# Auditory Temporal Processing Skills in Dancers and Non Dancers

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***Key Words***

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*Dance training*
*Dancing benefits*
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*Gap detection*
*TMTF*
*Training*

## Abstract

*Perception of temporal aspects of sound is crucial for discrimination, identification, and comprehension of speech, particularly in noisy backgrounds. Studies have shown superior temporal processing abilities in musicians compared to non-musicians attributable to their musical training. Dance is another form of art where body movements are choreographed to music necessitating active listening to the temporal aspects of music (tala and laya) in order to express them through movements. Considering that it involves similar task as in musicians the study explored trained dancers' auditory temporal processing abilities. Ten professional dancers and 10 non-dancers with mean age 24 and 22 years respectively, participated in the study. Gap detection threshold (GDT) and Temporal modulation transfer function (TMTF) were obtained to assess their temporal processing abilities. Comparison of mean scores of GDT and TMTF between the two groups revealed lower mean thresholds in GDT (2.42 vs. 2.66), and TMTF (at 16, 32, 64, 128 Hz) thresholds in dancers. MANOVA revealed significant difference in scores of TMTF (at 16, 32, 64 & 128 Hz). Based on these findings, it was concluded that dancers have better temporal processing compared to non-dancers owing to the training they undergo.*



## Background

Perception of temporal aspects of the sound is crucial to human beings as it forms the acoustic basis for speech identification (Picton, 2013). Functionally, the perception of temporal aspects of sounds serves to regulate speech perception in quiet as well as in adverse listening conditions. Auditory temporal perception abilities have also been identified to be important in music perception (Moore, 2007).

Music is known to have pervasive influence on human beings. With specific reference to the auditory system, musical training has been reported to result in superior functioning of the peripheral as well as central auditory system in humans (Kraus, 2012; Musacchia, Sams, Skoe, & Kraus, 2007; Micheyl, Carbonnel, & Collet, 1995; Ishii, Midori-Arashiro, & Desgualdo-Pereira, 2006; Jeon & Fricke, 1997; Nikjeh, Lister & Frisch, 2008; Oxenham, Fligor, & Mason, 2003; Rammsayer & Altenmuller, 2006). With temporal processing being no exception, trained musicians are reported to possess better auditory temporal processing skills compared to non-musicians (Sangamanatha, Fernandes, Bhat, Srivastava, & Udupa, 2012; Donai & Jennings, 2016; Ishii et al., 2006), a trait attributable to their systematic training in the perception and production of fine variations in amplitude, frequency, and temporal aspects of musical notes (Parbery-Clark, Skoe, Lam, & Kraus, 2009; Drake & Bertrand, 2001). Most of these studies have assessed the temporal perception of musicians using Gap Detection Test and/or Temporal modulation transfer function test.

A form of art which is closely related to music is dance. Dance is an expression of time and space, using the control of body movement and gestures to communicate (Anderson, 2010). Dance and music are inseparable where both complement each other (Nor & Stepputat, 2016) and the dancer's body and music attune with each other to express the nuances of rhythm through body movements (Ramaswamy & Deslauriers, 2014). Similar to musical training, dance training too emphasizes the perception of temporal aspects of sound when the body movements are expected to be in synchrony with it. Sometimes in dance, keeping a rhythmic metre constant, the body movements creatively travel at different rhythms within a fixed time cycle. It has been reported that accurate processing of brief durations is vital for producing actions as seen in dance (Mauk & Buonomano, 2004; Buonomano & Karmarkar, 2002).

In terms of Indian classical dance and music, 'taala' is the measure of time and 'laya' is the rhythm, or the temporal aspects of music. For the dancers as well as musicians it is mandatory to attain skill and knowledge of taala and laya to be able to master the art form. However, while the musicians train their ears specifically to perceive the intricacies in temporal, loudness and pitch variations in music, dancers represent the variations in music through their body. Also, musicians are required to produce the finer variations of time, frequency, and loudness using their biological system. In contrast dancers are required to auditorily analyze those finer details and reproduce in it terms of motor movements.

