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The Effects of Methylphenidate on Various Components of Visual Attention in Children with Attention-Deficit Hyperactivity Disorder

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Abstract

Objective: *Attention-deficit hyperactivity disorder (ADHD) is characterized by deficits and impairment in various components of visual attention. Methylphenidate (MPH) is the most commonly prescribed treatment for children with ADHD. The purpose of this study was to examine the effects of MPH on visual selective attention, sustained attention, and visual spatial attention in children with ADHD.*

Method: *The study sample included 43 children (32 boys, 11 girls: age range: 7-12 years) that met the DSM-IV criteria for ADHD and consecutively referred to the Child and Adolescent Mental Health and Psychiatry Department of Gülhane Military Medical School. ADHD was evaluated with the Child and Adolescent Behavior Disorders Screening and Rating Scale, and the Mini International Neuropsychiatric Intervention (MINI) was administered to exclude comorbid diagnoses. Visual selective attention and sustained attention were measured by verbal and non-verbal Cancellation Tests, while visual spatial attention was measured with the Line Orientation Test (LOT).*

Results: *MPH administration increased the number of correct target detections and decreased the number of omission and commission errors, and shortened the time required for completion on the verbal and non-verbal Cancellation Tests, and also produced a more systematic pattern on the organized letters and figures subtests. MPH administration also improved LOT performance.*

Conclusion: *The findings show that MPH medication was associated with improved visual selective attention, sustained attention, and visual spatial attention in children with ADHD.*

Key Words: *Attention deficit hyperactivity disorder, visual attention, methylphenidate*

INTRODUCTION

Attention-deficit hyperactivity disorder (ADHD) is a prevalent neurodevelopmental disorder, which is diagnosed in 3%-7% of school-aged children (American Psychiatric Association, 2000). It is characterized by deficits and impairment in the components of selective attention (involving the discrimination of a target stimulus from distracting stimuli), sustained attention, and visual spatial attention (Njiokiktjien and Verschoor, 1998; Brodeur and Pond, 2001; Kılıç et al., 2007).

Attention processes are maintained by neuronal network systems in different regions of the brain, which have strong reciprocal connections. The right hemisphere is suggested to be responsible for sustained attention and visual spatial attention (Posner and Petersen, 1990; Coull et al., 1998; Stefanatos and Wasserstein, 2001), and impairment in sustained attention and visual spatial attention are linked to possible right hemisphere dysfunction (Brumback and Staton, 1982; Rueckert and Grafman, 1996).

Psychostimulants are commonly prescribed for the treatment of ADHD and methylphenidate (MPH) is the most frequently prescribed (Safer et al., 1996). Controlled studies have indicated that psychostimulants are effective in ameliorating the basic symptoms of ADHD

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(Gillberg et al., 1997; Jadad et al., 1999; MTA Cooperative Group, 1999; American Academy of Pediatrics, 2001). Some findings indicate that in ADHD, MPH normalizes the decreased activation observed in the right hemisphere of the brain (Vaidya et al., 1998; Castellanos and Tannock 2002; Lee et al., 2005).

The present study aimed to examine the effects of MPH on the performance of children with ADHD on neuropsychological tests that measure selective attention, sustained attention, and visual spatial attention in which the right hemisphere is suggested to play a role.

INSTRUMENTS AND METHOD

Sample

The study included 43 children (32 boys, 11 girls) that consequently referred to the outpatient clinic of Child and Adolescent Mental Health and Psychiatry Department of Gülhane Military Medical School between March 2005 and March 2006 due to inattention, hyperactivity, and impulsivity problems. All the children were diagnosed with ADHD, based on DSM-IV diagnostic criteria, and were treated with MPH. The study's inclusion criteria were as follows: age: 7-12 years, must be in at least the first grade of primary school, learned to read in the first semester of the first grade, and no comorbid diagnoses, except oppositional defiant disorder. Children with severe visual or auditory sensory impairment, and any medical (e.g. epilepsy, cerebral palsy) or psychiatric problem (e.g. pervasive development disorder, schizophrenia) were excluded the study.

Procedure

Children were evaluated with DSM-IV in terms of inattention, hyperactivity and impulsivity problems and then the parents of the children that met the study's inclusion criteria were informed about the study. Parents provided informed consent for their children to participate in the study. The Mini International Neuropsychiatric Intervention (MINI) was administered to the children to exclude comorbid diagnoses.

