Prior Experience and Synchronization to North Indian Ālāp

THESIS

Presented in Partial Fulfillment of the Requirements for the Degree Master of Arts in the Graduate School of The Ohio State University

By
Ira Okrent Wertheim

Graduate Program in Music

The Ohio State University

2012

Master's Examination Committee:
Dr. Udo Will Advisor, Dr. Ryan Skinner Co-advisor and Dr. Thomas Wells
Copyright by

Ira Okrent Wertheim

2012
Abstract

Prior experience in the form of music training is studied through a clapping paradigm to North Indian ālāp. Seven Ohio State graduate students possessing prior experience in the form of traditional North Indian music study and seven Ohio State graduate music students who do not possess that prior experience clap to North Indian ālāp in a laboratory setting. Differences in subject performances are detected through statistical and musical analysis. The importance of prior experience as a determinant of synchronization pattern is examined. The study finds that prior experience does lead to significantly different patterns of synchronization for individuals with and without prior experience. Additionally, the study finds a correlation between prior experience and synchronization to the mukhra (a cadential melody).
**Dedication**

This document is dedicated to ones I love, my family.
Acknowledgments

I would like to acknowledge Dr. Udo Will for his guidance and insight during my time at OSU. Additionally, I would like to acknowledge Dr. Ryan Skinner, Dr. Martin Clayton, Dr. Mark Doffman, Andrew McGuiness, and Betsy and Dr. Joel Wertheim.
Vita

2007………………………………….B.F.A. Musical Arts, California Institute of the Arts
2012………………………………….M.A. Musicology, The Ohio State University

Publications


Fields of Study

Major Field: Music
Table of Contents

Dedication ......................................................................................................................... iii

Acknowledgments ............................................................................................................ iv

Vita ..................................................................................................................................... v

Publications ....................................................................................................................... v

Fields of Study ................................................................................................................... v

Table of Contents ............................................................................................................. vi

List of Figures ................................................................................................................... ix

Introduction: Relevant Questions and Literature Review .............................................. 1

The aim of the study ...................................................................................................... 8

A Brief Introduction to Hindustānī Classical Music ......................................................... 9

The Study ......................................................................................................................... 12

Subjects ........................................................................................................................ 15

Materials ........................................................................................................................ 16

Procedure ....................................................................................................................... 17

Data Processing ............................................................................................................ 19

Statistical Analysis....................................................................................................... 22
Question 1 ........................................................................................................................ 23
Do individuals possessing prior experience exhibit a different synchronization pattern than those who do not possess prior experience? ................................................................. 23

  Full Analysis Results ................................................................................................... 24

  Full Analysis Discussion ............................................................................................. 25

  Sectioned Analysis Results ......................................................................................... 25

Question two: Do spontaneously generated clapping tempos correlate with stimulus- driven clapping tempos? ............................................................................................................. 33

  Background ..................................................................................................................... 33

  Results .......................................................................................................................... 33

  Discussion ..................................................................................................................... 34

Question 3: Does muhkra lead to a different pattern of synchronization in experienced listeners? .......................................................................................................................... 35

  Background.................................................................................................................. 35

  Results and Discussion................................................................................................. 37

Concluding remarks ....................................................................................................... 39

References ........................................................................................................................ 40
List of Tables

Table 1 Descriptive Statistics for the full analysis sub-grouped by experience. ............. 24
Table 2 Kuiper test results for the full analysis sub-grouped by experience. .................. 24
Table 3 MWW multi-sample test result for the full analysis........................................ 24
Table 4 Descriptive statistics for the sectioned analysis sub-grouped by experience. ..... 26
Table 5 Kuiper Test results for sectioned analysis sub-grouped by experience.............. 28
Table 6 Mardia-Watson-Wheeler Multi-sample test results for the sectioned analysis.. 29
Table 7 Descriptive statistics for the sections that were demonstrated as being significantly different by the MWW multi-sample test................................................................. 29
List of Figures

Figure 1 A three panel Praat analysis window ................................................................. 20
Figure 2 Mean vector lengths for sectioned analysis ...................................................... 27
Figure 3 Mean vector lengths for sections selected by the Mardia-Watson-Wheeler test as being
significantly different .................................................................................................... 30
Introduction: Relevant Questions and Literature Review

How does prior experience affect the listener’s ability to synchronize to music? Does prior experience affect our ability to remember and otherwise process rhythmic stimuli? For musicians and listeners, prior experience comes in the form of listening, performing, practicing and creating. How does participating in these activities influence the music-making and perception that is regularly part of the musical experience?

In their essay appearing in *Music, Science and the Rhythmic Brain* (2011) “Introduction to Entrainment and Cognitive Ethnomusicology,” Will and Turow call attention to a shift from a Culturalist/Cognitivist paradigm to the embodied perspective in both cognitive science and the humanities. For the embodied mind, experience is the coupling factor that enables biological and cultural change to happen concurrently. To the embodied agent, the outside world exists not through the manipulation of external symbols and internal representations, but through the relationship between mind, body and culture. According to these authors, it is not sufficient to account for cognition in terms of computational processes divorced from the embodied mind or its environment. This dynamic raises question regarding the once-accepted dichotomous relationship between nature and culture.

Living within a particular culture provides a wealth of experience that shape perception (Will and Turow: 2011) (Will: 2011) (Stobart and Cross: 2000) (Toivianinen and Eerola: 2003) (Drake and El Heni: 2003). In other words, through enculturation one has experiences that
influence future actions/reactions. Some musical prior experiences afforded by enculturation are seemingly related to pulse and metric perception. For instance, in their study of Andean music, Stobart and Cross (2000) found that in past transcriptions Western musicologists had misrepresented the rhythmic structure as exhibiting anacrusis (a rhythmic pickup). An analysis of field recordings of Andean music and an informal behavioral of study Bolivian musicians and listeners demonstrated that, in contrast to older etic transcriptions, the subjects tended to perceive the first musical event as the beat regardless of whether the stimulus was Western music or Andean. This finding points to a difference in where Bolivian musicians/listeners and music researchers sense the pulse of musical performance.

Also, in a cross-cultural rhythm perception study on French and Tunisian listeners, Drake and El Heni (2003) found that, on average, subjects tap more slowly (at a higher metrical level) when listening to culturally familiar music. Interestingly, this was observed in both musicians and non-musicians. Additionally, when listening to culturally-familiar music, subjects were capable of tapping at more varied metrical levels, suggesting that prior experience with a musical style allows for more flexibility in pulse attribution.

