COMPARISON OF RHYTHM PERCEPTION

IN

DANCERS AND MUSICIANS

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MAY- 2012

To my dear Amma, Achan,

Kannan Chettan, Aneema chechi

'n my expecting niece/nephew n

significant others……………

CERTIFICATE

This is to certify that this dissertation entitled **"Comparison of rhythm abilities in dancers and musicians"** is the bonafide work submitted in part fulfillment for the degree of Masters of Science (Audiology) of the student (Registration No.10AUD004). This has been carried out under the guidance of a faculty of the institute and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled ***"Comparison of rhythm perception abilities in Dancers and Musicians"*** is the result of my own study under the guidance of Dr.K.Rajalakshmi, Reader in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted in any other university for the award of any diploma or degree.

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CHAPTER 1

INTRODUCTION

Rhythm is a pervasive phenomenon. Every event in the nature follows a rhythm; from heartbeat to the appearance of comet, everything has a regular occurrence. Rhythm is defined as an ordered recurrent alternation of strong and weak elements in the flow of sound and silence. The experience of rhythm involves movement, regularity, grouping, accentuation and differentiation (Handel, 1989). Rhythm perception and production is a basic skill which helps us to synchronize with music like tapping, clapping, dancing, playing musical instruments and synchronizing oneself with other performers. The perception of rhythm is a dynamic process and it involves the synchronization of external musical stimuli with internal rhythmic processes (Jones and Boltz, 1989). Batalha, Macara (2007) reported of no influence of gender in rhythm perception. Patel (2007) reported of language rhythm playing an important role in musical rhythm perception in people.

Anatomically, the correlates of rhythm perception are attributed to basal ganglia (Grahm, 2009) and also to Supplementary Motor Area (bilaterally) and also extend into regions of cingulate gyrus, basal ganglia (Geisler, 2008).

Two important factors in rhythm perception are meter and pulse or beat. These are periodic elements which are extracted from the musical composition. Meter and pulse are dynamic temporal referents that shape experiences of musical rhythms. A stable perception of meter and beat is very essential for rhythm perception. Though the rhythm perception is dependent on these dynamic temporal referents, they themselves are not stimulus properties.

Pulse or Beat

Rhythm perception involves chunking or sectioning the temporal pattern thus enabling the perception of beats. Beat is a perceived pulse that marks equally spaced points in time. Cooper and Meyer (1960) define pulse as ‘‘a series of regularly recurring, precisely equivalent’’ psychological events that arise in response to a musical rhythm. Perception of beats is on the basis of endogenous periodicity. It is because of beat perception that we are able to relate the onset of temporal intervals as multiple or subdivisions of the beat, thus perceiving related intervals and not as unrelated intervals which in turn help in rhythm perception and production (Drake and Gerard, 1989; Ross and Houtsma, 1994, Patel et al., 2005). Although pulse is a factor affecting perception of rhythm in a stimulus, it itself is not a stimulus property (Lerdahl & Jackendoff, 1983). Pulse provides a stable, dynamic referent from which the rhythm can be inferred. Stability is emphasized by Cooper and Meyer (1960), who observed that pulse, ‘‘once established, tends to be continued in the mind and musculature of the listener’’ even after a rhythmic stimulus ceases.

Beat perception also aids to guess future temporal events on the basis of perceived temporal regularity. Perception of beats is an important factor in remembering the rhythm as well as reproducing the rhythm (Patel, Essens & Povel, 1985; Iversen, Chen, & Repp, 2005).

There is a generalized synchrony of the pulse with the musical rhythm. Usually the pulse coincides with the onset of event in musical excerpt, but because of the complexity of the musical rhythm, pulses may or may not coincide with the periodic pulse and can even occur without any event onsets. For a rhythm that is periodic, there are more chances of the pulses to coincide with the event onsets in the musical excerpt. Cooper and Meyer (1960) argue that pulse continues even if musical events ‘‘fail for a time to coincide with the previously established pulse,’’. This suggests that once the beat is established there is some kind of temporal stability even if the beats no longer coincide with the event onsets.

Temporal arrangement of beats in a musical composition is very essential for beat perception. Regularly spaced beats are better perceived than irregularly spaced beats. Metrical rhythms are the rhythms in which the beat sequences can be equally partitioned can be better perceived and retrieved easier than a rhythm where the sequences cannot be partitioned equally.

Perception of beats occurs when we synchronize the external stimuli with an internally generated temporal pattern. The temporal properties which the listeners use to generate the internal rhythm are not clearly known. One property that may be important for beat perception in rhythm is the presence of simple integer ratio relationships between intervals in a sequence (Essens, 1986; Sakai et al., 1999). Another factor that aids beat perception is the perception of accents. Accents cause a particular note to feel more prominent than its surrounding notes. Previous research has shown that a listener's attention is attracted to accented events (Jones & Boltz, 1989). In musical contexts, the accents are created by non-temporal cues such as pitch, volume, and timbre, yet even rhythms without these cues can induce listeners to ‘‘feel’’ a beat internally (Abecasis, Brochard, Drake, Potter, Ragot,2003).

The accents can be:

Intensity accentuation: If every nth pulse in an isochronous pulse train is a little louder, pulses are heard as organized into groups of n, with the louder pulse heard as the beginning of each group (Fraisse, 1956). Also, the interval immediately before the louder pulse is heard as being slightly shorter.

