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Attention-Deficit/Hyperactivity Disorder and Scholastic Achievement: A Model of Dual Developmental Pathways

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A conceptual model has recently been hypothesized in which parallel but correlated developmental pathways exist for attention deficit behaviors and conduct problems. An important component of this model suggests that attention deficit behaviors are related to later scholastic underachievement, whereas conduct problems are unrelated to scholastic underachievement except by their common correlation with attention deficit and intelligence. The present study replicated the general model using a cross-sectional sample of 325 children, and examined whether hypothesized dual pathways (behavioral and cognitive) better account for the relationship between attention deficit, intelligence, and later scholastic achievement. Results of the structural equation modeling analysis were consistent with the hypothesized dual pathway model and suggest that school behavior and select cognitive abilities serve as important mediators between attention deficit, intelligence, and later scholastic achievement. Implications of these results for understanding the developmental trajectory of children with attention deficit and general theoretical models of ADHD are discussed.

Keywords: Attention Deficit Disorder, educational outcomes, developmental psychopathology.

Abbreviations: ADHD: Attention-Deficit/Hyperactivity Disorder; APRS: Academic Performance Rating Scale; CBCL: Child Behavior Checklist; CD: conduct disorder; CFI: Comparative Fit Index; CPT: Continuous Performance Test; K-BIT: Kaufman Brief Intelligence Test; NNFI: Bentler-Bonnett Nonnormed Fit Index; PAL-T: Paired Associate Learning Task; RMSEA: Root Mean Square Error of Approximation; SAT: Stanford Achievement Test; SEM: structural equation models; SRMR: Standardized Root Mean Squared Residual; TRF: teacher report form.

Introduction

A plethora of studies exists concerning the relationship between disruptive childhood behaviors (externalizing behavior problems) and later developmental outcomes (Farrington, Loeber, & Van Kammen, 1990; Henker & Whalen, 1989; Klein & Mannuzza, 1991; Loeber, 1988, 1991; Loeber & Dishion, 1983; Patterson, De Baryshe, & Ramsey, 1989; Weiss & Hechtman, 1986). Extant research indicates that children who exhibit early conduct or attention deficit behaviors are at greater risk for a range of later outcomes. These include learning problems, academic underachievement, offending, and other forms of social maladjustment (Barkley, 1990; Kazdin, 1995; Kratzer & Hodgins, 1997; Rutter, 1974; Szatmari, Boyle, & Offord, 1989).

The relationship between externalizing behavior problems in children and academic achievement in particular has been the focus of increased attention in recent years. Some have argued that early disruptive patterns of behavior and lower intelligence (IQ) serve to make children more vulnerable to increased risks of academic and cognitive problems (Fergusson, Horwood, & Lynskey, 1993; Mannuzza, Klein, Bessler, Malloy, & Hynes, 1997). Prevalence studies support this position. Estimates of learning problems in samples of children with Attention-Deficit/Hyperactivity Disorder (ADHD) range from 9% to 48%, depending on the method by which learning problems and ADHD are defined (August & Garfinkel, 1989, 1990; Cantwell & Satterfield, 1978; Halperin, Gittelman, Klein, & Rudel, 1984; Holborrow & Berry, 1986; Lambert & Sandoval, 1980). Similarly, an estimated 11% to 61% of children with conduct problems and delinquent behavior experience learning difficulties (Broder, Dunivant, Smith, & Sutton, 1981; Morgan, 1979; Pasternack & Lyon, 1982; Robbins, Beck, Pries, Jacobs, & Smith, 1983; Rutter & Yule, 1970; Wilgosh & Paitich, 1982). Others have speculated that children with attention deficit and conduct problems may follow different developmental trajectories (Frick et al., 1991; Lilienfeld & Waldman, 1990; Schachar, 1991). This view addresses the construct validity of the distinction between ADHD and conduct disorder (CD) and

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necessitates both internal (e.g. factor analysis, multitrait-multimethod model) and external (e.g. developmental outcome) validation studies.

Internal validation studies concerning the distinction between ADHD and CD have been reviewed, with the preponderance of evidence indicating that the two disorders are distinct but correlated dimensions of child behavior (Burns et al., 1997; Fergusson, Horwood, & Lloyd, 1991; Hinshaw, 1987). Studies focusing on external validation methodology suggest that ADHD but not CD is associated with future cognitive and learning problems, whereas CD but not ADHD is associated with future social maladjustment such as delinquency and antisocial behavior (Lilienfeld & Waldman, 1990; Schachar, 1991). These proposed relationships have been addressed in two relatively recent studies (Farrington et al., 1990; Frick et al., 1991).

Frick et al. (1991) examined the prevalence of academic underachievement in children with ADHD and CD, taking into account both the high rate of comorbidity between the two disorders and the influence of intelligence. ADHD was found to be a predictor of academic achievement, whereas CD was related to academic achievement only by means of its correlation with ADHD.

Farrington et al. (1990) examined the relationship between ADHD, CD, and long-term criminal outcomes in a cohort of British children. Their results indicate a highly significant relationship between conduct problems and later offending but only a weak relationship between ADHD behaviors and subsequent offending after controlling for comorbidity rates between the two disorders.

Collectively, the two studies suggest an intriguing conceptual model in which parallel but correlated developmental sequences or pathways exist, one for attention deficits and the other for conduct problems. In the first pathway, early attention deficit is viewed as a precursor of later academic underachievement, but is unrelated to the development of juvenile delinquency and antisocial behavior except by its common correlation with conduct problems. The second pathway assumes that the development of early conduct problems is a precursor of later juvenile delinquency and antisocial behavior, but is unrelated to academic underachievement except by its common correlation with attention deficit behaviors.

Fergusson and colleagues (Fergusson & Horwood, 1995; Fergusson et al., 1993) empirically tested the dual developmental pathway model concerning the proposed relationships between externalizing behaviors in early childhood and later outcomes in adolescents. In the earlier study, unidimensional scale measures were constructed based on mother and teacher ratings of conduct and attention deficit behavior problems for a large cohort of New Zealand children ($N = 704$ to 761) at ages 6, 8, and 10 years. Children's intelligence was assessed during interim years (age 8), whereas scholastic ability and parent–child measures of offending were obtained at 6- to 7-year follow-up intervals (i.e. at ages 12 to 13). A series of structural equation models (SEM) was developed to examine the relationship between early externalizing behaviors (conduct problems, attention deficit behaviors), intelligence, and later offending and academic achievement. A strong continuity between early conduct problems and later rates of offending but not academic achievement was evident when the correlated effects of attention deficit behaviors were taken into account. Conversely, attention deficit was related to later academic underachievement but not offending after controlling for the correlated effects of conduct problems. This relationship was partially accounted for by a strong correlation between attention deficit behaviors and intelligence, indicating that among children with similar IQ levels, those with attention deficits do less well academically.

A similar series of structural equation models was developed in Fergusson and Horwood's follow-up study (1995) of 709 children using nearly identical outcome measures with two exceptions. Parental and self-reports of offending were complemented by official police records for approximately 80 % of the sample, and additional measures of academic achievement (reading comprehension, mathematical reasoning) were included. Results corroborated their earlier findings, wherein associations between school achievement and delinquency were non-causal and resulted from the common and correlated effects of early disruptive behavior and IQ. That is, early conduct problems were precursors of later delinquency but unrelated to later academic achievement except by their common correlation with attention deficit behaviors and IQ. Conversely, attention deficit behaviors and IQ were precursors of later academic underachievement but unrelated to later delinquency except by their common correlation with conduct problems.

In their most recent study of this sample, Fergusson, Lynskey, and Horwood (1997) included measures of academic success and juvenile offending taken at 17 and 18 years of age. Results corroborated their earlier findings. Early attentional difficulties were related to later academic success but unrelated to later juvenile offending after controlling for early conduct problems, intelligence, and demographic, educational, and family factors.

