Pre-attentive auditory discrimination skill in Indian classical vocal musicians and non-musicians

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Abstract

Objective: To test for pre-attentive auditory discrimination skills in Indian classical vocal musicians and non-musicians.
Design: Mismatch negativity (MMN) was recorded to test for pre-attentive auditory discrimination skills with a pair of stimuli of /1000 Hz/ and /1100 Hz/, with /1000 Hz/ as the frequent stimulus and /1100 Hz/ as the infrequent stimulus. Onset, offset and peak latencies were the considered latency parameters, whereas peak amplitude and area under the curve were considered for amplitude analysis.
Study sample: Exactly 50 participants, out of which the experimental group had 25 adult Indian classical vocal musicians and 25 age-matched non-musicians served as the control group, were included in the study. Experimental group participants had a minimum professional music experience in Indian classic vocal music of 10 years. However, control group participants did not have any formal training in music.
Results: Descriptive statistics showed better waveform morphology in the experimental group as compared to the control. MANOVA showed significantly better onset latency, peak amplitude and area under the curve in the experimental group but no significant difference in the offset and peak latencies between the two groups.
Conclusion: The present study probably points towards the enhancement of pre-attentive auditory discrimination skills in Indian classical vocal musicians compared to non-musicians. It indicates that Indian classical musical training enhances pre-attentive auditory discrimination skills in musicians, leading to higher peak amplitude and a greater area under the curve compared to non-musicians.
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Keywords: Neuronal plasticity; Event-related potentials; Music

1. Introduction

Electrophysiology in audiology is an objective tool to check the integrity of the auditory system. Auditory evoked potentials are electrophysiological tests, which give information about a number of events happening in the peripheral and central nervous systems that are generally related to the sensory pathway (Starr et al., 1977; Golding et al., 2007). These sound-related evoked potentials are categorized as endogenous and exogenous potentials (Kraus and Nicol, 2008). The exogenous potentials are mainly recorded by external event related dimensions of the stimulus. The endogenous potentials are responses which are due to internal events such as perception and cognition (Sams et al., 1985; Novak et al., 1990). Studies have considered the possibility of studying auditory discrimination using a technique referred to as event-related potentials (Čeponien et al., 2002; Chang et al., 2014). Mismatch negativity (MMN) is an event-related potential that has been extensively studied by researchers to assess the pre-attentive auditory discrimination capability and storage of regularities in features of stimulus (Paavilainen, 2013).

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Peer review under responsibility of PLA General Hospital Department of Otolaryngology Head and Neck Surgery.
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Pre-attentive processing is the unintentional gathering of information from the environment. First, all gathered information is pre-attentively processed. Then, our brain sieves and processes the prime information. The important information is selected for further analysis by attentive processing (Atienza et al., 2001). Our auditory system has an imperative role in gathering sound information for pre-attentive processing. At the point where auditory stimulus or sound waves hits the tympanic membrane, it transmits the message to the auditory cortex by means of auditory nerve for pre-attentive processing. The proficiency to appropriately filter information from pre-attentive auditory processing to attentive auditory processing is crucial for normal development of speech perception (Seri et al., 2007). According to Koffka (1935), pre-attentive process uses the Gesalt laws of organization which says temporal proximity, physical similarity and good continuity is required to group the sound, which improves speech perception in quiet as well as in noise. For acoustic pre-attentive auditory processing, the temporal cortex is the primary site of activation, but research additionally demonstrated the association of frontal cortex as well (Habermeyer et al., 2009; Klamer et al., 2011). Studies also suggest that perception of minute variation in complex musical patterns triggers the right ventromedial prefrontal cortex (Habermeyer et al., 2009).

