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Factors affecting academic achievement in children with ADHD

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ABSTRACT

This study explored the impact of methylphenidate on the academic achievement of 85 children with ADHD. The study employed subjective (parent/teacher ratings) and objective (standardized tests) academic achievement measures, and assessed the impact of in-school academic supports, covariates (baseline performance, IQ, psychosocial adversity) and current and total use of medication over 12 months. The results highlight that neither medication nor academic supports significantly predict academic achievement over and above the covariates of baseline performance and IQ. Our results help to understand the inconsistencies in the literature and highlight the need for school-based interventions to improve academic performance in children with ADHD.

INTRODUCTION

Children with a diagnosis of attention-deficit/hyperactivity disorder (ADHD) commonly present with a wide range of characteristics and problems including academic underachievement and learning disabilities. In fact, it has been estimated that approximately 80% of children with ADHD experience academic underachievement and approximately one-third of children with ADHD have specific learning disabilities (Barkley, 2006; DuPaul & Volpe, 2009). The most common treatment for ADHD is stimulant medication, particularly methylphenidate, which is used with an estimated 2.8% of the school-aged population (Barkley, 2006).

The nature of the link between academic underachievement and ADHD remains unknown. However, it is commonly believed that academic difficulties are the result of the behavioural manifestations of ADHD (e.g., inattention, impulsivity, and hyperactivity). Numerous short-term medication trials have documented the salutary properties of methylphenidate (MPH) on attention span, impulse control, and motor activity level (for a review see Connor, 2006). Additionally, a variety of studies have shown that stimulants improve a number of cognitive/neuropsychological processes considered important for learning (Rhodes, Coghill & Matthews, 2006). Moreover, a number of studies have found that MPH enhances general classroom functioning as well as academic productivity and accuracy (Evans *et al*., 2001; Pelham, Bender, Caddell, Booth, & Moorer, 1985).

While there is substantial evidence of improvements in core symptoms of ADHD, important underlying cognitive processes, and academic productivity and accuracy, most reviews on this topic conclude that there is limited evidence for a direct impact of stimulant medication on academic achievement (Raggi & Chronis, 2006; Schachar *et al*., 2002). Although it appears that medication alone does not directly enhance academic achievement, many clinicians believe that medication may provide a “window of opportunity" for those trying to help these children develop academic skills. For example, many clinicians reason that with a reduction of core symptoms and improvements in underlying cognitive processes, the academic performance of children with ADHD may improve over an extended time period as the child is more available for learning academic skills.

Studies exploring the long term effects of MPH together with academic support have yielded mixed results. For example, Hechtman and colleagues (2004) found that short-term treatment with MPH did improve academic achievement, but that targeted academic programming in addition to MPH treatment was not associated with further improvements. Conversely, studies by Evans and colleagues (2001) and Barbaresi and colleagues (2007) found positive effects of MPH and academic interventions. One possible explanation for the contradictory results in this body of literature is the method of measuring academic achievement. Specifically, the MTA study (Hechtman *et al*., 2004), which did not find long-term improvement in academic achievement, used objective measures (standardized academic achievement tests) as outcome measures; while other studies (e.g., Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2007; Evans *et al*., 2001), which have found improvements in academic achievement, used more subjective measures (teacher ratings of students' academic achievement) as their outcome measures. Consideration of the specific measures being used to assess academic achievement is an important first step in reconciling the conflicting results in the literature and will further our understanding of the impact of MPH treatment on academic outcomes (Frazier, Youngstrom, Glutting, & Watkins, 2007).

In the current paper, we examine the impact of extended treatment with stimulant medication on academic achievement in a group of 85 children with ADHD. We explore the impact of methylphenidate on academic achievement using both objective (i.e., standardized achievement tests) and subjective (i.e., global ratings of achievement by parents and teachers) measures. We further examine whether academic achievement at 12 months is related to medication use (current or total amount of time on medication), degree of academic support at school, and other covariates such as age, sex and IQ.