Additionally, a study conducted by Toivianinen and Eerola (2003) on Finnish listeners who had prior experience with only Western music and South African listeners who had prior experience with both Western and African music, found that the two groups demonstrated different tapping behavior to the African musical styles. For instance, African listeners exhibited more consistent ITI (inter-tap intervals) to melodies containing dotted-eighth note rhythms as contrasted with the Finnish listeners. This result is likely caused by the Finnish listeners’ difficulty with the dotted-eighth note rhythm. In instances where Finnish listeners exhibited more
consistent ITI than the African listeners it was due to the fact that some African listeners had a tendency to feel the pulse shifted by an eighth-note or sixteenth-note, which is consistent with the poly-metric content of African music. Again, there appears to be a relationship between pulse attribution and prior experience. Based upon these studies, it is reasonable to hypothesize that prior experience, in the form of cultural experience, alters the listeners’ pulse perception. Specifically, there appears to be a relationship between the events causing a listener to attribute pulse and prior experience.

Much like the relationship between cultural prior experience and pulse perception, differences in perceptions of rhythmic complexity are seemingly related to prior experience with a musical style. Eerola, Himberg, Toiviainen and Louhivuori (2006) demonstrated that cultural experience contributes to perceptions of complexity in rhythm and melody. Western and African subjects rated complexity of both African and Western folk songs. While both subject groups were familiar with Western folk songs, only the African subjects were familiar with the African folk songs. The result was that Western subjects rated the African folk songs as rhythmically more complex than the African subjects did, while the African subjects, like the Western subjects, rated the Western rhythms similarly complex.

Additionally, studies have demonstrated that the prior experience in the form of rhythmic training alters perception, musical behavior and the formation of human neural connections.

Rhythmic expectations can be altered by prior experience. The electroencephalogram (EEG) is a method for measuring evoked response potentials (ERP). ERP are the electrical activity in the brain occurring in response to a stimulus. Comparing the differences between physiological rhythms produced during passive listening tasks is a means of understanding the
relationship between prior musical experience and rhythmic expectation. For instance the magnitude of a positive deflection at 300-700 milliseconds has been demonstrated to be a quantitative measure of expectancy violations (Renninger, Wilson, Donchin: 2006). If a group of subjects possessing prior experience demonstrates this positive deflection more-so than a group of subjects who does not possess prior experience, it is likely that the prior experience has made these subjects more sensitive to expectancy violations present in the stimulus. The EEG study conducted by Renninger, Wilson and Donchin found a significant correlation between prior experience and expectancy violation as measured by the P300 component. P300 is a positive deflection in the ERP waveform occurring at approximately 300 to 700 milliseconds (Renninger, Wilson, Donchin: 2006). This experiment was an oddball paradigm that consisted of the presentation of standard stimuli (occurring %80 of the time) and target stimuli (occurring %20 of the time). The study utilized context updating theory to support the hypothesis that the target stimuli would elicit the P300 response\(^1\). Subjects experienced in Western music and subjects experienced in Western and Javanese music participated in EEG study. Both subject groups exhibited a P300 to both non-diatonic tones in the western scale condition and tones outside the selected pathet in the Javanese scale condition. While slower in responding to the stimuli than the Western group, the Javanese group exhibited a greater P300. A possible explanation for this result is that some members of the Western control group possessed quasi-absolute pitch, which is believed to decrease the P300 response to non-diatonic pitches. What is certain is that cross-cultural prior experience requires further study.

\(^1\) Context updating theory posits that stimuli perceived by a subject are compared with the preceding stimuli to determine whether it is the same or different (Polich: 2007).
An MEG (magneto-encephalography) study conducted by Lappe, Trainor, Herholz and Pantev (2011) found significant changes in rhythm perception in non-musicians after two weeks of instrumental instruction, as evidenced by mismatch negativity. During passive listening to evenly spaced piano tones containing a single rhythmic deviation non-musicians who practiced piano demonstrated higher amplitude MMN² (mismatch negativity) than non-musicians who only listened to piano practice and assessed its accuracy. Thus, only a small amount of prior musical experience can already change the physiological response of the body to music.

Rhythm perception can be understood as the synchronization of the sensorimotor system with an external stimulus. Clayton (2007) describes entrainment, a specific type of synchronization, as:

“. . .[T]he process by which independent rhythmical systems interact with each other. ‘Independent rhythmical systems’ can be of many types: what they have in common is some form of oscillatory activity (usually periodic or quasi-periodic in nature); they must be independent in the sense of ‘self-sustaining’, i.e. able to be sustained whether or not they are entrained to other rhythmical systems (thus sympathetic vibration, as when a violin’s soundboard vibrates at the same frequency as one of its strings, is not an example of entrainment). In order for this interaction to exist some form of coupling must exist between the rhythmical systems, and this too can take many forms.”

Synchronization science had its foundation in the work of Christiaan Huygens, a physicist who discovered entrainment (synchronization of oscillators). Huygens noticed that, due to oscillatory energy, pendulums sharing a common support beam always approached a more synchronous relationship than pendulums not sharing a common support beam (Pikovsky: 2001). Entrainment is a ubiquitous phenomenon found in human behaviors such as music-making and socializing (Clayton, Sager and Will: 2005). Entrainment is also found in non-human behavior such as the flickering of fireflies and the resetting circadian rhythms (Clayton: 2012). While the

² Mis-match negativity is a measure of expectancy often correlated with musical training.
ability to synchronize to endogenous (internal) and exogenous (external) stimuli is innate and necessary for survival, the specifics of this behavior are reliant on both prior and current perceptual experience.

Jones, Drake and Baruch (2000) posit a dynamic attending theory in which a single array of biological oscillators that are capable of becoming entrained with external stimulus. In dynamic attending theory the referent period is the rate of a single attentional oscillator and is initially independent of environmental stimulus. Additionally, the referent period is likely reflected in spontaneously generated tempo (tapping or clapping). In a musical stimulus the referent level is most similar to the tactus. Drake, Jones and Baruch (2000) demonstrate that individuals focus attention on rhythmic events occurring at the referent level, a rate that is near their referent period. Attentional oscillators become locked into a stimulus through a process called attunement. Focal attending is the process where attentional oscillators become attuned to levels that are metrically higher or lower than the referent level.


As Will (2012) points out, intention and cultural belief systems can act as coupling or negative-coupling factors in musical entrainment. In a study on musical synchronization and group identity during a Congado ritual performance, Lucas, Clayton and Leante (2011) illustrate the role that communal identity plays in synchronization. One of the objectives of the musicians during the ritual performance is to represent their community and do so by performing the ritual
music independently of other communities’ musical groups. Different musical groups cross paths and their musical rhythms meld accordingly. The challenge to the performers of any particular group is that, in order to keep their group identity intact, the musicians must resist synchronizing with other musical groups. An analysis of a video recorded performance uncovers instances of inter-group entrainment. While groups are not entirely able to resist entrainment, it is their intention to exhibit their communal solidarity over that of another community that creates the unique synchronization dynamic. In other words, synchronization is influenced profoundly by intention and group identity. In Congado ritual music, prior experience through enculturation seems to play an important role in synchronization. In his analysis of this study, Will points out that group identity acts as a negative coupling factor, but questions whether performers can ever remain unaffected by co-occurring rhythms for a prolonged period of time.