The first administration of the neuropsychological tests that measure selective attention, sustained attention and visual spatial attention were conducted on the children with ADHD who did not take MPH at least 24 hours before the testing. In order to overcome the learning effect, the tests were administered a second time, at least 3 months later following the similar evaluation procedure. The second administration of the tests was conducted 1-1.5 hour after taking MPH (0.5 mg/kg) in the same order.

Instruments

ADHD was diagnosed based on the Child and Adolescent Behavior Disorders Screening and Rating Scale for DSM-IV (parent and teacher forms). Selective attention and sustained attention were assessed using verbal and non-verbal Cancellation Tests, while visual spatial attention was measured with the Line Orientation Test (LOT). Comorbid diagnoses were excluded using the MINI.

Sociodemographic Evaluation Form: This form was used to assess the developmental history of the children, including when they learned to read and write, school performance, peer relations, and family characteristics.

Mini International Neuropsychiatric Intervention Form: The MINI is a structured clinical interview form that was developed by Sheehan et al. (1998) in order to assess psychiatric problems in accord with DSM-IV and ICD-10. It was adapted to Turkish by Engeler (2004). In the validity study of the test, the relations among the scores of test and the scores of SCID-P and CIDI were compared. The form takes approximately 20 min to complete. The MINI has a child evaluation form for observers and parent evaluation form for parents. In this study, the parent evaluation form was utilized.

Child and Adolescent Behavior Disorders Screening and Rating Scale for DSM-IV (parent and teacher forms): This scale was developed by Turgay (1995) and measures disruptive behavioral problems based on DSM-IV diagnostic criteria. It was adapted to Turkish by Ercan et al. (2001). It is a self-report measure for parents and teachers. In the first section of the scale, items 1-9 assess attention problems and items 10-18 measure hyperactivity/impulsivity. In the second section there are 8 items that screen for oppositional defiant disorder.

Verbal and Non-Verbal Cancellation Tests: These tests measure cognitive abilities, such as visual search, sustained attention, attention speed, and visual spatial attention, which are related to the right hemisphere and, in particular, the parietal lobe. They were developed by Weintraub and Mesulam (Mesulam, 1985), and were adapted to Turkish by Karakaş et al. (2004) within the BILNOT battery. The reliability coefficients of the Turkish version of the Cancellation Test for children were statistically significant and ranged between 0.45 and 0.83 for correct target detection, omission errors, commis-

TABLE 1. The Cancellation Test Turkish form norms (Kılıç et al., 2002), scores obtained in the present study, and comparison of scores before and after MPH administration.

Sub-tests	Parameters	Standardization Study, Turkish Norms (Mean ± SD)	Present Study Before MPH (n = 43) (Mean ± SD)	Present Study After MPH (n = 43) (Mean ± SD)	P
Organized letters	Correct responses	58.03 ± 2.25	56.18 ± 5.42	58.79 ± 2.05	0.005**
	Omission errors	1.97 ± 2.25	3.90 ± 5.33	1.30 ± 2.06	0.003**
	Commission errors	0	0.09 ± 0.47	0.09 ± 0.29	1.00
	Total number of errors	1.97 ± 2.25	4.00 ± 5.28	1.39 ± 2.11	0.002**
	Duration (s)	161.92 ± 62.70	231.62 ± 68.86	206.27 ± 56.85	0.011*
Random letters	Correct responses	57.98 ± 2.03	56.56 ± 4.83	58.81 ± 1.73	0.007**
	Omission errors	2.02 ± 2.03	3.49 ± 4.88	1.21 ± 1.73	0.007**
	Commission errors	0	0.05 ± 0.21	0.02 ± 0.15	0.570
	Total number of errors	2.02 ± 2.03	3.53 ± 4.92	1.23 ± 1.73	0.007**
	Duration (s)	175.91 ± 60.94	231.16 ± 55.26	207.55 ± 61.59	0.02*
Organized figures	Correct responses	58.29 ± 1.97	60.37 ± 9.01	59.44 ± 1.59	0.534
	Omission errors	1.71 ± 1.97	2.86 ± 3.91	0.88 ± 1.48	0.004**
	Commission errors	0.62 ± 0.86	3.18 ± 8.43	0.32 ± 0.52	0.031*
	Total number of errors	2.33 ± 2.17	6.04 ± 9.57	1.21 ± 1.56	0.005**
	Duration (s)	162.37 ± 52.89	214.18 ± 50.14	192.00 ± 85.74	0.120
Random figures	Correct responses	58.07 ± 1.90	57.53 ± 7.15	59.05 ± 1.86	0.189
	Omission errors	1.93 ± 1.90	3.74 ± 4.24	0.98 ± 1.86	0.000**
	Commission errors	0.17 ± 0.38	1.28 ± 5.69	0.02 ± 0.15	0.155
	Total number of errors	2.10 ± 1.92	5.02 ± 6.91	1.00 ± 1.86	0.000**
	Duration (s)	138.29 ± 48.02	179.77 ± 52.68	155.23 ± 40.67	0.003**

