 years. The average number of years of music training was 3.4 years (range: 0 years – 7 years).

Stimuli

A target sequence of isochronous tones at 0.33 Hz (i.e., 3-second inter-onset intervals) consisted of a 100-ms sine tone with a fundamental frequency of 500 Hz. On unfilled trials, the 3-s interval between tones was silent. On filled trials, the target tones were accompanied by a rhythmic pattern that subdivided the 3-s interval into 12 basic 250-ms units of time. Three different arrangements of these 12 units were created through periodic intensity accents. The intensity accents were created using two different timbre settings of the tabla (Indian drum) on Swarsystems. The accented beat was established with a tali (downbeat) at 80 dB. The unaccented beat was established with a khali (upbeat) of 40 dB. The first two arrangements approximated simple meters: a simple duple (intensity accent on every second beat) and a simple triple (intensity accent on every third beat). The third arrangement consisted of complex subdivisions with intensity accents that occurred on the first, fourth, sixth, eighth, and eleventh beats and created alternating groups of two and three beats. Figure 1 provides a schematic diagram of how the three metrical arrangements are structured.

A MIDI sequencer and sampler, Swarsystems, was used to create the sound patterns in the filled trials using the tabla instrument. MIDI sequences were transformed to AIFF using Audacity, a digital audio editor application.

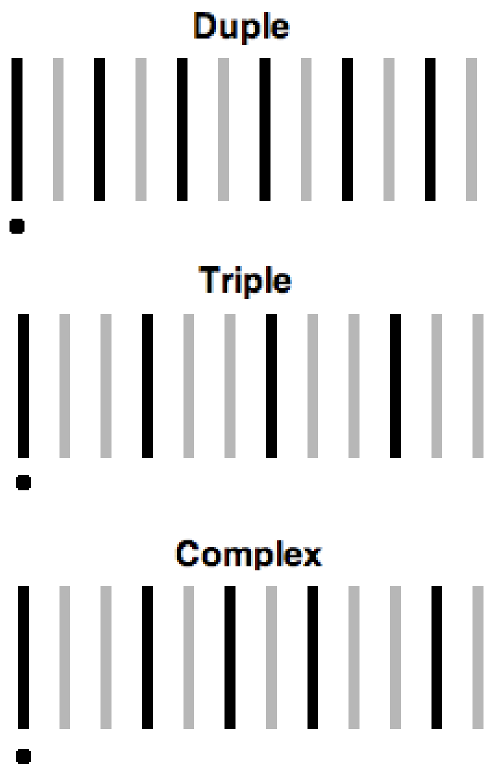

Figure 1: Schematic diagrams of the three metrical forms. Dots represent the target tap position for synchronization. Vertical bars represent beat locations, and darker shading represents intensity accents.

Each trial consisted of ten 3-s cycles for a total duration of 30 seconds. On unfilled trials, the stimulus consisted of 10 target events with an IOI of 3 seconds separated by silence. Filled trials were identical to unfilled trials except that intervals between target events were filled with one of three accompanying rhythms, as described above. There were two types of filled trials: “switch” and “no-switch.” On no-switch trials, the accompanying rhythm remained constant throughout all 10 cycles, yielding three types of no-switch trials (duple, triple, complex). On switch trials, the target was accompanied by one rhythm (triple, duple, or complex) for five cycles and a different, contrasting rhythm for the remaining five cycles, yielding six types of switch trials (duple-triple, duple-complex, triple-duple, etc., see Figure 2). Figure 2 summarizes the different types of filled trials. Stimuli were presented over stereo headphones by a Boss Micro-BR Roland Digital Recorder, which also simultaneously recorded taps.

		Starting Meter		
		Duple	Triple	Complex
Ending Meter	Duple	duple-duple	triple-duple	complex-duple
	Triple	duple-triple	triple-triple	complex-triple
	Complex	duple-complex	triple-complex	complex-complex

Figure 2: Different filled trial types. "Starting meter" is the metrical structure of the first five cycles, "Ending meter" is the metrical structure for the last five cycles. Shaded boxes indicate the trials where the Starting meter is the same as the Ending meter (non-switch trials).

Procedure

Participants were instructed to synchronize with the repeating target tone, starting with the second presentation of the tone. They were instructed to continue tapping at the same tempo throughout the sequence, and to ignore all sounds other than the target tones. They were given explicit instructions to predict the taps, and not react to them.

Participants were instructed to tap on a digital recorder, which recorded the sound of their taps as a waveform. They were instructed to tap using the index finger of their dominant hand on a specially marked spot on the digital recorder. The participants had full view of the recorder, and could see their hand tapping. The experiment began with a practice trial, during which the participant practiced tapping to a filled stimulus by focusing on the target tone and ignoring other accompanying tones. The specific subdivision type used for practice was randomly picked. The participants could repeat practice if they wanted to. Following practice, the experiment progressed in three blocks. The first and last blocks were comprised of unfilled trials. The middle block presented 18 filled trials with switch and no-switch filled trials intermixed (with each type of 6 switch and 3 no-switch trials presented twice). The order of presentation was pre-determined and counter-balanced, with the constraint that the same trial was never repeated consecutively. Each participant was given a unique order of trials.

CHAPTER 4

RESULTS

Tap times were defined by the temporal position (in milliseconds) of sound peak of the maximum amplitude in the digital recording of taps relative to the start of the trial. Three measures of tapping performance were derived: Absolute Asynchrony, Relative Asynchrony, and Coefficient of Variation (CoV). For Relative Asynchrony, tone tap asynchronies were computed by subtracting the tap time from the target time, such that a negative asynchrony would indicate the tap preceded the target tone. For Absolute Asynchrony, the absolute deviation from target was computed without regard to the direction (absolute value of the difference). Finally, CoV was calculated by dividing the standard deviation of the produced intervals by the mean of the produced intervals (McAuley et al, 2006, Grondin & Killeen, 2009). This gave us an index of variability independent of deviation error. Low CoV values indicated consistent production of an iterated interval over the course of the trial, regardless of whether or not the produced interval was consistent with the target interval.

For the baseline trials, Absolute and Relative Asynchronies and CoV were calculated for the entire length of the trial. For the switch trials, the post-switch taps (after switch) were compared to the pre-switch taps (before the switch). The pre-switch taps were all the taps till the tap coinciding with the switch, and the post-switch taps were all the taps following the switch. For the asynchronies, the last three taps pre-switch taps were compared to the first three post-switch taps.

For the CoVs, all the intervals before the switch were compared to all the intervals following the switch.

Baseline Trials

The unfilled and filled baseline trials were analyzed separately. In addition, the unfilled trials were compared to the filled (no switch) trials to determine whether subdivisions gave rise to higher accuracy. The data from the unfilled trials are presented first, followed by a comparison with baseline trials.

Unfilled Trials

Relative Asynchrony

A 2-way Trial Time (beginning vs. end of experiment) by Nationality (American vs. Indian) mixed design Analysis of Variance (ANOVA) was performed on mean relative asynchrony (Figure 1). There was no main effect of Trial Time, F (1,100) = 1.065, p = 0.305, Nationality, F (1,100) = 0.007, p = 0.931, and no Trial Time X Nationality interaction, F (1,100) = 1.587, p = 0.211. As shown in Figure 3 below, both groups underestimated the interval at both sessions (Americans: M = -111.92, SD = 165.01, Indians: M = -109.21, SD = 153.41).

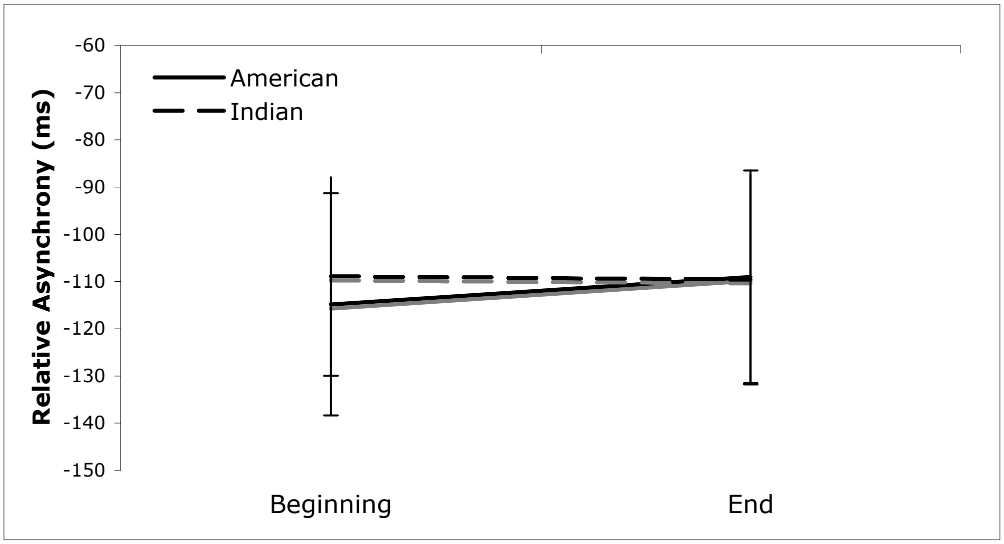

Figure 3: Relative asynchrony at beginning and end of experiment. Error bars denote standard error.