Näätänen and Alho (1997) showed MMN as an endogenous potential with a negative component elicited by any discriminable change in regular auditory stimuli. MMN is usually obtained by presenting a train of repetitive homogenous tones at a rate of approximately one tone per second. It is occasionally interspersed with a tone that differs physically (Gomes et al., 1995). Näätänen and Escera (2000) described MMN as "an electric brain response, a negative component of the event-related potential (ERP), elicited by any discriminable change (deviant) in some repetitive aspect of auditory stimulation (standard), usually peaking at around 100−200 ms from onset". MMN seems to depict a neuronal representation of the difference perceived between the auditory stimuli. Thus, MMN is well advised as an objective tool to check auditory discrimination skills at pre-attentive level. In which case, it could also be of clinical importance as speech perception, by its nature, depends on neuronal responses to changes in stimulus (Kraus et al., 1994). Music demands cognition, which requires specific and appropriate timing of many actions, such as perceiving the exact interval and control of pitch which are otherwise not involved in language. Enhanced auditory perception in musicians is likely to result from auditory perceptual learning during years of training, practice and experience. The musician's brain is presumed to be a good and appropriate model to investigate neuroplastic changes (Münte et al., 2002). Professional musicians have fine-tuned auditory skills which are achieved by aural training that they receive during their musical training. It is considered as an important component of their vocational formation (Herdener et al., 2010). A study done by Tervaniemi et al. (2006) assessed pre-attentive auditory discrimination skills in amateur musicians and non-musicians. They reported significantly larger MMN in amateur musicians compared to non-musicians. Another study by Boh et al. (2011) reporting a strong advantage for musicians in accompanying behavioral task of detecting the deviants while attending to the stimuli for all pattern lengths showed that long-term musical training differentially affects the memory capacity. Marie et al. (2012) investigated MMN in non-musicians native speaker of a quality language, Finnish, in which duration is a phonemically contrastive cue, with French musicians compared to French non-musicians. They reported that pre-attentive and attentive duration processing of duration deviants was enhanced in Finn non-musicians and French musicians compared to French non-musicians. They also observed that MMN in French musicians was significantly larger compared to Finns and French non-musicians. Along a similar line, Kuhnis et al. (2013) investigated neuronal representation of vowels and temporally manipulated CV syllables among string players and non-musicians with MMN odd ball paradigm. They showed that musicians are not only advantaged in the pre-attentive encoding of temporal cues but also in processing vowels. Previous literature from western countries have investigated MMN in western classical musicians and reported an enhanced pre-attentive auditory discrimination skill in musicians (Tervaniemi et al., 2006; Boh et al., 2011; Marie et al., 2012; Putkinen et al., 2014; Kuhnis et al., 2013). There is some basic mechanistic difference between Western and Indian classical music in terms of pitch structure and temporal patterning. Some basic elements of Indian music i.e. taala (rhythmic pattern), shruti (relative musical pitch), raaga (melody) and swara (the musical sound of a single note) are rarely found in western classical music. These features are difficult to perceive for western listeners without special training. In the case of vocal singers, control of pitch is important and is done by biomechanical and aerodynamic systems. Investigators agree that the ability to produce a precise pitch is very important for the professional vocal musician. Literature shows that accurate pitch control mainly depends on auditory perceptual monitoring, proprioceptive feedback of the laryngeal system and phonatory reflex systems (Jones and Munhall, 2000; Mürbe et al., 2004). The Recent literature reported enhanced auditory skills through different behavioral tests in Indian classical musicians (Sangamanatha et al., 2012; Mishra and Panda., 2014; Mishra et al., 2015; Kumar et al., 2015; Sanju & Kumar, 2015a, b). It is interesting to know the effect of Indian classical vocal music training and practice on pre-attentive auditory discrimination skills in musicians through an electrophysiological test like MMN. There is a lack of literature regarding pre-attentive auditory discrimination skills in Indian classical vocal musicians. Hence, there is a need to compare pre-attentive auditory discrimination skills in Indian classical vocal musicians with non-musicians.

2. Materials and methods

2.1. Participants

Two groups of participants (the experimental and control group) were involved in the study. The experimental group consisted of 25 female right handed Indian classical vocal musicians with a mean age of 24.52 ± 2.6 years

(age range 18–30 years). According to the inclusion criteria, only those with a minimum of 10 years of experience were taken. The participants of the experimental group in this study had an average experience of 12.3 years in Indian classical vocal music. All of them had started musical training after the age of 8 years. They practiced music for 19.2 ± 9.3 h per week regularly. As the control group, 25 female age-matched right-handed participants (age range = 18–30 years, mean = 24.8 ± 2.2 years) were included. None of them had any kind of formal training in music. The reason of taking only female participants was availability of more female participants in experimental as well as control group.

