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The Impact of a Motor-Cognitive Remediation Program on Attentional Functions of Preschoolers With ADHD Symptoms

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Abstract

Objective: The purpose of this study was to measure the impact of the motor-cognitive remediation program (MCRP) that uses sensorimotor and visual-motor imagery techniques on attentional functions in preschoolers with ADHD symptoms. **Method:** A total of 15 high-risk preschoolers were selected based on high ADHD symptoms. An experimental group participated in the MCRP and was compared with a control group. The MCRP consisted of 30 activities, 3 times a week, during 12 weeks. **Results:** Children in the experimental group improved significantly for orienting (selective attention) and executive control (inhibition, stopping, and engaging mental operations) compared with the control group. **Conclusion:** These results are a first step to support the postulate that training specific attentional functions by sensorimotor activities and visual-motor imagery has an impact on the cognitive network of attention. This study suggests the potential value of MCRP addressed to preschoolers with ADHD symptoms. *(J. of Att. Dis. 2017; 21(13) 1121-1129)*

Keywords

ADHD, preschool education, cognitive remediation, sensorimotor activities, visual-motor imagery

ADHD represents one of the most frequently diagnosed childhood disorders. The first symptoms of ADHD appear as early as 3 to 4 years of age. ADHD affects 3% to 7% of the school-aged children and is 3 to 9 times more common in boys than girls (American Psychiatric Association [APA], 2000; Barkley, 1997, 1998; Comings, 2001; Lussier & Flessas, 2001). The disorder also persists for a large proportion during adolescence (Hurtig et al., 2007) and in adult life (Barkley, Fischer, Smallish, & Fletcher, 2002; Biederman, Petty, Clarke, Lomedico, & Faraone, 2011; Faraone, Biederman, & Mick, 2006). Three subtypes of the ADHD have been proposed in the fourth revised edition of the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.; *DSM-IV-TR*; APA, 2000): predominantly inattentive, predominantly hyperactive-impulsive, and combined types. ADHD has many consequences on the child's emotional, social, motor, and academic achievement (Kooistra, Crawford, Dewey, Cantell, & Kaplan, 2005; Rigal, Chevalier, & Verret, 2006). Over the last 20 years, the primary symptoms of ADHD have been viewed as comprising poor investment and maintenance of effort, deficient modulation of arousal, and difficulties with impulse control. In fact, the symptoms are more related to a central impairment in self-regulation (Douglas, 1988). Barkley (1997), in a unifying theory of ADHD, has suggested that ADHD comprises a behavioral inhibition deficit linked to cognitive functions, or more precisely, to four executive functions: working memory, self-regulation of affect–motivation–arousal, internalization of speech, and reconstitution (behavioral analysis and synthesis).

To explain the cognitive deficits of ADHD, Guay and Laporte (2006) referred to Posner and Raichle's (1997) theoretical model of attention where three attentional functions are proposed, namely, (a) the alert mechanism or *alerting* (arousal, vigilance, sustained attention), (b) the orientation-inhibition function or *orienting* (selective attention, inhibition of nonrelevant information), and (c) the *executive control* to direct behavior toward a goal

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(attentional control, coordination of several specialized processes; Posner & Raichle, 1997; Swanson et al., 2000). The attention functions are specifically defined as, first, *alerting* with arousal, which is vigilance and sustained attention that refers to the maintenance of a mental effort for a period of time and the inhibition of irrelevant activity like suppressing background neural noise. Second, *orienting* with selective attention and inhibition consists of mobilizing relevant information processing and involves inhibition of nonrelevant stimulation. Third, the *executive control* refers to the coordination of multiple specialized neural processes such as cognitive inhibition and self-regulation by stopping mental operations, planning sequences of actions by ordering multiple responses, and direct behavior toward a goal (Swanson et al., 2000).

