Basal Ganglia 6 (2016) 63–70

Contents lists available at ScienceDirect

Basal Ganglia

journal homepage: www.elsevier.com/locate/baga

Two sides of the same coin: Impairment in perception of temporal components of rhythm and cognitive functions in Parkinson's disease

Amrita Biswas[a], Shantala Hegde[a,*], Ketan Jhunjhunwala[b], Pramod Kumar Pal[c]

[a] Department of Clinical Psychology, NIMHANS, Bangalore, KA, India
[b] Department of Clinical Neurosciences, NIMHANS, Bangalore, KA, India
[c] Department of Neurology, NIMHANS, Bangalore, KA, India

ARTICLE INFO

Article history:
Received 13 June 2015
Received in revised form 11 December 2015
Accepted 11 December 2015
Available online 14 December 2015

Keywords:
Rhythm
Meter
Rhythmic contour
Parkinson's disease
Cognitive deficits
Basal Ganglia

ABSTRACT

Background: Patients with Parkinson's disease (PD) have motor dysfunction, cognitive dysfunction, impairment in temporal processing and rhythm discrimination. Apart from beat-based rhythm discrimination, perception of other temporal components of rhythm such as meter, contour and beat perception in musical context has not been studied hitherto. So far relation between cognitive functions and perception and discrimination of temporal components of rhythm has not been examined.
Methods: Performance of PD ($n=21$) in comparison with matched healthy-controls (HC) on beat-discrimination, rhythmic contour, meter perception and beat-perception in musical context and on cognitive tests measuring immediate memory, focussed attention, verbal and visual working memory in the non-musical domain was examined
Results: PD performed poorly on all the cognitive tests and rhythm tests compared to HC ($p=<0.01$). Verbal working memory, and focussed attention correlated significantly with rhythm perception. Step wise linear regression analysis showed that focussed attention and verbal working memory predicted the performance on the rhythm tests and beat discrimination, beat perception in musical context and discrimination of rhythmic contour predicted performance on the cognitive tests. Findings indicate that patients with PD have deficits in rhythm perception and discrimination and there is a close inter-relation between cognitive processes and perception and discrimination of various temporal components of rhythm.
Conclusions: Cognitive functions are closely linked with rhythm perception. Cognitive functions and rhythm perception predict the performance on the other. The findings also have implication on planning rhythm-based intervention and cognitive remediation that may have mutual benefits in both the domains.

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1. Background

Rhythm is an integral part of musical behaviour and musical experience. Similar to musical structure, rhythm is composed of distinct components such as tempo, contour, meter and rhythms in melodic context demands different cognitive processes and are known to involve distributed networks of the brain areas and are different from those implicated in perception of pitch, melody, timbre and tonality [2,48,60,61]. Cortical and subcortical regions such as the motor system, especially in the supplementary motor area (SMA), premotor cortex (PMC), basal ganglia and cerebellum have been reported to involved while listening to rhythm (with or without beat) [4,8,10,20]. Motor timing and perceptual timing across different modalities have been linked to cerebellum and basal ganglia (BG) [46]. Parkinson's disease (PD) has been studied as a model by majority of previous neuropsychology studies to examine the time perception, rhythm perception as there is involvement of the motor areas, subcortical areas such as the basal ganglia and decreased secretion of dopamine by the striatum in PD [1,21,31]. In PD along with movement related problems such as

* Corresponding author at: Neuropsychology Unit, Department of Clinical Psychology, Govindaswamy Center, National Institute of Mental Health and Neuro Sciences, Bangalore-560029, KA, India/Cognitive Psychology & Cognitive Neurosciences Laboratory, #203, Neurobiology Research Center, National Insitute of Mental Health and Neuro Sciences, Bangalore-560029, KA, India.
Tel. +91 80 2699 5183.
E-mail addresses: shantalah@nimhans.kar.nic.in, shantala.hegde@gmail.com (S. Hegde).

http://dx.doi.org/10.1016/j.baga.2015.12.001
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tremor, rigidity, hypokinesia and postural instability, deficits in cognitive functions, in motor timing [37], simple timing tasks [3,24,41,54], temporal discrimination [50] rhythmic hand tapping task [66] and perception of rhythm with a regular beat [21] has been reported.

Along with deficits in time perception and rhythm perception, cognitive deficits in PD have been very well established and are known to deteriorate with progression of the disease [14,19,53,55,67]. Neural circuits connecting the frontal cortical regions and BG have been implicated for cognitive deficits reported in PD [34,59]. BG is implicated in playing a crucial role in higher order cognitive processes such as executive functions, learning and memory [5,15,22,38]. Studies on clinical conditions such as PD, Huntington's disease, Wilson's disease which have motor deficits as a cardinal feature, has shown evidence for the role of BG in motor as well as cognitive functions [12,27,49,65].