MPH: Methylphenidate.
*P < 0.05, **P < 0.01.

sion errors, and time required to complete (Kılıç et al., 2002). The Cancellation Test is based on the detection and marking of target stimuli on an A4 sheet of paper. The Turkish form consists of 4 subtests, in which the quality of the stimuli (various letters and figures) and the configuration of the material (organized or random) are very important. In organized tests, distribution of stimuli to lines and columns follows a sequence, whereas in random tests, stimuli are distributed randomly on sheets without any logical sequence. Nonetheless, the place-

TABLE 2. The effect of MPH on systematic patterning on the Cancellation Test.

Systematic patterning	Before MPH (n = 43)		After MPH (n = 43)		X^2	P
	Systematic	Non-systematic	Systematic	Non-systematic		
Organized letters	30	13	35	8	9.34	0.002**
Organized figures	25	18	33	10	4.30	0.039*
Random letters	1	42	4	39	2.21	0.137
Random figures	1	42	2	41	0.50	0.823

MPH: Methylphenidate.
*P<0.05, **P < 0.01.

ment of target stimuli is the same on all subtests.

Line Orientation Test (LOT): This test was developed by Benton et al. (1978) to measure visual spatial perception and, in particular, correct spatial positioning. Visual spatial perception has two components: visualization and orientation. LOT was reported to reliably measure visual spatial perception and observed to be related to the right hemisphere, specifically the right parietal lobe activity (Riccio and Hynd, 1992). The reliability and validity of LOT were reported by Kurt and Karakaş (2000) and Karakaş (2004), respectively. Each test in LOT consists of lines 3.8 cm long that are numbered from 1 to 11. The subjects are requested to determine which two equal length lines correspond to which two numbers.

Edinburg Lateralization Test: Oldfield (1971) developed this test in order to assess hand preference and the frequency of hand preference in 10 different activities. Subjects that use the same hand in every activity and those that frequently use the same hand in some activities are given 10 and 5 points, respectively. Thus, the hand preference rate of a subject is calculated; if a subject uses his/her right hand for every activity, then s/he is referred to as 100% right handed.

Statistical Analysis

In order to evaluate the effects of MPH on the test parameters, the paired-samples t-test and the Wilcoxon signed ranks tests were used. The non-parametric variables were compared with the Pearson's chi-square test. Statistical significance of all tests was $P < 0.05$.

RESULTS

The study sample consisted of 32 boys (74.4%) and 11 girls (25.6%). The ratio of boys to girls was 2.9. Mean age of the study group was 9.23 ± 1.28 years (age range: 7-12 years). Thirty-eight of the children were right handed and 5 were left-handed.

According to ADHD subtypes, 16.3% (n = 7) of the children had predominantly inattentive type, 9.3% (n = 4) had predominantly hyperactivity and impulsivity type, and 74.4% (n = 32) had the combined type. Parent and teacher ratings based on the Child and Adolescent Behavior Disorders Screening and Rating Scale for DSM-IV were similar ($P > 0.05$).

The norms of the Cancellation Test for 6-11-year-olds (Kılıç et al., 2002) and scores of the study group are presented in Table I. It can be seen that the number of correct target detections was lower, the number of omission and commission errors was higher, and the time required for completion was longer than the norms of the healthy standardization group (Table I).

When performance on the organized letters cancellation test before and after MPH administration was compared (paired-samples t-test), there were more correct target detections, fewer omission and total errors ($P < 0.01$), and the time required for completion decreased ($P < 0.05$) after the administration of MPH. When performance on the random letters Cancellation Test before and after MPH administration was compared, we observed that there were more correct target detections, fewer omission errors and total errors ($P < 0.01$), and the time required for completion decreased ($P < 0.05$) after the administration of MPH (Table I).

On the organized figures Cancellation Test, subjects had fewer omission and commission errors when their performance after MPH administration ($P < 0.01$). On

TABLE III. The effect of MPH on Line Orientation Test (LOT) performance.

