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Evaluation of the effect of methylphenidate on theory of mind ability and facial emotion recognition in children with ADHD

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ABSTRACT

Background and Objective: Attention deficit-hyperactivity disorder (ADHD) is often associated with difficulties in social and emotional relationships. This study aimed to investigate the effect of methylphenidate on theory of mind ability and facial emotion recognition in children with ADHD.

Methods: This was an interventional study. A total of 25, school-age children with ADHD were selected for this study at Roozbeh Hospital in Tehran, Iran in 2019. The method of diagnosing ADHD was using the semi-structured KSADS-PL interview, Conner's Parent Rating Scale, Raven's Progressive Intelligence Test, Happe Strange Stories Test, and Facial Emotion Recognition task. The children then took methylphenidate for 6 weeks and were reassessed using the mentioned instruments.

Findings: The mean age and IQ of the children in our study were 8.88±1.47 years and 114.53±11.91, respectively. After treatment, children showed significantly better performance in blocks of the Strange Stories Test, including mental state (p=0.05), physical (p=0.01), natural (p=0.01), and unlinked (p=0.02). A significant difference was observed in emotion recognition between pre- and post-treatment. After the intervention, children showed better accuracy in identifying angry (p=0.006), happy (p=0.022), and sad faces (p=0.002). The comparison of scores related to Conner's test after treatment with methylphenidate showed significant improvement in inattention (p= 0.002), hyperactivity (p= 0.008), and ADHD index (p= 0.005).

Conclusion: Methylphenidate can improve social cognition components, including theory of mind ability and emotion recognition in children with ADHD.

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Introduction

Attention deficit-hyperactivity disorder (ADHD) is characterized by attention deficit, hyperactivity, and impulsivity [1]. This disorder is a common neuropsychiatric disorder that affects 5-12% of children and 2.5% of adults all over the world [2].

Children with ADHD have difficulties in emotion regulation and interpersonal relationships, in addition to the core symptoms. This issue leads to conflicts with peers and ultimately rejection by them [3].

It has been shown that individuals with ADHD experience impairments in social and emotional relationships [4]. There are some explanations for poor social and emotional relationships in this disorder, including poor response inhibition [5], which leads to poor inhibitory control over behaviors in individuals with ADHD.

Social cognition refers to how individuals process and remember information in social contexts and use it to explain and predict individual behavior [6], and includes cognitive components underlying social relationships, such as theory of mind, emotion recognition, and social referencing [7]. There is a relationship between emotional and social development, and emotions can be considered a predictor of social relationships [8]. The basic component of emotion regulation is detecting and recognizing emotions [9]. Emotion regulation is the process by which people change the duration or intensity of their emotions to best respond to environmental challenges [10]. Emotion dysregulation has been considered a main component of ADHD [11] and a disabling aspect of the disorder [12]. It has been shown as an important factor in predicting the prognosis [3].

Another component of social cognition is the theory of mind, referring to the ability to understand what others think, intend, and feel [13, 14], which can help predict others' behavior and plan to change others' thoughts and actions [15]. Several studies have shown impairments in the theory of mind and emotion recognition abilities in individuals with ADHD [16-19].

Stimulants are typically the first choice for treating ADHD [20]. Patients suffering from this disorder need to be on medication for a long time [21]. It has been shown that stimulants, especially methylphenidate, can reduce the core symptoms of ADHD and improve the executive function deficits seen in this disorder [22]. Some studies showed the efficacy of methylphenidate in improving social skills, social behaviors [23, 24], emotion regulation [25, 26], and empathy [27] in people with ADHD.

According to a systematic review in 2022, methylphenidate can improve social impairments in children with ADHD, and further studies are needed to identify the mechanisms of the drugs and confirm such a conclusion [24]. In other studies, the administration of methylphenidate improved the theory of mind in children with ADHD [28-30]. In another study, methylphenidate led to improvements in facial emotion recognition abilities, but not to a significant level [31].

