Journal of the Neurological Sciences 343 (2014) 76–81

Contents lists available at ScienceDirect

Journal of the Neurological Sciences

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

The impact of cerebellar disorders on musical ability

Bernadette Tölgyesi [a], Stefan Evers [a,b,*]

[a] Department of Neurology, University of Münster, Münster, Germany
[b] Department of Neurology, Krankenhaus Lindenbrunn, Coppenbrügge, Germany

ARTICLE INFO

Article history:
Received 19 February 2014
Received in revised form 16 April 2014
Accepted 16 May 2014
Available online 27 May 2014

Keywords:
Cerebellum
Music perception
Musical ability

ABSTRACT

Background: The cerebellum contributes not only to motor coordination but also to cognitive processing. Emphasizing the cerebro–cerebellar connectivity, present literature declares a decisive role of the cerebellum in music perception.
Methods: Patients with cerebellar disorders ($n = 15$) due to infarction or genetically caused degeneration were tested on their musical ability and compared to matched healthy control subjects. We used a validated and standardized test of musical ability including the reproduction of rhythm and meter, melody comparison, emotion identification, pitch discrimination and the recognition of familiar melodies.
Results: The patient group presented significantly lower scores in the subtests meter, melody comparison and emotion identification as compared to healthy control subjects. Rhythm reproduction and pitch discrimination were not affected by cerebellar disorders.
Discussion: Testing musical ability in cerebellar disorders may serve as an additional tool to detect and quantify cognitive deficits, namely for music perception. As a consequence, it might be that musical stimulation can be helpful in cognitive impairment due to cerebellar lesions.

1. Introduction

The cerebellum plays an important role in motor control but it is also involved in cognitive processing. It has been shown that children who underwent removal of a cerebellar hemisphere or vermal tumours presented cognitive and behavioural deficits [1]. Adults after cerebellar injury exhibit deficits regarding executive function, cognition, affect, and behaviour, this was called “cerebellar cognitive affective syndrome (CCAS)” [2]. CCAS may lead to deficient emotion identification as well as to a failure of emotion regulation. Children with treated cerebellar tumours had mostly normal emotion identification but a restricted cognitive control of emotions [3], but there are also patients not showing any cognitive or behavioural pathology after cerebellar surgery at all [1]. Considering the cerebellum to be part of a network of interconnections to multiple cortical areas, it is obvious that cerebellar impairment might lead to cognitive symptoms.

Neuroimaging studies analysed the neural structures activated when musicians had to detect specific melodic, harmonic, or rhythmic errors [4]. The cerebellum showed activation during all three exercises, and in the rhythm task cerebellar activation was twice as high as compared to the harmony and the melody task. When musicians and nonmusicians discriminated pairs of rhythm, the nonmusicians showed much stronger cerebellar activity in the meter, tempo, and pattern discrimination; however, musicians had greater cerebellar activation during duration discrimination. This result may reflect differences in strategy, skill, and cognitive representation of musicians and nonmusicians [4] indicating the dependency of brain function on skill acquisition [5]. Furthermore, patients with pancerebellar degeneration were highly impaired in a pitch discrimination task and the degree of impairment indicated the severity of their pancerebellar ataxia [4].

Sensory stimulation alone activates the dentate nuclei of the cerebellum whereas motor control per se (like finger movements) does not lead to these activations [4]. Keeping in mind that motor behaviour inevitably requires sensory input, the evidence above does not contradict the deficient movement control of patients with cerebellar damage as the motor system relies on the connection to sensory information [2]. Given that time information processing is essential for motor control as well as for music perception [5], the testing of musical ability on cerebellar patients appears to be reasonable, in particular as even nonmusicians should be aware of basic musical knowledge.

Molinari et al. [5] tested one group of patients with cerebellar atrophy and a second with focal cerebellar damage compared to healthy control subjects when they had to detect rhythm frequency changes. Interestingly, just the cerebellar atrophy group presented significantly inferior results compared to control subjects, suggesting that cerebellar pathologies may influence the ability to appreciate rhythm changes [5]. In addition, cerebellar damage seems to affect the variability and thus the stability of motor response as both groups were tested in their ability to tap synchronously following an auditory stimulus [5].

* Corresponding author at: Department of Neurology, Krankenhaus Lindenbrunn, Lindenbrunn 1, 31863 Coppenbrügge, Germany. Tel.: +49 5156 782290.
E-mail address: everss@uni-muenster.de (S. Evers).

http://dx.doi.org/10.1016/j.jns.2014.05.036
0022-510X/

The involvement of the cerebellum in memory for rhythm was also verified by fMRI [6].

In the past, there has been intensive research on the projections from the cerebellum to other brain structures. One conclusion is that the medial mamillary bodies (important for the processing of recognition memory) show reciprocal conjunctions with the cerebellum [7]. The cerebellum might support cortical areas in the effort of retrieving information from explicit memory storage but admit that the role of the cerebellum concerning this retrieval remains yet unknown [8].

The literature above highlights the cerebellum as a brain structure of high interest for music perception, but nevertheless many mechanisms are still unknown. In the present study, we applied a clinical test of musical ability to patients with cerebellar damage, one group with cerebellar atrophy and another with a focal cerebellar lesion following a stroke, and compared their results with those of a healthy control group.