The Relative Asynchrony measure thus showed that when synchronizing with unfilled trials, both the groups performed comparably, with an overall negative mean. These results have two implications: firstly, they demonstrate that Indian listeners, who had passive cultural exposure to music that employs slow tempos, were not more accurate than American listeners, who had limited exposure to slow tempos. Earlier studies have found that explicit music training improves tapping to slow tempi, presumably due to the improvement in memory for rhythm and temporal integration over large time spans that music training bestows (Grondin, 2001). Our results, however, demonstrated that passive, culture-specific exposure to music with slow tempos did not produce an advantage. The second implication of these results is that both groups had a strong anticipatory tendency, as indicated by the negative means, which likely reflects an underestimation of the IOI (Wohlschlager & Koch, 2000). Negative asynchronies for long IOIs have been reported in prior studies (Aschersleben, 2002), but other studies have reported positive asynchronies, or tapping after the target, which may indicate a reactive strategy in which individuals are not synchronizing through prediction, but rather reacting to tones as they occur (Miyake, 2004). Our instructions could explain the higher rate of negative synchrony on unfilled trials, because participants in the present experiment were explicitly instructed to predict, not react, to tones. Overall, these results suggest that when asked to synchronize with a slow tempo, both Indian and American participants tended to underestimate the intervals, leading to increasing anticipatory errors and negative asynchronies.

Absolute Asynchrony

Similar to the above analysis with Relative Asynchrony, a 2-way Trial Time (beginning vs. end of experiment) by Nationality (American vs. Indian) mixed design ANOVA was performed on Absolute Asynchrony. There was a main effect of Trial Time, $F(1,100) = 7.222$, $p < .01$, with an overall decline in Absolute Asynchrony from the beginning (M = 197.33, SD = 14.37) to the end of the experiment (M = 191.35, SD = 16.14). There was also a main effect of Nationality, $F(1,100) = 6.950$, $p = .01$, with American listeners showing larger asynchronies overall (M = 196.93, SD = 10.06) than Indian listeners (M = 191.75, SD = 9.81) (see Figure 4).

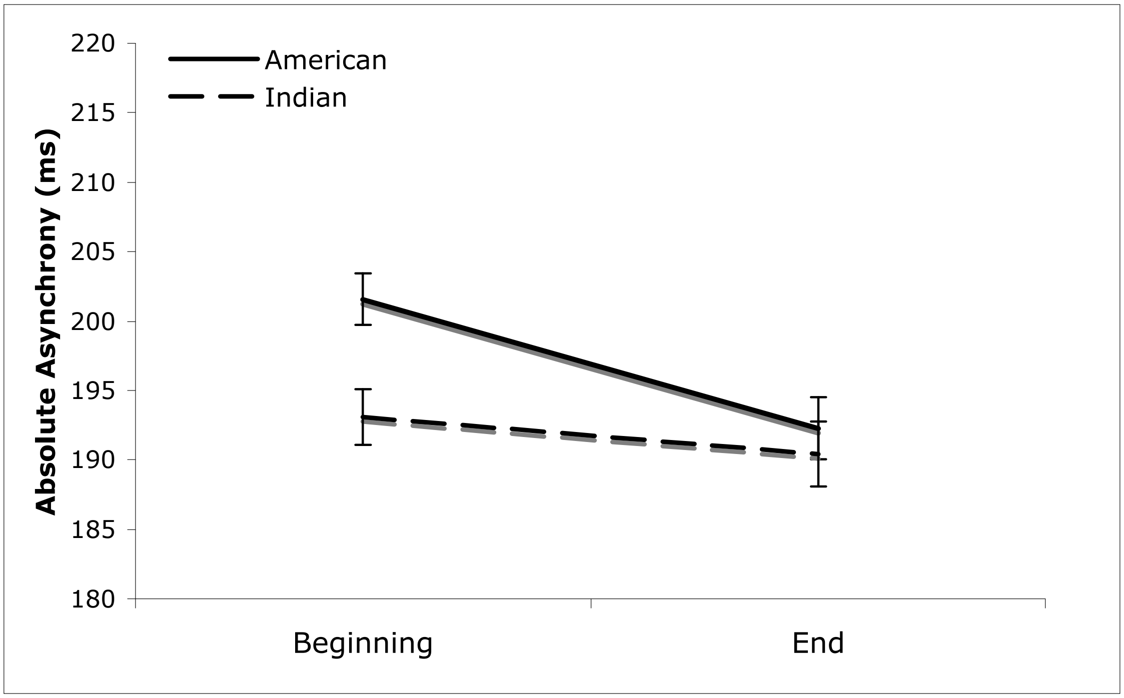

Figure 4: Absolute asynchrony at beginning and end of experiment. Error bars denote standard error.

These measures of Absolute Asynchrony showed that synchronizing to a slow unfilled sequence was better at the end of the experiment than it was at the beginning. It is thus possible that through the course of the experiment, the participants developed strategies of subdivision (such as those heard over the course of the trials), and used them to overcome the difficulty of synchronizing to the slow tempi. For Absolute Asynchrony, Indian listeners had lower asynchronies than American listeners, a finding that was not observed in the analysis of Relative Asynchrony.

Coefficient of Variation

A 2-way Trial Time (beginning vs. end of experiment) by Nationality mixed ANOVA was performed on the dependent variable CoV. There was a main effect of Trial Time, F (1,100) = 11.552, $p < 0.01$, with overall CoV increasing from the beginning (M = 0.024, SD = 0.011) to the end (M = 0.030, SD = 0.015) of the experiment (Figure 5). There was also a marginally significant main effect of Nationality, F (1,100) = 3.752, $p = 0.056$, with lower CoV means observed for American listeners (M = 0.025, SD = 0.0076) than for Indian listeners (M = 0.0288, SD = 0.011), and a greater relative increase in CoV over the course of the Experiment as shown by a marginally significant Trial Time X Nationality interaction, F (1,100) = 3.410, $p = 0.068$.

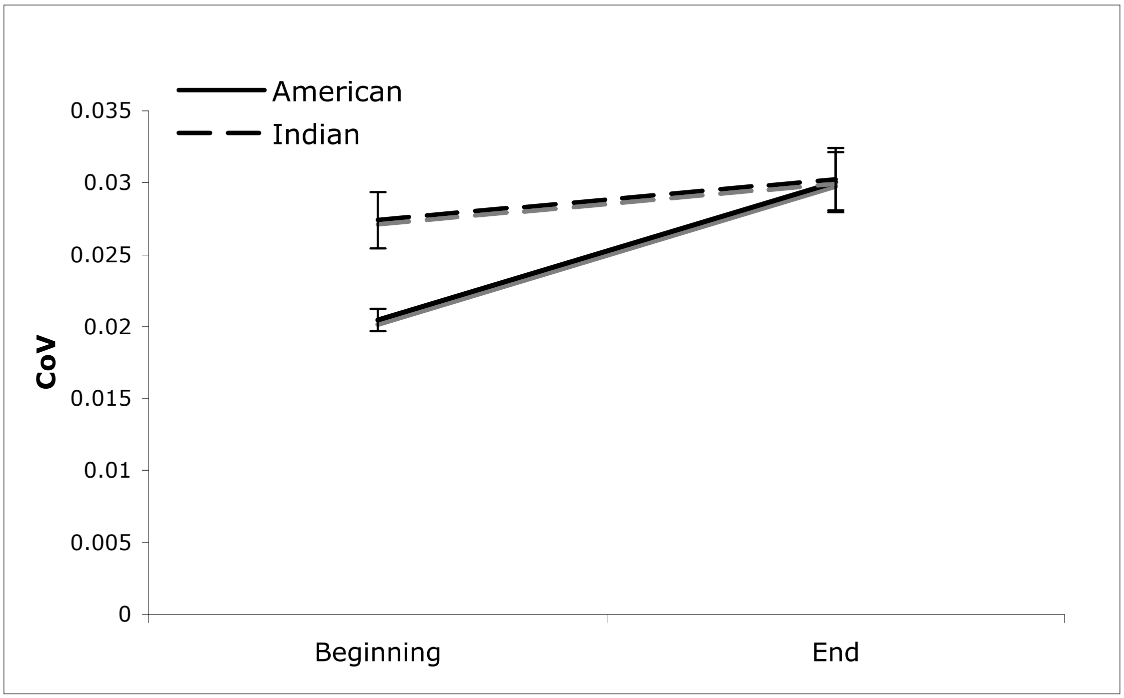

Figure 5: Coefficient of Variation for unfilled trials at beginning and end of experiment. Error bars denote standard error.

Overall, American participants were less variable than Indian participants, especially at the beginning of the experiment (Beginning – Americans: M = 0.020, SD = 0.0054, Indians: M = 0.027, SD = 0.014; End – Americans: M = 0.030, SD =

0.015, Indians: M = 0.030, SD = 0.015). This supports the interpretation that Indian participants were closer to the target, as indicated by their lower absolute asynchronies, perhaps because they were more variable than were American listeners. In other words, American listeners synchronized more consistently, although less accurately, than did Indian listeners. The measures of CoV also showed an effect of Position, such that overall, the participants had a higher asynchrony on the trials at the end of the experiment than on the earlier trials. To the extent that measures of asynchrony and variability in tapping performance reflect accuracy of processing, one obvious prediction is that both asynchronies and variability should be lowest for the group with greater culture-specific exposure to very slow tempos--the Indian participants. However, taken together our three dependent measures do not confirm this prediction, because although absolute asynchronies were lower for Indian than for American participants, variability was higher among Indian than American participants, and no group differences were found for relative asynchrony. Thus, the present results might indicate some cultural differences in tapping to slow tempos, but none of the results clearly indicate that one group is more accurate or has a general advantage over the other.