Medication and behavioral interventions are considered as evidence-based treatments for school-aged children with ADHD (Pelham et al., 2000; Pelham & Fabiano, 2008). The Multimodal Treatment Study of Children With ADHD (2004) suggested that stimulant medication is the most effective treatment for reducing ADHD core symptoms. Over the past decade, several approaches have shown promising results for the treatment of children with ADHD, namely, cognitive-behavioral modifications, parent training in child management skills, classroom management, or social-skill training (Barkley, 1997; Verreault, Verret, Massé, Lageix, & Guay, 2011). These therapies, however, do not teach appropriate strategies that help children to develop their attention capacities and cognitive self-regulation to remediate their cognitive deficits. Recently, cognitive remediation programs to improve cognitive functions were tested by using computerized cognitive tasks (e.g., Laporte & Guay, 2006; Guay, Parent, & Lageix, 2007; Klingberg et al., 2005; Pepin, Loranger, & Benoit, 1995; Slate, Meyer, Burns, & Montgomery, 1998; Trucha et al., 2011) or motor-cognitive remediation in a classroom setting (Chevalier, Achim, et al., 2003; Chevalier, Poissant, Bergeron, & Girard-Lajoie, 2003; Chevalier, Simard, & Rouillard, 2006). The preliminary results are promising for school-aged children, as they suggest an improvement in executive control capacities (Guay et al., 2007).

The importance to detect preschoolers with ADHD and to develop effective psychosocial and cognitive treatments is relevant because ADHD symptoms and impairments in preschoolers are similar to older children (Daley, Jones, Hutchings, & Thompson, 2009; Young & Myanthi Amarasinghe, 2010). Indeed, effective psychosocial and cognitive treatments are highly recommended to improve the functional adaptation (McGoey, Eckert, & DuPaul, 2002). There are controversies, however, with pharmacological interventions for ADHD with preschoolers because of a lack of evidence for effectiveness (Greenhill et al., 2006), concerns about side effects (Wigal et al., 2006), and ethical consents (Perring, 1997). As a result, parent training is considered as the primary treatment in preschoolers with ADHD, despite limited research support (Young & Myanthi Amarasinghe, 2010). Moreover, few current psychosocial interventions are dedicated to this population (Young & Myanthi Amarasinghe, 2010), supporting the need to develop effective treatments based on empirically supported theoretical approaches (Schoemaker & Kalverboer, 1994; Sigmundsson, Pedersen, Whiting, & Ingvaldsen, 1998).

Visual-motor imagery training has been proven efficient for increasing attention, especially alerting (sustained attention and vigilance) in school children (Chevalier & Girard-Lajoie, 2000). In that sense, this is a cognitive remediation form that does not use computerized tasks, but instead sensorimotor tasks. This movement-based approach was inspired by the "cognitive efficiency" of the Instrumental Enrichment program (Feuerstein, Rand, Hoffman, & Miller, 1980) and the theoretical models outlined by the program *Actualisation du Potentiel Intellectuel* (API; Audy, 1992). It consists of a multidimensional involvement in which auditory, kinesthetic, and visual modalities are solicited during the movement activities. In this approach, children participate in a cognitive-motor type of learning in which movement is an intrinsic part of the problem solving. By learning mental strategies based on representation of action, children can become gradually aware of their level of attention and planning (Chevalier, Achim, et al., 2003; Chevalier, Harnois, Girard-Lajoie, Simard, & Dupuis, 2005; Chevalier, Poissant, et al., 2003; Chevalier & Simard, 2006).

It has been suggested that children with ADHD have a "simultaneous nonverbal cognitive style" promoting imagery and that these abilities can be solicited in learning processes (Flessas & Lussier, 1995). Moreover, Gardner (1993) proposed that children with ADHD have a spatial and kinesthetic type of intelligence, supporting the use of fine and gross motor activities in dynamic and interactive types of activities (Armstrong, 2002). Sensorimotor interventions with children having ADHD have demonstrated positive results in the reduction of inattention and hyperactivity symptoms of preschoolers in a classroom setting and could be considered as an alternative treatment of ADHD in childhood (Chevalier & Laporte, 2010; Chevalier, Poissant, et al., 2003; Chevalier & Simard, 2006).

The aim of the *motor-cognitive remediation program* (MCRP) was to improve the attentional functions network of the Posner and Raichle's (1997) theoretical model of attention in 5-year-old preschoolers with ADHD symptoms. This model refers to the maintenance of a mental effort for a period of time and the inhibition of irrelevant activity. The purpose of the study was to measure the impact of the program on attentional functions (*alerting, orienting*, and *executive control*). Considering the brain plasticity during early childhood and the neuronal network relations between cognitive processes and motor behaviors, the basic postulate of the present study was that training specific attentional functions by sensorimotor activities would have a positive impact on attention functions of ADHD preschool children.

