EVALUATION OF MUSIC COGNITION IN CHILDREN AND ADOLESCENTS WITH ATTENTION-DEFICIT/ HYPERACTIVITY DISORDER

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ABSTRACT

Attention Deficit Hyperactivity Disorder (ADHD) has high prevalence among children and adolescents and is characterized by attention deficits, hyperactivity, and impulsiveness. ADHD mainly compromises attention and executive functions and is associated with difficulties in phonological awareness. Considering the relationship between musical performance and the development of compromised cognitive functions in ADHD, this study aimed to evaluate the musical neuropsychological profile of individuals with ADHD and to investigate the presence of musical processing deficits. Twenty Brazilian individuals aged 7 to 13 years, were divided into two groups of 10 participants: (1) a clinical group composed by individuals diagnosed with ADHD; and (2) a control group, consisting of individuals with typical development. We assessed participants from intelligence, language and music perception tasks. The results showed that individuals with ADHD had a significantly lower performance in the intelligence test, Melodic and Meter tests, and language tasks. There were no significant differences between the groups in the performance on Rhythm and Musical Memory tests. The difficulties found in global musical temporal processing (Meter) and melodic discrimination in the clinical group could emerge as secondary characteristics to the primary deficits of attention and working memory, or present as a comorbidity of ADHD (e.g. amusias).

1. INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD) has high prevalence among children and adolescents and is characterized mainly by attention deficits, hyperactivity, and impulsiveness [1, 2]. ADHD mainly compromises attention and executive functions (working memory, inhibitory response and self-regulation) [3, 4] and is associated with poorer performance in time perception [5, 6] and phonological skills tasks [6].

According to Barkley [1], ADHD presents as a primary deficit the lack of behavioral inhibition. This deficit could impair four executive functions: (1) working memory, (2) self-regulation of affect-motivation-arousal, (3) internalization of speech, and (d) behavioral analysis and synthesis (reconstitution). ADHD is a heterogeneous and multifactorial disorder, whose etiology has not yet been clearly identified, although evidence points to associated genetic and neurobiological aspects, mainly related to dysfunction of the fronto-subcortical pathways and imbalances in dopaminergic and noradrenergic systems [2, 7]. Individuals with ADHD often present other associated disorders. These comorbidities mainly include oppositional defiant disorder, conduct disorder, mood disorder (unipolar and bipolar), anxiety disorders and learning disorders [2, 7].

In addition to sustained attention deficits, some of the most frequent behavioral signs in ADHD diagnosis are disorganization, academic, auditory divided attention and hearing in noisy environment difficulties [8]. Studies suggest that children with ADHD present poor performance in auditory temporal tests with difficulties in perceiving frequency pattern and sound duration [6, 8, 9].

Regarding the assessment of musical memory and perception abilities in individuals with ADHD, fewer studies have been reported. Jones, Zalewski, Brewer, Lucker, and Drayna [10] have found a higher prevalence of ADHD in individuals with congenital amusia, indicating that there may be comorbidities between ADHD and musical perception deficits. Congenital amusia, also known as tone-deafness, is a developmental disorder characterized by a lifelong inability to musical processing, despite normal intelligence, memory and language abilities [11].

In a comparison group study, Carrer [12] evaluated the performance on sound and musical tasks of ADHD children with and without the use of stimulant medication, compared to typically developed children. He observed a poorer performance of the ADHD groups in temporal estimation of simple sounds tasks compared to the typically developed children group. Nevertheless, he argues that the positive average performance on most tasks observed in all groups could indicate that music modulates the symptoms of inattention in ADHD. Some studies have shown that music can be used to mediate attention and excitement in children with ADHD, and the presence of background music can reduce distraction and increase concentration on arithmetic school tasks [13]. In addition, music education is associated with better phonological awareness [14], and can contribute to the rehabilitation of children and adolescents with ADHD associated with dyslexia and other language disorders [7, 15].

There is evidence that musical training can enhance verbal, visuospatial, mathematical and reading skills [14, 16, 17, 18, 19]. Because of this association with the development of other cognitive functions, according to Särkämö, Tervaniemi and Huotilainen [20], music has been used clinically as part of the treatment of diseases involving motor, affective, attention, memory, self-regulation, and communication deficits. According to these authors, evidence suggests that music-based rehabilitation may be effective in many psychiatric, neurological, and developmental disorders, as well as chronic diseases that cause pain and anxiety. In this sense, music could also be used with children and adolescents who have ADHD, and knowing about musical neuropsychological profile of these individuals with ADHD may contribute to intervention strategies in this population. Considering this relationship between musical performance and the development of cognitive functions that may be compromised in ADHD, the present study aimed to evaluate the musical neuropsychological profile of individuals with ADHD and to investigate the presence of possible musical processing deficits.