Fergusson et al.'s model of two distinct but correlated developmental pathways relating early behavior and IQ to later academic achievement and social adjustment is compelling, albeit leaving unanswered whether specific mediating variables are responsible for the various relationships among constructs. For example, the relationship among attention deficit behavior, intelligence, and scholastic achievement may be mediated by the former two variables' influence on classroom academic performance, which in turn affects scholastic achievement. Support for this hypothesis is derived from multiple studies demonstrating that children with ADHD evidence significant behavioral difficulties in classrooms, receive more failing grades, and fail more grades than comparison children (Barkley, Fischer, Edelbrock, & Smallish, 1990; Minde et al., 1971; Minde, Weiss, & Mendelson, 1972; Weiss, Hechtman, Perlman, Hopkins, & Wener, 1979). A reported 25 % (Mannuzza et al., 1997) to 31 % (Weiss, Hechtman, Milroy, & Perlman, 1985) fail to complete high school. A second possibility is that attention and short-term memory problems mediate the relationship between intelligence, attention deficit behaviors, and later scholastic achievement. Evidence supporting this hypothesis derives from over two decades of research indicating significant attentional (Abikoff,

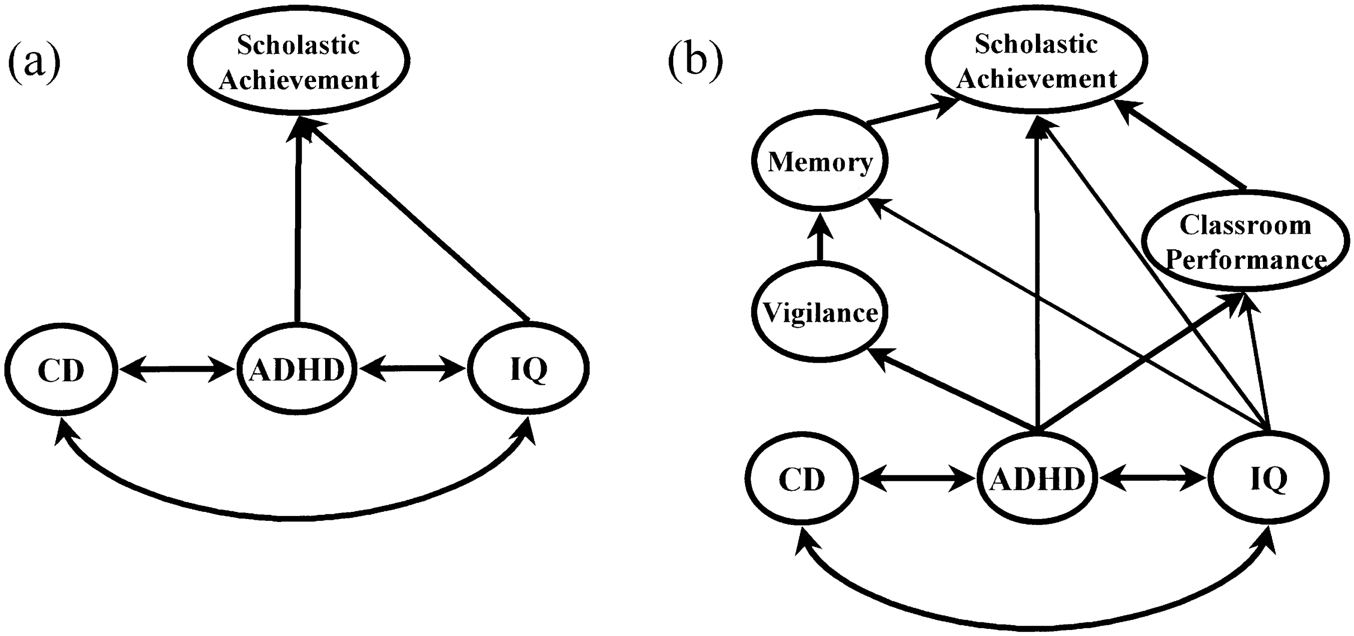

Figure 1. Conceptual models depicting the relationships among CD, ADHD, IQ, and later Scholastic Achievement. The general Replication Model is shown in the left (a) portion of the figure. The Dual Pathway Model is depicted in the right (b) portion of the figure, wherein cognitive (vigilance, memory) and behavioral (classroom performance) variables are hypothesized to mediate the relationship between ADHD and IQ and later Scholastic Achievement.

Gittelman-Klein, & Klein, 1977; Barkley, DuPaul, & McMurray, 1990; Douglas & Peters, 1979; Sykes, Douglas, & Morgenstern, 1973) and select types of short-term memory (Douglas & Peters, 1979; Kinsbourne & Caplan, 1979; Voelker, Carter, Sprague, Gdowski, & Lachar, 1989) difficulties in children with attention deficit behaviors.

The purpose of the present investigation was twofold. Initially, we sought to replicate the conduct problems–attention deficit–IQ–achievement portion of Fergusson et al.'s (1993, 1997; Fergusson & Horwood, 1995) model in a cohort of children residing in the United States using a cross-sectional, longitudinal design. The structure of the Replication Model is depicted in Fig. 1(a). A dual pathway hypothesis was subsequently examined using structural equation modeling. At the most general level, we hypothesized that the relationship between attention deficit behaviors and scholastic achievement reported by Fergusson et al. (and corroborated in the Replication Model) would be attenuated if particular variables proved to be important mediators for the two constructs. Guided by past research findings, two parallel pathways were hypothesized—one behavioral, and the other cognitive—to account for the relationship between attention deficit behaviors and long-term scholastic achievement. For the behavioral pathway, we postulated that daily classroom performance would serve as a significant mediator between attention deficit behaviors, IQ, and scholastic achievement. A parallel, cognitive pathway was also posited in which vigilance serves as a requisite skill for children's short-term memory, with both serving as significant mediators between attention deficit behaviors, IQ, and later scholastic achievement independent of the behavioral pathway. We also considered the magnitude of the regression coefficient linking early IQ and scholastic achievement (.66; $p < .0001$) reported by Fergusson and Horwood (1995), and felt that it would be attenuated after accounting for relevant contributions pertaining to the behavioral and cognitive pathways. That is, the significant relationship between IQ and later scholastic achievement should remain, but its relative magnitude should be lessened after accounting for the effects of IQ on classroom performance (behavioral pathway) and cognitive function (cognitive pathway). Finally, we expected to explain additional variance in scholastic achievement (indicated by a lower disturbance term or unexplained variance in SEM terminology) compared to Fergusson et al. owing to the inclusion of mediating variables in our expansion of the general model. The proposed structure of the Dual Pathway Model is depicted in Fig. 1(b).

Methods

Participants

The sample consisted of 325 children (146 males, 179 females) between 7 and 16 years of age (mean = 10.67, $SD = 2.39$) attending 2nd through 9th grades at a public and private school in Honolulu (Oahu), Hawaii. Approximately 74% of the State's population reside in the City and County of Honolulu (U.S. Bureau of the Census, 1990). Schools were selected based on available data suggesting that their ethnic and sociodemographic composition was a close approximation of children residing in Hawaii (State of Hawaii Data Book, 1996).

The public school is a research arm associated with the University of Hawaii whose primary mission is to develop and test curricula suitable for children of differing abilities and sociodemographic backgrounds. Children are admitted to the school based on ethnicity, gender, parental socioeconomic and marital status, residence location, and academic achievement to approximate the State's census.

A private school was selected for participation to obtain a sample reflecting the relatively large number of children (i.e.

19%) attending private schools in the State (State of Hawaii Data Book, 1996). The school admits students from throughout the State, although the majority of children reside in the urban Honolulu area.