2.2. Participant selection criteria

The participants selected for the study had hearing threshold within the normal limit as defined by AC and BC thresholds less that 15dBHL from 250 Hz to 8000 Hz and from 250 Hz to 4000 Hz respectively. They also had normal middle ear function as revealed by tympanometry and reflexometry. Otological problems were ruled out by otological evaluation with the help of a qualified otolaryngologist. Auditory Brainstem Responses for site of lesion were recorded to rule out any neurological problem in the subjects. An informed written consent was taken from all participants before involving them in the study.

2.3. Testing environment

All behavioral as well as electrophysiological tests were carried out in a sound-treated room. The permissible noise levels were as per the guidelines in ANSI S3.1 (1999). Laboratory room was well lit and air-conditioned for the tranquility of the investigators as well as the subjects.

2.4. Instrumentation

For pure tone audiometry, a calibrated dual channel clinical diagnostic audiometer (Orbitor-922) was used for all participants. For tympanometry and reflexometry, a calibrated GSI-Tympstar Immittance meter was used for all participants. Mismatch Negativity was recorded on all participants using Intelligent Hearing System with smart EP.

2.5. Procedure

The Modified version of Hughson and Westlake's procedure given by Carhart and Jerger (1959) was used for pure-tone audiometry across octave frequencies from 250 Hz to 8000 Hz for air conduction. Octave frequencies from 500 to 4000 Hz were tested for bone conduction. To carry out tympanometry, a 226 Hz probe tone was used, whereas 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz stimuli were used for ipsilateral and contralateral reflex.

Previous literature reported difficulty in identifying MMN at an individual level (Lang et al., 1995; McGee et al., 1997; Ponton et al., 1997). Dalebout and Fox (2001) reported that MMN identification rate was too low (29%) to allow reliability to be evaluated. To obtain a clear and distinguishable MMN for statistical analysis, a larger difference between the frequent and infrequent stimulus was considered in the current study. The stimuli taken were 1000 Hz and 1100 Hz, where 1000 Hz served as the frequent stimulus and 1100 Hz served as the infrequent stimulus. The reason for taking larger difference between frequent and infrequent stimuli was to elicit a distinct waveform of MMN, as previous literature reported distinct MMN as the discrimination became easier between frequent and infrequent stimuli. They also reported as the discrimination became easier, MMN was earlier in latency and greater in amplitude (Naatanen et al., 1987; Paavilainen et al., 1993b). In the present study the total duration of both stimuli was kept constant at 200 ms with 30 ms rise-fall time and a plateau of 140 ms. The Aux Viewer program was used for the preparation of stimulus. The wave file was then converted to stimulus file for AEPs using the software "Stimconv" provided by Intelligent Hearing System. Vertical montage with 'Fz' as the non-inverting electrode referenced to the nape of the neck was used to record MMN. The ground electrode was placed on the lower forehead. Eye blink responses were also recorded by another channel. Those sweeps with large eye blink artifact were not taken for averaging. The 1000 Hz and 1100 Hz pure tone stimuli were given in the odd ball paradigm in which the probability of frequent stimulus (1000 Hz) was 80% and that of infrequent stimulus was 20% at 70 dB nHL. The stimuli were presented at a repetition rate of 1.1/second in rarefaction polarity. To get MMN, the responses of −50 to 500 ms (with reference to stimulus onset) were averaged for 150 sweeps (20%) of infrequent stimulus and correspondingly 600 sweeps of frequent stimuli to maintain the 80%/20% frequent and infrequent stimulus ratio. The response was amplified to 50,000 times. The filter setting used was 0.1–30 Hz. Stimuli were presented binaurally. The participants were seated in a relaxed and comfortable position in order to avoid muscular artifacts and were made to watch a silent movie in order to promote passive listening. All the participants were asked not to pay attention to the auditory stimuli. Disc electrodes were placed on the cleaned skin surface of the targeted electrode sites. Absolute impedance was less than or equal to 5 kΩ and inter-electrode impedance was less than or equal to 2 kΩ while recording MMN. Apart from recording MMN in the conventional paradigm for each stimulus pair, LLRs (Long Latency Responses) were also recorded for the infrequent stimulus for 150 presentations, keeping the same recording parameters as for MMN.