Duration accentuation: If every nth pulse in a train is lengthened, pulses are heard as organized into groups of n with the longer pulse ending each group (Woodrow, 1951). Also, the longer pulse is heard to be more louder.

Interval differences: If the interval between every nth pulse is lengthened, the pulses are heard to be segregated into groups of n with the increased interval between groups (Povel & Okkerman, 1981). A small lengthening of the nth interval results in the first pulse in the group to be heard with increased loudness, while greater lengthening results in the last pulse in the group being heard with increased loudness.

Frequency differences: Frequency affects perceptual grouping in a variety of interacting ways. Each of the following, possibly co–occurring, variable tends to be heard as starting a group (Thomassen, 1982)

Perception of beats can also occur when the subjects place perceptual subjective accents in an iso-synchronous train of clicks. Thus an internally generated pattern of the temporal events can result in beat perception irrespective of the presence of accent.

Beat perception varies among listeners on the periodicity of the beats and beat perception can occur as the multiple of the periodicity of the temporal intervals. The most prominent temporal interval is referred to as tactus. While people tap to a rhythm, they tend to tap at a tempo which is close to the natural tempo of the metronome or musical piece. But people may also tap at tempo which is half as that of the original tempo. (eg: if the tempo is 160 BPS, people may tap at 160 BPS or can even tap at 80 BPS). While tapping to metronome, an important finding has been reported by Repp (2006) which is negative asynchrony. This the phenomenon in which, while the subject taps in synchrony with a metronome, the taps of the subject tend to be slightly earlier (milliseconds difference).

Meter

The terms “meter” and “metrical structure” refer to patterns of regularly recurring stronger and weaker pulses (Lerdahl & Jackendoff, 1983). Lerdahl and Jackendoff’s (1983) system, the fundamental pulse periodicity (the rate at which one might spontaneously tap with a musical rhythm) would be notated as a single row of beats, and the pattern of strong and weak pulses as additional rows of beats at related frequencies. Metrical structure or meter is temporal pattern created by the simultaneous perception of beats by different temporal scales. It is one of the most important aspects of rhythmic experience. The feeling of regularly occurring beats give to the percept of metrical accent (Leherdahl, Jackendoff 1983). Points where more beats coincide are felt strong, these are referred to as downbeats. On the other hand points where less beats coincide are felt weak, which are referred to as upbeats. The time points at which the beats of more levels coincide denote stronger pulses. Zuckerkandl (1956), meter is a series of waves that carry the listener continuously from one downbeat to the next.

The resonance theory for beat and meter perception (Large and Kolen,1994; Large, 2008) proposed that beat perception emerges from the entrainment of neuronal populations resonating at the beat frequency, itself giving rise to higher-order resonance at sub-harmonics of beat frequency, corresponding to the meter.

Need of the study

Rhythm is one aspect of music perception and speech perception in which there is a scarcity of literature when compared with other domains like pitch and intensity.

Most studies in rhythm perception have compared musicians and non-musicians. Though dancers are a population who also depend on rhythm perception for their performance only few studies have pondered into the rhythm perception abilities of dancers. Hence a comparative study of rhythm skills in musicians and dancers would throw light onto which group have superior skills.

The Bharatanatyam dance form and Carnatic music share similar musical compositions and are exposed to the same rhythms and they are trained similarly. But while performing and practicing, rhythm is maintained in different manner by the two groups. The Carnatic musicians maintain rhythm by tapping with the palm and Bharatanatyam dancers maintain practice by stamping it on their feet. Understanding the perception of rhythm in dancers and musicians will throw light on which mode of rhythm maintenance could be utilized for training rhythm to the speech and hearing impaired individuals.

Beat perception is one factor expected to have an effect on rhythm perception. But the role of beat perception in rhythm is not studied much. Thus investigating the role of beat perception in rhythm can help us understand as to how to impart rhythm training for individuals with poor rhythm skills.

Aims of the study:

The present study aims at:

1. To compare the rhythm perception skills of musicians and dancers.
2. To find out whether perception of beats influence identification and synchrony with the rhythm of a musical composition.
3. To find out whether years of experience plays a role in rhythm perception.

CHAPTER 2

REVIEW OF LITERATURE

The perception of rhythm has been studied extensively. The domains which have been chosen for studying rhythm perception included perception of underlying beat of a musical composition, perceiving the meter of a composition, finding out the neural correlates of rhythm perception, cultural influences in rhythm perception and perception of syncopated rhythm. Studies have been reported in different populations like musically trained and untrained people, dancers, infants and hearing impaired people. While most studies have used music related stimuli, there are studies which had used speech as the stimuli.

(a) Behavioral studies on rhythm perception

The Beat Alignment Test (BAT) is a test developed by Iversen and Patel (2008). It has 3 subtests namely (i) synchronization with a metronome, (ii) synchronization with a musical piece and (iii) subtest which assessed the beat perception abilities. Iversen, Patel (2008) using the BAT test assessed the rhythm perception abilities in general population. The results of 30 subjects were analyzed and the correlation of the two tests was studied. Results indicated that except for one subjects, all the others could find some kind of rhythm in all the music composition. Scores from the beat perception subtests revealed that subjects could identify on beat conditions majority of the time and that they made errors with the phase error and tempo error conditions. Hence the study concluded that offbeat conditions were confused with on-beat conditions and not the other way around.