An informational letter and consent and demographic information forms were mailed to parents of children attending both schools. The letter provided a basic description of the research project. The latter two forms were used to obtain written consent for children's participation and sociodemographic information (Duncan, 1961) concerning family members, respectively. Parental consent was obtained for 100% and 54% of the children attending the University-affiliated public school (participation is a required condition of admission) and private school, respectively. The obtained consent rate compares favorably with that reported in other school sample studies (e.g. Kearney, Hopkins, Mauss, & Weisheit, 1983; Severson & Ary, 1983). The ethnic composition of the sample was as follows: East Asian (36%), Part-Hawaiian (23%), Caucasian (11%), Southeast Asian (4%), Pacific Islander (less than 1%), and Mixed (25%). Subjects were considered "Part-Hawaiian" if any ethnicities within their ethnic background included Hawaiian. Subjects were considered "Mixed" if the ethnicities within their ethnic background could not be categorized by a single ethnic category.

Child Intelligence

The Kaufman Brief Intelligence Test (K-BIT) consists of two subtests designed to assess domains parallel to crystallized and fluid intelligence as described by Horn and Cattell (1966), and the verbal–performance dichotomy proposed by Wechsler (1991). It yields scores on vocabulary and a matrices task similar to Raven's Matrices test (Raven, 1989). These two scores combine to yield a composite IQ, which was used as a manifest variable in the structural equation models to provide an estimate of children's intelligence (mean = 111.10; *SD* = 11.14). The psychometric properties of the K-BIT and expected patterns of relationships with other measures of intelligence are well established and detailed by Kaufman and Kaufman (1990).

Classroom Academic Performance

The Academic Performance Rating Scale (APRS) is a 19-item teacher rating scale designed to assess academic functioning in children. The instrument provides scores indicative of general academic performance and classroom behavior as well as narrower dimensions of academic accuracy and productivity. The psychometric properties of the APRS and expected patterns of relationships with other measures of academic performance, classroom behavior, and achievement are well established (DuPaul, Rapport, & Perriello, 1991). In constructing the models, a latent variable termed "classroom performance" was derived using the academic success, academic productivity, and academic efficiency (percentage of academic assignments completed correctly) scores of the APRS.

Measures of Early Disruptive Behavior

The Child Behavior Checklist (CBCL) teacher report form (TRF) is a standardized teacher rating scale that includes eight clinical syndrome scales, as well as composite indices of externalizing (undercontrolled) and internalizing (overcontrolled) broad-band syndromes, adaptive functioning, and academic performance. The psychometric properties of the CBCL-TRF are excellent and detailed by Achenbach (1991). Scores derived from three of the eight clinical syndrome scales were used in the study. A manifest variable termed "ADHD" was used in the models and derived from the attention scale raw scores. Past research indicates strong convergence between CBCL attention problem scale scores with the diagnosis of ADHD based on total predictive value and odds-ratio analyses (Biederman et al., 1993), as well as receiver operating characteristic analysis (Chen, Faraone, Biederman, & Tsuang, 1994). A latent variable termed "conduct disorder" (CD) was used in the models based on delinquency and aggressive raw scale scores, which show strong convergence with structured interview-based psychiatric diagnosis of conduct disorder (Biederman et al., 1993).

ADHD and CD are intentionally viewed as continuous dimensions of behavior problems in accordance with the normative-developmental view of child psychopathology (Achenbach, 1990), recent genetic evidence (Deater-Deckard, Reiss, Hetherington, & Plomin, 1997; Gjone, Stevenson, & Sundet, 1996; Levy, Hay, McStephen, Wood, & Waldman, 1997), previous pathway models of childhood disorders (e.g. Fergusson & Horwood, 1995; Fergusson et al., 1991, 1993, 1997), and persuasive theoretical arguments favoring the phenomenological view of dimensionality (Sonuga-Barke, 1998). The synonyms ADHD and CD used throughout this study thus refer to descriptors of behaviors characteristic of children with ADHD and CD (as opposed to categorical diagnoses) as defined by the CBCL-TRF clinical syndrome scales.

Raw scores (versus T scores) were used in the analyses as recommended by Achenbach (1991) to take account of the full range of variations in CBCL-TRF syndrome scales. This is because the assignment of T scores at the nondeviant end of each syndrome tends to artificially truncate the range of scores owing to the normalizing transformations and equal-interval assignment of extreme T scores in the initial CBCL normalization sample.

Cognitive Measures

Vigilance. Two distinct Continuous Performance Test (CPT) paradigms were programmed for use in the present investigation. The selection of paradigms was based on a comprehensive literature review that reflected their prevalent use by researchers and purported linkage to different modes of information processing (Sergeant & van der Meere, 1990). The paradigms included an "AX" (respond if "A" is immediately followed by the letter "X") and "BX" version (respond when any letter immediately repeats itself). The former is related to the automatic mode of information processing (i.e. characterized as fast, parallel, and effortless) contrasted with the more difficult controlled processing paradigm (i.e. characterized as slow, serial, and effortful) such as the "BX" or double-letter model (Coons et al., 1981; Schachar, Logan, Wachsmuth, & Chajczyk, 1988; Sergeant & van der Meere, 1990). Identical task parameters were programmed for the two paradigms. These included total test duration (three, 3-minute consecutive blocks or 9-minute test duration), stimuli (total number, size, and location of alphabetic characters), respond mode (click mechanism on a track ball device), and target density (15 and 60 per 3-minute block or 45 and 180 total targets per 9-minute session in the low and high density conditions, respectively). Basic parameters are described below.

(1) *AX version*. The low and high target density "AX" version of the CPT used in the study require the child to respond (using the click mechanism of the track ball) each time the letter "A" is immediately followed by the letter "X". Visual stimuli consisting of letters of the alphabet are presented in the center of the monitor screen (3.5 cm high, 3.5 cm wide) at 1 sec intervals (0.2 sec display, 0.8 sec intertrial stimulus interval) throughout the 9 min duration of the test. Fifteen or 60 target stimuli ("A"

followed by "X") are randomly dispersed throughout each 3 min block of the CPT, with a total of 45 or 180 target stimuli occurring during the 9 min testing session for the low and high target density versions, respectively. Each 3 min block also contains 10 "A" stimuli not followed by an "X", and 10 "X" stimuli not preceded by an "A" randomly distributed nontarget distracters. A total of 540 letters are presented during the 9 min testing session in a quasi-random sequence (exceptions noted above).

(2) *BX version*. The low and high target density "BX" or double-letter version of the CPT used in the study requires the child to respond (using the click mechanism of the track ball) on each occasion wherein an identical letter of the alphabet is displayed consecutively (i.e. repetitions of the same letter). All remaining task parameters with the exception of distracter stimuli (see above) were identical to the AX version described above.

A higher-order latent variable termed "vigilance" was derived from two first-order latent variables (AX, BX) and used in the models. The latter two variables were derived using percentage of correct identifications (hits) of target stimuli for the AX (low and high target density) and BX (low and high target density) paradigms, respectively. Vigilance was assumed to be requisite behavior for short-term memory (see below) in the model (i.e. a child must pay attention to learn paired associations).

Short-term Memory. Paired Associate Learning Tasks (PAL-T) are tests of short- to intermediate-term memory (Carroll, 1993) that are related to classroom learning (Stevenson, 1972). The task was selected based on past research indicating that children with ADHD experience particular difficulty learning paired associations involving arbitrary relationships (for a review, see Douglas & Peters, 1979).

The task requires children to learn arbitrary associations between letter bigrams (e.g. "GJ") and single numerical digits (e.g. "3") in six blocks of five bigram-digit pairs. Bigram-digit stimuli are preprogrammed in a library file and presented on a color monitor. A bigram is presented in the middle of the computer screen with its associate digit below. Children are required to place the arrow on the digit and click the track ball device to insure orientation and facilitate learning. Following presentation of five bigram-digit pairs to be learned, a test phase ensues and requires children to correctly identify (using a track ball device) the digit (digits 0 through 9 are shown at the bottom of the screen) that was previously associated with the bigram. Incorrect responses during the test phase are followed by a computer tone and corrective feedback. Bigram-digit pairs are assessed three times in random order during the test phase. Following the test phase, a new block consisting of five bigram-digit associations is presented then tested for recall. The procedure continues until all six blocks of paired associations are presented and assessed for recall.