Clayton’s (2007) study of tānpurā performance during vocal ālāp, a Hindustānī musical form believed by many performers to be without pulse, uncovered entrainment in the form of simple integer rhythmic relations between the tānpurā player and singer. The importance of Clayton study cannot be over emphasized. Empirical support for the occurrence of entrainment during ālāp is a strong indicator that further synchronization studies using ālāp as stimuli will allow researchers to better understand synchronization to stimuli exhibiting “free-rhythm.”
The aim of the study

The central aim of the present study is to determine whether individuals with certain prior musical experience demonstrate different patterns of synchronization, as compared to individuals without that prior musical experience. In this study, prior experience is defined as the subject having studied Hindustānī music under a traditional teacher for at least one year. Hindustānī ālāp was chosen instead of a synthetic laboratory created stimuli because ālāp has free rhythm. Clayton (1996) provides two different definitions of free rhythm, “Free is the rhythm of music without metre… [and] the rhythm of music without pulse.” This study assumes that ālāp has an underlying rhythmic regularity. While not uncommon⁴, free-rhythm is a neglected topic in both Western and eastern musicology; one explanation for this deficiency is lack of an adequate notation system (Clayton: 1996).

The present study is warranted because the unique rhythmic qualities of ālāp are fertile ground for cultivating a deeper understanding of the relationship between prior experience and rhythmic synchronization. Readers unfamiliar with Hindustānī classical music, specifically the instrumental ālāp, should read the following section “A Brief Introduction to Hindustānī Classical Music.”

---

⁴ See Clayton 1996 for a detailed list of musical forms possessing free rhythm.
A Brief Introduction to Hindustānī Classical Music

North Indian classical music is a living performance tradition. The fundamental building blocks of North Indian classical music are rāg and tāl. Rāg is a melodic tradition passed on aurally from teacher to student one phrase at a time (Kaufman: 1968). While it is generally not written out, it exists as a set of latent melodic possibilities (Jairazbhoy: 1971). Rāg is neither simply a scale nor a set of melodies but a set of constraints that lies upon a continuum between the two (Magriel: 1997). These constraints dictate the relative importance and acceptability of certain notes, the types of acceptable scalar motion, and the typical phrases that are characteristic of the rāg (Kaufman: 1968). The performance of rāg is not an exercise but a means to express rasa or the mood of the rāg (Kaufman: 1968). In some cases the goal of rāg performance is not even human enjoyment but divine communication (Sanyal, Widdess: 2004).

North Indian classical music is either nibaddha or anibaddha (rhythmically bound or rhythmically unbound). Tāl is the framework that binds rāg in time or makes the music nibaddha. Martin Clayton provides a detailed discussion of tāl theory in his book Time in Indian Music. A single “cycle” of tāl is an āvart, an āvart is made up number of shorter sections called vibhāg and each vibhāg is made up of mātrā (mātrā are generally analogous to beats). Each vibhāg of the tāl cycle is marked by one of two hand-gestures called tāli and khālī (clap and wave). Tāli and khālī mark the relative importance of the rhythmic events in the tāl cycle. Generally, tāli events are stressed while khālī events are unstressed. More specifically, tāl is also represented as a series of
bol or onomatopoeic representations of drum sounds that are strewn together to create a thekā or a percussive pattern typical to each tāl. The amount that actual performance differs from the thekā is subject to an individual performer’s tastes and the aesthetic of the particular style of North Indian classical music. While the use of tāl differs depending upon the style of performance, it can be understood as a repeating rhythmic framework signifying the relative importance of musical events. The sām or the first beat of the tāl cycle gives the music a sense of closure and beginning (Clayton: 2000).

The anibaddha (unbound) portion of the performance is called ālāp. Ālāp is the unbound exploration of rāg. It is often performed on a solo melodic instrument accompanied by tānpurā (drone). It would be misleading to equate unbound with non-rhythmic because ālāp has an underlying rhythmic regularity at all stages (Sanyal, Widdess: 2004). Further, ālāp can be divided into three sections: ālāp, jor and jhālā. Ālāp generally begins at a very slow tempo and gradually increases in tempo as time progresses. During the ālāp section the performer first establishes the tonic note and gradually introduces each note of importance (Widdess: 1981). Generally, each new development expands the range of the melody. This development generally ends with a return to the tonic note and a cadence (mukhra) (Widdess: 1981).

Widdess characterizes the difference between the ālāp section and the jor as follows:

“The distinction between the first two parts is a rhythmic one: in the ālāp the rhythm is free, or appears to be so; in the jor, an explicit regular pulsation occurs…[the] jor features regular rhythmic plucking of the drone strings in accompaniment to the melody, whereas in the ālāp these strings are plucked at irregular intervals.” (Widdess, Sanyal, 2004, 149). The transition from anibaddha (free rhythm) to nibaddha (bound rhythm) that occurs between the ālāp section and jor section is accomplished by the use of a mukhra (the anacrusis to a melody).

Widdess and Sanyal describe the mukhra as:
“Traditionally the mukhra comprises two segments: the first (a) comprises several repetitions or a prolongation of the middle tonic, while the second (b) briefly touches neighboring notes, first below and then above the tonic, before finally returning to the tonic itself. The exact shape of the second segment varies to take account of the rāg, and the concluding return to the tonic may be left unstated... it [the mukhra] is always played in a regular, pulsed rhythm, even in the context of the ‘free rhythm’ of slow ālāp. (Widdess, Sanyal, 2004: 158).

Finally, the jhālā (third) section is generally characterized by an increase in speed and rhythmic/melodic complexity on both the melody and chikārī strings.
The Study

A study was conducted to illuminate the influence of prior experience on synchronization. Studying this relationship is made possible by conducting a laboratory study between two groups, one possessing prior experience and one not possessing prior experience. This study attempts to illuminate the influence of prior experience in the form of musical training. Specifically does prior experience influence how listeners clap to music and how they clap to certain structural features of that music. More specifically, this study seeks to answer to the following questions: 1) Do individuals possessing prior experience exhibit a different synchronization behavior then those who do not possess prior experience? 2) Does spontaneously generated clapping correlate with stimulus-driven clapping? 3) Do individuals with prior experience synchronize differently to the mukhra (a cadential melody).