It has been noted that people move their body as a natural response to music or auditory stimuli (Brown, Merker, & Wallin, 2000). This response had been observed in people across culture (Brown et al., 2000) and age range (Phillips-Silver & Trainor, 2007, Phillips-Silver & Trainor, 2005). It has also been reported that brief time intervals learnt through the auditory mode gets transferred to motor activities (Meegan, Aslin, & Jacobs, 2000). It is known that in Carnatic music taala, or rhythm is expressed physically by the musician through finger counts, hand wave or clap. It is also known that percussionists use lot of body movements like foot tapping, head nod. These elaborate how acoustic temporal cues are in coordination with body movements in musicians.

From the above, it may be deduced that body movements and auditory temporal processing are associated and body movements are probably linked to auditory processing of temporal aspects of music. A correlation between body movements and auditory temporal processing ability was drawn by Iordanescu, Grabowecky, and Suzuki (2013) wherein they demonstrated that initiating a simple action of pressing a key significantly increased auditory temporal sensitivity. It was concluded that action enhanced auditory temporal sensitivity and that there could be a link between the motor mechanisms and auditory temporal processing that boosts temporal precision of body movements.

The advantage of dance training, on auditory temporal processing was demonstrated by Silva, Dias and Pereira (2014). They found that dance has a positive effect on the auditory temporal resolution, as assessed by the Gap In Noise test. However, studies have not investigated the effect of dance training on other auditory temporal processing skills. Hence, in the present study, an attempt has been made to compare the performance of dancers and non-dancers on different tests of temporal processing.

## Material and Methods

The temporal processing abilities in a group of dancers were compared with that of an equivalent group of non-dancers. The temporal processing abilities evaluated included Gap detection test (GDT) and Temporal Modulation Transfer Function (TMTF) test .

### Participants

Twenty individuals, divided into two groups (dancers and non-dancers) served as participants for the study. They were divided into the two participant groups based on whether or not they had undergone dance training. These individuals were taken as participants for the study if they had pure-tone air conduction thresholds within 20 dB HL for all the octave frequencies between 250 Hz and 8 kHz in both ears and no history of middle ear related problems, confirmed on immittance audiometry. The audiological tests were conducted in sound treated audiometric rooms. Information regarding the demographic data, years of dance training, number of hours of dance practice and history of ear related problems was obtained from the participants through a structured interview. Informed consent was obtained from the participants before they were recruited for the study.

The first participant group constituted of professional dancers, age ranging between 21 to 28 years (mean age: 24;4 years, 2 males and 8 females). The individuals who had received dance training for more than seven years and practiced for more than 20 hours per week were selected for the study. The participants were trained in the Indian classical dance form of Bharathanatyam with a mean training initiation age of 7;9 years. Of these participants, two had passed senior grade examination and eight had passed proficiency grade examinations in dance conducted by the Karnataka Secondary Education Examination Board (KSEEB). Individuals with any musical training along with dance training were excluded from the study.

The second group was composed of individuals (2 males and 8 females) with no formal training in either dance or music with their ages ranging from 18 to 29 years (mean age: 22;1 years). Those who had exposure to music for less than 7 hours a week were included in the study. Out of the ten participants only two indulged in recreational dance twice or thrice a year. All the participants were native residents of Karnataka.

### Stimuli/Materials

The temporal processing abilities, assessed using GDT and TMTF, was determined separately for the two ears of the participants. The testing was carried out using maximum likelihood procedure (MLP) in the psychoacoustic toolbox. This toolbox implemented mlp in Matlab (Grassi and Soranzo, 2009) and the GDT and TMTF for different frequencies of modulation (8, 16, 32, 64, 128 Hz).