Rhythm perception skills are usually reflected in motor activity like clapping, walking, tapping etc. inorder to investigate this, Styns et al (2007) carried out a study to find out the ability of musicians to synchronize their walking tempo with a musical tempo. The study included both professional and amateur musicians. The task given to the subjects was to walk in synchrony with musical piece which was presented through the headphones. The walking tempo was measured using a small MP3 recorder placed in one of the shoe of the subjects. The second section of the experiment involved making the subjects tap the rhythm of the same musical pieces that they have been exposed to during the walking experiment. The taps were recorded and also a subjective rating scale to rate the familiarity, general mood of the song, tempo of the song. The results were analyzed for synchronization with the music for tapping and walking. Results revealed that for most of the walking rate was equal to the tapping rate. In few cases the walking tempi was half, or quarter as that of the tapping tempo while few others had walking tempi double or quadruple as that of the tapping tempo.

Factors influencing rhythm perception

Experience and exposure plays an important role in rhythm perception. Thus the person Inorder to study this , Batalha, Macara (2007) compared the rhythm skills in professional dancers and dance students. The test they used had three parts. The first part was transcription of rhythmic structures (temporal, intensity). In this part, each individual must perceive the rhythmic stimulus, recognize it as a structure, and symbolize it graphically. The second part of the experiment included synchronization with a rhythmic structure. The final part of the experiment was reproduction of a rhythmic sound structure and of a movement sequence. Results showed that in all the tasks professional dancers showed better scores but only the last task was statistically different. The authors also report of no sex difference in rhythm skills.

Role of accents in rhythm perception

When accents are placed on every nth beat in a series of pulses or beats, the rhythm perception changes since the listener tends to perceive a different meter when accents are imposed. Inorder to study the effect of accent on rhythm perception, Okkerman and Povel (1981) used isopitch and isointensity sequence (1000Hz, 50dB tone of 50msec duration),but varied the interval between 2 tones such that every other unfilled interval was slowly lengthened. Thus in this experiment, the accent was in terms of duration increase. When the unfilled interval was lengthened to 5-10% of the short interval, the subjects perceived a grouping of the tone such that the listeners perceived an increased intensity on the first tone. An increased intensity in the second tone was observed when the longer interval was increased more. The authors reported of the effect to be obtained at intervals from 50 msec up to 300 msec. The perceived increased intensity on the second tone in the group was measured to be equal to a real increase of 4 dB by increasing the real intensity of the first tone in the group until subjects reported the two tones to be perceived to be of equal intensity. The subjects began to group the series of pulses according to subjective intensity accents created as a result of the increased duration.

Rhythm perception is dependent on finding out the underlying pulse/ beats. This beat finding depends on perception of cues. Snyder and Krumhansl (2001) conducted two experiments which investigated the cues that listeners make use of to pulse finding. The participants had to tap a comfortable beat on a keyboard which in turn played a percussion sound. The stimulus materials were played using a metronome. The first part of the experiment compared musically trained and untrained subjects. The stimulus was presented in 2 versions: a pitch-varied version (the original excerpt) and a monotonic version that was designed to remove all melodic and harmonic cues to pulse. Results indicated that the absence of pitch information or musical experience did not affect the performance. In the second experiment, the subjects were 12 musically trained subjects on shorter musical excerpts of the ragtime compositions. Full versions, and right hand versions were played in both the two versions. Results showed that when the left hand part was removed , it significantly affected tapping performance on a number of measures, causing a lower percentage of tapping on the downbeat, more offbeat taps, more aperiodic taps, more switches between tapping modes, a higher variability of the inter-tap interval, and larger deviations from the beat. Thus results suggest that removing the left-hand part has a negative effect. The second experiment also suggested less effect of pitch varied and monotonic versions. Through the analysis of results authors suggested the following as the cues to pulse finding: a predictable alternating bass pattern in the left-hand part and a majority of notes on metrically predictable positions in both right and left hand parts. Thus temporal cues are important for beat perception and beat perception is indeed independent of pitch information

Training is one factor which can affect rhythm perception. Inorder to study the influence of training on rhythm perception, Leppe and Trainer (2011) conducted a study investigated the effect of piano training using a rhythmic focused exercise on responses to rhythmic musical material. All the subjects were non-musicians and they received piano training for two weeks as part of the experiment. The subjects were divided into two groups - one group was taught to play piano with a distinct musical rhythm (it was called the sensori-motor, SA group) and the other group (called the Auditory A group) listened and evaluated the rhythmic accuracy of the SA group. Magnetic Encephalography (MEG) was used to evaluate the training induced plasticity and Mis Match Negativity (MMN) was used for comparing response to occasional rhythmic deviancy in a repeating rhythm pattern before and after training. When compared between the groups, there was a significant enlargement of MMN and P2 to deviants in SA group following training when compared to the A group. The training induced changes were present bilaterally. Thus the authors suggested that during training if the auditory experience is strictly controlled, then the involvement of the sensori-motor system and the attentional resources required for rhythm production may lead to more plastic changes in the cortex when compared to mere attending to rhythm in auditory domain only.