After the experiment was conducted inference was drawn by comparing and contrasting the inter-group distributions. A clapping paradigm similar to that described in Clayton (2012) was be used to gather clapping times for analysis. Clapping was used for three reasons: 1) It is a clear and measurable indicator of perceived pulse, 2) It is the typical means of keeping time by both performers and audience members in Indian music performance (Clayton: 2000), 3) It is a common means of time-keeping during Western music listening. Subjects
clapped to three performances of ālāp of varying length performed on the sarod. Each performance was separated by three twenty-five second recordings of noise as to interrupt the rhythmic synchronization of the previous performance. The recordings were selected because they represented a variety of performers, rāg and rhythmic qualities (e.g. the performers approach to tempo differed for each recording and the selection from rāg Kafi Kanada is a single, long ālāp section, contrasting with the shorter ālāp sections of the two other selections). The sarod is a metal-necked lute that has both melody, chikārī (open) and taraf strings (strings that resonate sympathetically with melody and chikārī strings). Since taraf strings resonate as a result of more dominant melody or chikārī sounds their onsets are nebulous and impossible to extract (Clayton: 2000). The sarod was chosen for this experiment because stringed instruments played with a plectrum have a more defined onset then vocal, sarangi or bānsuri performance (Will, Clayton, Berg, Wertheim and Leante: 2013). The choice to use sarod instead of sitar was merely one of personal preference. Pink noise was utilized for its aperiodic qualities, in other words listening to pink noise between musical performances will disrupt any latent synchronization response. Finally, ālāp (ālāp, jor and jhālā) was chosen as the stimuli because it is a gradual transition from anibaddha to nibadah and there is a great deficiency in studies on music exhibiting ‘free-rhythm’ in the psychological and ethnomusicological literature (Clayton: 2000). The influence of prior experience was studied by having subjects clap pulse to recorded performances of Hindustānī ālāp. It is hypothesized that subjects with prior experience will demonstrate different patterns of synchronization to the recorded performances than subjects

---

4 Two (rāg Gaud Sarang and rāg Jaijaivanti) consisted of an ālāp, jor and jhālā structure, while one (rāg Kafi Kanada) consisted of an extended ālāp.
without prior experience. Further, these differences will be characterized by differences in variability.

Synchronization between the subject and stimuli is measured in phase-angles. Phase angles (Θ) are calculated by measuring the relationship between subject claps (tclap₁) and stimulus events (tsound₁ and tsound₁₊₁) (Clayton, Sager, Will; 2005)

Further, in this study two successive musical events, tsound₁ and tsound₁₊₁, are considered as a full reference cycle of 360°. The phase of a tap event with respect to the reference cycle is then calculated as follows.

\[
\Theta = \frac{(t\text{clap} - t\text{sound}_1) * 360}{(t\text{sound}_{1+1} - t\text{sound}_1)}
\]

The relationship between subject clapping and the musical stimuli is quantified in order to compare inter-group responses. In this study, prior experience is the independent variable of interest and phase angle is the dependent variables. Phase angle (0° to 360°) is utilized to quantify the synchronous relationship between humans and music. Since clapping is one of the most direct and musically relevant behavioral correlates of synchronization, a clapping paradigm is utilized as a means of examining the complex relation between prior experience and synchronization.
Subjects
The study utilized 14 Ohio State University graduate students. Seven of the subjects were non-music graduate students and met the criteria for prior experience in Indian music. Prior experience was defined as having studied Hindustānī with a traditional teacher for a minimum of one year. The seven subjects who did not meet the prior experience criteria were, however, graduate students in music. One of the graduate students possessing prior experience was not included in the final analysis as she did not follow the experiments instructions.
Materials

The stimulus was a single wave file that contained 3 musical performances and excerpts of pink noise. The performances were separated by pink noise as to prevent the synchronization response from the previous musical performance from influencing the synchronization response to the following musical performance. The performances of ālāp on sarod selected for this study consisted of: (1) Rāg Jaijaivanti by Buddhadev Das Gupta (1993, Nimbus, NI-5134), (2) Rāg Gaud Sarang by Vasant Rai (1975, Vanguard Nomad, SRV-73013) and (3) Kafi Kanada by Amjad Ali Khan (2002, Navras, NRCD-0159). The recordings were selected because they are recordings of ālāp that contain a variety of tempi, rhythmic-feels and timbre. Additionally, the extended ālāp section on the recording of rāg Kafi Kanada provides an opportunity to examine how subjects synchronize to ālāp over an extended period of time.
Procedure

Initially, subjects were briefed on the sequence of the experiment, in other words they were told that they would clap to silence, clap to the pulse of the recordings and listen passively to pink noise. Subjects were asked to clap to silence to see whether spontaneously-generated tempos were correlated with stimulus-driven tempos. The subjects were given a general oral instruction of “Listen, relax and clap to the pulse you hear.” The subject was also given written instructions that read as follows:

“Clap to silence at preferred tempo.
Listen to noise.
Listen and clap.
Listen to noise.
Listen and clap
Listen to noise
Listen and clap
Listen to noise
Clap to silence at preferred tempo
Stop at noise.”

Consistent with those instructions, the sequence of the experiment was as follows:

(1): The subject claps a pulse without stimuli for one minute. (“Clap to silence at preferred tempo.”) The silence is followed by twenty-five seconds of passive listening to noise. (“Listen to noise.”)

(2): The subject claps a pulse to one of the three recordings. (“Listen and clap.”) That musical recording was followed by twenty-five seconds of pink-noise that the subject listened to passively (“Listen to noise.”). This process is repeated with the two other recordings. (“Listen
and clap.” “Listen to noise.” Listen and clap.” “Listen to noise.”) The three recordings were presented in randomized order.

(3) The subject claps a pulse without stimuli for one minute again. (“Clap to silence at preferred tempo.”)

(4) The subject stops clapping when a recording of noise is heard. (“Stop at noise.”)