Filled Trials

Relative Asynchrony

To investigate whether the presence of subdivisions affected performance we compared filled baseline trials to unfilled trials using our three measures of asynchrony and variability. The asynchronies for the two Positions (beginning vs. end of experiment) of unfilled trials were averaged for these calculations. A mixed design ANOVA was performed on Relative Asynchrony, with Trial Type (duple, triple, complex, unfilled) as a within-subjects variable and Nationality (Indian, American) as a between-subjects factor. There was a significant main effect of Trial Type, $F(3,300) = 106.641$, $p < 0.001$ (Unfilled: M = -110.57, SD = 157.99, Duple: M = 42.38, SD = 43.10, Triple: M = 48.76, SD = 37.83, Complex: M = 74.61, SD = 69.26). Examination of Figure 6 reveals that asynchronies were negative in the unfilled trials (M = -110.57, SD = 157.99) but positive during filled trials (M = 55.25, SD = 50.07), suggesting that underestimation errors were prevalent for unfilled but not for filled trials. There was no main effect of Nationality, $F(1,300) = 6.203$, $p = 0.014$, but there was a marginally significant Trial Type X Nationality interaction, $F(1,300) = 2.335$, $p = 0.074$. To explore this interaction, post-hoc t-tests compared performance of Indian vs. American participants, separately for each type of filled trial. There were significant group differences only for complex meter, $t(100) = 9.096$, $p < 0.001$, but no significant group differences for duple, $t(100)= -1.082$, $p < 0.282$ or triple, $t(100) = 1.594$, $p = 0.114$. The significant group differences in the complex meter condition reflect greater relative asynchronies for the American group (M = 122.97, SD = 46.53) than for the Indian group (M = 55.33, SD = 25.60) (See Figure 6). Thus, American and Indian listeners performed comparably in all conditions except the complex-meter subdivision condition, in which Americans made more errors than did Indians.

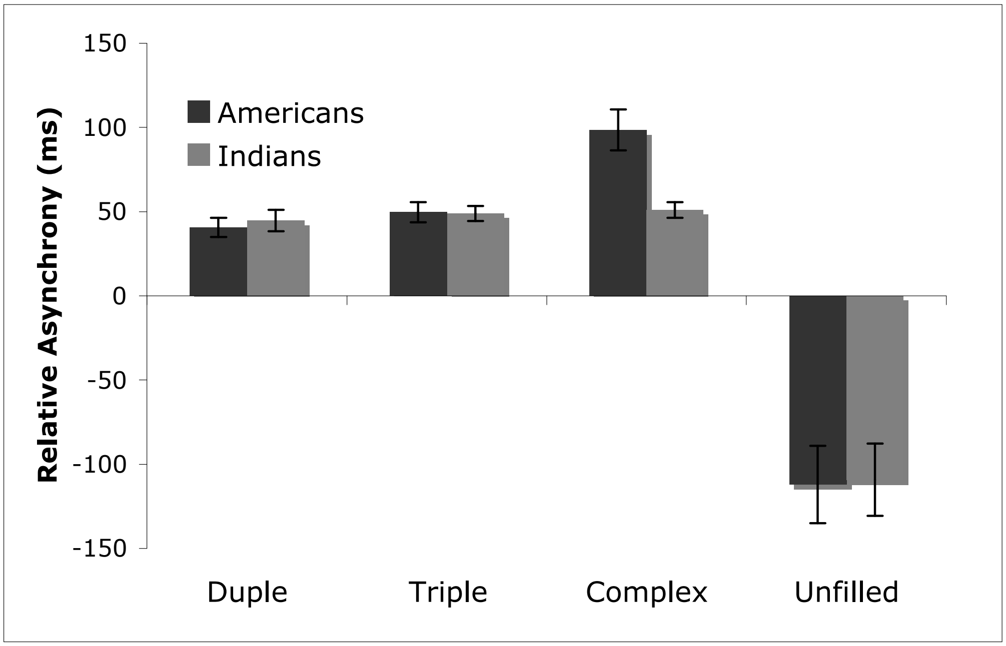

Figure 6: Relative Asynchrony for baseline trials. Error bars denote standard error.

The above results suggest that relative to unfilled trials, both groups benefited from subdivisions on filled trials. This is indicated by the shift from negative to positive asynchronies on unfilled vs. filled trials, respectively. This indicates that even though listeners were explicitly instructed to ignore them, the presence of subdivisions helped participants tap closer to the target rather than before it. One possibility is that listeners are simply more accurate at processing filled than unfilled intervals (Rammsayer & Lima, 1991). According to this theory, regardless of the nature of subdivision, performance should be better whenever any sort of sound is present during the long interval. An alternative possibility is that the subdivisions confer an advantage because they encourage the use of strategies such as metrical subdivision. If the strategic use of subdivisions enhances performance, then cross-cultural differences should be evident when some types of metrical subdivision are familiar and others are unfamiliar. The two groups performed equally well on the two simple meters (duple and triple), two familiar metrical structures, but there was a group difference when the subdivisions were consistent with complex meter, a metrical structure only familiar to the Indian group. This is consistent with conclusion that familiarity of the subdivision structure mediates subdivision benefits.

Absolute Asynchrony

The same analysis of baseline filled and unfilled trials was performed on the depending measure Absolute Asynchrony. A mixed design Trial Type (duple, triple, complex, unfilled) by Nationality (Indian, American) ANOVA revealed a main effect of Trial Type, $F(1,300) = 1123.421$, $p < 0.001$, a main effect of Nationality, $F(1,300) = 2768.826$, $p < 0.001$, and Trial Type X Nationality interaction, $F(3,300) = 41.333$, $p < 0.001$). Consistent with the analysis above, Absolute Asynchronies were greater for unfilled (M = 194.33, SD = 10.28) than for filled trials (M = 67.41, SD = 32.53). Additionally, Americans had larger overall asynchronies (M = 138.04, SD = 19.87) than Indians (M = 123.71, SD = 17.48). To explore the interaction, post-hoc t-tests comparing Indian and American listeners were performed separately for each type of filled trial. Again, significant group differences were found only for the complex meter condition, $t(100) = 3.648$, $p < 0.01$, but not for duple, $t(100) = -0.507$, $p = 0.412$, or triple, $t = -0.017$, $p = 0.186$. The group differences in the complex meter condition reflected that Americans had higher absolute asynchronies (M = 122.97, SD =46.27) than did Indians (M = 55.33, SD = 25.60), which accounted for the main effect of nationality since no group differences were found for any other condition. (See Figure 7).

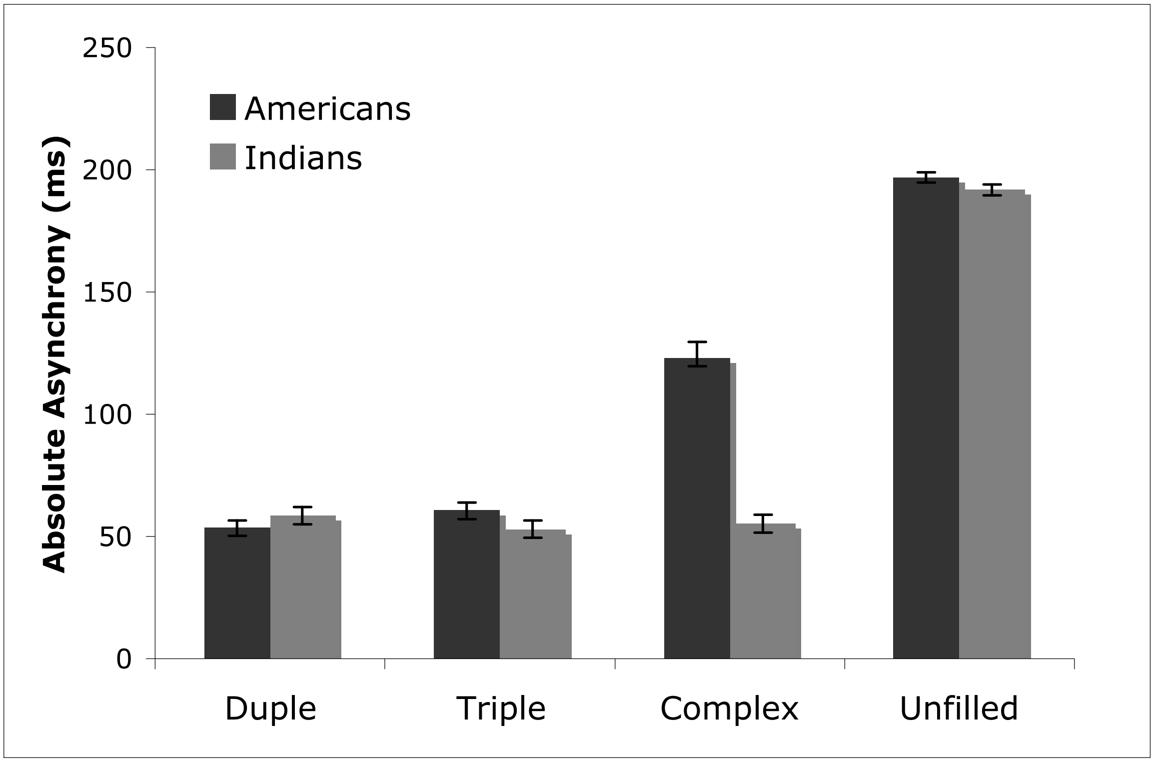

Figure 7: Absolute Asynchrony for baseline trials. Error bars denote standard error.