Many children with ADHD suffer from behavioral and interpersonal problems that are at least partly due to social cognition problems. Research on social cognition in patients with ADHD is scarce. There is a question of whether the medication can improve social cognition deficits seen in ADHD. There are a few studies to answer this question [32]. Deficits in empathy and theory of mind may play an important role in social cognition deficits [30]. Given the limited knowledge about how stimulants impact social cognition in children and adolescents with ADHD, we conducted the present study to evaluate the effect of methylphenidate on theory of mind and emotion recognition abilities using the Strange Stories Test and Facial Emotion Recognition task.

Methods

This was an interventional study conducted as a pre-test/post-test without a control group. Twenty-five children of school age diagnosed with ADHD referred to the child and adolescent psychiatry clinic in Tehran, Iran in 2019, were recruited for this study. Considering a 95% confidence interval, $\alpha=0.05$, $z=1.96$, and a test power of 95%, a sample size of 25 was calculated. The diagnosis was conducted by a fellow in child and adolescent psychiatry under the supervision of a board-certified child and adolescent psychiatrist according to DSM-5 criteria, based on clinical evaluation (clinical history) and interviews

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with children and their parents. The Kidde-Schedule for Affective Disorder and Schizophrenia interview was carried out to confirm the diagnosis and rule out comorbidity. Inclusion criteria included age 7 to 11 years, meeting DSM-5 criteria for combined type of ADHD, no history of medication use for this disorder, and parental and child consent to participate in the study. All children with an IQ of less than 80 based on the Raven test, with other psychiatric comorbidities or any neurological disorders except for oppositional defiant disorder and the presence of any physical impairment that would prevent them from performing the test, such as visual or hearing impairments, were excluded from the study. None of the children had received drug treatment before.

Measures

Kiddie- Schedule for Affective Disorders and Schizophrenia-Present and Lifetime version (K-SADS-PL): This semi-structured interview was used to assess present and past psychiatric disorders in 6-18-year-old individuals. Children and their parents participated in this interview. The Persian version of K-SADS-PL has shown good to excellent psychometric properties for many psychiatric disorders [33].

Conners' Parent Rating Scale-Revised: The short version of Conner's Parent Rating Scale (CPRS) was used to evaluate the severity of ADHD symptoms in the children. The revised version of CPRS demonstrated good reliability [34]. In Iran, CPRS was assessed in a clinical sample of 20 children compared to 20 typically developing children. The results showed that CPRS can discriminate children with ADHD from the normal group in all subscales. The internal consistency reliability for all subscales, oppositionality, inattention, hyperactivity, and ADHD index, was 0.88, 0.95, 0.89, and 0.90, respectively [35].

Raven Progressive Matrices (RPM): It is a common assessment of nonverbal intelligence and abstract reasoning. The child version of the RPM was used to estimate IQ in children aged 6–9 years old, and the adult version was used for children older than 9 years old. The RPM test has been validated and standardized for Iranian individuals aged 5 to 18 years old. Reliability coefficients for ages 9-18 ranged from 0.89 to 0.95 [36].

Happe Strange Stories Test: We used the Persian version of the Happe Strange Stories Test which had already been validated in Iranian children. The split-half internal reliability coefficient was 0.73, and the test-retest reliability confirmed good results for most stories (above 0.70) [37]. The test consisted of 40 short stories in five domains including mental, physical-human, physical-animal, nature, and unlinked sentences. The children were instructed to read each story presented on the screen and listen simultaneously to the narration of the story. Then they were asked to answer some questions regarding the vignette. The answers were recorded and scored based on the manual to evaluate the social understanding of children.

Facial Emotion Recognition Task: A computerized version of the facial emotion recognition task was developed based on the Radboud (see www.rafd.nl) face database. The faces had been validated in Iranian children and adolescents in terms of recognizing emotions. There was an 84% agreement rate between the selected and targeted emotions [38]. The task comprised a total of 144 pictures of two males and two females presenting happiness, sadness, anger, and neutrality. Each picture was presented for 2000 milliseconds with an interval of 1200 milliseconds. The children were instructed to press one of four buttons when they saw each picture. A practice block of 24 pictures was used to make the participants familiar with the task. The correct responses and response time were the main variables of the task.