Method

Participants

Participants having high risk of ADHD were recruited from eight schools from the south shore of Montreal. They came from 25 different preschool classes among these schools. Each class was randomly assigned into treatment or control group. High-risk children were selected based on ADHD symptoms: high scores (clinical value ≥ 50) in the Conners' Kiddie Continuous Performance Test (K-CPT; Conners, 2001) combined with high scores of hyperactivity (percentile ≥ 80) on at least one of the DuPaul diagnostic questionnaires (based on *DSM-IV*; APA, 1994) completed by the parent and the preschool teacher (DuPaul, Power, Anastopoulos, & Reid, 1998). Based on the Child Behavior Checklist for Ages 1.5-5 (CBCL 1.5-5; Achenbach & Rescorla, 2000), the participants were excluded when the scores of Anxiety, or Pervasive Developmental Disorder scales were significantly high.

The final sample consisted of seven high-risk children, four girls and three boys, assigned in the MCRP (M_{age} = 5.7, SD = 0.3). Among these children, only one was receiving medication. They were compared with eight nonmedicated high-risk boys in the control group, who did not participate in the program (M_{age} = 5.9, SD = 0.3).

Instruments

Orienting (selective attention) was measured using the Visual Attention subtest of the Developmental Neuropsychological Assessment Battery (NEPSY): a paper–pencil task of visual search targets among distracters (Korkman, Kirk, & Kemp, 1998). This subtest assesses the time and precision of a child's target search. Two tasks were administered to the 5-year-old participants: The first simple task was to detect a target (cats) between random stimuli, and the second more complex task was to detect two targets (faces) among several random permutations of stimuli.

Alerting (sustained attention) was measured using the K-CPT (Conners, 2001), a computerized task first designed to assess attention disorders in children. The test requires sustained attention and the control of impulsivity during a long, simple, and monotonous task. Pictures of objects appear on the screen, and the child's task is to press the spacebar for every picture that appears onscreen except for the ball. Omission scores refer to the child's sustained attention, and commission scores represent a measure of the child's impulsivity.

Executive control (inhibition) was measured with the Animal Stroop test (Wright, Waterman, Prescott, & Murdoch-Eaton, 2003): a computerized task that assesses the inhibition capacity of the child, in the presence of conflictual information. This test, adapted for children from 3 to 16 years of age, is derived from the Stroop test involving words of different colors renowned to assess inhibition capacity (Golden, 1975). The basic stimuli of the Animal Stroop test are pictures of animals such as a cow, a pig, a sheep, and a duck. In the inhibition condition, the face of the animal is replaced by the face of one of the three other animals (incongruent stimuli). The child's task consists of naming the body of the animal, which requires inhibiting the face of the animal. The preferred information processing oriented to the face or the head is well documented and creates the interference (Johnson, 1993; Premack & Premack, 2003). This task requires executive control because the participant is stopping and reengaging mental operations (Swanson et al., 2000).

MCRP

The MCRP is a multidimensional approach in which kinesthetic, visual, and auditory sensory modalities are called on during the activities so that children can become gradually aware of their level of attention and control (Chevalier, Achim, et al., 2003; Chevalier et al., 2005; Chevalier, Poissant, et al., 2003; Chevalier & Simard, 2006). This program is based on visual-motor imagery exercises inspired by mental training of high-level athletes (Chevalier, 1995; Chevalier & Renaud, 1990; Denis, Chevalier, & Eloi, 1989) as well as motor imagery studies with elementary schoolchildren (Auger, Atienza, Chevalier, & Monnier, 1996; Chevalier, Monnier, & Auger, 1995). The training promotes the development of attention control through movement. It is based on the hypothesis of a link between attention and motor imagery. For instance, imagery maintenance can develop attention and concentration on the task because imagery requires one mentally to generate and examine the properties of the represented object or situation (Chairopoulos, 1998; Denis et al., 1989; Kosslyn, Margolis, & Barrett, 1990).