Coefficient of Variation

A mixed design Trial Type (duple, triple, complex, unfilled) by Nationality (Indian, American) ANOVA was performed on the dependent measure CoV . There was a significant main effect of Trial Type, $F(1,300) = 170.885$, $p < 0.001$ and a marginally significant effect of Nationality, $F(1,300) = 3.816$, $p = 0.054$. There was no significant Nationality X Trial Type interaction, $F(3,300) = 1.281$, $p = 0.281$. As can be seen in Figure 8, CoV was higher in unfilled (M = 0.027, SD =

0.0094) than in filled trials (M = 0.011, SD = 0.0049), and as was reported separately above, Americans had a lower CoV (M = 0.014, SD = 0.0087) than did Indian listeners (M = 0.016, SD = 0.0099) (See Figure 8).

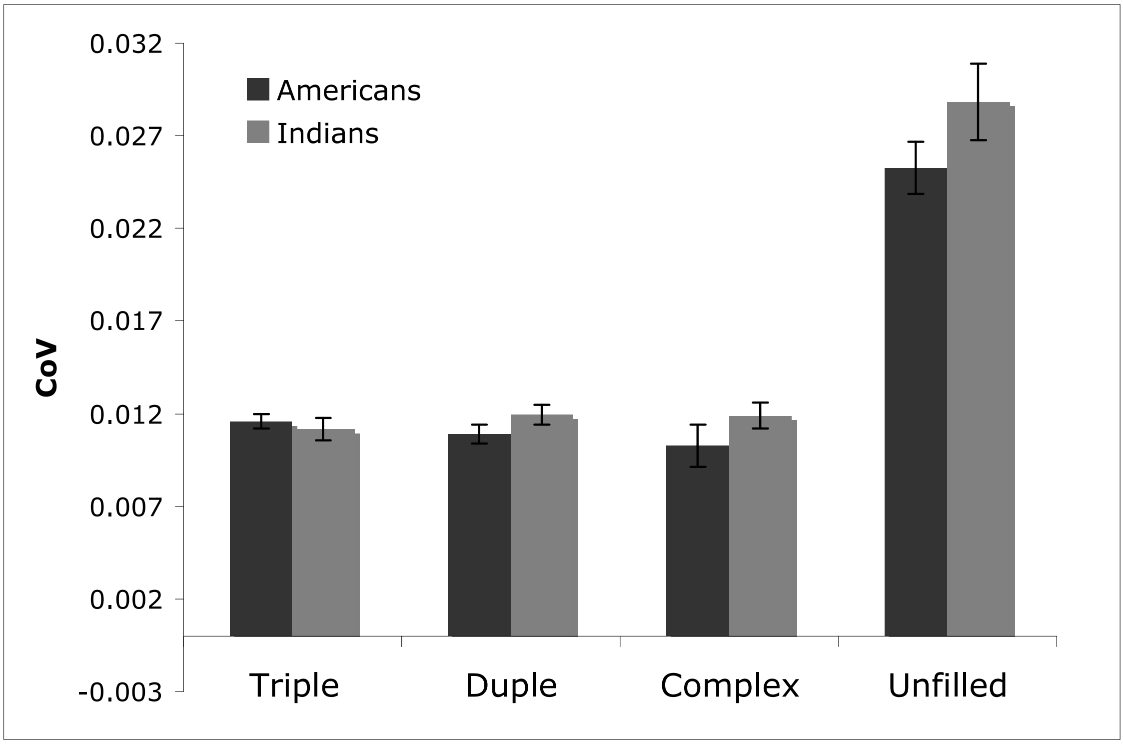

Figure 8: Coefficient of Variation for baseline trials. Error bars denote standard error.

Together, both relative and absolute asynchronies indicate greater error on the unfilled trials than on filled trials. Further investigation into the CoV on each type of subdivision indicated no difference in variability between each metrical type. Thus, although our results on asynchrony showed that the two groups differed on measures of accuracy, our results on CoV demonstrated that in terms of variability, there was no difference. This replicated the findings from the earlier section on CoV on unfilled trials, where overall, accuracy and variability seem to be independent of each other.

Overall, our results on the comparison of filled versus unfilled trials demonstrated an overall increase in asynchrony and decrease in variability in the filled conditions compared to the unfilled conditions. The Indians performed equally well on all three meters in terms of their Asynchronies, however, the Americans performed better on the simple meters versus the complex meters.

Switch Trials

The above analyses of filled and unfilled baseline trials gave us some indication that Americans and Indians were able to utilize metrical subdivisions in a culture-specific manner. However, it is nevertheless unclear whether or not these group asymmetries arise because of true metrical representations or merely because of familiarity with the various types of subdivisions. If indeed enhanced performance arises from true metrical representations, activation of a strong metrical representation should give rise to costs in performance when mental reorganization is necessary because of a change in the metrical subdivision. Thus, switching metrical subdivision half-way through the trial should provide valuable information about not only whether or not true representations are being utilized, but it also should give an indication of the strength of these representations, since the stronger the representation, the more resistant it should be to reorganization.

Relative Asynchrony

Figure 9 and 10 present the relative asynchronies at all positions for Indians and Americans respectively. The dashed vertical line denotes the point of meter switch. The Indian participants seemed to perform comparably across conditions. Importantly, there appeared to be a substantial, and comparable increase in relative asynchrony regardless of the nature of switch (see Figure 9).

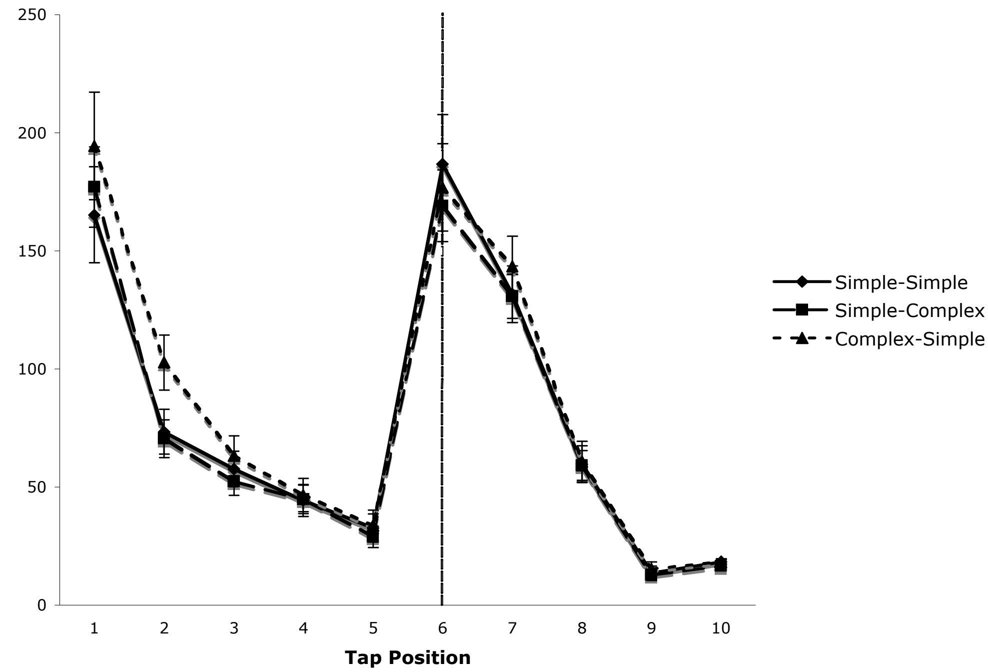

Figure 9: Relative asynchronies at all positions for Indians across conditions. Dashed vertical line denotes point of metrical switch.