The recordings of pink noise were created in Adobe Audition. The recordings were played by a desktop computer. Subjects listened to the stimulus through AKG K-301 stereo headphones. Each subject’s clapping was recorded by a Sony-ECM 77b Electret Condenser Microphone. Both the stimuli and condenser microphone were connected to a MM30 Yamaha mixer that outputted into another desktop computer running Adobe Audition. Subject responses were recorded on a stereo-track in Adobe Audition with the right channel containing the stimuli and the left channel containing the subject’s response. There were six versions of the stimulus file, each containing all three performances in a different order (e.g. 1, 2, 3, or 1, 3, 2, or 2, 1, 3 etc.). For each subject the stimulus for was chosen by a random number table generated in excel.
Data Processing

Praat (a freeware program for linguistic analysis) was used to obtain the timing data of the clap events and prepare them for the phase angle measurement. Praat was used to identify the times of the onset of each sound event. Graphically, the steepest slope of the energy curve (Figure 1, panel 2) served as a reliable reference point for the measurement of the onset of the stimuli. An onset detection script followed by visual control of the automatic labeling resulted in the identification of the onset times of both the subject’s claps and the musical events (the stimulus). The visual control of the automatic labeling consisted of removing faulty onset markings and moving improperly placed onset markings to approximately the steepest slope. Onsets were categorized according to the string on which the sounds were produced as either melody events or chikārī events. A three-tiered analysis window was created in Praat for each performance (figure 1). The three-tiered analysis windows contained the waveform of the music, an amplitude curve and a tier where onsets were marked as “points.” The steepest slope of the amplitude curve approximated the musical event onset and was marked by a “point.” These analysis windows contained all relevant stimuli onsets. Subject clapping data was also analyzed using an onset detection script. Event and tapping onset times were then stored in a separate file for synchronization analysis.
Not all stimuli or clapping events were included in the analysis. Rhythmically complex portions of the jhālā sections were reduced to accented musical events. More specifically, the point-tiers representing the most complex portions of the jhālā section (chikārī tremolo) were modified so as to only contain the onset times of accented musical events, as they were the most likely to induce pulse. This event exclusion criterion was applied because subjects were presumably reacting to accented musical events and because tremolo is merely a means of prolonging the accented musical event.

An additional exclusion criterion was applied to instances where three or more claps occurred between two contiguous musical events. It is presumed that in order to be influenced by
a musical event, a clap has to border that event. As a result, in these instances an event exclusion criterion was applied in such a way that the claps were reduced to only the first clap and last clap, each bounded by a music event.
Statistical Analysis

Circular statistical methods were used to detect the phase alignment between the clapping and the music. Circular descriptive statistics are a clear and concise means of measuring periodic behavior and, most importantly, they avoid a cross-over error that occurs when some types of periodic data are averaged (Fischer: 1993). The crossover error is avoided by treating 0° and 360° as equivalent. Linear statistical methods would produce 180.5° as the average of 1° and 360°, whereas circular statistics would properly average these two measurements as 0°. Additionally, the Kuiper test of uniformity is appropriate for entrainment analysis because phase alignment should present a significant deviation from uniform distribution (Clayton, 2007). Additionally, the Kuiper test is a non-parametric test and will be appropriate for most data (Fisher: 1993). Also, the Mardia-Watson-Wheeler (MWW) multi-sample test is employed to determine whether the distributions of two or more data-samples groups are significantly different in terms of mean-angle and angular variance (Kanji, 2006). The MWW multi-sample test is particularly relevant for this experiment as the data collected may not be unimodal and the MWW multi-sample test is non-parametric (Fisher: 1993). For this study statistical significance is inferred at an alpha value of 0.05.
Question 1

Do individuals possessing prior experience exhibit a different synchronization pattern than those who do not possess prior experience?

The choice to order the results and discussion starting with the general and ending with the specific was made in an effort to present the study in an orderly and logical fashion. The statistical analysis consists of 1) an overall analysis for all 13 subjects and all pieces of music, and 2) a sectioned analysis examining each of the three sections of each of the three performances.
Full Analysis Results

Generally, subjects with prior experience demonstrated greater variability to the stimuli overall. Subjects with prior experience exhibit a higher circular standard deviation, a relatively shorter mean vector length, lower concentration and higher circular variance (table 1). Overall, neither subject group exhibited a uniform distribution as demonstrated by significant Kuiper test statistic results (table 2). The significant Kuiper test result suggests that both subject groups’ clapping were synchronized to the musical performances. Additionally, it is reasonable to assert that subjects with and without prior experience demonstrate different patterns of synchronization to North Indian ālāp (MWW W: 637, p<1E-12) (table 3).

<table>
<thead>
<tr>
<th>Music</th>
<th>Experience</th>
<th>Circular STD</th>
<th>Mean Vector Length</th>
<th>Concentration</th>
<th>Circular Variance</th>
<th>Mean Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>0</td>
<td>111.215°</td>
<td>0.152</td>
<td>0.308</td>
<td>0.848</td>
<td>7.996°</td>
</tr>
<tr>
<td>All</td>
<td>1</td>
<td>122.219°</td>
<td>0.103</td>
<td>0.207</td>
<td>0.897</td>
<td>351.504°</td>
</tr>
</tbody>
</table>

Table 1 Descriptive Statistics for the full analysis sub-grouped by experience. Experience 0: non-experienced and Experienced 1: experienced.

<table>
<thead>
<tr>
<th>Music</th>
<th>Training</th>
<th>Kuiper V-Statistic (Uniform)</th>
<th>Kuiper p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>0</td>
<td>12.822</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>All</td>
<td>1</td>
<td>7.625</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

Table 2 Kuiper test results for the full analysis sub-grouped by experience. Experience 0: non-experienced and Experienced 1: experienced.

<table>
<thead>
<tr>
<th>Mardia-Watson-Wheeler W-statistic</th>
<th>Mardia-Watson-Wheeler p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>63.7</td>
<td>&lt; 1E-12</td>
</tr>
</tbody>
</table>

Table 3 MWW multi-sample test result for the full analysis.
**Full Analysis Discussion**

Why would subjects possessing prior experience demonstrate greater variability? There are a few reasonable explanations. First, greater overall variability does not necessarily imply greater intra-subject variability. Thus, much like the Drake and El Heni (2003), subjects with prior experience may differ amongst each other in where they feel pulse due to increased familiarity with the musical style. Second, the subjects with prior experience demonstrated greater variability in their responses because their experience levels differed. While subjects without prior experience were all graduate music students, the subjects with prior experience had experience ranging from 1 year of instruction to that of professional performers.