METHODS

Participants

Children who participated in a study by Schachar, Tannock, Cunningham, and Corkum (1997) were the participants for the current study. These children were required to have a diagnosis of ADHD, which was based on clinical diagnostic interviews with each child's parent(s) and teacher. Inclusion criteria were that the child demonstrated symptoms of ADHD at home and at school, the child had a history of ADHD symptoms prior to the age of seven, the child was between 5 and 12 years of age, at least one parent was able to communicate in English, and the family was willing to participate in a randomized clinical trial involving drug and psychosocial interventions. Children were excluded if they had any of the following: full-time attendance at a residential or day treatment program; evidence of a neurological disorder (e.g., epilepsy); previous treatment with medication for ADHD; a chronic or serious medical problem (e.g., diabetes); and/or an estimated Full Scale IQ of less than 80. A detailed description of the selection and diagnostic procedures can be found in Schachar *et al*. (1997).

Of the 91 original participants in the larger study (Schachar *et al*., 1997), 85 children (93.4%) completed the academic achievement measures at the 12-month assessment time point and were included in the present study. Characteristics of the sample of children completing the 12-month measures (n = 85) can be found in Table 1. The characteristics of the original sample of 91 children can be found in Schachar *et al*., 1997. It is important to note that the six children who did not complete the measures at 12 months had higher risk factors, were less likely to be currently on medication, and took less medication over the duration of the 12 month study than the participants in the current study.

Table 1. Descriptive characteristics of the sample

Characteristics	Study Sample (n = 85) M (SD)
Age (years)	8.39 (1.59)
Grade	2.81 (1.53)
Males:Females (number)	68:17
WISC-R estimated IQ (standard score)	108.89 (15.04)
ADHD (number of symptoms)	
Parent	10.74 (2.80)
Teacher	10.39 (2.66)
Psychosocial adversity index (raw score)	1.82 (1.34)
WRAT-R (standard scores)	
Reading	86.42 (19.41)
Spelling	83.45 (16.59)
Arithmetic	89.24 (16.32)
OCHS academic ratings (raw score)	
Parent	3.42 (1.03)
Teacher	3.71 (0.96)
Total medication (percentage)	63.53 (40.00)
Academic support (percent of time)	28.24 (33.44)
Medication status at 12 months	N (%)
No	26 (31%)
Yes	59 (69%)

Notes: Percentages are rounded to the nearest full number. WISC-R = Wechsler Intelligence Scale for Children - Revised; ADHD (number of symptoms) = number of symptoms of Attention–Deficit/Hyperactivity Disorder based on parent and teacher diagnostic interviews; Psychosocial adversity index = total number of risk factors with a minimum score of 0 and a maximum score of 6; *WRAT-R* = Wide Range Achievement Test - Revised; OCHS academic ratings (raw score) = rating based on 5-point Likert scale (1= excellent, 5 = poor); Total time on medication = percentage of time spent on medication over the 12-month trial; Academic support = percentage of time child was afforded special education resources at school.

Measures

Wide Range Achievement Test-Revised (WRAT-R). The *WRAT-R* (Jastak & Wilkinson, 1984) provided an objective measure of the children's academic performance and was administered at baseline and after 12 months of participation in the study. The *WRAT-R* is comprised of three subtests: reading (decoding of a list of single words); spelling (single words dictated from a list); and arithmetic (basic numerical operations). The standard scores were used in all analyses. Of the 85 children who participated in the current study, 71.8 % were performing at least one standard deviation below the mean on one or more of the *WRAT-R* subtests. The percentage of children performing more than one standard deviation below the mean on each subtest was also very high (reading g: 54.1%; spelling: 57.6%; arithmetic: 37.6%).

Parent & Teacher Ratings of Academic Achievement. Parents and teachers completed the Ontario Child Health Scale (OCHS; Boyle et al., 1987) at baseline and again after 12 months. This scale includes one item that asks the parent/teacher to rate the child's overall academic achievement on a five point Likert scale ranging from a "1" (excellent) to a "5" (poor). Any missing data at the 12-month assessment time point (parents: 3 missing values; teachers: 6 missing values) were replaced with the baseline rating for that item. It should be noted that given that one year had elapsed between the baseline and 12-month assessment, most children did not have the same teacher at both assessment points.