2.6. Response analysis

Conventional MMN recording was obtained in the odd ball paradigm which consisted of waveforms for the frequent and infrequent stimulus. This was followed by a second recording which was the conventional LLR for the

infrequent stimulus at the rate of 1.1/second, averaged for 150 sweeps. The LLRs obtained for the infrequent stimulus were later used to analyze MMN by comparing it with the infrequent stimulus waveforms of the conventional odd ball paradigm. This paradigm was adopted to rule out any chances of error marking in MMN parameters due to the difference in LLRs elicited by the two stimuli of the odd ball paradigm and also to reduce the N1 affect (Martin et al., 2008). MMN was located in the difference wave to obtain its onset, peak and offset latency. Similarly, peak amplitude and the area under the curve were also considered for measurement in MMN response for all participants. Onset latency was the time in millisecond at which the negativity started in the subtracted waveform. Offset latency was the time in milliseconds at which the negativity reached the baseline activity in the subtracted waveform. Peak latency was the time in millisecond at which negativity reached its peak in the subtracted waveform. Peak amplitude was the maximum amplitude of the peak of the negativity with respect to the baseline and area under the curve was the area under the negativity trough, derived from multiplying the peak amplitude with MMN duration.

2.7. Waveform analysis

Visual detection was used for recognition of the MMN response. The criteria defined MMN as the first negative broad peak in the latency range of 100−300 ms, i.e. the N_1-P_2 or P_2-N_2 complex of LLRs. The first negativity should have the amplitude of more than −0.3 μV and a positive peak should follow the negative peak. If any extra negativity occurred in the P_1 area, it was ignored by investigators.

2.8. Statistical analysis

Descriptive statistics was done to find out mean and standard deviation (SD) for all the measures of MMN, i.e. onset latency, offset latency, peak latency, peak amplitude and area under the curve. To reduce the chance of type 1 error, MANOVA was used to compare between Indian classical vocal musicians and non-musicians for each measure of MMN.

3. Results

To inspect the data collected from Indian classical vocal musicians and non-musicians, descriptive statistics and MANOVA was done. Out of 25 musicians and 25 non-musicians, MMN was present only in 17 (68%) musicians and 16 (64%) non-musicians. Hence, further statistical analysis was done only for these subjects. The various measures of MMN i.e. onset latency, offset latency, peak latency, peak amplitude and area under the curve, were noted down from the MMN waveform through visual inspection for individual subjects. Sample waveform of MMN in musicians and non-musicians are represented in Figs. 1 and 2, respectively. Descriptive statistics was done to find out mean and standard deviation (SD) for all the parameters of MMN (onset latency, offset latency, peak latency, peak amplitude and area under the curve) for the 17 Indian classical vocal musicians and 16 non-musicians (Table 1). Shapiro Wilk test was used to check the normal distribution of collected data from musicians and non-musicians. Based on the result of normality test, MANOVA was used to check any significant difference between musicians and non-musicians for each measure of MMN. From Table 1, the standard deviation for onset and peak latency was less (better) for musicians in comparison to non-musicians. The mean values of onset and peak latency for musicians
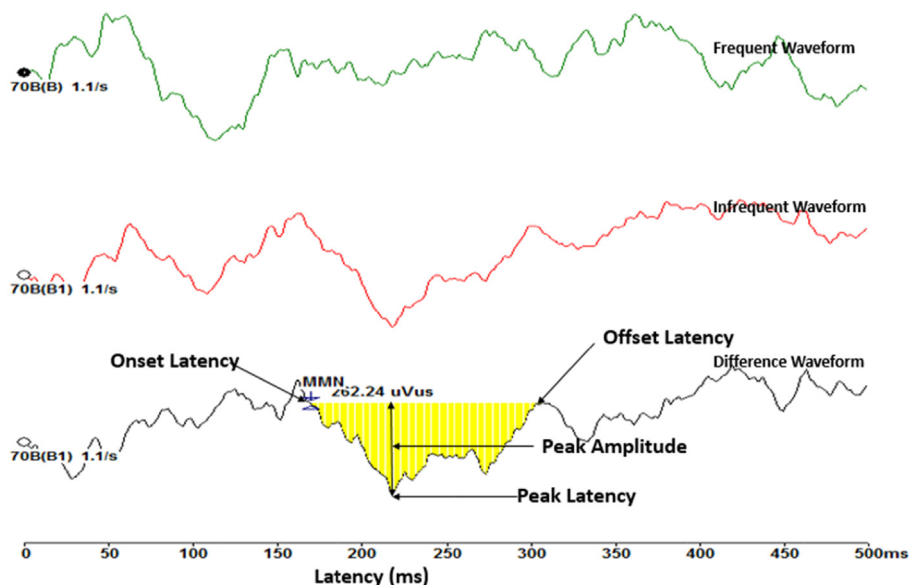

