Published in final edited form as:

J Learn Disabil. 2016 July ; 49(4): 410–423. doi:10.1177/0022219414555715.

An Examination of the Associations between ADHD, Homework Behavior and Reading Comprehension

Callie W. Little, M.S.[1], **Sara A. Hart, Ph.D.**[1,2], **Christopher Schatschneider, Ph.D.**[1,2], and **Jeanette Taylor, Ph.D.**[1]

Callie W. Little: little@psy.fsu.edu; Sara A. Hart: shart@fcrr.org; Christopher Schatschneider: schatschneider@psy.fsu.edu; Jeanette Taylor: taylor@psy.fsu.edu

[1]Department of Psychology 1107 W. Call Street, Florida State University, Tallahassee, FL, 32306, USA

[2]Florida Center for Reading Research 2010 Levy Avenue, Florida State University, Tallahassee, FL, 32310, USA

Abstract

Previous literature has indicated an important association between reading comprehension and both ADHD and homework habits. This investigation sought to extend previous knowledge by providing information about how ADHD and homework behavior (i.e., completing homework regularly) may jointly influence reading comprehension. Using a genetically sensitive design, this study examined the genetic and environmental influences on and between ADHD, homework behavior and reading comprehension. Participants for this study included 691 twin pairs (351 monozygotic, 340 same-sex dizygotic) from the Florida Twin Project on Behavior and Environment (FTP-BE) and 2647 twin pairs (865 monozygotic, 1782 dizygotic) from the larger Florida Twin Project on Reading (FTP-R) in grades 3 through 7. Three separate models, each representing a different definition of ADHD (full ADHD, Inattention only, and Hyperactivity/Impulsivity only), showed similar patterns of results, therefore, results of the full ADHD model are discussed. Overlapping genetic influences were found between ADHD, homework behavior and reading comprehension, but no shared environmental influences among all three. However, shared environmental influences overlapped between homework behavior and reading comprehension. Although the sources of this environmental overlap are unknown, these results have implications for improving homework practices and their subsequent influence on literacy skills through homework environments.

Reading comprehension is an essential ability and an important facet of achievement which consists of several component skills of language and reading such as decoding, reading fluency, language comprehension and vocabulary (Cain, Oakhill, Wagner, Schatschneider, & Phythian-Sence, 2009; Gough & Tunmer, 1986; Kim, Wagner, & Foster, 2011; Olson et al., 2011). Reading comprehension has critical importance for students' current and future success through facilitating the acquisition of new knowledge and information that is crucial to success in higher education as well as through successful navigation of daily processes such as reading prescriptions and road signs or finding people and businesses in a phone book (Berkman, Sheridan, Donahue, Halpern, & Crotty, 2011; Kirsch, 1993; Shanahan et al., 2010). Difficulties in reading comprehension by third grade can lead to later achievement difficulties and a higher chance of dropping out of high school or failing to attend college

(Hernandez, 2011). Reading comprehension is impacted by biological, behavioral and environmental influences, and understanding the role of these factors can lead towards understanding why some children struggle with reading for understanding (Keenan, Betjemann, Wadsworth, DeFries, & Olson, 2006).

One important correlate of reading comprehension is Attention-deficit/hyperactivity Disorder (ADHD). Attention-deficit/hyperactivity Disorder affects approximately 7% of U.S. children aged three to seventeen (Boyle et al., 2011). Attention-deficit/hyperactivity Disorder is characterized by higher than average hyperactivity and inattention, but has also been associated with deficits in executive functioning (Pennington, Groisser, & Welsh, 1993; Rapport et al., 2008). Difficulties in reading comprehension have been identified in conjunction with ADHD with ADHD and reading comprehension deficits occurring together more often than expected by chance (Brock & Knapp, 1996). Explorations of the bivariate relations between the Inattention and Hyperactivity/Impulsivity factors of ADHD and a composite of reading skills (including reading comprehension) have indicated that genetic influences shared between ADHD and reading skills are significantly influenced by inattention symptoms, but not always symptoms of hyperactivity (Willcutt, Pennington, & DeFries, 2000; Willcutt, Pennington, Olson, & DeFries, 2007). Attentional mechanisms have been hypothesized to play an important role in reading comprehension abilities (Shaywitz & Shaywitz, 2008). Further investigation has found evidence of significant relations between measures of attention and reading comprehension, suggesting that attention deficits in ADHD may have a direct impact on reading comprehension (Stern & Shalev, 2013). Additionally, deficits in working memory or executive functioning among individuals with ADHD may contribute to difficulties in reading comprehension, however, the relation between ADHD and reading comprehension is still not fully understood (Ghelani, Sidhu, Jain, & Tannock, 2004; Miller et al., 2013; Willcutt et al., 2000).