A latent variable termed "memory" was used in the models and derived by averaging percentage accuracy scores for the three two-block combinations (i.e. blocks 1 and 2, 3 and 4, 5 and 6, respectively).

Measures of Scholastic Achievement

The Stanford Achievement Test (SAT; 1996) is a national, group-administered test used to assess scholastic achievement across multiple domains in 3rd to 12th grade children and for purposes of college entry. A latent variable termed "scholastic achievement" was used in the models and derived from total reading, total math, and total language scale scores. Scale scores represent approximately equal units on a continuous scale, using numbers that range from 1 through 999, and are suitable for studying change in performance over time. SAT scores were collected between 3 to 4 years after children were initially tested at the clinic (note: the difference in time frame for collecting SAT data is related to when subsequent testing is conducted by the schools, viz., 3rd, 6th, 9th, 11th, and 12th grades).

SAT scores differ from measures of classroom academic performance (see APRS measure, above) in several important ways. Classroom performance traditionally refers to children's everyday behavior within a classroom, which entails a variety of behaviors (e.g. motivation, prior learning, concentration) and the completion of assigned academic work (i.e. how well they *perform* in class). Behaving appropriately and completing assignments accurately and in a timely fashion, however, does not translate directly into improved scholastic achievement (e.g. a child may have poor memory for learning facts or related academic information, and other factors contribute to scholastic achievement such as early schooling, IQ, and parent involvement). Conversely, scholastic achievement as measured by the SAT and similar instruments assess the extent to which children have learned or mastered information and can *recall* it accurately under standardized test situations. The two factors are clearly related (share variance), as one would expect. Higher levels of classroom performance account for significant variance in terms of long-term recall on standardized achievement tests, but other factors also contribute significantly to this measure, such as the ability to pay attention (vigilance) and memory, as hypothesized in the dual pathway model.

Socioeconomic, Age, and Other Factors

To control for the associations between early disruptive behavior and later academic outcomes, two potentially confounding factors measured concomitant with externalizing behaviors were considered in both models (i.e. Replication and Dual Pathway Model, respectively). Socioeconomic status (SES) of each child's family was computed using the Duncan Index (Duncan, 1961). The relationship between SES and the various independent and dependent variables were found to be low and nonsignificant for both models. The only exceptions to this pattern were the associations between SES and IQ ($r = .29$) and SES and ADHD ($r = -.11$). As a result, effects of SES were adjusted for in all the relationships depicted in the models, although SES was omitted from the diagrams for purposes of visual clarity.

Age effects were considered noncontributory for the Replication Model. Age-adjusted scores (IQ, SAT) were used in both models, and CD and ADHD were not significantly related to age (see Table 1). In contrast, it was necessary to partial age effects from the vigilance, short-term memory, and APRS measures owing to their significant and expected relationship with these variables (i.e. $\beta = .68$, .47, and .15, respectively). As a result, effects of age were adjusted for in all the relationships depicted in the models, although age was omitted from the diagrams for purposes of visual clarity. Raw correlations among measures (i.e. not residual scores) are presented in the table to enable independent replication of the models.

A final point concerning the use of APRS and CBCL rating scale scores merits discussion owing to the possible confound with respect to both method and information source, since both were based on teacher report. Method variance usually describes systematic variation in responses on separate psychometric instruments due to commonalities across measures with respect to formatting (e.g. scaling, phraseology, etc.). Conversely, information-source variance refers to systematic response sets arising out of respondents' idiosyncrasies independent of item content. Method variance is unlikely to have contributed to our results given that the two instruments in question utilize scales that differ markedly in range (i.e. 0–2 versus 1–5) and

Table 1
Matrix of Correlations and Standard Deviations of Measures of ADHD, CD, IQ, Classroom Performance, Vigilance, Memory, Scholastic Achievement, Age, and SES

		CD			Classroom performance			Vigilance				Memory			Scholastic achievement				
								AX		BX									
Measure	ADHD	Del	Agg	IQ	AS	AP	AE	Low	High	Low	High	B12	B34	B56	Rdg	Math	Lang	Age	SES
ADHD	1.000																		
CD																			
Delinquency	.576	1.000																	
Aggression	.610	.788	1.000																
IQ	−.276	−.260	−.169	1.000															
Classroom performance																			
AS	−.609	−.349	−.317	.572	1.000														
AP	−.772	−.502	−.468	.483	.868	1.000													
AE	−.685	−.432	−.417	.472	.864	.893	1.000												
Vigilance																			
AX Low	.042	−.008	.021	.126	−.031	.013	−.053	1.000											
AX High	−.070	−.073	−.094	.161	−.007	.048	−.004	.726	1.000										
BX Low	−.105	−.103	−.078	.117	.012	.080	.000	.487	.651	1.000									
BX High	−.186	−.128	−.118	.186	.097	.144	.071	.523	.675	.763	1.000								
Memory																			
B12	−.184	−.117	−.106	.211	.142	.167	.109	.385	.433	.493	.489	1.000							
B34	−.176	−.169	−.132	.231	.163	.169	.143	.393	.462	.528	.500	.658	1.000						
B56	−.150	−.132	−.106	.245	.157	.164	.134	.426	.490	.535	.528	.626	.726	1.000					
Scholastic achievement																			
Reading	−.289	−.218	−.189	.456	.370	.334	.281	.378	.488	.520	.502	.517	.548	.622	1.000				
Math	−.359	−.249	−.232	.386	.402	.408	.367	.331	.454	.520	.472	.534	.544	.589	.805	1.000			
Language	−.417	−.269	−.262	.459	.434	.423	.403	.266	.411	.452	.453	.457	.488	.515	.781	.751	1.000		
Age	.062	.078	.058	−.154	−.227	−.201	−.280	.474	.532	.614	.508	.497	.514	.553	.521	.522	.341	1.000	
SES	−.112	−.095	−.078	.294	.214	.189	.225	−.047	−.093	−.053	−.035	.014	−.007	.025	.115	.070	.101	−.111	1.000
SD	4.790	1.043	4.598	11.872	5.258	7.149	1.427	10.454	11.905	20.293	19.143	2.768	3.138	3.491	45.124	51.754	38.955	2.392	18.661

Del = CBCL Delinquency scale score; Agg = CBCL Aggression scale score; AS = Academic Success; AP = Academic Productivity; AE = Academic Efficiency; B12 = Blocks 1 & 2; B34 = Blocks 3 & 4; B56 = Blocks 5 & 6; Rdg = SAT Reading total scaled score; Math = SAT Math total scaled score; Lang = SAT Language total scaled score.

response-option content. Moreover, the risk of bias due to reliance on a single information source for data related to classroom behavior and academic performance has to be weighed against the benefit of using informants who are best equipped to provide data related to children's everyday classroom functioning.

The remaining question concerns the psychometric distinctions between the two constructs, which is traditionally evaluated by examining the known psychometric characteristics of each scale and examining the convergent–divergent validity of the two measures. The psychometric properties of the two scales have been described (Achenbach, 1991; DuPaul et al., 1991) and evidence concerning the convergent–divergent validity of the instruments can be ascertained by examining the correlation matrix presented in Table 1. APRS factors correlate more highly with each other than with ADHD ratings, and the factor loadings associated with the APRS (depicted in Fig. 3) reveal strong internal validity.

Procedures

Each child was seen once per week over a 2-week time period at the Children's Learning Clinic and classroom teachers completed the CBCL-TRF and APRS during this time frame. Children's intelligence (K-BIT), vigilance (CPT), and ability to learn arbitrary paired associations (PAL-T) were individually assessed by trained graduate students for approximately 1.5 hours during each of the two clinic visits. Ordering of testing was counterbalanced and scheduled such that only two CPTs were administered on a given day with a minimum of 45 min between administrations. Breaks (5 min) were scheduled between tests to minimize fatigue.