**Sectioned Analysis Results**

The descriptive statistics suggests that both subject groups differ in terms of their variability (table 4). For instance, the group that possessed prior experience demonstrated a less variable synchronization pattern during the 1) ālāp of Gaud Sarang, 2) the ālāp of Jaijaivanti and 3) the second ālāp section of Kafi Kanada. The group that did not possess prior experience exhibited less variability than the group possessing prior experience for 1) the jor of Gaud Sarang, 2) the jhālā of Gaud Sarang, 3) the jor of Jaijaivanti, 4) the jhālā of Jaijaivanti and 5) the first ālāp section of Kafi Kanada. Additionally, the group without prior experience exhibited relatively less variability to the third ālāp section of Kafi Kanada. See figure 5 for a visual comparison of variability as measured by mean vector length.
<table>
<thead>
<tr>
<th>Music</th>
<th>Experience</th>
<th>Circular Standard Deviation</th>
<th>Mean Vector Length</th>
<th>Concentration</th>
<th>Circular Variance</th>
<th>Mean Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS.1</td>
<td>0</td>
<td>145.535°</td>
<td>0.04</td>
<td>0.079</td>
<td>0.96</td>
<td>28.579°</td>
</tr>
<tr>
<td>GS.1</td>
<td>1</td>
<td>132.356°</td>
<td>0.069</td>
<td>0.139</td>
<td>0.931</td>
<td>326.225°</td>
</tr>
<tr>
<td>GS.2</td>
<td>0</td>
<td>79.796°</td>
<td>0.379</td>
<td>0.819</td>
<td>0.621</td>
<td>33.27°</td>
</tr>
<tr>
<td>GS.2</td>
<td>1</td>
<td>99.834°</td>
<td>0.219</td>
<td>0.449</td>
<td>0.781</td>
<td>359.138°</td>
</tr>
<tr>
<td>GS.3</td>
<td>0</td>
<td>110.215°</td>
<td>0.157</td>
<td>0.318</td>
<td>0.843</td>
<td>17.383°</td>
</tr>
<tr>
<td>GS.3</td>
<td>1</td>
<td>130.73°</td>
<td>0.074</td>
<td>0.149</td>
<td>0.926</td>
<td>330.023°</td>
</tr>
<tr>
<td>J.1</td>
<td>0</td>
<td>162.104°</td>
<td>0.018</td>
<td>0.037</td>
<td>0.982</td>
<td>359.455°</td>
</tr>
<tr>
<td>J.1</td>
<td>1</td>
<td>153.277°</td>
<td>0.028</td>
<td>0.056</td>
<td>0.972</td>
<td>331.066°</td>
</tr>
<tr>
<td>J.2</td>
<td>0</td>
<td>84.073°</td>
<td>0.341</td>
<td>0.725</td>
<td>0.659</td>
<td>350.434°</td>
</tr>
<tr>
<td>J.2</td>
<td>1</td>
<td>101.541°</td>
<td>0.208</td>
<td>0.425</td>
<td>0.792</td>
<td>340.304°</td>
</tr>
<tr>
<td>J.3</td>
<td>0</td>
<td>114.697°</td>
<td>0.135</td>
<td>0.272</td>
<td>0.865</td>
<td>11.213°</td>
</tr>
<tr>
<td>J.3</td>
<td>1</td>
<td>123.505°</td>
<td>0.098</td>
<td>0.197</td>
<td>0.902</td>
<td>6.318°</td>
</tr>
<tr>
<td>KK.1</td>
<td>0</td>
<td>137.234°</td>
<td>0.057</td>
<td>0.114</td>
<td>0.943</td>
<td>298.405°</td>
</tr>
<tr>
<td>KK.1</td>
<td>1</td>
<td>138.656°</td>
<td>0.053</td>
<td>0.107</td>
<td>0.947</td>
<td>75.773°</td>
</tr>
<tr>
<td>KK.2</td>
<td>0</td>
<td>141.917°</td>
<td>0.047</td>
<td>0.093</td>
<td>0.953</td>
<td>53.882°</td>
</tr>
<tr>
<td>KK.2</td>
<td>1</td>
<td>133.858°</td>
<td>0.065</td>
<td>0.131</td>
<td>0.935</td>
<td>49.772°</td>
</tr>
<tr>
<td>KK.3</td>
<td>0</td>
<td>141.533°</td>
<td>0.047</td>
<td>0.095</td>
<td>0.953</td>
<td>331.17°</td>
</tr>
<tr>
<td>KK.3</td>
<td>1</td>
<td>160.786°</td>
<td>0.019</td>
<td>0.039</td>
<td>0.981</td>
<td>70.246°</td>
</tr>
</tbody>
</table>

Table 4 Descriptive statistics for the sectioned analysis sub-grouped by experience.
The Kuiper test shows deviations from uniformity (suggestive of synchronization) for both subject groups during 1) the jor of Gaud Sarang, 2) the jhālā of Gaud Sarang, 3) the jor of Jaijaivanti, 4) the jhālā of Jaijaivanti and 5) the second ālāp section of Kafi Kanada (table 5). According to the Kuiper test, only the non-experienced group was able to synchronize to the ālāp
osf Gaud Sarang. Additionally, neither group was able to synchronize to 1) the ālāp of Jaijaivanti, 2) the first ālāp section of Kafi Kanada or 3) the third ālāp section of Kafi Kanada.

<table>
<thead>
<tr>
<th>Music</th>
<th>Kuiper V Experience 0</th>
<th>Kuiper p-value Experience 0</th>
<th>Kuiper V for Experience 1</th>
<th>Kuiper P-value Experience 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS.1</td>
<td>1.472</td>
<td>&gt;0.15</td>
<td>1.948</td>
<td>&lt;0.025</td>
</tr>
<tr>
<td>GS.2</td>
<td>11.292</td>
<td>&lt;0.01</td>
<td>6.188</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>GS.3</td>
<td>4.576</td>
<td>&lt;0.01</td>
<td>2.54</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>J.1</td>
<td>1.229</td>
<td>&lt;0.15</td>
<td>1.324</td>
<td>&lt;0.15</td>
</tr>
<tr>
<td>J.2</td>
<td>12.825</td>
<td>&lt;0.01</td>
<td>7.514</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>J.3</td>
<td>4.419</td>
<td>&lt;0.01</td>
<td>2.847</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>KK.1</td>
<td>1.709</td>
<td>0.10&gt;p&gt;0.05</td>
<td>1.288</td>
<td>&gt;0.15</td>
</tr>
<tr>
<td>KK.2</td>
<td>1.789</td>
<td>&lt;0.05</td>
<td>1.993</td>
<td>&lt;0.025</td>
</tr>
<tr>
<td>KK.3</td>
<td>1.651</td>
<td>0.10&gt;p&gt;0.05</td>
<td>1.096</td>
<td>&gt;0.15</td>
</tr>
</tbody>
</table>

Table 5 Kuiper Test results for sectioned analysis sub-grouped by experience. GS.1 is the only section where one group passed the test of significance and the other did not. Experience 0: non-experienced. Experience 1: experienced.

A Mardia-William-Watson multi-sample test detected significant deviations in variability between subject groups for 1) the jor of Gaud Sarang, 2) the jhālā of Gaud Sarang, 3) the jor of Jaijaivanti and 4) the first ālāp section of Kafi Kanada (table 6). The descriptive statistics for the aforementioned sections suggest that in all cases where the subjects’ synchronization differed significantly, the experienced group demonstrated greater variability (table 7). See figure 3 for a
visual comparison of variability for the aforementioned sections as measured by mean vector length.