**Procedure**

After the structured interview with the participants and the basic audiological evaluations, the individuals who satisfied the criteria to belong to either the dancer group or the non-dancer group underwent testing to assess their temporal processing abilities. The stimuli for GDT and TMTF test were routed from an Acer ASPIRE ONE D270 notebook and were presented through TDH-39 headphones of an audiometer (GSI 61) calibrated according to ANSI-S3.1 (1999) standards. The stimuli were presented at each participant's most comfortable level (varying from 45 to 60 dB HL). The general procedure followed for both the tests was as follows.

A three-interval forced-choice method was employed to arrive at the threshold with a 80.9% correct response criterion. In every trial, three intervals of the stimulus was presented where two intervals contained a reference stimulus and one randomly selected interval contained a variable stimulus. The participant's task was to identify the interval that had the variable stimulus. Initially, in the mlp tool box, several psychometric functions were hypothesized with different mid-points ranging the stimuli levels where subject's threshold was expected. Later, the subject's response was utilized to select the maximum likely psychometric function and the next variable value (gap or modulation depth) to be presented was calculated at the desired point (in the present study it is 80.9%) on the maximum likely psychometric function (Soranzo & Grassi, 2014). On completion of 30 trials of stimulus presentation, the threshold was obtained from the most likely psychometric function obtained from the procedure at the 80.9% correct response criterion.

**Gap Detection Test:** The participant's ability to detect a temporal gap in the centre of a 750 ms broadband noise was measured. The noise had 0.5 ms cosine ramps at the beginning and end of the gap. In the three-interval forced-choice task, the standard stimulus was always a 750 ms broadband noise with no gap whereas the stimulus with the gap served as the variable stimulus. The participants were instructed to indicate the interval in which a gap occurred. The threshold for gap detection was arrived at after the presentation of thirty sets of the stimuli.

**Temporal Modulation Transfer Function:** Temporal modulation refers to a reoccurring change (in frequency or amplitude) in a signal over time. A 500 ms Gaussian noise was sinusoidally amplitude modulated at modulation frequencies of 8, 16, 32, 64 and 128 Hz and was presented at most comfortable level. The stimuli had two 20 ms raised cosine ramps at onset and offset. Modulated and unmodulated stimuli were equated for total RMS power. A three-interval forced-choice method was used for response acquisition. Depth of the modulated signal was varied from 0 to -40 dB [modulation depth = 20 log(m), where m = modulation detection threshold in percentage] (Jain, Mohammed, and Kumar, 2014). The participants indicated the interval that was different from the other two intervals.

**Analyses**

The data obtained from the age matched participants in the two groups (dancers & non-dancers) were analysed to check for any statistical difference. A Shapiro Wilks test was administered to analyze the normality of data distribution in the two groups for GDT and TMTF tests. The test of normality revealed normal distribution of data in both groups across ears. One way MANOVA was done to see the significant difference between the two groups for the scores of GDT and TMTF. An independent t-test

*Table 1: Mean, standard deviation, F value and df (error) of GDT for right and left ears of the two groups of participants*

| Ear | Right | | Left | |
|---|---|---|---|---|
| Group | Dancers | Non-Dancers | Dancers | Non-Dancers |
| Mean (millisecond) | 2.33 | 2.59 | 2.51 | 2.73 |
| S.D | 0.52 | 0.55 | 0.64 | 0.67 |
| F(1, 18) | 1.15 | | 0.55 | |
| df (error) | 18 | 18 | 18 | 18 |