Fig. 1. A sample waveform of mismatch negativity in Indian classical vocal musicians along with the response measures.
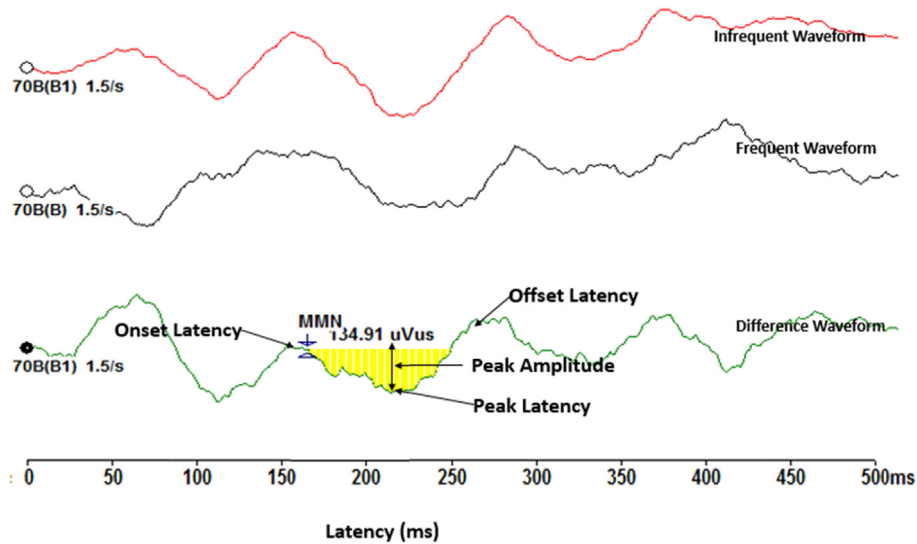
Fig. 2. A sample waveform of mismatch negativity in non-musicians along with the response measures.

were also less (better) in comparison to non-musicians. However, the mean value of offset latencies was similar between the two groups. Fig. 3 shows an error bar graph for onset, offset and peak latency in musicians and non-musicians.

MANOVA was carried out to compare differences between Indian classical vocal musicians and non-musicians for onset latency, offset latency and peak latency. Results of MANOVA showed marginally significant difference for onset latency [$F_{(1, 31)} = 3.57$; $p = 0.06$; $\eta^2 = 0.103$], whereas no significant difference was observed for offset latency [$F_{(1, 31)} = 0.00$; $p = 0.98$; $\eta^2 = 0.00$] and peak latency [$F_{(1, 31)} = 1.01$; $p = 0.32$; $\eta^2 = 0.032$] between musicians and non-musicians in spite of higher mean observed for peak latency in musicians.

Descriptive statistics was done to find out mean and standard deviation (SD) of the area under curve and peak amplitude for the Indian classical vocal musicians and non-musicians. From Table 2, the mean peak amplitude and area under the curve were higher (better) for musicians in comparison to non-musicians. However, standard deviation (SD) was less for non-musicians in comparison to Indian classical vocal musicians (Table 2). Figs. 4 and 5 show error bar graphs for peak amplitude and area under the curve in musicians and non-musicians respectively.

MANOVA was carried out to compare peak amplitude and area under the curve between Indian classical vocal musicians and non-musicians. Results revealed statistically significant

difference for peak amplitude [$F_{(1, 31)} = 11.32$; $p = 0.00$; $\eta^2 = 0.267$] and area under curve [$F_{(1, 31)} = 7.64$; $p = 0.00$; $\eta^2 = 0.198$] between Indian classical musicians and non-musicians.