Prior to formal testing children were required to (a) identify letters of the alphabet to insure letter recognition, and (b) participate in 1 min practice sessions on the CPT and PAL-T. Children were seated such that the computer monitor was approximately 0.5 m from the child with the center of the screen at eye level. An experimenter was present throughout all testing, situated approximately 3 m behind the child during administration of the CPT and PAL-T. For the CPT, a different, randomly determined sequence of letters and targets adhering to the identical experimental parameters described above was used during each successive testing session (i.e. pre-built into a CPT library file).

In summary, all teacher ratings and clinical assessment were collected at a single point in time, whereas SAT scores were obtained at 3–4-year follow-up.

Results

A two-tier approach was used to address the primary purposes of the study. In the first tier, we sought to replicate the primary associations posited in Fergusson et al.'s (1993; Fergusson, & Horwood, 1995) model. Attention deficit behaviors (ADHD) were expected to show a direct, yet moderate, relationship with later scholastic achievement after accounting for its correlations with IQ and CD [see Fig. 1(a)]. Conversely, conduct problems (CD) were expected to be unrelated to later scholastic achievement after accounting for its correlations with ADHD and IQ. A Dual Pathway Model was evaluated subsequently [see Fig. 1(b)], wherein specific behavioral and cognitive variables were hypothesized to mediate the relationship between ADHD, IQ, and later scholastic achievement. Both models were fitted to the covariance matrix of 19 indicator variables shown in Table 1 (8 variables for the Replication Model; all 19 for the Dual Pathway Model) using EQS (Bentler, 1989; 1992a) and methods of maximum-likelihood estimation. In keeping with convention, the measurement portion of each model is discussed prior to explication of the structural components of the models (Hoyle & Panter, 1995).

Model identification for the replication and dual pathway models was achieved by fixing the unstandardized loading of one indicator variable for each of the latent variables in the models. This procedure is followed because latent variables are not directly measured and thus require a measurement scale in order for the computer to calculate estimates of effects that involve them. Fixing the unstandardized loading of one indicator per factor to 1.0 gives the latent variable the same metric as that indicator (i.e. a 1-point increase in the factor is associated with a 1-point increase in the indicator variable). Once the unstandardized loading is fixed, EQS estimates the total and error variance associated with the indicator from which its standardized loadings (as shown in the figures) can be determined.

Absolute and incremental fit indices were used to evaluate the extent to which the proposed models accounted for observed relationships among variables. The selection of specific fit indices was based on extensive review of the structural equation literature and recommendations contained therein (see Bentler, 1992b; Kline, 1998; Maruyama, 1998).

Absolute indices.

(1) The Root Mean Square Error of Approximation (RMSEA; Browne & Cudeck, 1993) represents the average difference between correlations expected on the basis of a model's assumptions and those observed among measured variables. This index includes an adjustment for the number of variables incorporated into a model so that parsimony is taken into account. Values falling below .10 indicate adequate fit (Kline, 1998). Departure of this index from the desired range is evaluated for statistical significance by means of a 90% confidence interval.

(2) The Standardized Root Mean Squared Residual (SRMR) is an index based on the average of standardized covariance residuals. Standardized covariance residuals represent the differences between observed and model-implied correlations. Values less than 0.10 indicate that a model adequately accounts for the observed correlations among variables incorporated into a model.

Incremental indices.

(1) The Comparative Fit Index (CFI: Bentler, 1990) indicates the proportional improvement in overall fit of a model relative to a null model in which all the observed variables are assumed to be uncorrelated. An obtained CFI value of .98, for example, indicates that the overall fit of the model is 98% better than that of the null model estimated with the same sample data.

(2) The Bentler-Bonnett Nonnormed Fit Index (NNFI) indicates the proportion in the improvement of the overall fit of the researcher's model relative to a null model, and additionally adjusts the proportion of explained variance for model complexity.

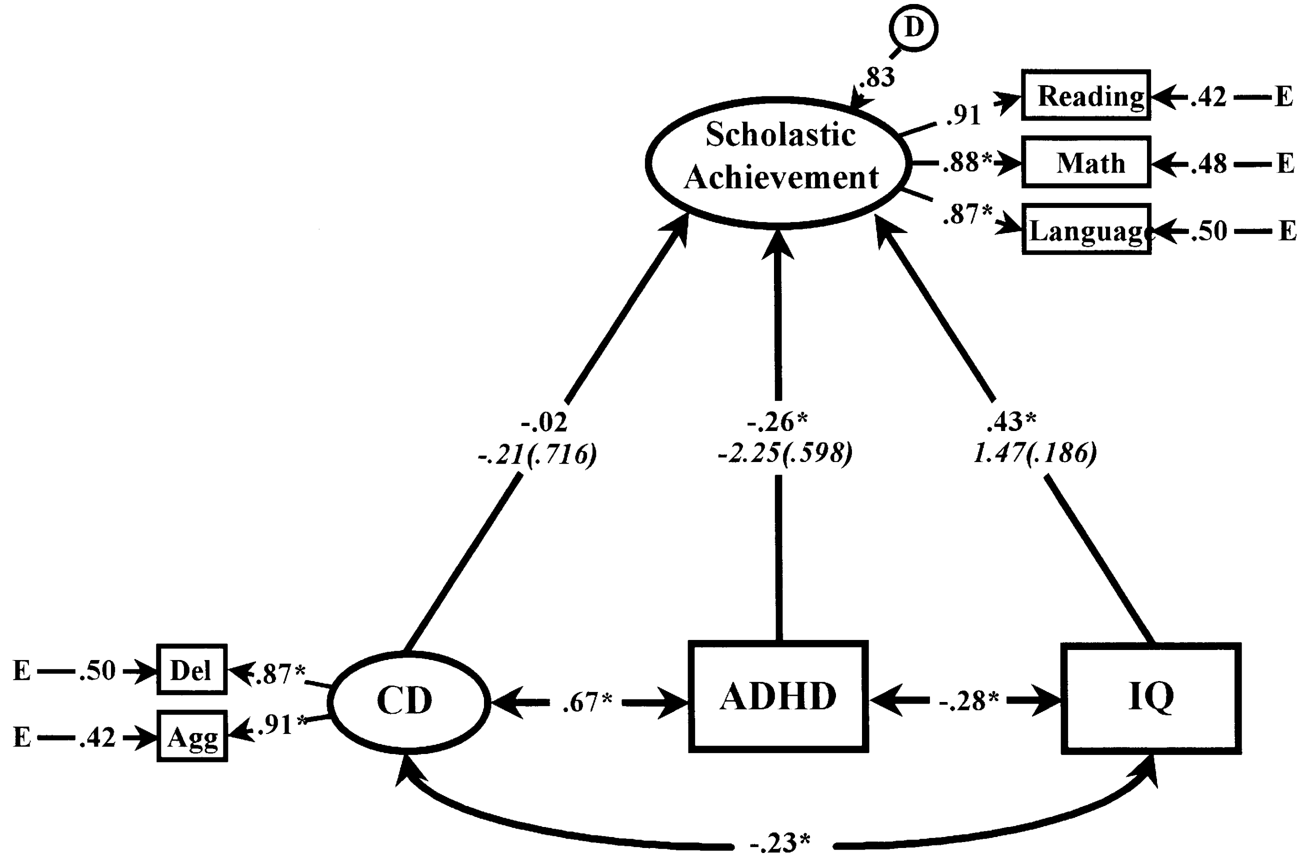

Figure 2. Fitted Replication Model depicting the relationships among CD, ADHD, IQ, and later Scholastic Achievement. Rectangles and ovals represent manifest (measured) and latent variables, respectively. Double-headed arrows represent nondirectional correlations and associated coefficients. Single-headed arrows between CD, ADHD, IQ and Scholastic Achievement represent regression pathways and associated standardized coefficients. Unstandardized values and standard errors (in brackets) are shown in italics immediately below the standardized coefficients. Single-headed arrows between latent constructs (CD, Scholastic Achievement) and measured variables represent confirmatory factor analysis paths and associated factor loadings. E = measurement error. D = disturbance term value and indicates error in the prediction of the latent variable. $*p < .05$. Comparative Fit Index (CFI) = .98.