Procedure

Twenty-five patients were selected from children referred to the child and adolescent psychiatry clinic at Roozbeh Hospital, Tehran, Iran according to the inclusion and exclusion criteria for this study. All children in our study, after being diagnosed with ADHD and signing a consent form by their parents, were assessed at the Neurocognitive Laboratory of the Research Center for Cognitive and Behavioral Sciences, using the K-SADS-PL, CPRS, Strange Stories Test, and Facial Emotion Recognition task. The patients were then given methylphenidate

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(Ritalin) at a dosage of 0.5 to 1 mg per kg based on their responses. After 6 weeks of treatment, they were reevaluated using the same instruments except for the K-SADS-PL. The interviews and evaluations of the subjects were conducted by a fellow in child and adolescent psychiatry under the supervision of a board-certified child and adolescent psychiatrist, and each session took about 2 hours. The drugs used were from the Novartis Company, and the patients were monitored monthly. After the study was completed, the patients continued to be followed up in the clinic.

Statistical Analysis

The data were analyzed using the SPSS-24 software. A paired t-test was performed to evaluate and compare the difference between pre- and post-treatment variables, with a significance level set at P<0.05.

Results

Twenty-five children who were evaluated and diagnosed with ADHD before the treatment completed the study. The mean age and IQ of the children in our study were 8.88±1.47 years and 114.53±11.91, respectively. Nineteen of the children were male, and four were female.

Based on a Paired T-test, after treatment with methylphenidate, children performed significantly better on all blocks of the Strange Stories Test (p< 0.05) except for the Animal block. Regarding emotion recognition, there were significant differences between pre- and post-treatment in correctly recognizing angry, happy, and sad faces (p<0.05). There was no significant difference in identifying neutral faces after a six-week treatment with methylphenidate. There were no significant changes in terms of the time taken to recognize the emotions after treatment. Additionally, the comparison of the scores related to Conner's test after treatment with methylphenidate revealed that children showed significant improvement in all components, except for oppositional behaviors (Table 1).

Table 1. Performance before and after Treatment with methylphenidate

Variables of tests		Stage	Mean±SD	Difference average	t	df	P
Happe Strange Stories	Mental state	Pre-test	5.91±2.810	-1.318	-2.041	21	.05
		Post-test	7.23±2.137				
	Physical	Pre-test	7.64±3.230	-1.955	-2.562	21	.01
		Post-test	9.59±2.130				
	Animal	Pre-test	5.64±3.230	-.909	-1.168	21	.25
		Post-test	6.55±2.304				
	Natural	Pre-test	7.41±2.971	-2.091	-2.640	21	.01
		Post-test	9.50±2.686				
	Unlinked	Pre-test	7.41±2.955	-2.409	-2.529	21	.02
		Post-test	9.82±3.527				
Facial Emotion Recognition	Angry	Pre-test	13.39±7.987	-6.174	-3.038	22	.006
		Post-test	19.57±9.297				
	Happy	Pre-test	26.78±9.918	-5.304	-2.475	22	.022
		Post-test	32.09±5.410				
	Neutral	Pre-test	21.83±8.931	-2.254	-1.119	22	.275
		Post-test	24.09±9.756				
	Sad	Pre-test	14.00±8.410	-5.913	-3.513	22	.002
		Post-test	19.91±9.223				
Conners' Parent Rating	Oppositionality	Pre-test	9.09±4.660	-.130	-.055	22	.957
		Post-test	9.22±10.544				
	Inattention	Pre-test	11.39±4.998	4.043	3.445	22	.002
		Post-test	7.35±3.857				
	Hyperactivity	Pre-test	10.74±4.423	3.826	2.922	22	.008
		Post-test	6.91±3.907				
	ADHD Index	Pre-test	22.26±7.399	7.043	3.156	22	.005
		Post-test	15.22±7.586				

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Discussion

Individuals with ADHD have impairments in social interaction competency [39, 40] which can be explained by their behavioral disinhibition [41] as well as deficits in social cognition [32]. It has been shown that children and adolescents with ADHD have deficits in theory of mind ability [42] as well as in recognizing emotions [4, 16, 17]. It is not clear whether medication can improve these deficits in social cognition. Therefore, we conducted this study to evaluate the efficacy of methylphenidate on the theory of mind ability and recognizing emotions.