2. Methods

2.1. Participants

All patients had been hospitalized at the Department of Neurology, University of Münster. Inclusion criterion for the musical testing was a structural cerebellar damage without any other neurological or psychiatric disorder. Patients had either a cerebellar infarction (at least 2 cm hemispheric infarction as proven by MRI; $n = 11$) or a genetically confirmed diagnosis of Machado–Joseph disease ($n = 4$). No medication affecting the central nervous system was allowed. Prior to the testing, participants were asked about graduation, profession, musical training, and hearing ability. All patients were native German speakers and gave written informed consent. We also included 30 healthy control subjects without any clinical signs of cerebellar impairment, without any neurological and psychiatric disorder in their history, and without centrally acting medication. The control subjects were matched according to sex, age, and graduation.

2.2. Testing musical ability

The clinical test of musical ability is supposed to examine basic musical perception and processing not presuming that participants had any special musical training in the past. It was applied to cerebral stroke patients as well as healthy control subjects demonstrating that it indicates impairment of cerebral functions concerning musical perception and processing [9].

Short rhythmic or melodic tracks on CD (played by instruments) were presented to the participants via earphone using a laptop. Subjects were informed that once the audio samples were heard they could not be repeated, so decision should be made straight after the single tracks. Before starting each subtest the upcoming task was explained in detail until the patient assured comprehension. To allow the subjects to focus just on hearing they gave verbal answers which were noted immediately by the examiner on a response sheet. The examiner was blinded for the subtype of cerebellar disorder. The musical testing is subdivided into five parts:

1) Rhythm and metrum: The participant had to reproduce sixteen (1 to 3: 2/4 time; 4 to 10: 4/4 time; 11 to 16: 3/4 time) short rhythmic sequences by tapping with a pen on a table. For each of the samples correctness of rhythm and meter was evaluated separately and noted, resulting in a maximum score of 16 points for rhythm and 16 points for metrum.
2) Comparing melodies: A first melodic sequence serving as a standard melody was shortly followed by a second melody. The latter should be compared to the standard melody. The sixteen samples included four different standard melodies. Subjects should just tell if the second melody was identical (7×) or different (9×). It was not necessary to specify the location of the interval changes (minor or major second, third, fourth, fifth, octave). Each correct comparison produced one point, overall 16.
3) Emotions: This subtest consisted of twelve improvisational short pieces of 3 to 4 bar duration. Each sample should represent one of these emotions: anger (3×), fear (3×), sadness (4×), happiness (2×). Before the actual testing, the four emotions were written down and placed in front of the participant so he could concentrate on listening without memorizing them continuously. After each track subjects were advised to choose which of the named emotions would reflect the heard sample best. Subjects were not informed about the total number each emotion would occur during the testing. A full score of 12 points could be reached in this task.
4) Pitch discrimination: A piano played 12 different tone pairs on which the first tone should be compared to the second. The participant had to judge whether the second tone was higher or lower than the first (7 higher, 5 lower). The intervals ranged from minor second to minor seventh (minor second 3×, major second 1×, minor third 3×, major third 1×, perfect fourth 2×, perfect fifth 1×, minor seventh 1×). Each correct pitch discrimination was given one point resulting in a total score of 12 points for this subtest.
5) Melody recognition: The patients listened to fourteen short tracks consisting of either the beginning of a familiar song (10×) or an improvisation (4×). The songs were: "Te Deum" by Charpentier; "Frère Jacques" (folk song); "Der Mond ist aufgegangen" (German lullaby); "Kommt ein Vogel geflogen" (German folk song); "Eine kleine Nachtmusik" by Mozart; "Yesterday" by The Beatles; "Love me tender" by Elvis Presley; "Oh Tannenbaum" (German Christmas carol); "Air" by Bach; and "Schneewalzer" by Koschat. All were played by various instruments not using commercial recordings but ensuring that familiar melodies would be clearly recognizable through these samples. At the end of each track participants should tell if they identified the melody as a familiar song or not. Concerning the scoring it was not necessary to name the song title. For each correct answer subjects received one point (14 points maximum).

2.3. Statistical analysis

The test resulted in a total score of 86 maximum. It was constructed in the way that most of the tasks are very easy to fulfill. Thus, the test has a high ceiling effect, i.e. only clearly and severely affected subjects show abnormal results.

Data are presented as arithmetic mean and standard deviation. Comparisons were made by nonparametric testing. We used the Mann–Whitney-*U*-test for group comparison. Significance level was set $p = 0.05$.

3. Results

The age of the 15 patients (7 males, 8 females) ranged from 36 to 73 years. Mean patient age was 56 years. The exact data are presented in Table 1. Graduation ranged from secondary school to university degree. One participant had a hearing aid but stated to have no problems with hearing during the musical testing. Eleven patients attended regular music lessons at school, six of them also played an instrument (less than ten years). Four of the participants neither had regular music lessons at school nor played any instrument. In the control group, 25 attended music lessons at school regularly with 15 of them playing an instrument (less than ten years).

The results of the musical ability test are presented in Table 2. For three subtests (metrum, melody comparison, and emotion) and for the total test score, we obtained significant differences between the patients and the control subjects. In three subtests, no significant differences were observed. Regarding the mean total score of the control subjects (i.e., 69.7 points) as an average normal score, the lower level of a normal test result was 52 points (i.e., minus two standard