2. METHOD

2.1. Participants

Twenty Brazilian individuals aged 7-13 years, were divided into two groups of 10 participants: (1) a clinical group composed by individuals diagnosed with ADHD, and (2) a control group, consisting of individuals with typical development. Groups were matched by sex and educational level. We recruited students from public and private schools from Divinópolis-MG. These schools do not offer formal musical instruction.

Participants on clinical group had been previously diagnosed with ADHD. Inclusion criteria of control group were: (1) have a normal academic performance; (2) have a normal intelligence quotient; (3) do not present neurological, visual or hearing diseases; (4) do not have formal music education. Table 1 shows sample characteristics regarding age, sex and institution type (public or private). There were no significant differences between groups in terms of age (U = 45.5, Z = -.34, p = .734, two-sided).

Table 1. Sample characterization.

Group	Average age (SD)	Gender (%)	Institution type (%)
ADHD	10.22 (2,06)	30% female	60% public
Contro l	10.07 (1,85)	30% female	60% public

Materials

For the data collection, we used the following tasks that evaluate musical cognition, numeric cognition, intelligence and reading:

2.1.1.*Montreal Battery of Evaluation of Musical Abilities (MBEMA):* MBEMA evaluates music cognition from three musical tests (Melody, Rhythm and Musical Memory). MBEMA follows the same principles of the Montreal Battery of Evaluation of Amusia (MBEA) [21]. However, MBEMA is an abbreviated version for children [22]. In Melody and Rhythm tests participants have to judge if the two melodies heard are the same or different from each other. In the Musical Memory test participants must say if they have heard or not the presented melody before. For evaluate beat perception we added the Meter test from the MBEA. In this test, participants should decide if the presented melody is a march (double meter) or a waltz (triple meter) [21].

2.1.2.*Brazilian School Achievement Test (Teste de Desempenho Escolar - TDE):* This test aims to evaluate the school performance of children and adolescents, and it is divided in three subtests: (1) Writing, (2) Arithmetic, and (3) Reading. In the Writing subtest participants should write 34 dictated words of increasing syllabic complexity. Arithmetic subtest consists of three oral-presented and 35 written-presented arithmetic operations. Reading subtest consists of 70 stimuli, which must be read aloud by the participant [23].

2.1.3.*Raven's progressive matrices tests (RPM):* RPM is a non-verbal test that evaluates *g*-factor of intelligence. RPM demands the ability of thinking clearly and logically. The test consists of identifying the missing element that completes a figure pattern [24, 25]. In this study, we used the Color scale for individuals under eleven year's old and Standard scale for participants over eleven years old.

2.1.4.*Phoneme elision (PE):* This task aims to evaluate participants' phonological awareness abilities. Firstly, the participants must listen to a word and repeat it. Secondly, the examiner takes a specified phoneme in the word out and individuals has to recognized and say what is the new formed word (e.g., "sola" without /a/ is "sol" [in English, it would be similar to "cup" without /k/ is "up"). The test comprises 28 items. In eight items, the child must delete a vowel, and in the other 20, a consonant. The phoneme to be suppressed could be in different positions within the words, which ranged from two to three syllables [26].

2.1.5.*Pseudowords Repetition and Reading tasks:* These tasks consist of 40 inexistent words (pseudowords) which obey to language phonological restrictions. In the Repetition task participant should repeat the pseudoword heard and in the Reading task they must read the presented pseudowords [27]. Pseudowords reading task is one of the best indicators of the ability to read by the phonological decoding mechanism (phonological route). Difficulties in this task constitute a cognitive marker for specific dyslexia. Errors in this task can also indicate attention or decoding difficulties. Pseudowords repetition task has been considered as an index of phonological working memory capacity.

2.2. Procedures

The review board of the State University of Minas Gerais (ETIC no. 1.123.506/15) approved this study. After obtaining permission from the school principals, the research project was presented in the classrooms. The parents or guardians of the interested students received an invitation letter and provided informed consent. All participants performed the tasks in one testing session of approximately 2 hours at adequate and properly prepared rooms provided by the school principals. Testing was conducted by a team of undergraduate psychology students with training in psychometrics, which was led by the first author of this article. We used Mann-Whitney U test (two-sided) with an alpha level of .05 for comparing groups results in all tasks.