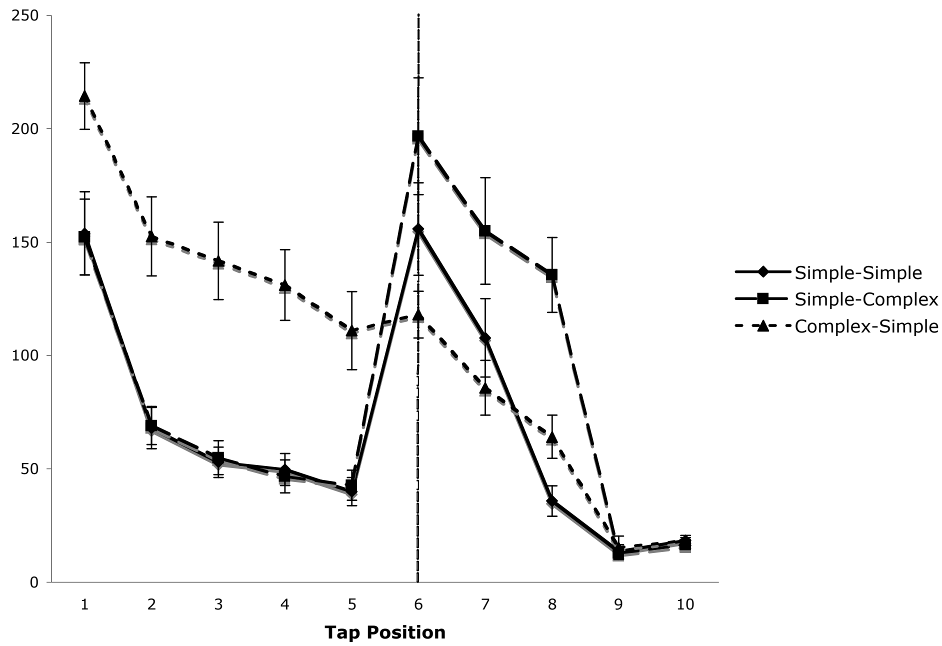

Figure 10: Relative asynchronies at all positions for Americans across conditions. Dashed vertical line denotes point of metrical switch.

In contrast, for the American participants, there seemed to be comparable performance pre-switch on the simple-complex and the simple-simple conditions, and a substantially larger relative asynchrony pre-switch for the complex-simple condition. Interestingly, after the switch, there was a large increase in relative asynchrony when the switch was away from a simple meter, but a decrease in relative asynchrony when the switch was away from a complex meter (see Figure 10).

In order to confirm these trends, statistical tests were performed. For all statistical analyses of asynchrony, the last 3 asynchronies before switch were averaged to give a measure of pre-switch asynchrony, and the first 3 asynchronies after switch were averaged to give a measure of post-switch asynchrony. We focused on the three asynchronies before and after the switch because we hoped they would be optimal for demonstrating costs of switching, since the taps that immediately precede the switch should maximally reflect a subdivision advantage, whereas the taps immediately following the switch should be maximally disrupted. This was also confirmed by positions 3-5 and 6-8 in Figures 9 and 10.

The dependent measure Relative Asynchrony was submitted to a mixed design ANOVA, with Position (before vs. after switch) and Switch type (complex-simple, simple-simple, simple-complex) as within-subjects factors and Nationality (Indian vs. American) as a between-subjects factor, revealing significant main effects of Position, $F(1,99) = 203.69$, $p < 0.001$, and Switch Type, F, $(2,198) = 25.69$, $p < 0.001$). The main effect of Position was due to higher post-switch (M = 120.84, SD = 102.13) than pre-switch (M = 60.16, SD = 63.85) asynchronies. On average, asynchronies were highest in the Complex-Simple condition (M = 98.71, SD = 9.37), followed by the Simple-Complex condition (M = 93.24, SD = 53.75). The Simple-Simple condition had the lowest asynchrony (M = 79.56, SD = 36.81). Most important for the present study, there was a significant two-way Switch Type X Nationality interaction, $F(2,99) = 80.77$, $p < 0.001$, and a significant 3-way Switch Type X Nationality X Position interaction ($F(3,198)= 51.17$, $p < 0.001$). Inspection of Figure 11 reveals that Indian participants consistently showed higher post-switch than pre-switch asynchronies, but American participants only showed pre- to post-switch increases in asynchrony whenever the trial began with simple meter; in the complex-simple condition, Americans' asynchronies actually decreased over the course of the trial.

To further illustrate the contrasting pattern of performance for American and Indian subjects, and specifically, to examine the magnitude of the cost of switching, pre- to post-switch difference scores were calculated by subtracting pre-switch asynchrony from post-switch asynchrony. Figure 12 depicts the difference scores for both groups across the different Switch Types.

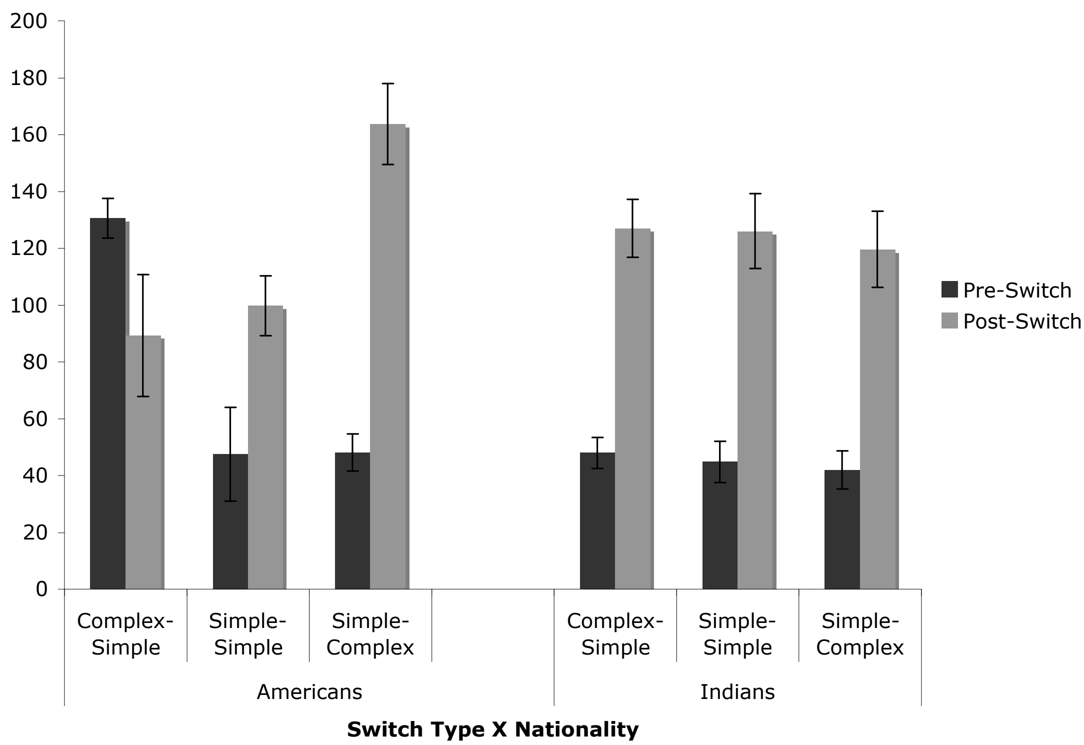

Figure 11: Relative Asynchronies pre- and post-switch in Americans and Indians. Error bars denote standard error.

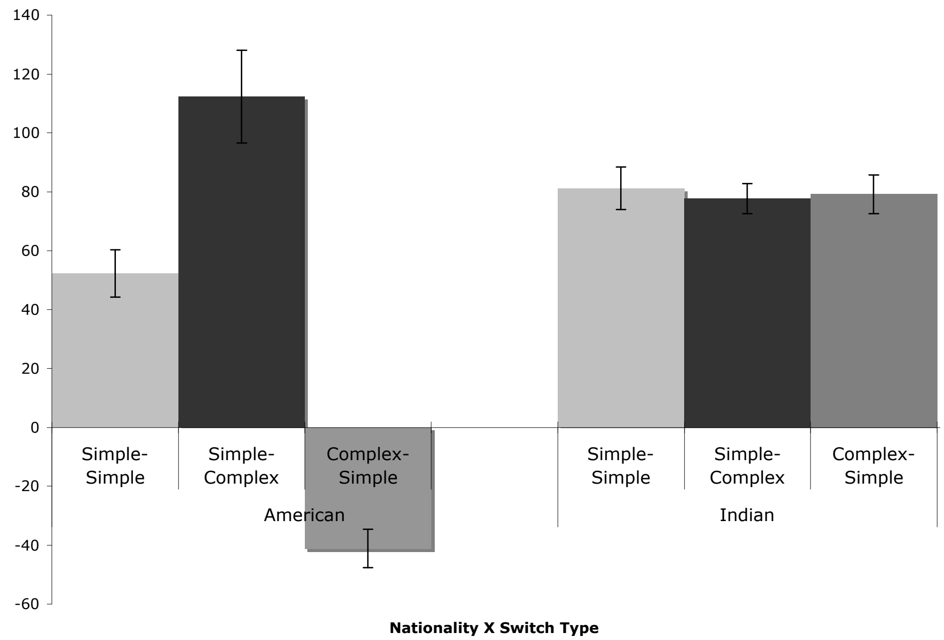

Figure 12: Difference Scores: Post-switch – Pre-switch for each Switch Type. Error bars denote standard error.

A negative difference score reflected a benefit of switching (that is, a greater Asynchrony before the switch than after), and a positive Difference Score reflected a cost of switching (greater Asynchrony after the switch than before). From the figure, it can be observed that whereas the difference scores for the Indians were fairly consistent and positive regardless of Switch Type, for Americans, difference scores varied by Switch Type, with the highest positive scores in the simple-complex condition, moderately high positive scores in the simple-simple condition, and negative scores in the complex-simple condition, reflecting that asynchronies decreased on trials that began with complex subdivisions.