Tapping to complex meters and tapping to rhythms without accents is hypothesized to be difficult owing to their complexity, Hannon, Snyder, Large (2006) assessed this ability in general population of North America. His aims were to assess people's ability to synchronize and continue their tapping to complex meter patterns in the presence and absence of musical cues to meter. The participants were made to tap to drum patterns structured according to two different 7/8 meters common in Balkan music. Each of the meter in the testing had three nonisochronous drumbeats per measure, forming intervals in a *short-short-long* (SSL) or a *long-short-short* (LSS) pattern. In the first part of the study; synchronization phase, the subjects were made to tap in synchrony with a drum pattern that was accompanied by either a matching or a mismatching Balkan folk melody. In the next part, the subject had to continue tapping with the drum pattern turned off (accompanied by the same melody or by silence). During synchronization phase the ratio of long to short tap interval was between the target ratio of 3:2 and a simple meter ratio of 2:1. As long as the melody was present, the participants were able to maintain the ratios but when the melody was no longer present, the ratios could not be manintained. The variability in tapping and the locations of taps during both syncho=ronisation and continuation phase has shown that, temporal grouping in the drumpattern was more important in rhythm perception than the meter itself. These findings demonstrate that people raised in North America find it difficult to produce complex metrical patterns, especially in the absence of exogenous cues and even when musical excerpt was provided to help with tapping.

Training and exposure are believed to play an important role in rhythm perception. This was studied by Grahn and Rowe (2009) where he compared the rhythm perception in musicians and non-musicians. There were 3 conditions in the study; the conditions were such that they varied in the degree to which an external reinforcement versus internal generation of the beat was required. Among the 3 conditions, 2 had either an reinforcement in volume or duration to mark the beat. The third condition was unaccentuated for which the subjects had to generate their own internal beat. In all conditions, when there was a beat perceived putamen activity was seen in the fMRI recordings. Also an increased connectivity between the putamen and the Supplementary Motor Area, the premotor cortex and the auditory cortex was seen.

Another factor that affects beat perception is metricality of pulses. To investigate this, Patel, Iversen (2004) studied the effect of metricality on synchronization with a beat. The study aimed at investigating whether the metrical structure of a non-isosynchronous rhythm improve synchronization with a beat compared to synchronization with an isosynchronous sequence at a beat period. The study also aimed at finding about people’s ability to extract beat from rhythmic visual sequences with metrical structure. They presented rhythmic patterns which were either isochronous or non-isochronous in either the auditory or visual modality, and by asking the subjects to tap to the beat which was prescribed to occur at 800-ms intervals. Results showed that for auditory patterns, a strongly metrical structure did not improve overall accuracy of synchronization compared with isochronous patterns of the same beat period, but it influenced the higher level tap patterning. However in weakly metrical patterns, the synchronization was affected. For the visual patterns, the participants were generally unable to synchronize to metrical non-isochronous rhythms, or to rapid isochronous rhythms. The latter result suggests that beat perception and synchronization are better with auditory mode than visual mode.

Povel and Essens presented research (Povel and Essens, 1985) on the association of ‘‘internal clocks’’ with temporal onset signals. They described an algorithm which could, given a set of inter-onset intervals as input, identify the clock which a listener would associate with such a sequence of intervals. Their research was basically interested on finding out the way in which perceived accents leads to the internal clock. Their research purports to examine time intervals in general rather than being restricted to musical stimuli.

(b) Studies on neural correlates of rhythm perception- Functional imaging studies

Studies by Peretz (1985), Halpern and Zatorre,(1999) has shown that musical processing for tonal music involves the right hemisphere in musically untrained individuals . According to Peretz (1990) there is a right hemisphere involvement during rhythm perception. But this was contradicted by Robin et al (1990) who reported left hemisphere dominance for rhythm perception.

Krings etal (2000) and Meister (2006) compared processing of rhythm in musicians and non-musicians and found that musicians recruited only smaller portions of the motor cortex. The authors reported this to be because of training factor in the musicians which would enable them to use the neural resources effectively.

Limb (2006) studied the neural correlates of rhythm perception by comparing musicians versus non-musicians. The task was a passive rhythm perception task. Results of the study revealed a greater activity in left hemisphere for rhythm perception task for musically trained subjects than for untrained subjects. Authors concluded that musical training makes rhythm perception into more of an analytical task which would have lead to more activity in the left hemisphere. The authors also noted more activity in the perisylvian cortices (left frontal operculum, superior temporal gyrus, inferior parietal lobule).

Grahm etal (2006) studied the neural correlates of beat perception using functional Magnetic Resonance Imaging and he extended the research by studying Parkinson's patients. Results of the study revealed that novel beat patterns generated activity in the basal ganglia, when compared to the non-beat patterns. The results of the study also reported that when normal people were able to discriminate changes in beat patterns, Parkinson's patients were not able to do this task. Hence the authors opined basal ganglia to play a very important role in rhythm perception. Also fMRI revealed basal ganglia activity when the subjects were generating an internal rhythm. Authors also reported of a functional connectivity between the putamen (basal ganglia) and cortical motor areas to be higher for perception of beat rhythms when compared to the non-beat rhythms. Also studies have proved an increased connectivity between the cortical motor and auditory areas in people with musical training. Hence the role of basal ganglia in beat perception and hence rhythm perception was proved in the study.

Large, Zanto (2006) studied the neural correlates of rhythmic expectancy. They measured Evoked potentials that occured when an expected event is omitted from a regular series of stimulus events as in simple rhythms with temporal structures typical of music. Results of the experiment suggested that middle-latency gamma band (20-60 Hz) activity (GBA) has an essential role in auditory rhythm processing. Evoked (phase-locked) GBA occurs in the presence of physically presented auditory events and reflects the degree of accent. Induced (non-phase-locked) GBA reflects temporally precise expectancies for strongly and weakly accented events in sound patterns. Thus far, these findings support theories of rhythm perception that posit temporal expectancies generated by active neural processes.