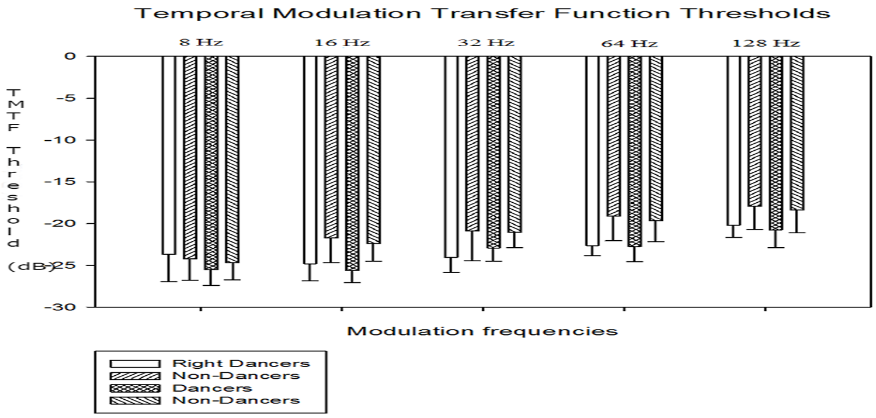


*Figure 1: Mean modulation detection threshold and standard deviation for dancers' right ear, non dancers' right ear, dancers' left ear and right non dancers' left and ear.*

*Table 2: F value, df (error) and p-value of TMTF for right and left ears of the two groups of participants*

| | Ear | | | | | |
|---|---|---|---|---|---|---|
| | Right | | | Left | | |
| Modulation frequency | F | df | p | F | df | p |
| 8 Hz | 0.16 | 1 | 0.68 | 3.61 | 1 | 0.07 |
| 16 Hz | 7.41 | 1 | 0.01 | 15.92 | 1 | 0.001 |
| 32 Hz | 6.35 | 1 | 0.02 | 5.89 | 1 | 0.02 |
| 64 Hz | 12.20 | 1 | 0.003 | 9.99 | 1 | 0.005 |
| 128 Hz | 5.24 | 1 | 0.03 | 4.69 | 1 | 0.04 |

was done to check for any significant difference between the mean age of the two groups.

## Results

Administration of an independent t-test revealed no significant difference between the participant's mean age in the two groups ($t = 1.59$; $p = 0.13$). The data were further analysed to check for any difference between the two groups of participants.

The mean and standard deviation of right and left ear GDT scores of the two participant groups, along with the results of MANOVA (for between group comparisons) are given in Table 1. TMTF scores of the two groups and the MANOVA results for the same are depicted in Figure 1. As can be observed from Table 1, there was no difference in the mean of gap detection thresholds of participants in the dancer group and that of the non-dancers. Also, results of one way MANOVA showed that the mean differences were not statistically significant.

The mean and standard deviation of the scores TMTF test on both the groups for modulation frequencies 8 Hz, 16 Hz, 32 Hz, 64 Hz and 128 Hz are provided in Figure 1. Observation of the mean and standard deviation of the scores for each frequency (Figure 1) shows that the mean scores became less negative as the modulation frequency increased. This was true for dancers as well non-dancers in both ears. However, dancers were seen to have more negative scores than non-dancers, indicating their skill to detect higher frequency modulations better. The results of MANOVA revealed a significant difference between the two groups for TMTF scores, for 16 Hz, 32 Hz, 64 Hz and 128 Hz (Table 2). However, no significant difference was seen for 8 Hz modulation frequency in either ear.

## Discussion

The findings of the present study are discussed in terms of the findings of the two temporal processing tests that were administered (GDT & TMTF test). The comparison between the two groups of participants, for each of the temporal processing tests, is discussed.