In addition to its direct association with deficits in reading comprehension, ADHD may influence behavioral practices associated with the development of reading comprehension. Homework has been long associated with school achievement in domains of math, science and reading, with research suggesting higher reading comprehension skills are associated with higher levels of homework assignment and completion (Artelt, Baumert, Julius-McElvany, & Peschar, 2001). There is evidence that ADHD may negatively influence homework practices and hinder student abilities gained through good homework practices (Power, Werba, Watkins, Angelucci, & Eiraldi, 2006).

Homework is typically defined as school work that is assigned to be completed outside of school hours, usually at home, and is considered by many education practitioners as an essential part of the learning process (Cooper, Lindsay, Nye, & Greathouse, 1998). Although homework practices differ considerably between classrooms, grade levels, school subjects and students, research on the effect of homework on academic achievement has produced results supporting a consistently positive trend between good homework behavior and academic achievement with amount of homework completed showing a stronger relation to academic achievement than the amount of time spent on homework (Cooper, Robinson, & Patall, 2006; Dettmers, Trautwein, & Lüdtke, 2009). Also, results from existing studies have indicated a trend where relations between homework and achievement are positive but

mostly low and non-significant in early elementary school, but become moderate and significant towards middle and high school. However, homework in early elementary school may serve to facilitate metacognitive skills, such as self-monitoring, which can provide a foundation for later reading skills and improved study habits (Ramdass & Zimmerman, 2011).

Children with inattention problems connected with ADHD are more likely to experience problems completing homework such as failing to properly record the assignment, rushing through the assignment, difficulty remaining on task, and higher prevalence of careless mistakes. A 2006 study compared homework behavior with parent and teacher ratings on a measure of behavioral symptoms related to ADHD. Results indicated that more attentional difficulties and greater hyperactivity were correlated with more homework problems (Power et al., 2006). These findings were subsequently replicated (Langberg et al., 2010) but, in general, research in this area is under-represented to date. Given the well supported finding linking ADHD with reading comprehension difficulties, and the association between homework and reading comprehension that is supported not only by research but practice, it is likely that there is an important relation among ADHD, homework behavior and reading comprehension.

Beyond simply examining the relations among ADHD, homework behavior and reading comprehension, quantitative genetic methodology can be used to elicit the nature of the genetic and environmental influences on and among the three. In particular, twin studies can be used to compare the known genetic and environmental similarity between monozygotic and dizygotic twins to examine the proportion of variance attributable to genetic influences (or heritability; h^2), shared environmental influences (i.e., non-genetic influences that make siblings more similar; c^2), and non-shared environmental influences (i.e., non-genetic effects that make siblings different, plus error; e^2). Previous studies have estimated genetic and environmental influences for reading comprehension and ADHD, however, to date there are no genetically sensitive studies on the nature of homework behavior.

The quantitative genetic research on reading comprehension has found evidence of moderate to high heritability (h^2=.32–.82) (Hart, Petrill, & Kamp Dush, 2010; Keenan, Betjemann, Wadsworth, DeFries, & Olson, 2006; Logan et al., 2013), low to moderate shared environmental influences (c^2=.01–.47) (Betjemann et al., 2008; Logan et al., 2013; Petrill et al., 2007), and low non-shared environmental influences (e^2=.13–.31; Keenan et al., 2006; Betjemann et al., 2008; Byrne et al., 2009). For ADHD, heritability influences tend to be high (h^2=.53–.90) with shared environmental influences moderate and significant (c^2=.26–.30) and, similar to reading comprehension, non-shared environmental influences low and nonsignificant (e^2=.00–.05; Hart et al., 2010; Willcutt et al., 2000). Heritability estimates for the ADHD Inattention factor range from moderate to high (h^2=.35–.86) and for the Hyperactivity/Impulsivity factor range from low to high (h^2=.05–.82) (Hart et al., 2010; Willcutt & Pennington, 2000; Willcutt et al., 2001; Willcutt, Pennington, Olson, & DeFries, 2007). Shared environmental estimates are moderate for both Inattention (h^2=.31) and Impulsivity/Hyperactivity (h^2=.26) and non-shared environmental estimates are low for Inattention (h^2=.03) and Impulsivity/Hyperactivity (h^2=.00) (Hart et al., 2010). Investigation of the relation between reading comprehension and ADHD has indicated a general genetic