To confirm these trends, the difference scores for each group were submitted to a one-way ANOVA for each Switch Type (simple-simple, simple-complex, complex-simple), followed by post-hoc Bonferroni pairwise comparisons. For the American listeners, there was a significant main effect of Switch Type, $F(2,152) = 50.74$, $p < 0.001$. Post-hoc tests suggested that all Switch Types were significantly different from each other ($p < 0.001$ across all comparison). For the Indian listeners, however, there was there was no significant main effect of Switch Type, $F(2, 152) = 0.076$, $p = 0.927$, with comparable performance across Switch Types. Overall, these results indicate that American listeners had a cost of switching only when there was a switch away from a simple meter, but Indian listeners showed a cost of switching regardless of the nature of the switch.

Absolute Asynchrony

Figure 13 and 14 depict the absolute asynchronies across taps for the different switch condition for Indians and Americans respectively. From Figure 13, it is evident that similar to our findings from relative asynchrony, for the Indian participants, the absolute asynchrony consistently increased following a switch in metrical pattern regardless of the nature of switch. In contrast, for the Americans, there seemed to be an increase in asynchrony only when the meter switches away from a simple meter (see Figure 14).

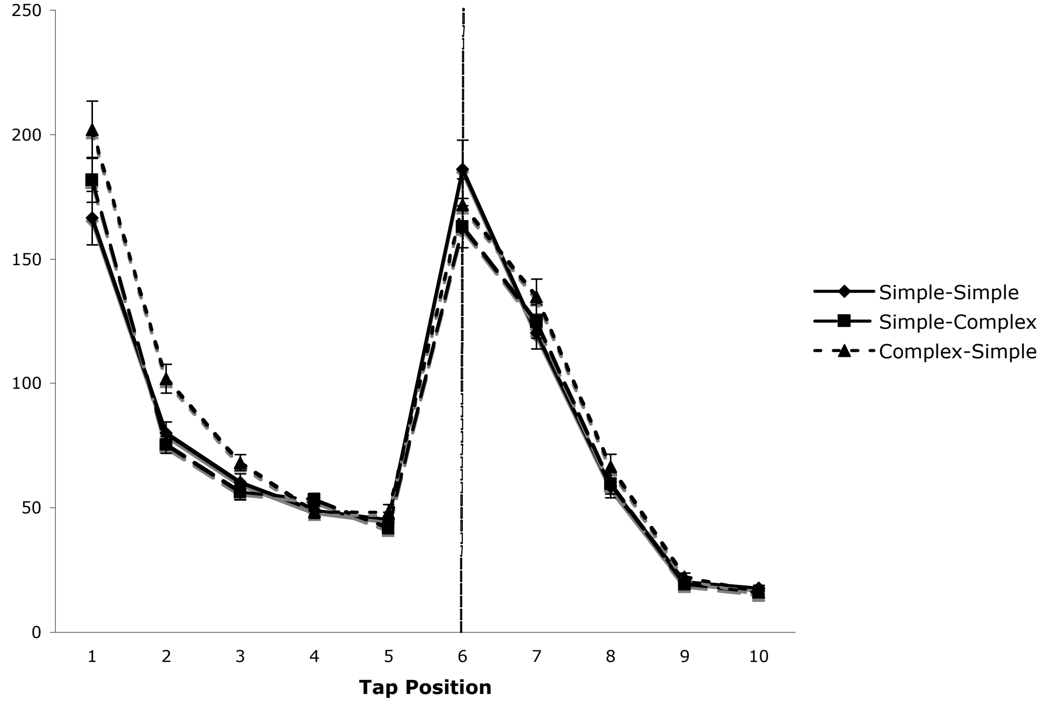

Figure 13: Relative asynchronies at all positions for Indians across conditions. Dashed vertical line denotes point of metrical switch.

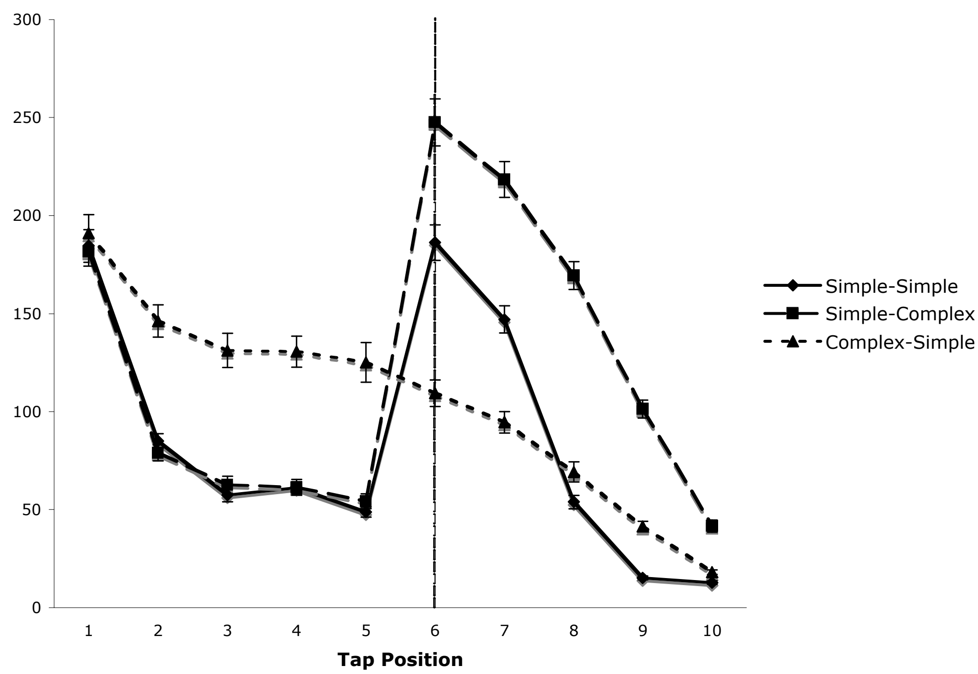

Figure 14: Relative asynchronies at all positions for Americans across conditions. Dashed vertical line denotes point of metrical switch.

The dependent measure Absolute Asynchrony was submitted to a mixed design ANOVA, with Position (before vs. after switch) and Switch type (complex-simple, simple-simple, simple-complex) as within-subjects factors and Nationality (Indian vs. American) as a between-subjects factor. There was a significant main effect of Switch Type, $F(2,198) = 44.799$, $p < 0.001$, such that overall, the asynchrony was highest in complex-simple (M = Position, $F(1,99) = 762.187$, $p < 0.001$, a Switch Type X Position interaction, $F(2,99) = 189.526$, $p < 0.001$, and a 3-way Switch Type X Position X Nationality interaction, $F(2,99) = 208.577$, $p < 0.001$. Post-hoc Position by Switch Type ANOVAs were then performed separately for each Nationality. Indian participants consistently showed higher post-switch than pre-switch asynchronies, but American participants only showed pre- to post-switch increases in asynchrony whenever the trial began with simple meter. In the complex-simple condition, Americans' asynchronies decreased over the course of the trial (see Figure 15).

To further explore the effect of the different Switch Types on Asynchrony, difference scores were calculated for before and after the switch, using the formula described earlier. Figure 16 illustrates the Difference Scores for each Switch Type for Americans and Indians.

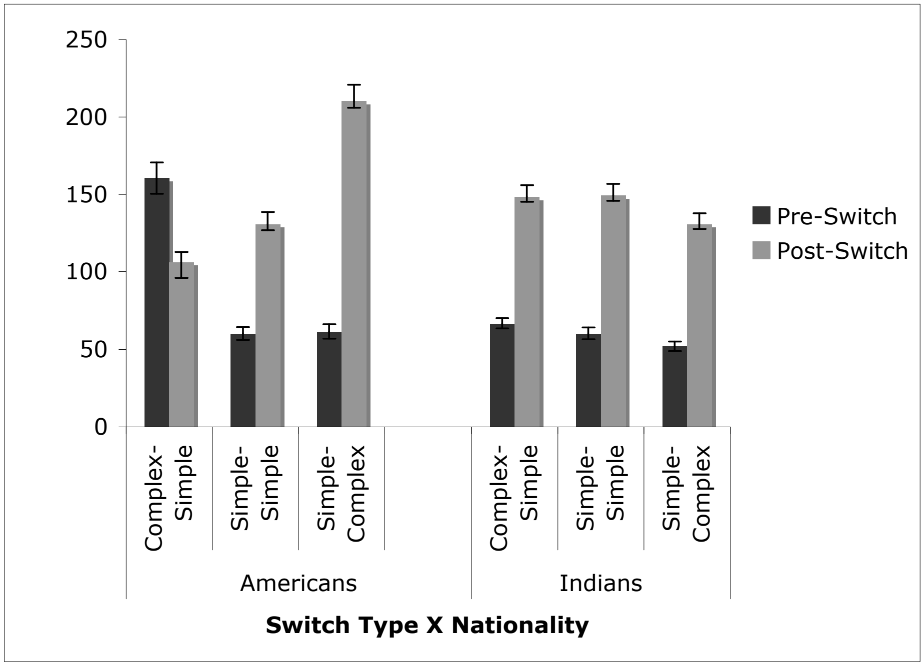

Figure 15: Absolute Asynchronies pre- and post-switch in Americans and Indians. Error bars denote standard error.