### Effect of training in dance on the thresholds of Gap Detection Test

The mean gap detection thresholds obtained in the present study were in agreement with the studies that explored temporal resolution abilities in musicians in comparison to non-musicians(Kumar, Sanju, &, Nikhil, 2016; Kumar, Rana, &, Krishna, 2014). The procedure used in the current study was similar to that utilised in the earlier research carried out on musicians . In this study comparison of mean thresholds between groups revealed no difference between dancers and non-dancers. The only study that explored temporal resolution in dancers and non-dancers also revealed no significant difference in GDT threshold between the two groups (Silva, Dias, & Pereira, 2014). However, they found significant difference in percentage correct identification of gap between the two groups. With this evidence it may be presumed that dance training might help improve the accuracy of gap detection than improving their resolution ability. A number of studies which compared temporal resolution abilities between musicians and non-musicians to see the advantage of musical training on auditory temporal resolution abilities have revealed equivocal results. Nevertheless, a number of studies have revealed significant difference in gap detection task between musicians and non-musicians (Donai, & Jennings, 2016; Kumar, Sanju & Nikhil, 2016; Kumar, Rana, & Krishna, 2014; Mishra & Panda, 2014). This finding difference between musicians and dancers may be because of the need for the dancers to follow ongoing fluctuations rather than finding the fine intricacies in the music like musicians. However, this hypothesis needs further exploration. In contrast few other studies show no significant difference in gap detection thresholds between two groups (Vasuki, Sharma, Demuth, & Arciuli, 2016; Monteiro, Nascimento, Soares, & Ferreira, 2010). The inconsistencies in the results calls for further exploration into the factors that affect gap detection ability like duration of training, age at which musical training started and other methodological differences.

### Effect of Training in Dance on the Thresholds of Temporal Modulation Transfer Function

Overall, the observations revealed better temporal processing skills in dancers in terms of TMTF scores. The difference however was statistically significant only in the TMTF tests, at 16, 32, 64 and 128 Hz. The study conducted by Poikonen, Toiviainen, and Tervaniemi (2016) reported improved pre-attentive processing of changing timbral brightness in dancers compared to musicians and laymen as assessed by evoked potentials (P50). The authors also opine that finer changes in temporal structure of music are essential for dancers to bring in precise rhythmical movements and with years of experience this necessity can sensitize the early auditory process. Hence the present finding that is better temporal modulation detection in dancers compared to non-dancers can be attributed to the years of training that dancers have undergone for musical pieces.

Furthermore, basal ganglia are critical in controlling voluntary movements (Hoover, & Strick, 1993) and in dancers the continuous music used in dance training is believed to enhance the top-down controlling of the basal-ganglia to the auditory cortex (Poikonen, Toiviainen & Tervaniemi, 2016). Also, there is evidence of enhanced functional integration in the cortico-basal ganglia loops suggesting improved sensorimotor function in dancers as a result of long term dance training (Li et al., 2015). Moreover, there exists anatomical evidence for the activities in basal ganglion neurons to sensory operations (Middleton, & Strick, 2000). Hence, with all these evidences our finding of better temporal resolution in terms of TMTF thresholds can strengthen the hypothesis of improving temporal perception through dance training. In TMTF, the better threshold in dancers was significant at all modulation frequencies except 8 Hz. Study conducted by Viemeister (1976) reported constant modulation depth requirement for modulation detection compared to higher frequency modulations. The modulation at higher frequencies requires higher modulation depth as the auditory system smoothens the modulations at higher frequency. In the present study the non-dancers have performed similar to dancers at 8 Hz may be because at low frequency modulation it is easier to detect modulation. However, the possible advantage of dance training in detecting finer temporal changes has become evident at higher modulation frequencies. Dance training involves imbibing rhythms through the body, and the observation that a finer variation in an auditory stimulus is perceived despite any special training in that direction was novel. To the best of our knowledge, previous studies have not explored the auditory temporal processing abilities in dancers in terms of amplitude modulation detection task. Better temporal processing skills have been shown to be important for localization, listening in quiet as well as in the presence of noise and perceiving music (Eggermont, 2015). More research evidence in this direction would reveal the usefulness of dance training as a means for improving auditory temporal processing skills.

## Conclusions

The results of the gap detection test on the ten dancers and ten non-dancers showed no significant difference between the gap detection thresholds between the groups . However, the dancers' thresholds on the TMTF test were significantly better than the non-dancer group, revealing better temporal resolution skills in individuals trained in dance. The study has explored the efficiency of only a section of temporal processing skills in dancers. In order to be able to recommend dance as a means of training for improving temporal perception, further investigation has to be carried out in this direction on a larger population in different age groups.

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