Estimated Intellectual Ability. A brief measure of intellectual ability (the short version of the WISC-R, Block Design and Vocabulary subtests; Wechsler, 1974) was administered to all children during the initial assessment.

Psychosocial Adversity. An index of psychosocial adversity was based on the sum of the following items on the OCHS:

1) stressors in the last six months (e.g., moving residence),
2) single-parent status,
3) less than complete high school education for the parent with the highest education,
4) either parent treated for "trouble with nerves",
5) subsidized housing, and
6) unemployment.

Each of the six variables was coded as present (1) or absent (0) and then summed to give an overall index with a range of 0 to 6 with higher scores indicating greater psychosocial adversity. Psychosocial adversity was used as a covariate in our analyses because of initial differences between the MPH and placebo group on this measure (see Schachar *et al*., 1997).

Academic In-School Support. The amount of educational intervention for academic problems after 12 months of involvement in the study was coded on a 40-point scale. At each assessment time (baseline, 4, 8, and 12 months), information was gathered from teachers about the educational resources the child was receiving within the school setting. The teachers were asked to provide the amount of time each day that the student was afforded special education services. This information was collated and coded on a ten point scale (e.g., 5 out of 10 equalling 50% of time receiving special education services). Then, the scores over the four follow-up periods were summed and divided by 40 to determine the average proportion of time that the child was afforded special educational interventions at school over the 12-month period.

Total time on medication. The total length of time (in months) that each child took methylphenidate during the 12 month period of the study was recorded and converted to a percent. For example, if a child had been originally assigned to placebo but crossed-over to methylphenidate at 4 months and remained on this medication for the duration of the study, his/her total months on active medication would be 8 months (66.7% of the 12 months of the study). Of the 85 children, 17 (20%) children did not receive any medication over the 12 months (10 children were not taking any medication for ADHD symptoms and 7 children were taking placebo), 8 (9%) children received medication for 1 to 4 months, 10 (12%) children received medication for 5 to 8 months, and 50 (59%) children received medication for 9 to 12 months. This variable represents the *cumulative effects* of medication.

Medication Status at 12 Months. After the completion of the 12-month assessment, the blind on medication status was lifted to determine whether each child was originally assigned to the methylphenidate or the placebo group. At 12 months, 32 out of 43 (74%) children originally assigned to medication continued to take medication, while the remaining 11 had discontinued the medication. Of the 42 children originally assigned to the placebo group, 17 (40%) continued to take either a placebo (n = 7) or no medication (n = 10). The remainder of these children (n = 25; 60%) changed, at the request of their parents, from placebo to medication over the 12-month period. For the current study, we grouped children as either "on active medication (coded as 1) or "not on active medication (coded as *0*) at the 12-month assessment time period. Children who were not taking any medication or who were taking a placebo were both included in the "no active medication" group. This variable was included in the analyses as a measure of the *current effects* of medication.

Procedure

A complete description of the research design of the larger study is provided by Schachar and colleagues (1997). In summary, after the initial diagnostic interviews and child assessment (which included the *WRAT-R*), children who reached study criteria were randomized to methylphenidate or placebo and their parents were randomized to a parent-training group or parent self-help and advocacy group in a fully crossed design. The subjects were requested to maintain their original assignment for 12 months. After randomization, each child went through an initial 3 to 4 week titration phase during which time methylphenidate or placebo was increased in 5 mg steps toward a target dose of 0.7mg/kg in each oral dose given twice daily (at breakfast and lunch).

Throughout the 12-month treatment phase, the medication (both MPH and placebo) was monitored frequently and the dose was adjusted to ensure an optimal balance between behavioural impact and side-effects. The target dose of MPH was reached by very few children (n = 3), with the average dose being approximately 0.5 mg/kg given twice daily. This dose of medication was found to be effective in improving the core symptoms of ADHD in the classroom (Schachar *et al*., 1997). Given the naturalistic design of the study, which was adopted to achieve high generalizability of the study's results, the families were told to continue with any current involvement in programs providing additional help for their children including additional school support for academics.