4. Discussion

Out of 25 Indian classical vocal Musicians and 25 non-musicians, MMN was present only in 17 Indian classical vocal musicians and 16 non-musicians. In our study, absence of MMN in some of the subjects may be due to their inability to follow instruction of 'passive listening' during recording of MMN. So, data from those subjects on whom MMN was absent were excluded. MMN was studied by Koelsch et al. (1999) on professional violinists and non-musicians. The results showed that a distinct MMN was evoked in professional
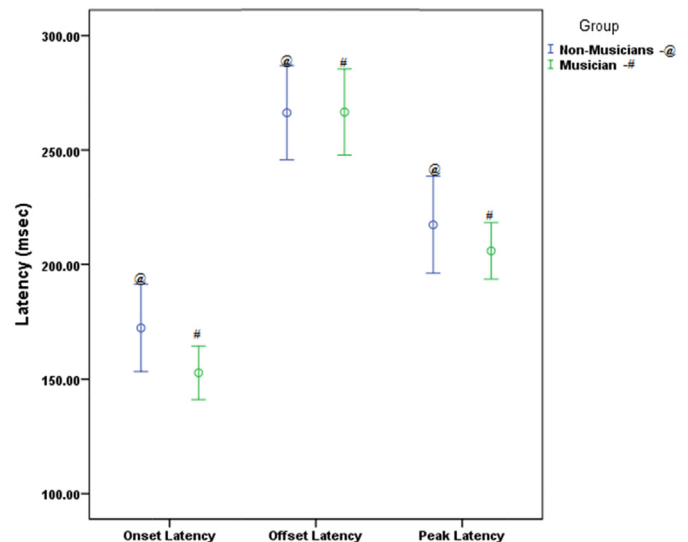
Table 1
Mean and standard deviation (SD) of onset latency, offset latency and peak latency for the Indian classical vocal musicians and non-musicians.

Parameters	Onset Latency (ms)		Offset Latency (ms)		Peak Latency (ms)	
	Mean	SD	Mean	SD	Mean	SD
Non-musicians	172.37	35.66	266.25	38.48	217.43	39.62
Musicians	155.23	23.26	268.43	34.36	204.64	23.98

Fig. 3. Error bar graph of onset latency, offset latency and peak latency for Indian classical vocal musicians and non-musicians.

Table 2
Mean and standard deviation (SD) of peak amplitude and area under the curve for the Indian classical vocal musicians and non-musicians.

Parameters	Peak Amplitude(μv)		Area under curve (μVμsec)	
Groups	Mean	SD	Mean	SD
Non-Musicians	2.78	0.80	131.75	39.68
Musicians	4.06	1.32	218.65	110.36

violinists but MMN was absent in non-musicians. Previous studies have also reported MMN to be robust at the group level, but identification of MMN can be difficult at an individual level (Lang et al., 1995; McGee et al., 1997; Ponton et al., 1997). Dalebout and Fox (2001) also reported that MMN identification rate was too low (29%) to allow reliability to be evaluated. A study by Sanju and Kumar (2016) also showed that MMN was present only in 66% of the normal hearing population.

4.1. Findings in onset, offset and peak latency of MMN

The present study showed a marginally significant difference in onset latency between Indian classical vocal musicians and non-musicians, and no significant difference in offset and peak latency between Indian classical musicians in comparison to non-musicians. The present outcomes are in consonance with previous literature (Nikjeh, 2006). In addition, there are studies done on different populations that have obtained similar outcomes (Lonka et al., 2013; Jansson-Verkasalo, 2014; Sanju & Kumar, 2016). However, there are a few studies that are not in agreement with the present findings (Nikjeh et al., 2009; Holdefer et al., 2013).

Nikjeh (2006) compared MMN in formally trained instrumental musicians and age-matched non-musicians using harmonic tones. The result showed no significant difference in latency of MMN between instrumental musicians and non-musicians. Since there are not many researchers who have
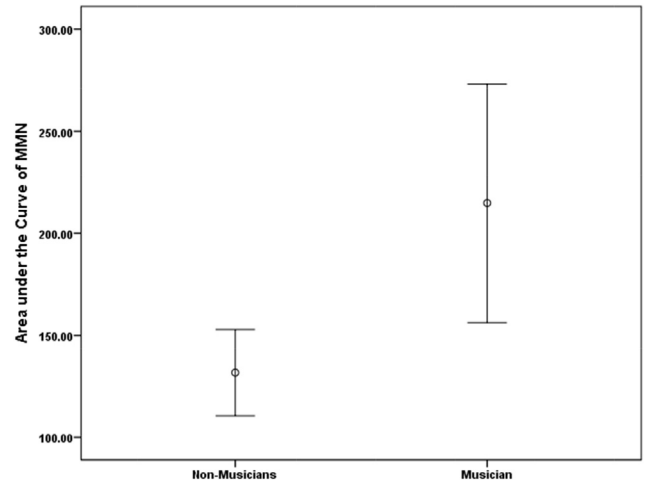