Our study found that children with ADHD had better performance on Happe's Strange Stories components, including mental states, and physical, natural, and unlinked sentences. These results align with the findings of Maoz et al. (2014), who measured the theory of mind ability in 24 children with ADHD using two theory of mind computer tasks: the ToM computerized task (TCT) and the Faux Pas Recognition task (FPR). In their study, the Fantasy and perspective-taking cognitive components, as well as the empathetic concern and perspective distress emotional components of the theory of mind showed improvement after treatment with Ritalin [30].

In addition, the results of Gumustas's study revealed an improvement in empathy skills after treatment with Ritalin using the Empathy Response Task [43]. Also, according to the results of Gloubchick's study (2017), a significant increase in the Empathy Quotient was observed after treatment with Ritalin [27]. Based on these studies, it seems that methylphenidate can improve the affective component of the theory of mind in individuals with ADHD, which is consistent with our study.

However, the exact effect of this medication on the cognitive component of theory of mind (ToM), which can be assessed by Happe's Strange Stories, has not been well understood. We found an improvement in ToM function using Happe's Strange Stories Test after treatment with methylphenidate. It has been shown that theory of mind tasks activate the orbitofrontal cortex [44]. The function of this area is mostly mediated by the dopaminergic system [45-47]. Therefore, the increased level of dopamine induced by methylphenidate in the orbitofrontal cortex can improve theory of mind ability in youth with ADHD who suffer from a hypo-dopaminergic system [45].

The findings of our study can also be interpreted as the improvement of the Happe Strange Stories components may result from medication affecting other cognitive functions, including working memory and sustained attention, as shown in several studies [22, 48-50].

Another finding of our study was the improvement in emotion recognition accuracy, including anger, happiness, and sadness after treatment with methylphenidate in children with ADHD. Our findings are consistent with Demirci's study (2016), indicating that methylphenidate significantly increased the accuracy of emotion recognition in children with ADHD [51]. Moreover, Beyer et al. (2014) also demonstrated a significant improvement in facial emotion recognition among individuals with ADHD after treatment with methylphenidate [31].

Imaging studies have shown that the orbitofrontal prefrontal and ventromedial prefrontal cortex along with the insula, amygdala, and fusiform gyrus, play important roles in emotional processing under the supervision of the prefrontal cortex [52]. Since methylphenidate improves the functions of the prefrontal areas, this performance enhancement may be due to the direct effect of this medication.

It can also be interpreted that the main reason for the increased accuracy of emotion recognition after treatment is the direct effect of stimulants on cognitive deficits seen in these people. However, we did not find any improvement in recognizing neutral faces which is inconsistent with this interpretation. It means that emotion recognition improvement is independent of attention function improvement after treatment.

Additionally, our study measured the intensity of ADHD symptoms using Conner's test before and after treatment. The results showed that all components, except for oppositional behaviors, were significantly different before and after the treatment. Our results should be interpreted in light of some limitations, including the small sample size, the short duration of the study, and the lack of a control group. Furthermore, in our study, the results of our study did not compare results based on gender or age.

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Conclusion

In conclusion, the results of our study showed that methylphenidate also improved the social and emotional cognitive components observed in children with ADHD. Therefore, this medication can also be used to improve social and affective deficits seen in this disorder.

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Ethical Considerations

The study received approval from the ethical research committee of the Tehran University of Medical Sciences (IR.TUMS.MEDICINE.REC.1397.656).

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Conflict of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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