Ideally, low RMSEA and SRMR values should be observed in conjunction with high CFI and NNFI values. This pattern shows that a proposed model accounts satisfactorily for observed variances and covariances, and that the observed variances and covariances are large enough to be meaningful.

Replication Model

The measurement component of the Replication Model describes the relationships between the two sets of manifest variables (i.e. Set 1: Delinquency and Aggression; Set 2: Reading, Math, and Language) and their respective latent constructs (i.e. CD and Scholastic Achievement). The factor loading of an indicator variable represents its correlation with the construct it is presumed to measure. The psychometric reliability of the indicator is equal to the proportion of its variance explained by the underlying construct. Thus, an indicator's reliability is determined by squaring its factor loading. The proportion of its variance that is unexplained (i.e. unique) is the complement of this value (i.e. 1 minus squared loading). This value can also be obtained by squaring the value labeled "E" in Fig. 2.

The squared loadings for reading, math, and language SAT composite scores were .83, .77, and .76, respectively, indicating good internal consistency of these measures (see Fig. 2). A similar range of factor loadings was found for CD, indicating strong internal consistency.

The structural component of the Replication Model describes the linkages between the three independent (CD, ADHD, IQ) and one dependent variable (Scholastic Achievement). These variables are assumed to be related by the following causal structure:

(1) Conduct problems (CD), attention deficit behaviors (ADHD), and intelligence (IQ) are assumed to be correlated, exogenous, or independent variables;
(2) ADHD is directly related to later Scholastic Achievement after controlling for its correlation with IQ, and IQ is directly relate to Scholastic Achievement after controlling for its correlation with ADHD;
(3) CD is unrelated to Scholastic Achievement after controlling for its correlation with ADHD and IQ.

Fit indices were calculated initially in our evaluation of the Replication Model. Absolute (RMSEA = .07; 90% confidence interval = .05–.10; SRMR = .001) and incremental fit indices (CFI = .98; Bentler-Bonnett NFI = .96) coupled with low residuals (Average Absolute Standardized Residuals = .01) indicate a strong fit between the variance/covariance matrix for the sample data and hypothesized model.

The patterns of associations observed among independent variables was identical to those in Fergusson et al.'s (1993; Fergusson & Horwood, 1995) model. A positive correlation emerged between CD and ADHD ($r = .67$; $p < .0001$), and negative correlations emerged between IQ and the two disruptive behavior constructs (IQ-ADHD, $r = -.28$, $p < .0001$; IQ-CD, $r = -.23$, $p < .0001$). The magnitude of effects between variables was similar albeit somewhat smaller than those reported by Fergusson et al. (1993; Fergusson & Horwood, 1995).

The relationships between the independent variables and later Scholastic Achievement were strikingly similar in magnitude to those reported by Fergusson et al. (1993; Fergusson & Horwood, 1995). There was strong continuity between IQ and Scholastic Achievement. The standardized regression coefficient linking these constructs was .43 ($p < .0001$). In contrast, the relationship between ADHD and Scholastic Achievement was significant but more moderate in magnitude. The standardized regression coefficient linking these variables was $-.26$ ($p < .0001$). Conduct problems (CD) were not significantly related to scholastic achievement ($\beta = -.02$, n.s.), after accounting for its correlation with ADHD (.67) and IQ ($-.23$).

Collectively, these results strongly parallel those in Fergusson et al.'s (1993; Fergusson & Horwood, 1995) original model, despite the use of a different design and a sample drawn from a different nation. ADHD, CD, and IQ are all correlated with one another, whereas only ADHD and IQ are directly predictive of later Scholastic Achievement. As a final consideration, note the disturbance term in Fig. 2 (see "D"), which indicates error in the prediction of Scholastic Achievement. The obtained disturbance value of .83 for Scholastic Achievement in this model suggests that a considerable proportion of variance (69%) is unaccounted for by the indicators, and that additional variables or pathways between early IQ, disruptive behaviors, and later scholastic achievement may be required.

Dual Pathway Model

The Dual Pathway Model tests the plausibility of pathways hypothesized to mediate the relationship between ADHD and Scholastic Achievement. Specifically, it posits that classroom performance mediates this relationship by means of a "behavioral" pathway, and that vigilance and memory mediate this relationship by means of a "cognitive" pathway [see Fig. 1(b)].

The measurement component of the Dual Pathway Model describes the relationships between five sets of indicator variables (Set 1: Delinquency and Aggression; Set 2: percentage hits on AX and BX versions of the CPT at two levels of target density [low and high]; Set 3: percentage accuracy scores for three two-block combinations on the PAL-T; Set 4: APRS scores for each of the three factors—Academic Success, Academic Productivity, and Academic Efficiency; Set 5: SAT Reading, Math, and Language composite scores) and their respective latent constructs (CD, Vigilance, Memory, Classroom Performance, and Scholastic Achievement). Factor loadings within the measurement component of the Dual Pathway Model ranged between .75 and .97, indicating good internal consistency for each of the latent variables (see Fig. 3).

The structural component of the Dual Pathway Model describes the linkages between the three independent (CD, ADHD, IQ) and four dependent variables (Vigilance, Memory, Classroom Performance, and Scholastic Achievement). The relationships among these variables are presumed to reflect the following causal structure:

(1) Conduct problems (CD), attention deficit behaviors (ADHD), and intelligence (IQ) are assumed to be correlated, exogenous or independent variables;
(2) CD is unrelated to Scholastic Achievement after its correlations with ADHD and IQ are taken into account;
(3) ADHD is related to later Scholastic Achievement by means of two corresponding pathways, one behavioral (Classroom Performance) and the other cognitive (Vigilance and Memory);
(4) Within the cognitive pathway, vigilance represents a requisite skill for memory;
(5) IQ exerts both direct and indirect effects on later scholastic achievements, the latter by means of its influence on daily classroom performance;
(6) IQ exerts a direct influence on children's short-term memory, but not vigilance based on extant literature.

Within the structural component of the Dual Pathway Model, the significant correlations among the three independent variables CD, ADHD, and IQ were identical to those found in the Replication Model.

Fit indices were calculated initially in our evaluation of the Dual Pathway Model. Absolute (RMSEA = .08; 90% confidence interval = .07–.09; SRMR = .005) and incremental fit indices (CFI = .94; Bentler-Bonnett NFI = .92) indicate a strong fit between the variance/covariance matrix for the sample data and hypothesized model.

Inspection of the behavioral pathway reveals significant relationships among all specific components after allowance is made for measurement error in the indicator measures (see "Es" in Fig. 3). Strong and statistically significant continuity was evident between ADHD and Classroom Performance. The standardized regression coefficient linking these variables was $-.67$ ($p < .0001$). The relationship between Classroom Performance and later Scholastic Achievement was also significant but more moderate as indicated by a regression coefficient of .19 ($p < .0001$). (Note: The standardized regression coefficient of .19 indicates that children differing by 1 *SD* in classroom performance differed by 0.19 *SD* in later SAT scores after controlling for individual differences in IQ and ADHD.)