Test	**Before MPH** (n = 43) (Mean ± SD)	**After MPH** (n = 43) (Mean ± SD)	**p**
LOT (finding the correct orientation)	15.21 ± 4.04	18.21 ± 4.33	0.000**

MPH: Methylphenidate.
**P < 0.01.

the random letters Cancellation Test, subjects had fewer omission and total errors and required less time to complete the test after MPH administration (P < 0.01) (paired-samples t-test) (Table I).

When performance of visual search on the Cancellation Test before and after MPH administration was compared we observed that in the organized letters and organized figures Cancellation Tests, the frequency of systematic patterning was significantly higher after the administration of MPH (P = 0.002 and P = 0.039, respectively; chi-square test) (see, Table II).

The frequency of finding the correct orientation on LOT significantly increased after MPH administration, as compared to before MPH administration (P = 0.000; paired-samples t-test) (Table III).

DISCUSSION

Many studies indicate that omission and commission errors are common in the Cancellation Tests among people with ADHD (Aman and Turbott, 1986; Voeller and Heilman, 1988; Byrne et al., 1998; Kılıç et al., 2007). The Cancellation Tests results, as a measure of sustained attention performance, indicate that children with ADHD require more time to complete the test than normal children (Mirsky et al., 1999). Moreover, some studies report that ADHD children have a non-systematic patterning performance, as compared to control group children (Seidman et al., 1997; Kılıç, 2002). The present study showed that the mean number of correct target detections was lower and the time required to complete the test was longer for ADHD children before they took MPH, as compared to age-matched norm scores of the standardization study conducted by Kılıç et al. (2002). This indicates that the ability of children with ADHD to focus and sustain attention was impaired, and that they had problems with effective time management.

There are contradictory findings concerning the possible effects of MPH on selective and sustained attention. Van der Meere et al. (1999) observed no effects of MPH on selective and sustained attention components. In contrast, Byrne et al. (1998) and Musten et al. (1997) showed that pre-school aged children with ADHD that received stimulant treatment improved their performance on the Cancellation Tests and had significantly fewer omission errors. Brodeur and Pond (2001) indicated that following the intake of MPH, selective attention performance improved and the effects of distractive stimuli on performance diminished, which they suggested was related to decreased impulsivity. The present study showed that after taking MPH, the number of correct target detections increased, the number of omission errors and commission errors decreased, the time required to complete the Cancellation test decreased, and that systematic patterning increased on many of the Cancellation test subtests.

Njiokiktjien and Verschoor (1998) posited that visual spatial impairment occurs in as many as 60% of children with ADHD. Similarly, Garcia-Sanchez et al. (1997) observed that people with ADHD have impaired visual spatial, visual perception, and visual structuring functions, as compared to healthy controls. Researchers report that the functions related to impairment in the posterior right hemisphere of the brain can be discriminated by LOT. MPH is suggested to improve visual spatial ability in ADHD cases (Elliott et al., 1997; Bedard et al., 2004). Our findings show that following MPH administration LOT performance improved (LOT assesses correct spatial orientation and perception); correct orientation of visual stimuli increased, which indicates that MPH had a positive effect on visual spatial orientation and perception.

Several studies have emphasized the dominant role of the right hemisphere in attention performance and suggest a role for right hemisphere dysfunction in the pathogenesis of ADHD (Brumback and Staton, 1982; Rueckert and Grafman, 1996). MPH was reported to normalize low-level activation in the right prefrontal

cortex of the brain (Vaidya et al., 1998; Castellanos and Tannock, 2002; Lee et al., 2005). Nevertheless, Campbell et al. (1996) conducted a placebo-controlled study with ADHD children and based on their findings suggest that MPH decreases the level of right hemisphere activation. The present study evaluated right hemisphere functions –selective attention, sustained attention, and visual-spatial perception –in children with ADHD before MPH and after MPH administration. On most of the neuropsychological tests we administered, which evaluate right hemisphere function, we observed an improvement following MPH administration, which suggests that MPH might have improved right hemisphere functioning.

In the present study approximately 75% of the children had the combined subtype of ADHD; therefore, our findings cannot be generalized to predominantly inattention and predominantly hyperactivity/impulsivity subtypes. Our results are only related to visual attention and do not include other attention modalities, such as auditory attention. Moreover, we did not psychometrically assess the children's cognitive and mental abilities, which is a limitation of the study.

To conclude, findings of the present study suggest that MPH medication was associated with improved visual selective attention, sustained attention, and visual spatial attention in children with ADHD. Neuropsychological tests are recommended for evaluating the clinical effectiveness of MPH.

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