effect is shared between the two, as well as specific genetic influences that act on reading comprehension and ADHD independently (Hart, Petrill, et al., 2010; Willcutt et al., 2000; Willcutt et al., 2007). When ADHD factors of Inattention and Hyperactivity/Impulsivity were examined with reading comprehension separately, differential genetic influences were present. Genetic influences shared between Inattention and reading comprehension were moderate and significant (h^2=.39), but those shared between Hyperactivity/Impulsivity and reading comprehension were low and nonsignificant (h^2=.05; Willcutt et al., 2000). Previous results have also found significant shared environmental overlap between reading comprehension and ADHD, indicating that these two phenotypes share both genetic and common environmental influences (Hart, Petrill, et al., 2010).

Existing literature has indicated an important association between both ADHD and reading comprehension, and homework with reading comprehension. The current investigation sought to build on previous knowledge by providing information about how both ADHD and homework behavior may jointly influence reading comprehension. Previous research has suggested that ADHD consists both of an Inattention factor and a factor of Hyperactivity/Impulsivity, and potentially these factors are differentially related to reading comprehension (Willcutt et al., 2007). Interestingly, the homework behavior literature has suggested that there is no differential relation between Inattention and homework behavior and Hyperactivity/Impulsivity and homework behavior (Langberg et al., 2010; Power et al., 2006). Given the uncertainty in the ADHD literature, all modeling was conducted with ADHD operationalized as a single factor and then again with ADHD operationalized as separate Inattention and Hyperactivity/Impulsivity factors. Using a genetically sensitive design, this study explored the genetic and environmental influences on and between ADHD, homework behavior and reading comprehension. It is hypothesized that homework behavior may be influenced by environmental factors and will show significant shared environmental influences (e.g., Hanscombe, Haworth, Davis, Jaffee, & Plomin, 2011). Additionally, based on literature suggesting that all three factors may be similarly impacted by an underlying mechanism such as working memory or executive functioning (Miller et al., 2013), it was hypothesized that there would be significant shared genetic influences between all three variables.

Method

Participants

Participants for this study included 691 twin pairs (351 monozygotic, 340 same-sex dizygotic) from the Florida Twin Project on Behavior and Environment (FTP-BE) and 2647 twin pairs (865 monozygotic, 1782 dizygotic) from the larger Florida Twin Project on Reading (FTP-R) (Taylor, James, Reeves, & Bobadilla, 2006; Taylor et al., 2013). The homework and ADHD scores were obtained from the FTP-BE sample and the reading comprehension scores were obtained from the FTP-R. Table 1 lists the number of participants for each variable. Participants were approximately 11 years old (M = 11.72, SD = 1.08) at the time their reading measures were collected (Spring 2011) and approximately half the sample was female (52.41%). Reading scores were obtained from twins in 3rd (when FCAT is first administered) to 7th grade. The racial and ethnic breakdown of the participants

represent the demographic characteristics of the greater state of Florida, specifically 53.94% White, 22.09% Hispanic, 15.86% Black, 4.58% Multi-racial, 1.65% Asian and the rest falling under American Indian or American Islander. The majority of participants (58.51%) was eligible for free or reduced price lunch.

Procedures and Measures

During the summer of 2010, both parents and children (age nine and older) completed questionnaires that were mailed to their homes. Zygosity of the twin pairs was determined via a parental five-item questionnaire on physical similarity (Lykken et al., 1990). Parents completed measures on the twins' behavior and the home environment, including ADHD measures and homework behavior. The twins also reported on their homework behavior. Reading comprehension data was collected by trained administrators as part of statewide achievement testing required by normal school attendance, and test scores were uploaded into the Progress Monitoring and Reporting Network (PMRN) via a web-based data collection system. For the present study, all reading comprehension data for 3rd to 7th grade participants was collected in Spring 2011, the time point most immediately following questionnaire data collection with multiple reading comprehension measures available. All parents of twins provided informed consent and twins' provided assent to participate as approved by the Florida State University Institutional Review Board.