MCRP components. The MCRP program is subdivided into six groups of six principal activities for teachers and parents to develop *alerting* (vigilance, sustained attention), *orienting* (selective attention), and *executive control* for 5-year-old children.

The program was implemented by teachers, 3 times a week, during 12 weeks. The program was given for all children within preschool classes. To provide the generalization of learning, complementary motor skills activities were planned each week and realized by the child's parent at home.

Teacher's program included six groups of activities. Each week, a base activity was completed by five secondary activities, to generalize skills through classroom setting. A total of 30 sensorimotor activities were included in the program. The parent's component also included 30 sensorimotor activities in six principal groups. The first principal activity was similar to the school activity, and five complementary situations were provided to parents.

Procedures

The research project was initiated under the supervision of the school board education service. School principals were contacted by the school board education service to recruit teachers interested in the study. Parents who gave permission for their child to participate in the study returned the completed registration and consent form by mail. Then, to screen for ADHD symptoms, parents were invited to complete two questionnaires: ADHD Rating Scale–IV (DuPaul et al., 1998) and CBCL 1.5-5 (Achenbach & Rescorla, 2000).

Testing for the project was conducted at the children's schools. All testing was carried out with informed consent from the participants and their parents, in accordance with the University Ethics Committee. Parents of children under medication were asked not to give them their daily dosage 24 hr prior to the evaluation. All children were tested during the morning or at the very beginning of the afternoon. Tests were conducted by independent evaluators, in two sessions, completed in 30 min with the K-CPT at the first session and with the Visual Attention subtest of the NEPSY and the Animal Stroop test at the second session (30 min). They were performed before the program (pretest) and within a week after the end of intervention (postest).

Statistical analysis. Group equivalence was tested using independent samples *t* tests to check the usefulness of controlling for initial differences. Pretest levels of all variables were similar. To assess the effects of the program, analyses of variances 2 × 2 (Groups × Times) were conducted to examine the differences between the control at-risk group (CR) versus the experimental group who participated in the MCRP, under each dependent variable of interest: *alerting*, *orienting*, and *executive control*. ANOVA assumptions were established using visual inspection, the Shapiro–Wilk procedure for normality, and Levene's test for homogeneity of variance. Significance level was set at $p < .05$. Due to technical difficulties, there were missing data for some children, such as being absent at testing or the child refusing to do the task. Therefore, the number of participants will be indicated for each of the following analyses.

Results

Orienting (Selective Attention)

The results of the ANOVA 2 × 2 (groups × times) on the NEPSY (faces) visual attention omission errors revealed a significant time effect, $F(1, 11) = 7.25$, $p = .021$, $\eta^2 = .30$, and a significant interaction effect, $F(1, 11) = 5.53$, $p = .038$, $\eta^2 = .23$, between the CR and the MCRP groups. This analysis was conducted with 13 participants, 8 CR and 5 MCRP. Participants in the MCRP reduced significantly the number of omission errors in this visual search task that requires selective attention (Table 1).

Table 1. Means and Standard Deviations for Selective Attention.

	Control at risk		Motor-cognitive remediation program	
	Pre	Post	Pre	Post
M	8.75	8.25	12.20	4.80
SD	6.52	5.92	2.80	3.70
n	8	8	5	5

Note. NEPSY = Developmental Neuropsychological Assessment Battery. Based on results from *NEPSY visual attention omission errors (faces)*.

Alerting (Sustained Attention)

Participants in the MCRP did not reduce significantly the number of omission errors in the K-CPT continuous task that requires sustained attention (Table 2).

Executive Control (Inhibition)

The results of the ANOVA 2 × 2 (groups × times) on the Animal Stroop incongruent error revealed a significant time effect, $F(1, 11) = 13.82$, $p = .003$, $\eta^2 = .46$, and a significant interaction effect, $F(1, 11) = 4.98$, $p = .047$, $\eta^2 = .16$, between the CR and the MCRP groups. Analyses were conducted with 13 participants, 8 CR and 5 MCRP. Participants in the MCRP reduced significantly the number of errors in this interference task that requires inhibition and executive control (Table 3).

Discussion

The present study investigated the impact of the MCRP on cognitive functions for preschoolers having a high risk of ADHD. Results suggest that training specific attentional functions by sensorimotor activities produced significant effects on two attentional function networks, *orienting* (selective attention) and *executive control* (inhibition).