Studies carried out on clinical conditions, such as Parkinson's disease (PD) has provided evidence on the involvement of the overlapping brain areas such as the basal gangalia, fronto-striatal areas, cerebellum in time and rhythm perception as well as higher cognitive functions. It suggests a close connection between deficits in perception of temporal patterns, cognitive functions and motor functions. Scientific investigations in understanding the neural correlates of rhythm perception and production have been a recent endeavour. Studies so far have examined beats, metronome sounds to examine rhythm perception, discrimination abilities in patients with PD [21]. Rhythm perception, rhythm discrimination in musical context, meter perception and rhythmic contour have not been examined in this clinical condition hitherto. Also, deficits in time perception, rhythm perception and cognitive deficits have been examined independently. There are no systematic studies till date examining the deficits profile in rhythm perception as well as cognitive deficits and in what way the two domains predict the functioning of the other.

The aim of the present study was to examine deficits in perception of rhythm in its different temporal components such as beat, rhythmic contour, meter, and beat- perception in musical context in patients with PD. The aim was also to examine the relationship between deficits in rhythm perception and deficits in cognitive processes in non-musical domain such as immediate memory, focussed attention, verbal and spatial working memory, and set shifting ability.

2. Methods

2.1. Participants

Patients with Parkinson's disease (PD) (10 male and 11 female) and age, gender and educated matched healthy participants (HC) comprised the sample. The average age was 53 (SD = 9.4), ranging from 35 to 68 years. The average number of years of formal education was 12 (SD = 4.27), ranging from 5 to 17 years. PD were assessed on the unified Parkinson's rating scale (UPDRS) to assess the severity of motor dysfunction. The mean UPDRS score was 24.14 (SD = 11.12), ranging from 10 to 48. The patients were at Hoehn and Yahr stage 1–4 [28] with the mean 2.26 (SD = 0.6), ranging from 1.5 to 4. The mean age of the onset of illness was 45.86 (SD = 11.06). PD were recruited from Neurology in-patient and out-patient services and movement disorder clinic at the National Institute of Mental Health and Neuro Sciences (NIMHANS), Bangalore, India. The control group, normal healthy volunteers (HC) were recruited by personal contacts in the community and using case-wise matching method. The study protocol was approved by the academic expert committee of the Department of Clinical Psychology, NIMHANS, which scrutinises the ethical guidelines followed in the study. Written informed consent was obtained from participants. Participants, i.e., PD and HC were right handed and were assessed using Edinburgh handedness inventory [43]. Hindi Mental Status Examination (HMSE) [17] was used to screen out patients with a gross cognitive impairment. Patients and normal healthy participants who scored less than 24 on the HMSE were excluded from the study. PD were screened and ruled out for any psychiatric condition using the Kessler's 6 Screening Scale (K6) [32]. PD had score less than 12, indicating that none had any co-morbid psychiatric condition. None of the participants had any formal training in any form of music (Indian or Western, vocal or instrumental).

3. Materials and procedure

3.1. Rhythm perception

(a) Beat discrimination ability was assessed using the beat-based (metric simple) rhythm discrimination test [21] and The Seashore Rhythm Test (SRT) [52,56].

As described in the original work of this test [21] thirty trials of the beat based (metric simple) rhythmic sequences of 5, 6 and 7 intervals were presented in randomized order. Each sequence was presented twice, followed by a third presentation. The third presentation was either similar to the first two presentations (standard) or different (deviant). A random sequence of the thirty rhythm sequences was created and uploaded as a library and presented via windows media player. Each rhythm presentation was separated by 1100 msec. Participants were asked to report if the third sequence was the same as the first two presentation or different. Total correct scores were recorded.

The Seashore Rhythm Test (SRT) [52,56] was administered using the audio compact disc and presented via windows media player. The SRT measures the ability to discriminate variations in rhythmical patterns. The test consists of 30 pairs of rhythm patterns and is presented using metronome sound. The participants were asked to report if the two rhythm patterns are the same or different. Total correct scores were recorded.

(b) Ability to discriminate rhythmic contour was assessed using the Rhythmic Contour subtest of the Montreal Battery for Evaluation of Amusia (MBEA) [47]

In this test thirty pairs of melodic sequences are presented. Participants would listen to each of the paired stimuli and report whether the two stimuli were same or different. In some of the pairs the second melodic sequence had different duration values of two adjacent notes. In this subtest the meter and total number of the sounds would be the same, but the rhythmic grouping by temporal proximity would be different. Total correct scores were recorded.

(c) Meter perception in musical context was assessed using the Metric sub-test of the Montreal Battery for Evaluation of Amusia (MBEA) [47]

In this test, two-phrase sequences are used. Half of the thirty harmonized melody sequences presented are in duple meter (march) and half in triple meter (waltz). Participants were asked to categorize the melodies that were presented as either march or waltz. A march rhythm is a two beat rhythm with a strong beat followed by a weak beat and a waltz rhythm is a three beat rhythm, where a strong beat was followed by two weak beats. The total number of correctly indentified meter in the melodic sequences formed the total score.

(d) Beat perception in musical context was assessed using the Beat Alignment Test (BAT) [30]. This test includes four subtests: spontaneous tapping, synchronization to a metronome, synchronization to musical passages, and a perceptual test of beat perception in musical passages. For the present study only the last sub-test-perceptual test of beat perception in musical passages

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