ADHD measures

Strengths and Weakness of ADHD symptoms and Normal behavior Rating Scale (SWAN): The SWAN, included in the parent questionnaire, measures two facets of ADHD, Inattention and Impulsivity/Hyperactivity from items designed to match diagnostic criteria from the DSM-IV. Items use a 7-point Likert scale ranging from 1 = *Far Below Average* to 7 = *Far Above Average* to indicate typical performance within a month of administration on behaviors such as "Follow through on instructions and finish schoolwork/chores" and "Modulate verbal activity (control excess talking)" (Swanson et al., 2005). Cronbach's alpha in this sample was.79 for the Inattention subscale and .80 for the Hyperactivity/Impulsivity subscale.

Disruptive Behavior Disorder Rating Scale (DBD): The Disruptive Behavior Disorder Rating Scale (DBD) was also used as a measure of ADHD Inattention and Hyperactivity/ Impulsivity facets. Questions from the DBD contain the 36 diagnostic criteria for ADHD, ODD and CD randomly ordered across diagnostic categories using a 4-point Likert scale ranging from *Not at all* (0) to *Very Much* (3) (Pelham Jr, Gnagy, Greenslade, & Milich, 1992). Items were reverse scaled so that higher scores indicate fewer reported symptoms of ADHD. Cronbach's alpha in this sample was.79 for Inattention and .81 for Hyperactivity/ Impulsivity.

Homework Behavior

Effortful Control Scale: Homework behavior was measured by an item from the *Effortful Control Scale* (ECS) included in both the parent questionnaire and twin self-questionnaire. The ECS focuses on attentional and effortful control in children and adolescents with regard to various behaviors including completing homework. Parents rated the item, "My child does

not complete his/her homework" and children rated the item, "I do not complete my homework" using a scale of 1 = *Not at all like my child/me* to 5= *Very much like my child/me* (Lonigan & Vasey, 2009). Scores from these items were recoded so that a higher rating indicated higher instances of homework completion or better homework behavior.

Reading Comprehension

FCAT 2.0 Reading: The Florida Comprehensive Assessment Test (FCAT) consists of criterion-referenced assessments in mathematics, reading, science, and writing, which measured student progress toward meeting the Sunshine State Standards (SSS) benchmarks (FLDOE, 2001). The reading portion of the FCAT consists of several narrative and expository passages for students to read, followed by multiple choice comprehension questions. FCAT 2.0 standard scores, ranging from 100–500, were used in the analyses. Reliability for FCAT Reading Comprehension from item response theory (IRT) ranges from .90 in 3rd grade to .92 in grades 5–12 (Foorman & Petscher, 2010).

FAIR Reading Comprehension: The Florida Assessment for Instruction in Reading (FAIR) reading comprehension subtest is a computer-based assessment given at three time-points during the school year (fall, winter and spring) to students in the state of Florida. Students read between one and three short passages that are either narrative or expository. Following each passage, students respond to between seven and nine multiple choice questions based on the passage. The test uses computer adaptive testing, in that passages and questions are adapted based on student performance on previous items. Scores from FAIR reading comprehension are used to determine the probability of success on the reading portion of the Florida Comprehensive Assessment Test (FCAT) as well as overall reading comprehension (Foorman, Torgesen, Crawford, & Petscher, 2009). Reading comprehension standard scores from the spring time period were used in the current analyses because they are obtained nearest in time to FCAT reading comprehension scores during the school year. The generic estimate of reliability from item-response theory (IRT) for FAIR reading comprehension ranges from .88 to .92 for 3rd through 7th grade students (http://www.fcrr.org/fair/Technical%20manual%20-%203-12-FINAL_2012.pdf).

Analyses

Following descriptive analyses, the 3 factor models were tested, phenotypically and then, structural equation modeling was used to examine the univariate estimates of genetic and environmental influence on all measured variables as well as multivariate analyses of the genetic and environmental variance and covariance among ADHD, homework behavior and reading comprehension. The fit of each model to the data was evaluated through several fit statistics: the χ^2 statistic, Akaike's Information Criterion (AIC), the root mean square of approximation (RMSEA) and Bentler's Comparative Fit Index (CFI; Hu & Bentler, 1999). Chi-square values closest to the degrees of freedom indicate a better fitting model. Although, non-significant chi-square values are preferred, this statistic is highly sensitive to large sample sizes and should be evaluated with caution (Kline, 2011). Akaike's Information Criterion is a modified version of χ^2 (taking into account model complexity) thus with both χ^2 and AIC indices, lower values indicate a better fitting model. Values of the CFI above .95 indicate close model fit, whereas for the RMSEA, values less than .08 are indicative of good