At 12 months, the children completed another assessment, identical to the baseline assessment, and parents and teachers completed questionnaires identical to those completed during the initial assessment phase. During the 12-month assessment, all children were tested under what was their typical medication regime at that time (i.e., MPH, placebo, or no pills). The 12-month child assessment was scheduled during daytime hours so that children receiving methylphenidate would be assessed during the hours when the medication was considered to be active (i.e., 1 to 3 hours after ingestion). The children were administered the *WRAT-R* by a trained, master's level psychometrist under the supervision of a registered psychologist. Parents and teachers completed the questionnaires prior to the appointment time.

Analyses

Given the number of children who crossed over from their original medication assignment, an intent-to-treat design was not considered a reasonable approach to the analysis of the data. Instead, a regression approach was chosen as it maintained power to detect differences by including all children who participated in the study. Additionally, this analytic approach allowed for the examination of the impact of medication status at 12 months (*current effects*) and the percentage of time the child had been on MPH over the 12 month trial (*cumulative effects*) on academic achievement.

The first step in the analyses involved inspection of zero-order correlations among measures of achievement, treatment, and potential covariates to determine if there were any variables that should be excluded from the analyses. Next, a series of five multiple regressions were conducted to examine academic outcome at 12 months (one analysis for each subtest of the *WRAT-R* as well as one each for the parent and teacher academic ratings). Potential variables to include in the regression analyses were the covariates (baseline performance on the outcome measure of interest, age, IQ, sex, psychosocial adversity, total academic resources, academic resource status at 12 months) and treatment variables (current medication status and total amount of medication taken over the 12 month period).

RESULTS

Preliminary analyses examining the correlations among the measures of academic performance (i.e., three *WRAT-R* subtests, parent and teacher ratings), covariates (baseline academic measures, age, IQ, sex, psychosocial adversity, academic in-school supports) and medication variables (current medication status, total medication) are presented in Table 2. Given that these correlations were conducted as a preliminary analysis prior to running the regression analyses, there was no correction for multiple comparisons. Rather, these results were used to determine which variables to include in the regression analyses. Age and sex were not significantly correlated with the outcome measures, so these variables were not included in the regression analyses. In-school supports was not included in the regression analyses as they were only correlated (negatively) with the WRAT-R reading subtest at 12 months (p=.04), indicating that more supports had been given to children with lower reading achievement as assessed at 12 months.

Table 2. Correlations among academic outcome variables and independent variables (p-values)

RATINGS	*WRAT-R*			ACADEMIC	
Variable	Reading	Spelling	Arithmetic	Teacher	Parent
Baseline Measure	.88 (.000)	.83 (.000)	.71 (.000)	.26 (.02)	.14 (.19)
Age	.05 (.67)	-.03 (.82)	-.22 (.05)	.11 (.30)	.17 (.13)
IQ	.52 (.000)	.42 (.000)	.55 (.000)	-.28 (.01)	-.24 (.03)
Sex*	-.05 (.68)	-.06 (.59)	-.15 (.18)	.10 (.34)	.09 (.44)
Adversity	-.24 (.03)	-.25 (.02)	-.25 (.02)	.15 (.16)	.22 (.04)
Total Resources	-.23 (.04)	-.16 (.11)	-.11 (.33)	.08 (.47)	-.09 (.41)
Total Medication	.13 (.24)	.13 (.24)	.23 (.03)	-.36 (.002)	-.37 (.000)
Medication Status*	.02 (.87)	.04 (.72)	.19 (.09)	-.27 (.01)	-.38 (.000)

N = 85 for all analyses

* = Spearman Rho analyses were conducted for these dichotomous variables, whereas Pearson correlations were conducted for all the other continuous variables

Notes: Reading, Spelling & Arithmetic = subtests from the Wide Range Achievement Test-Revised; Academic ratings = ratings provided by parents and teachers (1= excellent to 5 = poor); Baseline measure = same measure as outcome measure but given at baseline; Adversity = index of psychosocial adversity (higher number higher adversity); Total resources = percentage of time receiving academic resources over the 12 month trial; Resource status = whether receiving resource at 12-month assessment time; Total medication = percentage of time on active medication over the duration of the 12 month trial; Medication status = child's medication status at 12-month assessment.