3. RESULTS

The Mann-Whitney U test results for the difference between clinical (ADHD) and control groups performance are presented in Table 2 for the following tasks: (1) Montreal Battery of Evaluation of Musical Abilities (MBEMA- Melody, Rhythm and Memory tests), (2) Montreal Battery of Evaluation of Amusia (MBEA – Meter test), (3) Brazilian School Achievement Test (TDE - Writing, Arithmetic, and Reading tests), (4) Raven's progressive matrices tests (RPM), (5) Phoneme elision (PE), (6) Pseudoword Repetition task (PRP), and (7) Pseudoword Reading task (PRD).

	Mean Rank		**Sum of Ranks**					
Tasks	***ADHD[a]***	***Control[a]***	***ADHD***	***Control***	**Mann-Whitney U**	**Wilcoxon W**	**Z-score**	**p-value**
MBEMA - Melody	7.90	13.10	79.0	131.0	24.0	79.0	-1.995	.046[b]
MBEMA - Rhythm	8.40	12.60	84.0	126.0	29.0	84.0	-1.596	.111
MBEMA - Memory	9.40	11.60	94.0	116.0	39.0	94.0	-.841	.400
MBEA - Meter	7.55	13.45	75.5	134.5	20.5	75.5	-2.240	.025[b]
PRP	10.25	10.75	102.5	107.5	47.5	102.5	-.190	.849
PRD	6.85	14.15	68.5	141.5	13.5	68.5	-2.779	.005[c]
PE	7.20	13.80	72.0	138.0	17.0	72.0	-2.511	.012[b]
RPM	7.10	13.90	71.0	139.0	16.0	71.0	-2.578	.010[b]
TDE - Writing	6.45	14.55	64.5	145.5	9.5	64.5	-3.072	.002[c]
TDE - Arithmetic	8.25	12.75	82.5	127.5	27.5	82.5	-1.703	.088
TDE - Reading	7.10	13.90	71.0	139.0	16.0	71.0	-2.582	.010[b]

[a] n=20, [b] p < .05, [c] p<.01

Table 2: Mann-Whitney U test results for difference between clinical (ADHD) and control groups performance.

We found that clinical group (ADHD) had a significantly lower performance than control group in MBEMA (Melody), MBEA (Meter), language tasks (PRD and PE), RPM test and in TDE's Writing and Reading tests. There were no differences between groups concerning PRP task, Arithmetic test (from TDE), and in the MBEMA's Rhythm and Musical Memory tests.

4. DISCUSSION

From the results obtained we could observe that individuals of clinical group (ADHD) showed, in relation to control group, a lower problem-solving capacity and difficulties in tasks that evaluates phonological awareness, reading and writing. Nevertheless, individuals with ADHD showed a preserved performance in tasks related to math processing and phonological working memory capacity. They also presented a profile of musical abilities with impairment of meter and melodic perception and preservation of the rhythm and musical memory perception.

Data obtained from the language tasks may indicate the presence of associated deficits in ADHD. Dyslexia is the most frequently comorbidity associated with ADHD [28] and it is characterized by difficulties in acquiring basic reading skills such as word identification and phonological decoding [29]. The pattern of performance in ADHD group constituted of difficulties in reading, writing and phonological skills found in our study could indicate the presence of individuals with associated dyslexia in this group. However, the results did not show deficits in the phonological working memory, which is related to the accuracy of phonological representation in long-term memory. These results are controversial since reading difficulties are associated with poor performance on pseudowords repetition tasks [30].

It is worth mentioning that since there were differences between the groups regarding the general intelligence measure (Raven), with worse performance for the ADHD group, the results obtained by this group in the other tasks should be considered with caution. Despite this, studies show that there are no direct correlations between intelligence and performance in writing and reading tasks, since normal intellectual development is a condition for the diagnosis of dyslexia and other language disorders [31, 32]. In this sense, the inferior performance of the clinical group individuals in the intelligence task is not sufficient to explain their poor results in the reading and writing tasks.

In addition to the language processing difficulties, the data indicated that individuals with ADHD presented worse melodic perception (pitch), and meter perception in relation to the control group. The difficulties in melodic perception could represent a comorbidity of ADHD. The MBEMA's Melodic task aims to evaluate the melodic organization of musical perception, which is composed by contour, interval and scale dimensions [21]. The contour refers to the shape of a melody created by the patterns of the change in pitch direction, which can be ascending or descending. The interval refers to the pitch distance between two adjacent musical notes and requires a more analytical perception. The scale is a dimension related to tonal functions [21].