Fig. 5. Error bar graph of the area under the curve for the Indian classical vocal musicians and non-musicians.

explored in the area of music, studies with MMN done in different populations are considered for the support of the present study. Lonka et al. (2013) measured MMN in individuals with cochlear implants and reported that MMN latencies to frequency deviance did not show any changes over time. Similarly, Jansson-Verkasalo et al. (2014) compared MMN in children with and without stuttering. The results showed no significant difference in peak latency of MMN between the two groups. The finding of the current study is in contrast with the finding of a study done by Nikjeh et al. (2009). They assessed MMN in trained musicians and non-musicians. The results showed that musicians had shorter (better) MMN latencies to frequency changes in pure tones than non-musicians. In both groups, as the frequency difference between standard and deviant stimuli increased, MMN latency decreased (better). They also observed that mismatch negativity latencies for harmonic tone and speech syllable were significantly lesser (better) for musicians when compared to non-musicians.

Bishop (2007) reported that latency measures were not reliable in MMN. They suggested that amplitude measures were more reliable than latency and most studies in this area have reported only amplitude measures. Sanju and Kumar (2015a, b) also showed no significant difference in latency measures across gross and fine differences between auditory stimuli. This result was attributed to poor reliability and high variability in latency measures of MMN. A similar study can be replicated on a large number of subjects to validate the findings.

4.2. Findings in peak amplitude and area under curve of MMN

The results of the present study showed that peak amplitude and area under the curve were significantly higher (better) in Indian classical vocal musicians compared to non-musicians. This indicates enhanced pre-attentive auditory discrimination skills when it is measured in terms of peak amplitude and area
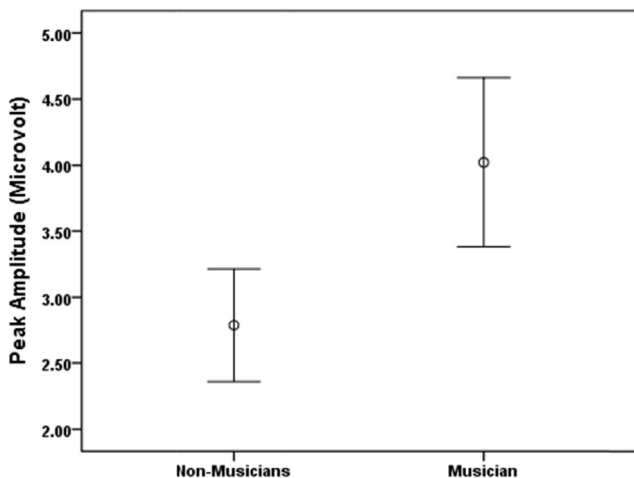

Fig. 4. Error bar graph of peak amplitude for the Indian classical vocal musicians and non-musicians.

under the curve. The present study's outcome is well supported by other researchers (Tervaniemi et al., 2006; Nikjeh et al., 2009; Boh et al., 2011; Marie et al., 2012; Kuhnis et al., 2013; Habibi et al., 2014; Putkinen et al., 2014). However, the findings of the current study are in contrast to a few studies (Tervaniemi et al., 2005) as reported in the literature. Tervaniemi et al. (2006) recorded MMN with changes in acoustic features (gap, duration, frequency, location and intensity) and abstract features (interval size and melodic contour) as stimulus in non-musicians and amateur band musicians. The results showed that musicians had a larger MMN amplitude (better) and a greater area under the curve (better) as compared to non-musicians fora location change. Whereas, no statistically significant group differences were observed in response to other feature changes or in abstract-feature in mismatch negativity. This study shows that even amateur musicians have neural sound processing advantage when compared with non-musicians. Marie et al. (2012) investigated pre-attentive skills in musicians and non-musicians using MMN. The results revealed that mismatch negativity peak amplitude was significantly larger (better) in musicians compared to non-musicians for frequency deviants. A similar study was done by Kuhnis et al. (2013) investigating MMN in musicians and non-musicians using vowels and temporally manipulated consonant-vowel syllables as stimuli. They found that musicians were not only advantaged in the pre- attentive encoding of temporal speech cues than non-musicians, but most notably also in processing vowels. Habibi et al. (2014) recorded event-related brain potential responses in musicians and non-musicians to discrepancies of rhythm between pairs of unfamiliar melodies based on western classical rules. They noticed that musicians were able to detect rhythm deviations significantly better than non-musicians. Putkinen et al. (2014) recorded MMN for changes in melody, rhythm, musical key, timbre, tuning and timing in musically trained children. When compared to non-trained children, the musically trained children showed a significantly larger amplitude in MMN for all changes in stimuli. Therefore, it can be inferred that musical training helps in enhancing auditory discrimination for musically central sound dimensions in pre-adolescence.