Abecasis et al (2006) investigated the physiological basis of subjective accenting in isochronous sequences. The testing aimed at disrupting listener's expectancies in different positions of auditory equi-tone sequences and the responses to these were measured using brain-event related potential. The results showed significant difference in the late parietal event related potential evoked in the odd-numbered and even-numbered tones. These results suggested that a binary metric structure was perceived. Thus the authors concluded that the subjective accenting is a cognitive and attention dependent phenomenon and is partly affected by musical expertise.

Iversen, Ohgushi, Patel (2007) studied the effects of culture on perceptual grouping of simple rhythmic sequences in English and Japanese speakers. Results of the experiment showed cultural differences influencing rhythm perception. Authors concluded from the study that musical experience is not universal and is indeed influenced by experience. The authors attributed this experience to be the rhythm of the language of the speakers and thus the rhythm of the language to be influencing the musical rhythm perception.

Iversen (2008) studied the influence of cultural difference in rhythm perception and production. He studied both the perception and production of both linguistic and musical rhythm by Korean and English school children. The findings of the study indicated that there was cross-cultural similarity in rhythm.

Geisler et al (2008) studied the neural correlates of speech rhythm using fMRI. German pseudo-word sentences (with exaggerated and natural rhythm) were used as the stimuli. The subjects were asked to perform a rhythm task and a prosody task. The results of the study indicated a bilateral activation in the Supplementary Motor Area and the activity also extended into regions of cingulate gyrus, basal ganglia. For the rhythm task, in addition to these areas, activity in the right inferior frontal gyrus was also seen. There was a difference in terms of lateralization for the exaggerated sentences and normal sentences in both the rhythm task and prosody task. For the explicit tasks there was more of the right posterior superior temporal gyrus, the right supra-marginal gyrus and right parietal operculum, while for the implicit processing there was activation of the left supra-marginal gyrus, the left posterior superior temporal gyrus and the left parietal operculum. The study thus revealed the role of Supplementary Motor Area (SMA) and the insula for perception of acoustical temporal intervals and a task related function of the right Inferior Frontal Gyrus for accent pattern processing. Furthermore the data indicated that a right secondary auditory cortex is involved in the explicit processing of the suprasegmentals and that the right auditory cortex activity has top-down influences.

Chen et al (2008) studied the auditory-motor integration in the context of musical rhythm and the enhanced ability of musicians to execute precisely timed sequences using Functional Magnetic Resonance Imaging. Both musicians and non-musicians were made to tap to progressively more complex and less metrically structured auditory rhythms. Results of the study showed that musicians recruited the prefrontal cortex to a greater degree than non-musicians, whereas secondary motor regions were recruited to the same extent. The authors also suggested that the superior ability of musicians to deconstruct and organize a rhythm’s temporal structure relates to the greater involvement of the prefrontal cortex mediating working memory.

(c) Cultural influence on rhythm perception

Hannon, Soley (2012) did a cross-cultural comparison of American and Turkish listeners in rhythm perception. The task was to detect temporal disruptions which varied in (varying in size from 50-250 ms in duration) to three types of stimuli: simple rhythms found in both American and Turkish music, complex rhythms found only in Turkish music, and highly complex rhythms that are rare in all cultures. Results showed that Americans were most accurate when detecting disruptions to the simple rhythm, but they were not accurate in complex and unfamiliar rhythm conditions. In contrast to this, Turkish participants performed accurately in both simple and complex rhythm conditions, but even they did not perform accurately with unfamiliar rhythms. Thus cultural difference are evident in rhythm perception, this might be because of listening experience specific to a particular culture and also musical knowledge is important in rhythm perception.

(d) Syncopated rhythm

Merriam Webster's dictionary defines Syncopation in rhythm as a temporary displacement of the regular metrical accent in music caused typically by stressing the weak beat as defined.

Fitch, Rosenfeld (2007) studied perception of syncopated rhythm in 16 subjects having musical experience from 0 to 15 years. The tasks included pulse tracking, rhythm reproduction, and recognition tasks in which the subject has to recognize the same rhythms after 24 hours time. Results showed that for syncopated rhythm the subjects had to reset the phase of their internally generated pulse. Thus the authors concluded that the more complex the rhythmic stimuli, it leads to a reorganization in the cognitive representation of the temporal structure of the events. From the recognition tasks, authors have found out that people tend to encode less complex rhythm into the long term memory than complicated ones.

Infant rhythm perception

Infant rhythm perception was studied by Zentner and Eerola (2010). 120 infants were exposed to various musical and rhythmic stimuli including isochronous drumbeats. Results showed that infants have more rhythmic movements to music and rhythmically regular sounds than to speech sounds.

CHAPTER 3

METHOD

A. *Participants*

20 subjects trained in Carnatic music and 20 subjects trained in Bharatanatyam dance were recruited for the present study. Age range of the subjects varied between 19 years and 29 years.

Subject selection criterion

The subjects were otologically and audiologically normal with hearing thresholds not exceeding 20dB at any frequencies between 250-8000Hz. The subjects were also ruled out of any middle ear infections and any history of neurological disorders.

All the recruited subjects had received 5 years or above 5 years training in music or dance.

A. *Instrumentation*

- A calibrated audiometer with TDH 39 headphones was used for Air Conduction testing and radio ear B-71 was used for bone conduction testing.
- GSI Tympstar was used for ruling out middle ear infections.
- Audacity software was used for generating the stimuli and for recording the responses.

C.*Procedure*

The testing consisted of 2 parts.