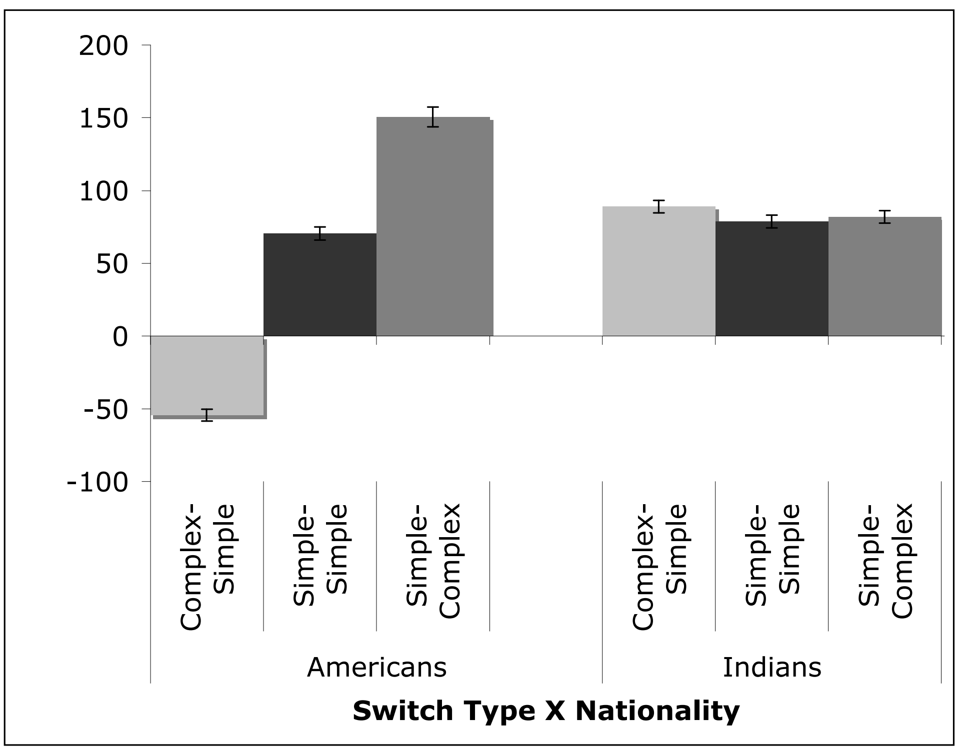

Figure 16: Difference Scores: Post-switch – Pre-switch for each Switch Type. Error bars denote standard error.

The difference scores were submitted to a one-way ANOVA for each Nationality followed by post-hoc Bonferroni tests. Overall, these results indicated that within the American group, there was a main effect of Switch Type, F (2,151) = 386.64, $p < 0.001$. Further post-hoc tests reflected the fact that all switch types were significantly different from each other (all $p < 0.001$). As expected, the difference score was highest (greatest cost) for the switch from complex to simple (M = 150.63, SD = 48.73), followed by the switch from simple-simple (M = 70.53, SD = 31.90). The lowest cost of switching (or benefit of switching) was seen in the switch from complex to simple (M = -54.43, SD = 37.16). However, although any switch led to a significant change in asynchrony, there was an increase in asynchrony (cost of switching) only when switching away from a simple meter, but a decrease in asynchrony when switching away from a complex meter (no cost of switching). As expected, the difference score was highest (greatest cost) for the switch from complex to simple (M = 150.63, SD = 48.73), followed by the switch from simple to simple (M = 70.53, SD = 31.90). The lowest cost of switching (or benefit of switching) was seen in the switch from complex to simple (M = -54.43, SD = 37.16). For the Indian listeners, however, there was no main effect of Switch Type, $F(2, 152) = 1.472$, $p = 0.233$. This implies that regardless of the switch type, the cost of switching was comparable. Specifically, there was a similar difference score, depicting comparable cost of switching for simple to simple (M = 88.97, SD = 29.43), simple to complex (M = 78.67, SD = 30.96), and complex to simple (M = 81.87, SD = 38.33).

Coefficient of Variation

Because the accuracy of the variable CoV increased with the number of taps, all taps prior to the switch were used to calculate pre-switch CoV and all taps subsequent to the switch were used for post-switch CoV. A mixed design Position (before vs. after switch) by Switch type (complex-simple, simple-simple, simple-complex) by Nationality (Indian vs. American) ANOVA revealed a significant main effect of Position, $F(1,99) = 16.06$, $p < 0.001$, with the CoV decreasing over the course of the trial from pre-switch (M = 0.015, SD = 0.0072) to post-switch (M = 0.0012, SD = 0.0067). One possible explanation for this finding is that the post-switch CoVs were calculated over all taps. By the end of the trial, the variability was at its lowest, affecting the overall CoV post-switch. There was also a significant main effect of Switch Type, $F(2,198) = 40.03$, $p<0.001$ with higher CoV seen in Simple-Simple (M = 0.016, SD = 0.0065) and Simple-Complex (M = 0.0016, SD = 0.0062) than in Complex-Simple (M = 0.013, SD = 0.0087) conditions (see Figure 17).

To summarize, our results from the switch conditions highlighted the presence of, and nature of representations for the various meters in the two groups. Although the results from CoV were inconsistent with our predictions, both asynchrony measures demonstrate a clear cost of switching from a familiar meter to a different meter across both groups. Group differences were most evident in the complex-simple condition, the only condition in which the starting meter was familiar to one group and not the other. Thus, switching meters increased synchronization errors in all switch conditions for Indian listeners, who were familiar with both simple and complex subdivisions, but only switching from simple meter yielded increased errors among Americans, who were only familiar with simple subdivisions. This indicates that the Americans had a strong representation that needed to be reorganized only when there was a switch away from a familiar, simple-meter representation. Presumably because they were unable to form a stable representation of the complex subdivision did Americans show no cost of switching when the trial started with complex meter. On the other hand, the Indian group showed a strong cost of switching regardless of the nature of switch. This is evidence to suggest that the Indian participants had a strong representation for both simple and complex meters and that the strength of these representations was comparable.

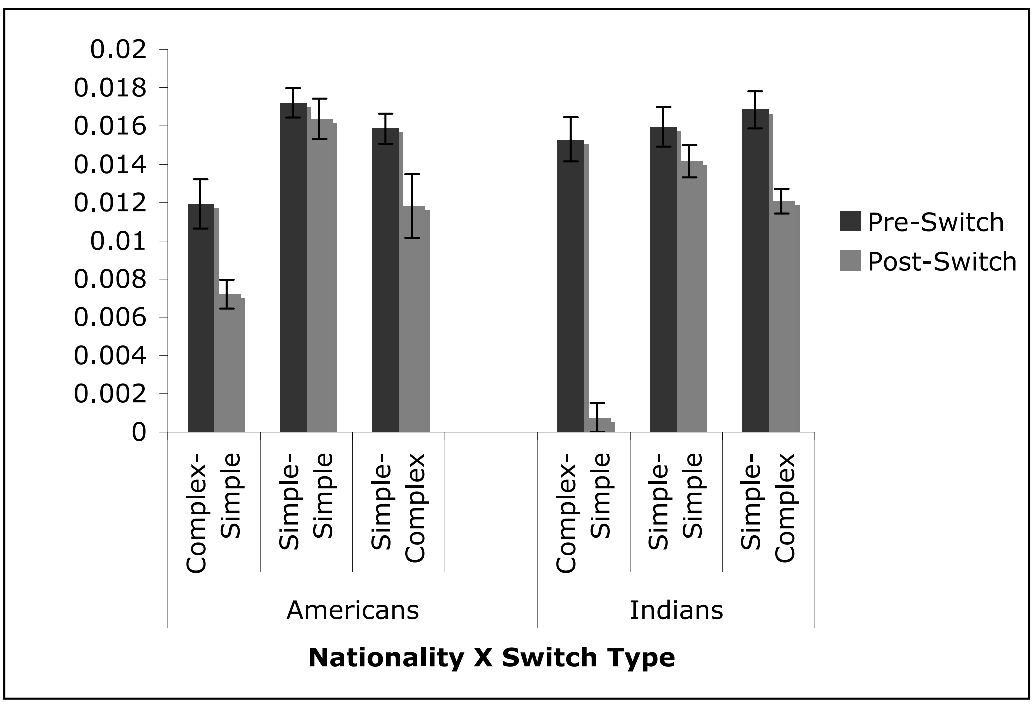

Figure 17: CoV pre- and post-switch for Americans and Indians. Error bars denote standard error.

CHAPTER 5

GENERAL DISCUSSION

The present study examined three primary questions about the role of culture-specific experience in temporal processing: 1) Does culture-specific experience enhance tapping to very slow tempos, thus widening the optimal temporal window for listeners who are accustomed to slow tempos in music? 2) Do subdivisions aid in tapping to slow tempos, especially when those subdivisions conform to culture-specific meters, and 3) How robust are metrical representations of simple and complex meters among listeners who have varying levels of experience with such meters?