The remaining variables were correlated with more than one of the outcome measures and therefore were included in the regression analyses. The baseline measure was correlated with all but parent ratings, indicating that better performance at baseline on the *WRAT-R* subtests and on the teacher ratings were associated with better performance on the same measure at 12 months. IQ was correlated with all outcome variables, indicating that higher IQ was associated with stronger performance on the *WRAT-R* subtests as well as with parent and teacher ratings. Psychosocial adversity was correlated with all outcome variables except teacher ratings. These correlations indicate that higher adversity was related to poorer performance on the outcome measures. Finally, the two medication variables were both correlated with parent and teacher ratings indicating that a longer duration of medication and current medication use were related to better subjective ratings of academic achievement. Total medication was also correlated with performance on the *WRAT-R* Arithmetic subtest with longer duration of medication being correlated with better performance on this subtest at 12 months.

Table 3 presents the results of the multiple regression analyses for the *WRAT-R* Reading, Spelling, and Arithmetic subtests. For all three *WRAT-R* subtests, the full model accounted for a large and significant amount of variance in outcome measure (Reading: $R^2 = .79$, $F(5,79) = 60.24$; $p = .000$; Spelling: $R^2 = .70$, $F(5,79) = 36.85$, $p = .000$; Arithmetic: $R^2 = .59$, $F(5,79) = 22.64$, $p = .000$). The only variable which accounted for a significant amount of variance in the 12-month reading and spelling scores was the baseline measure of the same academic area. The 12-month performance on the arithmetic subtest was predicted by baseline performance on this measure, but IQ also explained a significant proportion of the variance in arithmetic scores. Neither of the medication variables significantly predicted performance at 12-months on any of the *WRAT-R* subtests.

Table 3. Multiple Regression Analysis predicting WRAT-R subtests at 12 months

	B	*SE*	*β*	*T*	*p-value*
***WRAT-R* Reading**					
Baseline Measure	.90	.07	.82	13.27	.000
IQ	.14	.09	.10	1,70	.09
Adversity	.08	.94	.01	.08	.94
Total Medication	.07	.06	.12	1.13	.26
Medication Status	-2.42	4.81	-.05	-.50	.62
***WRAT-R* Spelling**					
Baseline Measure	.88	.68	.78	11.04	.000
IQ	.10	.09	.08	1.14	.26
Adversity	-.79	.99	-.06	-.80	.42
Total Medication	.06	.06	.12	.93	.36
Medication Status	-2.61	5.09	-.07	-.51	.61
***WRAT-R* Arithmetic**					
Baseline Measure	.53	.08	.55	6.42	.000
IQ	.30	.09	.28	3.32	.001
Adversity	-1.69	.96	-.14	-1.76	.08
Total Medication	.02	.06	.05	.30	.96
Medication Status	.27	5.09	.01	.05	.76

Notes: Baseline measure=same measure as outcome measure but given at baseline; IQ = estimated IQ based on WISC-R; Adversity = index of psychosocial adversity; Total medication = percentage of time on active medication over the duration of the 12 month trial; Medication status=child's medication status at 12 month assessment.

Table 4 presents the results of the multiple regression analyses for teacher and parent ratings of academic performance. The models for both parent and teacher ratings were significant, but accounted for less of the variance in outcome scores than did the models for the WRAT-R subtests. The amount of variance explained for each outcome measure was: Parent: R^2 = .22, $F(5,79)$=4.48; p = .001; Teacher: R^2 = .31, $F(5,79)$ = 7.02, p = .000). The only significant variable for teacher ratings at 12 months was the baseline teacher ratings of academic achievement. This finding is similar to the findings for the WRAT-R subtests. For parent ratings of academic achievement at 12 months, the only significant predictor was IQ. Baseline parent ratings were not predictive of outcome ratings. Neither of the medication variables were significant predictors.