(i) Synchronizing with the rhythm of a musical piece

Each participant was given 5 stimuli (Carnatic instrumental pieces) one at a time. The musical excerpt had duration in the range of 25-30sec. The participants were made to listen to the stimuli twice and were asked to tap and report about the perceived rhythm of the piece. The participant's taps were recorded during the recording trail (3rd trail) and were mixed with the original composition using the Audacity software. The clinician also made a note of the subject's tapping and about the meter of the composition as perceived by the subjects. The taps were compared with the original rhythm of musical excerpt and were also checked for the presence of any tapping errors in terms of phase or tempo. The participants were also asked about the familiarity of the musical composition.

The different rhythms selected were such that they formed the frequently taught and most common rhythms in both Carnatic music as well as Bharatanatyam dance.

(ii) Perceptual judgment of imposed rhythms on a musical piece

For this part of the experiment, the subjects were presented with a musical composition upon which a click train had been imposed. The click trains are superimposed in 3 conditions; hence there are three variations of the same composition. The three conditions are given below:

On beat condition: For generation of this condition, the click train was generated with the same tempo as that of the compositions. The original tempo of the song was calculated by computing the beats per second (BPS). BPS was calculated by tapping to the song and calculating the number of taps per second. A click train generated with the same BPS was aligned to the composition in such a way that, the first click coincided with the original beats of the composition. Thus the clicks fell exactly on the points were we expect the composition’s beats fall. A musically trained listener was made to judge whether the tempo was matching the composition’s tempo.

Off beat condition (tempo error): For this condition the click train was generated in such a way that tempo of the click train was either greater or lesser than the actual tempo of the composition. For this condition, the original tempo of the song (BPS) was found out and was aligned with the composition for checking matching of the tempi. Once both the tempi matched, then the particular click train was removed and another click train was generated with a tempo which is 20% lesser than (slower tempo) or 20% faster than (faster tempo) that of the original tempo of the composition. This click train was aligned to the composition in such a way that, the first click of the composition falls on beat with the beat of the composition, but the tempo being different from the composition’s original tempo.

Off beat condition (phase error): For generation of this condition, the click train with the same BPS as that of the song was generated, but the click train was aligned in such a way that, the first click fell either before or after the point where the actual beat of the song falls such that every time the clicks fell either before or after the intended beat.

The above mentioned three conditions were randomly mixed and the participants were required to report whether the click train imposed on a musical piece (Carnatic composition) follows the rhythm of that particular composition. The subjects were exposed to 3 iterations of a stimuli such that in one falls in on-beat, in one, there is a off-beat in terms of phase error (early or late) and in a third one, there is a off-beat in terms of tempo error (slow or fast). Each subject was exposed to 5 stimuli, twice during testing. The subjects were asked to report whether the clicks were falling on-beat with the composition or off beat with the composition. If the clicks are falling off –beat, the subjects were asked to report whether there was an error in terms phase or tempo. If the error was reported to be phase, then subjects had to report whether the clicks were early or late with reference to the beat of the composition and if the error was reported to be in tempo, then the subjects had to report whether the beats were faster or slower when compared with the original composition.

The subjects were also asked regarding the years of experience with music or dance and familiarity with the musical compositions included in the study.

D. *Scoring*

Test one: Synchronization with a musical composition

Test one consisted of 5 compositions. For each composition, a maximum score of 3 was given, which was consisted of the scores for the three domains tested. The three domains tested are: Identification of the rhythm of a composition, synchrony of the subject's tapping phase with the phase of the composition and synchrony of the subject's tapping tempo with the tempo of the composition. A correct response in each domain was awarded 1 point. Thus, each composition gets a maximum of 3 points. Hence the maximum total score in the Test one is 15.

Test Two.

The stimuli in Test two was composed of 5 compositions each iterated 3 times (3 different conditions), thus making a total of 15 presentations of the stimuli. Identification of offbeat condition was awarded with 0.5 point. A score of 1 was awarded when the subject identified the exact offbeat condition in terms of whether it is a tempo error or phase error. The maximum score of 2 was awarded when (i) subject correctly identified whether in tempo error i.e the click tempo as fast or slow than the composition's beats or (ii) subject correctly identified whether in phase error, the clicks were early or delayed with reference to the original composition. Hence the maximum score for each stimulus is 2. Thus a total score of 30 is the maximum score in Test 2.

CHAPTER 4

RESULTS AND DISCUSSION

The present study aimed to compare the rhythm perception skills in dancers and musicians. Twenty dancers and twenty musicians were recruited for the test. There were two tests carried out for comparison of the rhythm perception abilities, Test one: Synchronization with a musical composition and Test two: Perceptual judgment of imposed beat in a musical composition. The data from 40 subjects (20 dancers and 20 musicians) was subjected to statistical analysis. The data was tabulated and analyzed using SPSS (17.0). Inorder to compare the rhythm skills in dancers and musicians, a one way MANOVA was carried out between both the groups for the test scores obtained in the two tests, another one way MANOVA to compare the skills across the domains tested in each test, and correlation of various parameters of the two tests and correlation of the rhythm skills and experience of the subjects.

4.1**:** *Comparison of scores obtained in each domain tested in Test 1 between musicians and dancers (Musicians: Group A, Dancers: Group B).*

The main aim of the study was to compare the rhythm skills of dancers and musicians. Thus the scores obtained for each domain in Test one was compared across the two groups using a one way MANOVA. The domains tested were (i) identification of the rhythm (ii) tempo synchrony (iii) phase synchrony. The mean, standard deviation, F value, significance level are shown in Table 4.1.