A similar study was done by Nikjeh et al. (2009) using mismatch negativity on trained musicians. In this study, they reported that amplitude was significantly higher (better) for musicians with a pure tone as stimulus, but there was no significant difference seen in terms of the amplitude of MMN elicited by harmonic tones and speech syllables. They suggested that "musicians may have been slower to detect pure tones because they perceived this audible stimulus energy as irrelevant sensory stimuli. However, once the stimuli were detected, musicians automatically discriminated changes in pure tone frequency earlier than nonmusicians without an increase in response amplitude, suggesting more efficient acoustic processing". They also showed that the size of frequency deviance significantly affected the neural response, i.e. with increase in difference between frequent and infrequent stimuli, the MMN latency decreased and amplitude increased.

The current study is in contrast to the study by Tervaniemi et al. (2005). MMN was recorded in professional musicians in their study. They were presented with frequent standard sounds and rare deviant sounds at 0.8%, 2% and 4% higher in frequency. They reported no significant difference in peak amplitude between musicians and non-musicians when MMN was recorded in reading condition. They attributed these results to musical expertise that could have exerted its effects at merely attentive level of processing but not at the pre-attentive level. Similar to most previous studies (Boh et al., 2011; Marie et al., 2012; Kuhnis et al., 2013; Habibi et al., 2014; Putkinen et al., 2014), the present study also shows that amplitude and area under the curve measure of the MMN have a significant effect from Indian classical musical training.

5. Clinical implication of the study

The present study shows that Indian classical vocal musical training have enhanced pre-attentive auditory discrimination skills in Indian classical musicians. Earlier studies have reported poor pre-attentive auditory processing in several clinical populations, i.e. central auditory processing disorders (Näätänen et al., 2012), dyslexia (Kujala and Näätänen, 2001), Parkinson's disease (Pekkonen, 2000), Alzheimer's disease (Pekkonen, 2000), schizophrenia (Perez et al., 2014), developmental language disorders (Bishop, 2007) and cochlear implant (Kuo et al., 2014). Indian classical musical training can be used to enhance pre-attentive auditory discrimination skills in these clinical populations. Earlier literature shows enhanced speech perception in quiet and noise in musicians compared to non-musicians (Parbery-Clark et al., 2009). Auditory scene analysis is defined as the internal process of segregating and subsequent grouping of auditory system for better speech perception (Bregman, 1990). Auditory scene analysis is based on the assumption that pre-attentive process uses the Gesalt laws of organization which says temporal proximity, physical similarity and good continuity is required to group the sound, which improves speech perception in quiet as well as in noise (Koffka, 1935). Enhanced pre-attentive skills in musicians is reported by many researchers (Marie et al., 2012; Kuhnis et al., 2013; Habibi et al., 2014; Putkinen et al., 2014). Therefore, it can be hypothesized that musical training can be used for enhancement of pre-attentive auditory discrimination skills in these populations and may result in improvement in speech perception.

6. Conclusion

The current study shows enhanced peak amplitude and area under the curve of MMN in Indian classical vocal musicians compared to non-musicians. This indicates better pre-attentive auditory discrimination skills in Indian classical vocal musicians compared to non-musicians. It can also be stated that Indian classical vocal musical training has an effect on pre-attentive auditory discrimination skills in musicians, leading to higher peak amplitude and area under the curve. It can also be hypothesized that musical training (Indian classical) can be

used to improve pre-attentive auditory discrimination skills in clinical populations including those with central auditory processing disorders, learning disability, Parkinson's disease, schizophrenia, Alzheimer's disease, children with cochlear implant and developmental language disorders.

Acknowledgment

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