Table 4. Multiple Regression Analysis predicting OCHS academic ratings at 12 months

	B	*SE*	*β*	*T*	*p-value*
Parent					
Baseline Measure	.05	.10	.05	.49	.63
IQ	.02	.01	-.23	-2.24	.03
Adversity	.06	.09	.08	.72	.48
Total Medication	.00	.01	-.02	-.09	.93
Medication Status	-.76	.44	-.35	-1.72	.09
Teacher					
Baseline Measure	.43	.11	.41	3.90	.000
IQ	-.01	.01	-.16	-1.65	.10
Adversity	-.02	.08	-.02	-.18	.86
Total Medication	-.01	.01	-.28	-1.40	.17
Medication Status	.28	.44	.12	.62	.54

Notes: Baseline measure=same measure as outcome measure but given at baseline; IQ = estimated IQ based on WISC-R; Adversity = index of psychosocial adversity; Total medication = percentage of time on active medication over the duration of the 12 month trial; Medication status=child's medication status at 12 month assessment.

DISCUSSION

Similar to findings of other studies (e.g., DuPaul & Volpe, 2009) our sample of children with ADHD had high rates of academic challenges. Approximately 72% of the sample was underachieving (i.e., performing at least one standard deviation below the mean on at least one subtest of the *WRAT-R*), despite the fact that the average estimated IQ was at the higher end of the Average range. The results of the current study highlight:

1) that medication effects are more likely to be found on subjective measures than objective measures, especially if other factors such as IQ and baseline performance are not controlled for in the analyses; and
2) neither medication (current or cumulative) nor in-school academic supports significantly predict academic achievement over and above the covariates of baseline performance and IQ.

Based on the correlational analyses a disassociation was found between the impact of medication on objective (i.e., standardized assessment) and subjective (i.e., questionnaire) measures of academic achievement. The results indicate that teacher and parent ratings of children's academic achievement were more positive when the child was receiving medication. However, there was no significant improvement found in the performance of these same children on a standardized measure of achievement. Therefore, our results are consistent with Frazier and colleagues' (2007) finding of larger effect sizes for MPH on parent and teacher ratings than on objective academic measures and highlight the importance of choosing an outcome measure that reflects actual, rather than perceived, performance in the area of interest.

The results of our regression analyses indicate that when confounding variables are taken into account, the relationship between treatment with medication and academic performance is not significant. The main predictor of outcome for all but the parent ratings was the child's performance on the baseline measure of academic achievement. IQ was also a significant predictor for performance on the *WRAT-R* Arithmetic subtest and was the only predictor of 12-month parent ratings of academic achievement. These results are consistent with the conclusions of previous research, which indicated that medication has little to no impact on long-term academic achievement (Raggi & Chronis, 2006; Schachar *et al*., 2002).

A secondary, yet interesting, finding of the current study was that there was no relationship between academic achievement at 12-months and the amount of in-school interventions. This finding raises the question of what resources children would need to demonstrate significant improvements in academics and whether medication could facilitate learning under these specific educational interventions. In the current study the children received a range of school-based intervention (e.g., resource help, time with a teacher assistant, special education placement), but not every child received academic interventions nor were the interventions received necessarily evidence-based. Thus, the present results do not discredit the possibility of MPH treatment creating a "window of opportunity" for learning. Stimulant medication may increase the learning potential of children with ADHD but only in combination with specific effective education programs that are implemented during the "window of opportunity" with this population. We cannot rule out the possibility that medication in combination with high quality, evidence-based interventions may have resulted in enhanced learning. In exploring the development of programs specifically aimed at children with ADHD, future research should recognize that it will be necessary to monitor the nature of academic interventions as well as the long-term trajectory of academic skill development (Purdie, Hattie, & Carroll, 2002) along with medication regimes in order to get a clear picture of how intervention with medication affects academic skill development.