The difficulties found for the clinical group in the musical processing, referring to the melodic organization, may indicate that individuals with ADHD presented congenital amusia as a comorbidity, since the deficit in pitch perception is characteristic of the individuals with congenital amusia [33, 34]. The results also corroborate the study of Jones et al. [10], which verified a higher prevalence of ADHD in patients with congenital amusia. The relationship between ADHD and congenital amusia may be modulated by developmental epigenetic mechanisms [2, 35, 36]. Nevertheless, this relationship should be more investigated in studies with larger samples and specifically designed to attend to this hypothesis. We should highlight that the difficulties related to melodic processing in individuals with ADHD, instead of indicating the presence of congenital amusia, may be secondary to the attention deficit of this disorder or be related to a more spread deficit in working memory [37].

Regarding performance in tests that evaluate temporal dimensions in musical cognition, the results indicated a pattern of dissociation between meter and rhythm processing in individuals with ADHD, since they showed poor performance in the Meter but not in the Rhythm test. According to Peretz, Champod and Hyde [21], rhythm and meter dimensions are the component parts of the temporal organization of music processing. The rhythm depends on more analytical processing and refers to the temporal grouping between two events, which may vary in time proximity. The meter refers to the beat of a melody, that is, to the basic temporal regularity between a sequence of musical events, and it is related to more global aspects of musical temporal dimension.

The pattern of dissociation between meter and rhythm processing found in this work corroborates the studies showing double dissociations between these dimensions, in which one of the components is preserved, while the other is impaired [21, 38]. The difficulties of perception in beat regularity found in this study also corroborate Carrer's [12] study, in which ADHD individuals who did not use medication presented lower performance on temporal synchronization tasks. The deficits in timing processes in ADHD are evidenced on several temporal domains. According to Rubia, Halari, Christakou and Taylor [39] the neurocognitive dysfunctions in temporal processes are crucial to the impulsiveness disorder of ADHD.

Low performance on temporal processing and sound duration discrimination tasks in individuals with ADHD could be also related to the tasks demands which require attention and distinct stimulus differentiation skills. Studies indicate the relevance of executive functions and attention in temporal processing deficits presented by ADHD individuals [40, 41]. When temporal stimulus demands excessively from the sensorial capacity, other cognition functions, such as working memory and sustained attention, are recruited in order to support temporal processing [42]. This can be an explanation to the difficulties presented by ADHD individuals in the Meter test. However, individuals with ADHD did not show difficulties in Rhythm test, which also is part of the temporal dimension of music perception. This result pattern may be due to the higher demand of the Meter test compared to the Rhythm test. In the Meter test the individual must understand the melody beat regularity that was heard, and after answer if it is a waltz, or a march (trinary or binary tempo). In the Rhythm test the individual must hear the melodies and say if they are the same or different, and this difference consists of an alteration in the rhythm pattern. Besides that, the Meter task demands a higher working memory capacity and attentional processes, which as seen before, influences temporal processing in individuals with ADHD.

We must emphasize that the inferior performance of individuals of the clinical group in the intelligence test may have influenced the results in the musical tests. According to Schellenberg [43, 44], musical training may be associated with performance in intelligence tests and there seems to be a positive correlation between musical abilities and intelligence. However, it cannot be said that the inferior performance of the individuals of the clinical group in some musical tests was due to the lower intellectual capacity of these individuals in relation to the control group, since they presented a lower performance only in the Meter and Melodic tests. The results suggest, therefore, that difficulties in temporal processing (i.e. meter) and melodic discrimination (i.e. pitch) may be characteristic of ADHD or present as a comorbidity of this disorder.

Even though individuals with ADHD have deficits in music perception, musical training can help these individuals on rehabilitation of compromised functions. Learning a new skill promotes physical and chemical changes in the brain, helping to establish efficient neural network. Musical training is related to development of attentional and memory skills [20, 45]. In this sense, musical training in individuals with ADHD can constitute an alternative for developing rehabilitation or compensation strategies to their compromised cognition functions.

5. CONCLUSIONS

Though deeper investigation about music processing in individuals ADHD is necessary, the presented study results reveals that this population had primarily difficulties on understanding beat regularity in a melody, which can be related to the global temporal processing difficulties of those individuals, besides deficits on pitch processing, which could indicate congenital amusia in association to ADHD. The difficulties found in global musical temporal processing (Meter) and melodic discrimination in the clinical group could emerge as secondary characteristics to the primary deficits of attention and working memory, or to present as a comorbidity of ADHD (e.g. amusias). Knowledge of the musical neuropsychological profile of individuals with ADHD may contribute to intervention strategies in this population, since musical training is related to better performance in tasks involving verbal, visuospatial, attentional and memory skills.

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