The p values for identification domain is p= 0.596, for tempo synchrony domain is p= 0.771 and phase synchrony domain is 0.912. Hence the statistical analysis showed that there is no significant difference between the two groups across any of the domains tested in Test one.

Table 4.1

Mean, Standard Deviation, F value, Significance for the two groups for the Test 1.

Domains tested	**Group (no: of subjects)**	**Mean**	**Standard deviation**	**F value**	**Significance**
Identification	A (20)	3.700	1.52523	0.286	0.596
	B (20)	3.4500	1.43178		
Tempo synchrony	A	4.2500	1.06992	0.086	0.771
	B	4.1500	1.08942		
Phase Synchrony	A	3.9000	1.48324	0.012	0.912
	B	3.8500	1.34849		

The result of the statistical analysis implies that the rhythm perception abilities in dancers and musicians are comparable. Subjects in both the groups could identify the rhythm, synchronize with the musical composition according to its phase and tempo to the same extent. The reason for getting no significant difference between the two groups in the test can be attributed to factors like similarity in training imparted to both the groups, the rhythms selected for testing. The two groups considered under the study i.e. dancers and musicians would have both been exposed to the same kind of music during learning i.e., Carnatic Music since the rhythms and compositions used in the Carnatic music are commonly used in Bharatanatyam dance training. Also the rhythms used in the tests were common to both Carnatic music and Bharatanatyam dancers. This can be the reason for getting no significant difference among the groups in Test one.

4.2 *Comparison of the scores obtained for the identification of the three conditions in test two between musicians and dancers.*

Further to compare the rhythm skills under Test two, a one way MANOVA was carried out. The two groups were compared for their ability to identify 3 conditions of imposed beats on a musical composition namely- on-beat condition, off beat-tempo error condition, off beat-phase error condition. The mean, standard deviation, F value, are given in Table 4.2.

The obtained p values for each condition are: on-beat condition, p= 0.854; for the tempo error condition, p=.122 and phase error, p =.443. Hence the statistical analysis has shown that there is no significant difference between the 2 groups for identification of different conditions in the Test Two.

The results of the statistical analysis showed that both dancers and musicians have similar abilities in perception of beats. The perception was similar for perception of on-beat condition, off beat phase error condition and off beat tempo error condition. Previous study on general population (untrained in rhythm) by Iversen and Patel (2008) had indicated that on-beat conditions were identified more correctly than the tempo error or phase error condition. Such a pattern is not observed in musicians and dancers i.e. they identified offbeat condition and on beat conditions easily. This could be attributed to the training effect and similarity in training rhythm in both the groups. The reported study of Iversen and Patel (2008) was carried out on general population who received no training in rhythm, hence the authors could not find out the similarity in perception of rhythm in their subjects.

Table 4.2

Mean, Standard deviation, F-value, Significance for the two groups for Test Two

Conditions	**Group (no: of subjects)**	**Mean**	**Standard deviation**	**F value**	**Significance**
On beat	A	8.8000	1.88065	0.034	0.854
	B	8.9000	1.51831		
Off beat tempo error	A	7.2500	1.91600	2.504	0.122
	B	6.3000	1.88065		
Off beat Phase error	A	5.8250	2.39118	0.601	0.443
	B	5.2500	2.29702		

4.3. *Comparison of the total scores for both the test between the 2 groups*.

For comparing the rhythm skill for the two tests (total score) for the two groups, the total scores obtained for each test were calculated and were compared using one way MANOVA.

Table 4.3

Mean, Standard deviation, F value for total scores of the two tests for the two groups

Test	**Group (no: of subjects)**	**Mean**	**Standard deviation**	**F value**	**Significance**
Test 1	A (20)	11.6500	3.96398	0.020	0.888
	B (20)	11.4500	3.72014		
Test 2	A (20)	21.9750	5.86128	0.758	0.389
	B (20)	20.450	4.69574		

From the statistical analysis, p value was calculated for each test separately, p= 0.888 for the Test One score and p= 0.389 for Test Two. Results from the statistical tests revealed no significant difference between the 2 groups for the two tests.

The reasons for the non-significant difference between the two groups are because of similar training and rhythms chosen for testing. The rhythms chosen were present in both Carnatic music and Bharatanatyam dance. The compositions were also selected in such a way that it is not very common, so as to remove prior knowledge of the rhythm. It was noted during the testing that for those subjects who had been exposed to the compositions before i.e. those who were trained in that particular composition had better scores than for those subjects for whom the compositions were novel.

4.4 *Computation of the correlation between the two tests*

The second aim of the study was to find whether, perception of beat influences the synchronizing to a rhythm. To study this, correlation between the two tests used in the study was carried out. Correlation was found by considering the total 40 participants as a single group. The results of the analysis showed significant correlation for the two tests, [Pearson's correlation coefficient: 0 .690 at 0.05 level of significance]. Correlation results are shown in Table 4.4.

Previous work on general population by Iverson and Patel (2008) on the correlation of beat perception and synchrony with a composition's rhythm showed weak correlation (correlation coefficient = 0.38; $p<0.03$). But in the current study, there is a positive correlation between the two indicating the enhanced abilities in dancers and musicians, owing to training effects and better exposure and familiarity with the compositions.