Additionally, specific remedial programs that are implemented with children with ADHD should be empirically supported by research literature. A number of interventions (see Jitendra, DuPaul, Soonneki, & Tresco, 2008; Raggi & Chronis, 2006; Trout, Lienemann, Reid, & Epstein, 2007) have been shown to be efficacious or promising for use with children with ADHD who have impaired academic achievement. These interventions, rather than simple extra-help, should be included in research studies. It is also important to consider systemic changes to maximize the potential for benefit. These include ensuring smaller class sizes (Nye, Hedges, & Konstantopoulos, 2000), including sufficient exercise in students' days (Ridgway, Northup, Pellegrin, LaRue, & Hightshoe, 2003), and using software to promote task engagement (Ota & DuPaul, 2002).

The methodology applied in the current study has a number of strengths and limitations. In terms of strengths, the use of both subjective parent and teacher ratings and objective standardized achievement measures allowed for direct comparison of the impact of MPH on academic achievement with both types of measures within the same sample. Secondly, the utilization of regression analysis allowed for flexibility with the management of attrition from the original assigned medication group. This is particularly important in long-term clinical trials as attrition rates are often high. A third strength was that all children were on their current medication for post-testing and medication status over 12 months was recorded to allow us to examine both the current and cumulative effects of medication on academic performance.

The limitations of the current study result from two primary factors. First, given the study's naturalistic design, we could not control for some important variables. For example, teachers changed over the duration of the 12 month period. Secondly, given that the study was an analysis of data collected in the Schachar et al (1997) study, we were not able to explore in greater detail the nature of the educational resources afforded to the children. Other limitations potentially include the choice of the *WRAT-R* as an outcome measure, as it taps only three academic areas (decoding, spelling and numerical operations). It may be that medication could impact on other areas, such as those requiring multi-tasking (reading comprehension, listening comprehension, written expressive language). Furthermore, the *WRAT-R*, like other standardized tests of academic achievement, has high stability of scores over time thus making it difficult to detect changes. Despite its limitations, the *WRAT-R* has been and its more recent editions (the *WRAT-3* and *WRAT-4*) continue to be a very popular choice amongst researchers examining academic achievement (e.g., Mayes, Calhoun, Bixler, & Zimmerman, 2009). Another possible limitation is the relatively low dose of medication the children were receiving. The target dose (0.7 mg/kg/dose) was not reached by most children; however, it should be noted that this amount of medication was found to significantly improve ADHD symptoms in the school setting and therefore would be considered a therapeutic dose. There is currently some debate as to whether a dose effect on learning exists (Evans *et al*., 2001; Solanto, 2000; Tannock, Schachar, Carr, & Logan, 1989). It is possible that learning may be affected by higher doses of medication than what it takes to change behaviour; however, there is no supporting evidence for this in the literature.

The results of the current and past studies (Raggi & Chronis, 2006; Schachar *et al*., 2002) clearly indicate that medication alone does not significantly improve academic achievement. These results call into question the traditional theoretical model which has proposed a causal relationship between

ADHD and academic underachievement (e.g., McGee & Share, 1988). If there is a direct causal link between attention deficits and academic achievement then it would follow that improvements in attention, through the use of medication, would directly impact academic achievement. However, this does not appear to be the case.

Future research needs to clarify the relationship between ADHD and poor academic achievement as well as the impact of specific educational programs that target academic underachievement in children with ADHD. These programs need to be evaluated and the impact of medication in facilitating learning needs to be explored. Meanwhile, professionals working with children who have ADHD and exhibit academic underachievement need to ensure that these children are provided with high quality programs identified in the research which are targeted at improving academic skills in children with ADHD. It is critical that professionals do not assume that children will display improved academic achievement once medication treatment for ADHD symptoms has been initiated. An increased awareness of the limitations of medication with regard to academic achievement needs to be fostered. Finally, professionals should not rely on subjective measures (e.g., global ratings, school reports, etc.) in order to evaluate the child's academic progress, as these measures do not provide a pure measure of academic achievement.

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