ADHD has many consequences on the child's social, cognitive, motor, and academic achievement (Barkley, 1997, 1998; Kooistra et al., 2005). Original interventions are relevant because there is a fundamental need for effective interventions for ADHD in childhood (Schoemaker & Kalverboer, 1994; Sigmundsson et al., 1998). Indeed, this

Table 2. Means and Standard Deviations for the Sustained Attention.

	Control at risk		Motor-cognitive remediation program	
	Pre	Post	Pre	Post
M	14.00	16.50	14.83	13.83
SD	9.27	11.01	6.68	9.83
n	8	8	6	6

Note. K-CPT = Conners' Kiddie Continuous Performance Test. Based on results from the K-CPT *omission errors*.

Table 3. Means and Standard Deviations for Executive Control.

	Control at risk		Motor-cognitive remediation program	
	Pre	Post	Pre	Post
M	7.88	6.13	13.40	6.40
SD	3.87	3.64	5.81	6.69
n	8	8	5	5

Note. Based on results from *the Animal Stroop incongruent errors*.

study is a first step in support of the use of MCRP, designed for preschool children having ADHD.

MCRP has been based on robust theoretical models. Constructs refer, first, to Posner and Raichle's (1997) theoretical model of attention. These authors proposed three attentional network functions: (a) *alerting* (vigilance, sustained attention), (b) *orienting* (selective attention), and (c) *executive control* (coordination of multiple neural processes). The MCRP was developed and tested to improve attentional functions, mainly *alerting* (vigilance, sustained attention), *orienting* (selective attention), inhibition, and *executive control*. The postulate was that training specific attentional function in preschoolers with high ADHD symptoms would improve these processes at the end of the treatment.

Results were found significant for the Visual Attention subtest of the NEPSY, a paper–pencil task of visual search of targets that requires selective attention and inhibition of distracters. These results can be linked to an improvement in *orienting*, a network proposed by Posner and Raichle (1997) in their theoretical model of attention, that refers to orientation-inhibition and requires mobilizing neural resources or selective attention and inhibiting other networks or distracters.

A significant difference was also found with the Animal Stroop (Wright et al., 2003) computerized task test that assesses the inhibition capacity of the child in presence of conflictual information that requires vigilance and selective attention. These results can be linked to an improvement in *executive control*, a network proposed by Posner and Raichle (1997), referring to the coordination of multiple neural processes, namely, in this task, vigilance, sustained attention, selective attention, inhibition, planning, stopping, and reengaging mental operations.

These results of improvement in two attentional function networks, *orienting* and *executive control*, by the end of the training, join recent developments in cognitive remediation with computerized exercises (Klingberg et al., 2005; Trucha et al., 2011). For example, a study by Guay et al. (2007) showed an improvement in executive control with children with ADHD from 6 to 8 years of age, after 12 weeks of a cognitive remediation program based on computerized tasks requiring sustained attention and divided attention. These results are supported by a review on the efficiency of cognitive training by Pepin et al., (1995) mentioning the sensitivity and efficiency of training attention, when specific attention tasks target attentional functions.

Limitation

Some methodological issues must be discussed. The small sample used in the study and missing data in some cases limit the statistical power of the study. This could have underestimated significant results. Therefore, we must remain cautious in generalizing the results to the entire population. Thus, although positive, the results must be considered as preliminary and will have to be replicated.

An important point is that the MCRP was implemented during class time by the teacher. The evaluations, however, were conducted by independent evaluators who were blind to the condition of the participant. The present design could thus be useful to guide future research. It could be pertinent to look at the outcomes on the ADHD core symptoms as well as on generalization in time and in different child settings.

Conclusion

In conclusion, these encouraging results support the postulate that training specific attentional functions by sensorimotor activities may have an impact on the cognitive network of attention. The MCRP program can result in an improvement of attention processes. This highlights the relevance of sensorimotor intervention programs addressed to preschoolers with ADHD symptoms. Nevertheless, despite those optimistic outcomes, this study is the first step in the validation of the MCRP program. Results should be interpreted with caution. Nonetheless, the results promote the development of future studies in this domain.

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