Significant relationships were also found for all variables specified in the cognitive pathway after allowing for

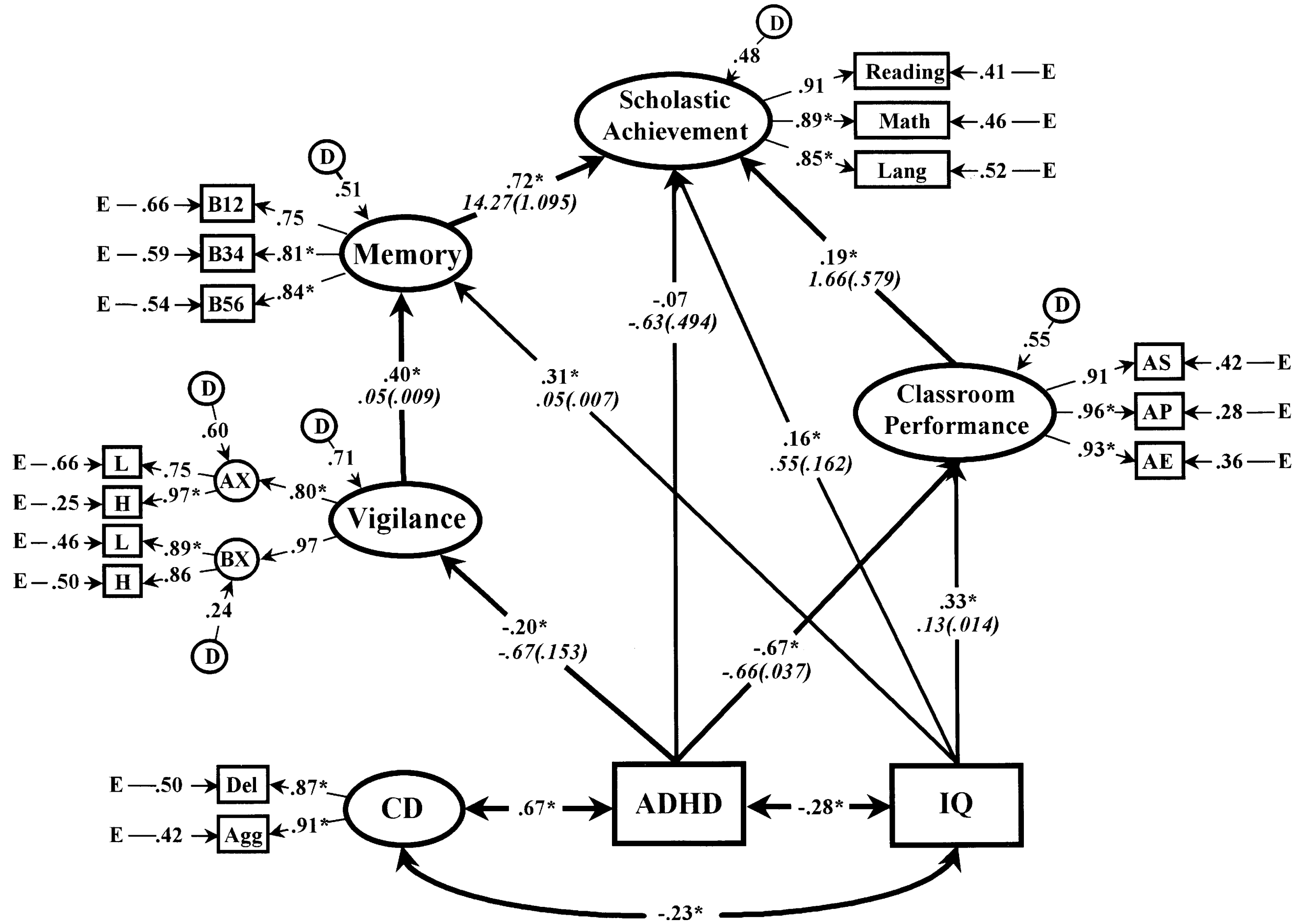

Figure 3. Fitted Dual Pathway Model depicting the relationships among CD, ADHD, IQ, and later Scholastic Achievement and the mediating influence of cognitive (vigilance, memory) and behavioral (classroom performance) variables. Rectangles and ovals represent manifest (measured) and latent variables, respectively. Double-headed arrows represent nondirectional correlations and associated coefficients. Single-headed arrows between CD, ADHD, IQ and mediating cognitive (vigilance, memory) and behavioral (classroom performance) variables and later Scholastic Achievement represent regression pathways and associated standardized coefficients. Presented in italics below each standardized coefficient are their respective unstandardized values with standard errors in parentheses. Single-headed arrows between latent constructs (CD, Scholastic Achievement, Vigilance, Memory, Classroom Performance) and measured variables represent confirmatory factor analysis paths and associated factor loadings. E = measurement error. D = disturbance term value and indicates error in the prediction of the latent variable. $*p < .05$. Comparative Fit Index (CFI) = .94. Measurement of memory was derived using combined two-block trials (B12, B34, B56) from the PAL-T. Measurement of vigilance was derived using two versions of the CPT (AX, BX) with each version administered under low (L) and high (H) target density conditions. Measurement of classroom performance was derived from three subscales of the APRS (AS = academic success; AP = academic productivity; AE = academic efficiency). Measurement of Scholastic Achievement was derived from three composite indices of the Stanford Achievement Test (Reading, Math, and Language).

measurement errors in the indicator measures. ADHD was moderately predictive of Vigilance, and Vigilance moderately predictive of Memory as evidenced by the standardized regression coefficients linking these two pairs of variables ($-.20$, $p < .0001$; and .40, $p < .0001$, respectively). The final component of the cognitive pathway, Memory, was strongly prognostic of later Scholastic Achievement. The standardized regression coefficient linking these two variables was .72 ($p < .0001$, see Fig. 3).

The direct relationship between Intelligence (IQ) and later Scholastic Achievement remained significant but was weakened considerably compared to the Replication Model (i.e. the standardized regression coefficient was reduced from .43 to .16). Inspection of the model (see Fig. 3) suggests that both behavioral and cognitive pathways mediate the association between IQ and Scholastic Achievement (i.e. the influence of IQ on Scholastic Achievement is due primarily to its association with mediating pathways). For example, IQ was moderately predictive of Classroom Performance and Memory, as evidenced by the standardized regression coefficients linking these two pairs of variables (.33, $p < .0001$; and .31, $p < .0001$, respectively).

Comparison of the Replication and Dual Pathway Models reveals two interesting findings. First, the significant relationship between ADHD and Scholastic Achievement observed in the Replication Model was negligible ($-.07$) and nonsignificant in the Dual Pathway Model. Second, the disturbance term indicating error of prediction (i.e. unexplained variance) in Scholastic Achievement is much smaller in magnitude in the Dual

Pathway Model (.48) than in the Replication Model (.83). This indicates that the Dual Pathway Model explains a greater proportion of variance in Scholastic Achievement than the Replication Model (77% vs. 31%).

Finally, the direct relationships between CD and Vigilance and between CD and Classroom Performance were subsequently analyzed to test the possibility that CD directly affects Vigilance and Classroom Performance after controlling for its correlations with ADHD and IQ. The results revealed that both direct relationships were weak and nonsignificant ($\beta = -.12$, $\beta = .03$, respectively).

Discussion

The initial purpose of this study was to replicate the segment of the general structural model proposed by Fergusson et al. (1993; Fergusson & Horwood, 1995) that describes the developmental progression of early externalizing behaviors (ADHD, CD) to later scholastic achievement. Our results corroborate Fergusson et al.'s findings. Teacher ratings of CD and ADHD behavior problems were strongly correlated with one another and inversely related to intelligence. Both IQ and ADHD showed strong continuity with later scholastic achievement, whereas CD was related to scholastic achievement only by means of its correlations with ADHD and IQ. Moreover, the general pattern of results was identical to those reported by Fergusson et al. Collectively, these findings indicate a successful replication of the general structural model posited by Fergusson et al., and are particularly noteworthy given differences in sample (smaller, more ethnically diverse) and design (cross-sectional versus longitudinal; the use of different measures for assessing constructs) characteristics between the two studies. The relatively high disturbance term value associated with scholastic achievement, however, indicates that a considerable proportion of variance (69%) associated with the prediction of long-term scholastic achievement remains unexplained by the Replication Model. This strongly implies that a comprehensive model relating disruptive behavior to achievement must incorporate additional variables.