To address the first and second questions, we examined how listeners tap to tempi with IOIs of 3 s in the presence and absence of subdivisions. Earlier studies have shown that extremely slow tempi, with inter-onset intervals longer than a few seconds, lead to decreased accuracy and increased variability in production tasks (Drake, Jones & Baruch, 2000; Pöppel, 1971; Mates, Muller, Radil & Pöppel, 1994). However, previous studies have also indicated that events within the interval provide the listener with a sense of structure that improves their ability to discriminate such long intervals (Rammsayer & Lima, 1991). In the present study, subjects synchronized with inter-onset intervals of 3 s filled with silence or with subdividing tones. Even though subjects were instructed to ignore them, subdivisions were expected to aid in synchronization to slow tempos. Given the finding that music training can improve performance on perception and production of slow tempi (Grondin, 2001), and given that Indian music contains very slow tempos, often exceeding 3 seconds (Naimpalli, 2005), we asked whether greater exposure to Indian music might enhance tapping to slow tempos. This question was addressed by comparing American and Indian listeners' synchronization error and variability on trials containing no subdivisions (unfilled trials) to trials containing subdivisions (filled trials). If culture-specific exposure to slow tempos somehow leads to the widening of the temporal processing window, Indian listeners should outperform American listeners on unfilled trials. Alternatively, tempo constraints may apply regardless of culture-specific experience, in which case both groups would be expected to improve in filled vs. unfilled trials. Even if Indian listeners did exhibit superior processing of long unfilled intervals relative to Americans, both groups might nevertheless benefit from subdivisions. Our results suggested that both groups performed equally poorly on the unfilled trials, suggesting that the extensive exposure to slow tempos did not lead to any measurable widening of the temporal window. Further, both groups improved in the filled versus unfilled trials, suggesting that the temporal window seems to be a culture-general phenomenon, without a strong effect of exposure to music that violates this constraint.

To address our second question, we varied the nature of subdivisions on filled trials to assess whether culture-specific metrical representations influence subdivision benefits. If subdivisions enhance performance, then cross-cultural differences should be evident when some types of metrical subdivision are familiar and others are unfamiliar. Thus, Western listeners were expected to show greater improvement on filled trials over unfilled baseline trials only when subdivisions were consistent with triple and duple meters but not necessarily when subdivisions were consistent with complex meter. By contrast, Indian listeners were expected to benefit from all subdivision structures because all three subdivisions should have been familiar (Clayton, 2000).

The two groups performed equally well on the simple meters, however, the Indian listeners outperformed the American listeners on the complex meter. Thus, it indicates that the Indian listeners were able to utilize the complex meter better than the American listeners, supporting the second possibility. However, even with the American listeners, they performed significantly better with the complex meters than they did with the unfilled trials. This could imply that although they were not as proficient as the Indian listeners were at utilizing the complex meters, the very fact that the interval was filled enabled them to perform better than they did with the unfilled intervals.

In summary, our findings on synchronizing with filled and unfilled trials showed that overall, participants performed better (higher accuracy and lower variability) on filled trials than on unfilled trials. Within the filled trials, the two groups differed on their performance on different subdivision types, such that Indian listeners perform synchronized more accurately than American listeners did on complex meter, but the two groups performed equally well on the simple meters.

While these findings do demonstrate that Indian listeners are able to utilize complex meters better than American listeners in order to perform synchronization tasks, they do not tell us anything about whether Indian listeners have a representation for these complex meters. Thus, our third, and arguably, central question of this study was whether cross-cultural differences in the cost of switching subdivisions would reveal something about the underlying metrical representations in American versus Indian adults.

If extensive exposure to complex meters enables us to develop strong mental representations, then these representations should lend themselves to equally proficient performance in simple and complex meters when the representations can be utilized. However, if the representations for the complex meters are truly as strong as the representations for simple meters, then they should be equally resistant to change when the representation needs to be reorganized. “Complex meters” have been documented in various musical cultures, but one assumption implicit in the literature is that complex meters are inherently more difficult than simple meters, as shown by the tendency among even musicians to prefer isochronous (1:1) or simple rhythmic ratios (2:1) and to assimilate complex to simple ratios (Large, 1996). Thus, one might expect representations of complex meters to be weaker or less stable than representations of simple meters.

Musical rhythms from North American contain mostly simple-integer ratios thus conforming to proposed processing constraints on rhythm perception. A lifetime of exposure to Western rhythmic structures probably results in specialized perceptual processes or metrical categorization based on only those ratios, and strong culture-specific representations of simple meter (Hannon & Trehub, 2005a). Indian rhythms, however, violate assumptions about simple integer ratios and presumably their metrical representations should be affected by exposure to such music (Clayton, 2000; London, 1995; Merriam, 1981). Nevertheless, Indian listeners might have weaker representation of meters that violate intrinsic processing constraints. Thus, complex meters may require a non-metrical strategy or a less genuine metrical representation. Thus, we assume that when representations are particularly strong, they should, once activated, be more resistant to change. That is, to the extent that the subdivisions in our stimuli activate stable and robust metrical representations, it should be difficult to re-organize that representation in the face of conflicting evidence, as given by the sudden switch to a new subdivision structure.

To address this question, effect of switching meters was compared for both groups of listeners. It was hypothesized that Western adults should make use of the subdivision strategy only in simple metrical contexts where they could use culture-specific metrical representations, and therefore a cost of switching should be observed only after a metrical structure has been inferred. Thus, if the switch was from a simple meter to a complex meter, performance of Western listeners should drop because they are switching from a subdivision arrangement that induced a strong metrical representation to one that induced no metrical representation. For the same reason, if the switch was from a complex meter to a simple meter, their performance should improve. Moreover, an increase in asynchrony should also be observed when switching from one familiar metrical representation to another familiar representation, thus predicting a similar increase in asynchrony when switching from one simple meter to another.

In contrast, Indian listeners should show an increase in asynchrony across all conditions that caused a switch, because they are expected to have metrical representations for all subdivision structures. Specifically, since Indian listeners presumably processed with equal ease the simple and the complex ratios, a switch from a complex ratio to a simple ratio should require a switch in strategy, from a subdivision that induces a strong metrical representation to a different metrical representation. They should therefore show an increase in asynchrony when the switch was from a simple ratio to another simple ratio, or a simple ratio to a complex ratio.

Our results supported these predictions. For the American listeners, there was a considerable increase in asynchrony after the switch when the switch was away from a simple meter, regardless of whether it was to another simple meter, or to a complex meter. In contrast, there was a decrease in asynchrony when the switch was from a complex meter to a simple meter. For the Indian listeners, however, there was an increase in asynchrony regardless of the nature of the switch. This drop in performance is evidence for the presence of a representation. Moreover, the greater the decrease in performance, or the higher the cost of the switch, the stronger is the nature of the representation. Keeping this in mind, it is evident from our findings that the American listeners had a strong representation for the simple meters. This is indicated by the decreased accuracy when there was a switch away from the simple meters. However, the American listeners seemed to have no strong representation for complex meters, as evidenced by the fact that there was an improvement in performance when there was a switch away from complex meters. The finding that Indian listeners showed a comparable cost of switching across all conditions is strong evidence supporting the notion that Indian listeners have robust representations for simple as well as complex meters. This is the first study to date to provide evidence that complex meters are genuine metrical representations, comparable to representations for simple meters.

CHAPTER 6

CONCLUSIONS

Cognitive representations influence our ability to efficiently perceive and react to the world around us. This study aimed to examine the role of culture on cognitive representations of music. Specifically, we aimed to study whether passive exposure to music was sufficient to enable us to form representations for complex metrical patterns in our ability to synchronize to music.

Earlier studies had described two temporal constraints which come into play in our ability to accurately process metrical patterns. Firstly, tempi that were too slow were found to be more difficult to perceive and produce than faster tempi. Our results showed that Indian listeners, who had a lifetime of exposure to slow tempi, did not perform better than American listeners. This suggests that that constraints on slow tempi might be very deep rooted, perhaps innate, and not easily shaped by culture-specific musical experience. Thus, it might be argued that music from cultures that use such slow tempi might provide listeners with additional cues, such as ensuring that all intervals are filled. Further, it might be likely that music that employs such slow tempi might emphasize melodic movement over precise temporal synchrony. Although no studies have been published to this effect, merely listening to slow music from such cultures suggests that this might be true. Future comparative studies of music with fast and slow tempos should address this question.

Our study also examined the role of subdivision on our ability to synchronize with these slow tempi. Our results reflected the fact that overall, subdivisions do aid in synchronization, however, the nature of subdivision is key. That is, although performance over the filled intervals were indeed better than performance over the unfilled intervals, there was a difference between our two groups on the filled intervals. Specifically, listeners who had a lifetime of exposure to complex meters were better able to use these meters to their advantage than listeners who had no such exposure.

Further, the strength of the representations was examined by examining the cost of sudden metrical changes on accuracy. It was evident from our results that with a lifetime of exposure to complex meters, the Indian listeners acquired genuine representations for novel complex meters, that by our measures look identical in strength when compared with their representations of equally familiar duple and triple meters. On the other hand, American listeners, who did not have that exposure, were able to use the complex meters to a certain degree (as evident in the filled versus unfilled trials), however, they did not have a strong mental representation for these meters. These results indicate that exposure to music that violates the assumptions of simple integer ratio patterns, enables listeners to develop representations to cope with such metrical patterns.

Overall, our study answers fundamental questions about mental representations: how they are formed, and what is necessary in order to form these representations. Further studies that examine these constraints in children might give us interesting insight into how much exposure is sufficient in order to overcome these constraints and form these representations.

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