<table>
<thead>
<tr>
<th>Music</th>
<th>MWW W-Statistic</th>
<th>MWW P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS ālāp</td>
<td>3.028</td>
<td>0.22</td>
</tr>
<tr>
<td>GS jor</td>
<td>112.425</td>
<td>&lt; 1E-12</td>
</tr>
<tr>
<td>GS jhālā</td>
<td>27.436</td>
<td>1.10E-6</td>
</tr>
<tr>
<td>J ālāp</td>
<td>0.493</td>
<td>0.781</td>
</tr>
<tr>
<td>J jor</td>
<td>71.283</td>
<td>&lt; 1E-12</td>
</tr>
<tr>
<td>J jhālā</td>
<td>2.921</td>
<td>0.232</td>
</tr>
<tr>
<td>KK ālāp one</td>
<td>7.778</td>
<td>0.02</td>
</tr>
<tr>
<td>KK ālāp two</td>
<td>0.303</td>
<td>0.86</td>
</tr>
<tr>
<td>KK ālāp three</td>
<td>2.862</td>
<td>0.239</td>
</tr>
</tbody>
</table>

Table 6 Mardia-Watson-Wheeler Multi-sample test results for the sectioned analysis. Significant differences between subject groups were detected for 1) the first ālāp section of rāg Kafi Kanada 2) the jor in rāg Gaud Sarang and the jor in rāg Jaijaivanti 3) the jhālā in rāg Gaud Sarang.

<table>
<thead>
<tr>
<th>Music</th>
<th>Training</th>
<th>Circular Standard Deviation</th>
<th>Mean Vector Length</th>
<th>Concentration</th>
<th>Circular Variance</th>
<th>Mean Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS.2</td>
<td>0</td>
<td>79.796°</td>
<td>0.379</td>
<td>0.819</td>
<td>0.621</td>
<td>33.27°</td>
</tr>
<tr>
<td>GS.2</td>
<td>1</td>
<td>99.834°</td>
<td>0.219</td>
<td>0.449</td>
<td>0.781</td>
<td>359.138°</td>
</tr>
<tr>
<td>GS.3</td>
<td>0</td>
<td>110.215°</td>
<td>0.157</td>
<td>0.318</td>
<td>0.843</td>
<td>17.383°</td>
</tr>
<tr>
<td>GS.3</td>
<td>1</td>
<td>130.73°</td>
<td>0.074</td>
<td>0.149</td>
<td>0.926</td>
<td>330.023°</td>
</tr>
<tr>
<td>J.2</td>
<td>0</td>
<td>84.073°</td>
<td>0.341</td>
<td>0.725</td>
<td>0.659</td>
<td>350.434°</td>
</tr>
<tr>
<td>J.2</td>
<td>1</td>
<td>101.541°</td>
<td>0.208</td>
<td>0.425</td>
<td>0.792</td>
<td>340.304°</td>
</tr>
<tr>
<td>KK.1</td>
<td>0</td>
<td>137.234°</td>
<td>0.057</td>
<td>0.114</td>
<td>0.943</td>
<td>298.405°</td>
</tr>
<tr>
<td>KK.1</td>
<td>1</td>
<td>138.656°</td>
<td>0.053</td>
<td>0.107</td>
<td>0.947</td>
<td>75.773°</td>
</tr>
</tbody>
</table>

Table 7 Descriptive statistics for the sections that were demonstrated as being significantly different by the MWW multi-sample test.
Figure 3 Mean vector lengths for sections selected by the Mardia-Watson-Wheeler test as being significantly different. Experience level 0 = non-experienced. Experience level 1 = experienced. GS=Gaud Sarang, J=Jaijaivanti and KK=Kafi Kanada.
Sectioned Analysis Discussion

The sectioned analysis complicates the discussion because it appears that in one way or another both subject groups differ in regards to variability and synchronization. Yet, it is simplified greatly when the Mardia-Watson-Wheeler test results are used to determine whether or not seemingly different responses are statistically significant. Again, the MWW test compares two independent random samples to see whether or not they differ significantly in their mean vector and/or circular variance (Kanji: 2006) and the Kuiper tests is used to see whether a given distribution differs significantly from a random distribution (Fisher: 1993). While the subject groups ability to synchronize (Kuiper test) do not differ in any of the sections that tested as significantly different for the MWW test, their variability as demonstrated by both the MWW and the descriptive statistic do. Why did the experienced group demonstrate a more variable pattern of synchronization to the sections selected as significantly different by the MWW multi-sample test? The two explanations presented in the preceding discussion are still compelling. The higher variability demonstrated by subjects with prior experience does not necessarily suggest that subjects were less synchronized to the stimuli. As mentioned above, Drake and El Heni (2003) found that listeners possessing prior experience demonstrated higher inter-subject variability because they were able synchronize at varying pulse levels. Also, the subjects possessing prior experience had experience that ranged from amateurs with 1+ year of formal training to professional performers, while the individuals without prior experience all studied
music at the graduate level. If, in fact, the subjects with prior experience were exhibiting greater inter-subject variability, it could likely be a result of varying experience.

Why was one subject group able to synchronize with the ālāp of Gaud Sarang, while the other subject group was not (table 5)? A reasonable explanation is that the ālāp section is anibaddha (rhythmically unbound). Thus, its slow tempo and free-rhythm presented difficulty for the subjects without prior experience.

It is interesting to note that the subjects with prior experience approached a 1:1 synchronization ratio for the jor of Gaud Sarang, while the subjects without prior experience did not. This is demonstrated by the subjects with prior experience mean vector of 359.138° with a standard error of 4.415° and a 95% Confidence Interval (-/+ for μ of 350.483° 7.792°. While the subjects with prior experience approached a 1:1 synchronization ratio, the subjects without prior experiences did not as they demonstrated a mean vector of 33.27° with a standard error of 2.528° and 95% Confidence Interval (-/+ for μ of 28.313° 38.226°. While the subjects without prior experience demonstrated less variability for during the jor of Gaud Sarang, on average they clapped later than both the musical onsets and the subjects with prior experience during the jor of Gaud Sarang.
Question two: Do spontaneously generated clapping tempos correlate with stimulus-driven clapping tempos?