For the second part of the study, we hypothesized that two parallel pathways (one behavioral, the other cognitive) may account for a significant proportion of the unexplained variance in the Replication Model. A review of extant literature and theory suggested that ADHD-related behavior problems may interfere with scholastic achievement by virtue of their impact on classroom performance and select cognitive abilities. That is, ADHD should be negatively associated with both vigilance-memory abilities (cognitive pathway) and classroom performance (behavioral pathway), but exert its greatest influence on the latter. Both pathways should show continuity with long-term scholastic achievement. The direct relationship between ADHD and scholastic achievement in the Replication Model should thus be severely attenuated or rendered nonsignificant to the extent that the mediating pathways explain the contiguous relationship between ADHD and scholastic achievement. Results from the structural equation model analysis were consistent with this hypothesis and imply that ADHD affects both behavioral and cognitive mediating variables which, in turn, account for the association between ADHD features and scholastic achievement.

Variables specified within the behavioral and cognitive pathways were also hypothesized to mediate the strong continuity between IQ and later scholastic achievement as suggested by Fergusson et al.'s (1993; Fergusson & Horwood, 1995) original model and our replication thereof. That is, the strong continuity between early IQ and later scholastic achievement should be attenuated but not eliminated if the influence of IQ on scholastic achievement is partially accounted for by its association with memory (cognitive pathway) and classroom performance (behavioral pathway). Results from the structural equation analysis were consistent with this hypothesis. The direct effect of IQ on long-term scholastic achievement was relatively weak (i.e. $< 3\%$ of the variance) after accounting for the mediating effects of behavioral and cognitive variables.

Collectively, the expanded Dual Pathway Model accounts for substantially more variance in scholastic achievement than the Replication Model does (i.e. 77% vs. 31%). This is indicated by the reduced disturbance term associated with scholastic achievement in the Dual Pathway Model. The association between IQ and memory is similar in magnitude to the relationship between IQ and classroom performance. This suggests that IQ affects both pathways to a similar extent. In contrast, ADHD behavior problems bear a stronger relationship to classroom performance than vigilance. This finding may reflect several factors. ADHD behavior ratings and classroom performance share common method and information-source variance, as both measures are derived from teacher ratings. Alternatively, previous studies documenting vigilance deficits in children with ADHD have traditionally contrasted reasonably well-defined, clinically referred children with normal controls as opposed to using a nonreferred sample and ADHD continuous score ratings. A more robust relationship between ADHD and vigilance would probably be obtained using children with documented pervasive and more severe symptomatology. Finally, it may be that vigilance captures only a small proportion of the cognitive deficits characteristic of ADHD. For example, vigilance is generally found to be weakly or unrelated to intelligence (for a review, see Rapport, Chung, & Denney, 1999), whereas both vigilance and general cognitive ability (IQ) bear a stronger association with specific cognitive abilities such as memory. The stronger continuity between memory (contrasted with classroom performance) and scholastic achievement, coupled with the relatively weak direct relationship between IQ and scholastic achievement, suggests that memory and other select cognitive processes may play an important role in understanding children's scholastic achievement as well as core features of ADHD.

The linkage between ADHD and poor cognitive and academic performance (August & Stewart, 1982; Hinshaw, 1987; McGee, Williams, & Silva, 1984; Schachar, Rutter, & Smith, 1981), and between ADHD and scholastic achievement (August & Garfinkel, 1989; Cantwell & Satterfield, 1978; Carlson, Lahey, & Neeper, 1986; Holborow & Berry, 1986; Lambert & Sandoval, 1980; Leung & Connolly, 1994; Schachar et al., 1981;

Schachar & Tannock, 1995; Share, Moffitt, & Silva, 1988) is well documented. These findings are evident even after controlling for comorbid conduct problems in children with ADHD (Farrington et al., 1990; Fergusson & Horwood, 1995; Fergusson et al., 1993; Frick et al., 1991; Loney & Milich, 1982; McGee, Williams, & Silva, 1985; Stewart, Commings, Singer, & DeBlois, 1981) and comorbid ADHD problems in children with conduct problems (Farrington et al., 1990; Loney & Milich, 1982; McGee et al., 1984). Our results substantiate this relationship and support the view that classroom behavior and memory processes mediate the impact of ADHD on scholastic achievement. Whether select cognitive problems are general to ADHD or unique to subgroups of these children poses an interesting empirical question. August and Garfinkel's (1989) study of nonreferred, elementary school children with identified ADHD or CD problems based on multiple rating scale score cutoffs provide some support for this latter possibility. Behavioral and cognitive subtypes of ADHD were identified. Only the cognitive subtype alone was associated with severe academic underachievement, information processing deficits, and lower general intelligence.

The relationship between ADHD and general intelligence reported by Fergusson et al. (1993; Fergusson & Horwood, 1995) and corroborated herein poses an interesting conceptual dilemma. For example, ADHD may be a cause of cognitive delay, cognitive delay may place children at greater risk for developing behavior problems, or the relationship may be spurious and reflect the presence of other vulnerabilities. Past studies and reviews indicate that early behavior problems may precipitate later underachievement and, conversely, that behavior problems may emerge anew from a history of school failure in select groups of children (Hinshaw, 1992; Maughan, Gray, & Rutter, 1985). Epidemiological (McGee et al., 1985; Schachar et al., 1981; Taylor, Sandberg, Thorley, & Giles, 1991) and comparative studies contrasting diagnostic groups (August & Stewart, 1982; Werry, Elkind, & Reeves, 1987) have consistently demonstrated that ADHD is negatively associated with IQ, but have not disentangled issues concerning causality and directionality. Goodman and Stevenson's (1989) examination of 570 twins, however, shed some light on the controversy. Their results indicate that ADHD symptomatology is related to cognitive dysfunction even after controlling for IQ. Since the influence of IQ was statistically controlled, this finding suggests that ADHD is associated with one or more specific cognitive deficits rather than a general intellectual limitation.

A more recent study by these authors (Goodman, Simonoff, & Stevenson, 1995) using an epidemiological sample of 411 twins of normal intelligence also found significantly more behavior problems among children with lower IQ based on a multivariate comparison of different predictors. The authors concluded that the pathway from lower IQ to psychopathology is neither entirely mediated by lower academic attainment nor entirely explained by general cognitive ability, and suggests that between-individual variations in neuronal organization may account for the correlated variations in IQ and behavior. Subtle differences in brain circuitry between children with ADHD and normal controls (Castellanos et al., 1996; Chabot & Serfontein, 1996), combined with heritability estimates of attention (Gjone et al., 1996) and impulsivity (Levy et al., 1997), suggest that ADHD represents a quantitative extreme of the general population. These issues await further study.

The value of the present study was to identify the developmental sequences that arise from the correlated effects of ADHD and intelligence, which are well established by 8 years of age (Fergusson & Horwood, 1995; Fergusson et al., 1993), to later scholastic achievement by means of their mediating influence on children's classroom behavior and select areas of cognitive function. In considering this goal, several caveats are in order. Our sample size was smaller than previous studies invoking a SEM approach, involved a nonclinical sample, was limited to a 4-year follow-up period of evaluation, and relied exclusively on teacher ratings for identifying ADHD- and CD-related behavior problems. Nevertheless, our results were highly consistent with those of previous studies examining the developmental progression of early externalizing behavior problems, IQ, and later scholastic achievement, and provide a strong fit between the hypothesized model and data while controlling for measurement error. It is important to point out, however, that SEM (like ANOVA or regression) cannot be used specifically to test directional hypotheses. Directional associations are distinguished from nondirectional relationships either by logic (e.g. SES cannot cause biological gender), theory or, most persuasively, by research design. Thus, the strength of our hypothesized model rests on past research findings that have established relatively clear relationships among the proposed variables and constructs, but leave open the possibility that alternative models may adequately account for the observed relationships.

Finally, our findings have some implications for the field. The developmental trajectory of children with ADHD is reasonably well established by structural models and long-term outcome studies (e.g. Klein & Mannuzza, 1991). Information concerning the range and specific types of cognitive difficulties and the means by which they mediate long-term outcome and particularly scholastic achievement, however, remain poorly understood. We speculate that specific aspects of working memory and their related anatomical and neuronal underpinnings are implicated in ADHD and merit empirical scrutiny in future studies.

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