For each domain, the influence of Test one over Test two was found out by finding out the correlation between domains tested in Test one with the corresponding condition in Test two. Thus off-beat phase error condition in Test two was checked for correlation with phase synchrony in Test one. Similarly off beat tempo error condition in Test two was checked for correlation with tempo synchrony domain in Test one. The analysis resulted in significant correlation between detection of tempo error and the tempo synchronization ability (Pearson's Correlation Coefficient: 0.383 at 0.05 level of significance) and significant correlation between detection of phase error and phase synchronization ability (Pearson's correlation coefficient: 0.571at 0.01 level of significance). Correlation results are shown in Table 4.4.

Thus the positive correlation results between domains of Test one and Test two indicated that correct detection of an off-beat tempo error aids in better synchrony with the tempo and a correct detection of an off-best phase error aids in better synchrony with the phase.

The third aim of the study was to find whether experience plays a role in rhythm perception. Thus correlation of the subjects' test scores and the subject's experience was calculated using Pearson's Correlation coefficient. Results of the analysis have showed that experience was positively correlated significantly with test one scores [Pearson's correlation coefficient: 0.679 at 0.05 level of significance]. Correlation was calculated between identification scores in test one and experience of the subjects. Results of the analysis, showed significant correlation between the two [Pearson's correlation coefficient: 0.710 at 0.01 level of significance]. Correlation results are shown in Table 4.4.

Table 4.4

Results of correlation

Variable one	**Variable two**	**Correlation**
Test one	Test two	.690 **
Tempo error	Tempo synchrony	.383*
Phase error	Phase synchrony	.571**
Experience	Test one	.679**
Experience	Identification of rhythm	.710**

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Thus results of statistical analysis have showed that experience plays an important role in rhythm perception. In both the groups, subjects with greater years of experience got better scores in rhythm. Thus experience is a factor which affects rhythm perception.

Previous study by Batalha and Macara (2008) had also got similar results. Their study has shown that when compared to dance students, professional dancers have better rhythm perception abilities. This is owing to better experience and exposure to the rhythm. In the present study, both dancers and musicians showed a positive correlation with experience. Thus confirming the fact experience plays an important role in rhythm perception.

Thus the results of the present study indicate that:

1. There is no significant difference in rhythm skills between dancers and musicians on identification of the rhythm, tempo synchrony and phase synchrony.
2. There is no significant difference between dancers and musicians in the three conditions (a) on beat condition (b) off beat tempo error condition (c) off-beat phase error condition.
3. Test one has a positive correlation with Test two. Hence beat perception has a positive correlation with identification and synchronization with the rhythm.
4. Experience is positively correlated with rhythm perception.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Rhythm is an important domain in music perception as well as in speech perception. Rhythm perception depends on perception of beats underlying a composition and also perception of the meter. Knowledge about the beats and meter will help in better perception and production. Neurological correlates and behavioral studies have shown rhythm perception to be enhanced in musically trained population. Also several studies have shown experience and exposure to have a positive correlation with the rhythm perception. Dancers and musicians are two populations who depend on rhythm perception for their performance and have received formal training in rhythm perception.

The present study aimed at comparing the rhythm perception skills in dancers and musicians. The second aim of the study was to find out whether perception of beats affects the ability to synchronize to the rhythm of a musical composition. The third aim of the study was to study the effect of experience on rhythm perception.

The method of the study consisted of two tests: Test one, which is synchronizing to the rhythm of a musical composition and Test two, which is perceptual judgment of beats imposed on a musical composition. Under Test one, three domains were studied for namely; identification of the rhythm, synchronizing to the tempo of the rhythm and synchronizing to the phase of the rhythm of the composition. Under Test two, identification of the three conditions namely: on-beat condition, off beat tempo error condition and off beat phase error condition.

Scores obtained for the twenty dancers and twenty musicians were subjected for statistical analysis. One way MANOVA was carried out for comparing the scores for the two tests and for the domains tested in each tests across the two groups. Inorder to find the effect of beat perception on synchronizing with a musical composition, correlation between the first and second test was carried out. Inorder to find the effect of experience on rhythm perception, correlation between the rhythm perception scores and years of experience was also calculated.

Results of the statistical analysis have shown that there was no significant difference between dancers and musicians in rhythm perception. There was no significant difference between the scores for the domains tested in tests across the groups compared. Test two was positively correlated with Test one and also experience positively correlated with rhythm perception performance.

Thus the conclusions drawn from the study are:

1. There is no significant difference in the rhythm perception in dancers and musicians.
2. Perception of beats influences the perception of rhythm and synchronizing with the rhythm in both the groups.
3. Experience plays a major role in rhythm perception in both the groups.

CHAPTER 6

IMPLICATIONS OF THE STUDY

From the results of the present study, it is clear that beat perception is an important factor in rhythm perception. Rhythm training through pulses for the rhythm impaired population can be opted to improve their rhythm perception.

The study has shown dancers and musicians to have similar rhythm perception abilities. Hence the mode of rhythm practice does not have an effect on rhythm perception. Therefore any mode of practice can be used for training the rhythm for rhythm impaired population like hearing impaired population.

For hearing impaired population, rhythm training can improve their perception as rhythm is an important supra segmental feature of speech.

FUTURE DIRECTION

- The study can be employed to study rhythm perception in various forms of music such as Hindustani and Carnatic and on different instrumental performers. It is also worthwhile to study the same on dancers with various forms of classical/folk dancing.
- There are few studies reported in literature on the areas in the brain for coding rhythm, tempo etc. In future brain mapping studies can be carried out to understand more about the role of different areas of brain for coding rhythm.

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