Background

Drake, Jones and Baruch (2000) present a dynamic attending framework that consists of referent period, referent level, focal attending and attunement. The referent period is the rate of an attentional oscillator independent of external stimulus. The referent period is likely reflected in spontaneously generated tempo. The referent level is the stimulus level that ones’ attention attaches onto. The referent level is similar to the tactus in music. Attunement is the process by which an attentional oscillator becomes locked into a stimulus periodicity. The dynamic attending framework suggests that spontaneously generated tempi should be correlated with stimulus induced tempi. Focal attending is the process by which the subjects attention is focused away from the referent level and focused on either higher (slower) or lower (faster) stimulus levels.

Results

1) A regression analysis was performed with the first instance of spontaneous clapping as the independent variable and the first ālāp section heard by each subject as the dependent variable. This analysis yielded a non-significant result with R=.210 and an ANOVA SC1 x A.1 (F=.505 Sig.=.492).
2) An additional regression analysis was performed with the first instance of spontaneous clapping as the independent variable and the second ālāp section heard as the dependent variable. This analysis yielded a non-significant result with R=.117 and an ANOVA SC1 x A.1 (F=.151 Sig.=.705).

3) Yet another regression analysis was performed with the first instance of spontaneous clapping as the independent variable and the third ālāp section heard as the dependent variable. This analysis yielded a non-significant result with R=.069 and an ANOVA SC1 x A.1 (F=.052 Sig.=.824).

4) Finally, a regression analysis was performed with the first instance of spontaneous clapping as the independent variable and the second instance of spontaneous clapping as the dependent variable. It yielded a significant result with R=.869 and an ANOVA SC1 x A.1 (F=34.015 Sig.<0.005). As demonstrated by the higher R-Value, a significant ANOVA results and a significant coefficient result, there is a significant correlation between the first and second sections of spontaneous clapping.

Discussion

The non-significant result of the regression analysis of spontaneously generated clapping and subject clapping to the ālāp sections suggest that that the spontaneously generating clapping was not correlated with clapping to the ālāp sections at a 1:1 ratio. This suggests that subjects were utilizing a more sophisticated form of focal attending to synchronize to the ālāp sections. It is likely that subjects demonstrated more complex synchronization ratios, like the ones discussed in Will (2011). Additionally, the correlation between the first period of spontaneous clapping and the second period of spontaneous clapping suggests that the pink-noise was effective in
interrupting any lingering synchronization from the preceding stimulus to any of the following stimuli.

**Question 3: Does muhkra lead to a different pattern of synchronization in experienced listeners?**

**Background**

The muhkra is a cadential melody that occurs during the alap and marks the transition from ālāp to jor and jor to jhālā. Widdess and Sanyal elaborate:

“As traditionally the muhkra comprises two segments: the first (a) comprises several repetitions or a prolongation of the middle tonic, while the second (b) briefly touches neighboring notes, first below then above the tonic, before returning to the tonic itself. . . As well as a conventional melodic shape – which in effect summarizes the rāg in miniature. The muhkra has a distinctive rhythmic structure. It is always performed in a regular, pulsed rhythm, even in the context of the ‘free rhythm’ of slow ālāp. The reiterated tonic in the first segment, and the first three notes of the second segment, are sung in equal durations, leading to the most emphasized note, which is usually the highest, and may be prolonged for two beats before dropping back to the tonic. This emphasized note is called the sām of the muhkra. . . the approach to the sām of the muhkra does introduce a sense of metrical anacrusis or up-beat, followed by a downbeat on the sām. . .” (Sanyal, Widdess: 2004, 158)

Again, while all claps were accounted for, claps having an ICI (inter-clap interval) longer than 4-5 seconds were eliminated as they presumably reflect a loss of attention. Because prior experience helps individuals categorize and recognize current perceptual experience more readily, it is reasonable to assume that individuals with prior experience synchronize differently to muhkra than individuals without prior experience. For instance, given this hypothesis, it is reasonable to assume that individuals with prior experience will exhibit a less-variable relationship to the muhkra than those without prior experience. This assumption is valid because,
except the transition from the jor to the jhala, the mukhra often marks the transition from
anibaddha rhythm to a nibaddha rhythm. Additionally, the mukhra that separates the jor and the
jhālā sections is a unique rhythmic transitions not found in Western music. It is reasonable to
assume that this type of transitional passage is unfamiliar to non-experienced listeners. In order
to test this hypothesis, subject responses to seven (7) different nine-second portions of seven (7)
different mukhra are compared to a uniform distribution (Kuiper test). If the subjects’ clapping
differs significantly from a uniform distribution, it is reasonable to assume that the subject is
synchronized to the music.
Results and Discussion

A total of seven mukhra were analyzed for this portion of the study (Four occurring during the alap section, two that serve as a transition from the alap to the jor section and one that served as a transition from the jor to the jhala section). As the mukhra were generally of different lengths, musically relevant portions of nine seconds were selected for analyses. The musical selections began at the beginning of the mukhra and did not contain notes not contained in the mukhra. Individuals with prior experience generally responded with fewer claps to both mukhra (400), while individuals without prior experience clapped more often (442). The Mardia-Watson-Wheeler multi-sample test (1344.692 at a $p < 1E-12$) supports the claim that individuals with prior experience exhibit a different pattern of synchronization to the selected mukhra from those without prior experience. A Kuiper test performed on all seven mukhra responses supports the hypothesis that individuals without prior experience were not synchronized with the mukhra ($p < 0.10, 0.05$), while individuals with prior experience were ($p > 0.01$). Finally, individuals with prior experience demonstrated a less variable relationship to the mukhra portions (Experienced: Concentration 0.309, circular variance 0.847 and mean vector length 0.153. Non-experienced: Concentration 0.132, circular variance 0.934, mean vector length 0.066).

Why is it that individuals’ with prior experience demonstrate a less-variable relationship with the mukhra? While it is not possible to provide a definitive answer, further research may show a stronger correlation between prior experience in the form of training and the pattern of synchronization exhibited to the mukhra. Additionally, with the exception of a mukhra separating the jor from the jhala section, the mukhra serves as a transition between anibaddha
and nibadah (free time and bound time). It is reasonable to assume that the perceptual experience of the mukhra is an unfamiliar and disorienting juxtaposition to non-experienced listeners and the contrary with respect to experienced listeners.
Concluding remarks

Accuracy in assessing musical note onset times is a necessity in future studies of ālāp and synchronization. While great care was taken in labeling onset times in this study, it is possible that even slight variability in onset placement created unwanted noise in the data. It is possible that this methodological flaw could be solved by creating a taxonomy of intensity curves and defining their onsets outright.

The present study serves as a building block for future studies in rhythmic synchronization. Firstly, this study demonstrates that the relationship between prior musical experience and rhythmic synchronization is not simple, nor unimportant. In fact, prior experience is a variable that must be accounted for in many studies of music perception. Further studies that offer predictive insight into the relationship between synchronization and prior experience are warranted.
References