model fit (Browne & Cudeck,1993). For multivariate analyses, rather than using measured variables we used a latent factor model, which provides construct validity and provision of reliable variables (e.g., measurement error free; Gayan & Olson, 2002). Therefore, as a first step, latent factors were created for each of the three constructs. A latent factor of ADHD was created from four measured variables, namely scores from the SWAN Inattention and Hyperactivity/Impulsivity subscales and the DBD Inattention and Hyperactivity/Impulsivity subscales. A latent factor for Homework Behavior was created using the parent- and child-report of the ECS item. Finally, a latent factor of Reading Comprehension was created using scores from the FAIR reading comprehension test and the FCAT (see Figure 1). In order to determine if the relation between ADHD, homework behavior and reading comprehension differed across Inattention and Hyperactivity/Impulsivity factors, three separate multivariate models were tested: a full model with ADHD consisting of both Inattention and Hyperactivity/Impulsivity (as described above) and two reduced models with ADHD represented by either the Inattention factor (see Figure 2) or Hyperactivity/Impulsivity factor alone (see Figure 3).

The variance and covariance among the factors for each of the three models was then decomposed into additive genetic influences, shared environmental influences (environmental effects that serve to make siblings more similar) and non-shared environmental influences (environmental effects that serve to make siblings less similar; Neale & Cardon, 1992). As a latent factor model was used, there was no measurement error included in the non-shared environmental solution. The trivariate Cholesky model produces three sets of biometric (genetic and environmental) factors. The first set of these biometric factors represent the genetic (A_1), shared environmental (C_1) and non-shared environmental (E_1) influences on the overlap between ADHD, homework behavior and reading comprehension. The second set of biometric factors (A_2, C_2 and E_2) represent the genetic and environmental influences on the overlap between homework behavior and reading comprehension, controlling for the first set of biometric factors. Finally, the third set of biometric factors (A_3, C_3 and E_3) represent the genetic and environmental influences that are unique to reading comprehension, after accounting for the first two sets of biometric factors. Phenotypic confirmatory factor analyses were conducted in Mplus 7.11 and genetically sensitive structural equation models were fit to z-scored data corrected for age, age×age, and gender (McGue & Bouchard, 1984) using Mx (Neale, Boker, Xie, & Maes, 2006).

Results

Descriptive statistics for the observed scores of all measures are included in Table 1. The ECS and DBD measures showed positive, but moderate skewness (<3). This could be due to some floor effects for participants who did not report any extreme behaviors on DBD or very many extreme homework behaviors on ECS.

Correlations between all measures are included in Table 2. Correlations between the measures of ADHD were moderate to high and significant (r=.39–.60 p <.0001) as were correlations between the measures for factors of Inattention (r=.60 p <.0001) and Hyperactivity/Impulsivity (r=.56 p <.0001). The correlation between parent- and self-reported homework behavior was moderate and significant (r = .42, p<.001). Correlations

between both ADHD measures and homework behavior were moderate and significantly positive (r=.15–.31, p <.0001) as well as correlations between ADHD and reading comprehension (r=.17–.40, p <.001). Both measures of reading comprehension were significantly and positively correlated with homework behavior (r=.26–.29 p <.0001).

Intraclass correlations

Zygosity-based intraclass correlations were analyzed to assess the levels of additive genetic, shared environmental and non-shared environmental influences on each measure (see Table 3). Correlations between monozygotic twins (MZ) were generally higher (r_{MZ} = .39–.94) than those between dizygotic twins (r_{DZ} = .45–.68), indicating genetic effects for ADHD, homework behavior and reading comprehension. In addition to genetic influences, shared environmental influences were indicated because MZ correlations are less than twice the magnitude of the DZ correlations. The exception to this was the intraclass correlations for self-reported homework behavior which were higher for DZ twins (r=.48) than MZ twins (r=.39), suggesting environmental influences and/or measurement error. However, Fisher's test indicated no significant difference between these correlation coefficients (p=.09;Cohen, 1977).

Univariate Analysis

Univariate results from the structural equation model fitting of the data for each measure are displayed in Table 3. Results indicated significant genetic influences for ADHD factors (h^2=.49–.83). Parent-reported homework behaviors indicated significant genetic influences (h^2=.57); however, self-reported homework behavior was not significantly genetically influenced (h^2=.01). Shared environmental influences were significant for SWAN hyperactivity (c^2=.43) alone among ADHD measures. Results from parent-reported (c^2=.31) and self-reported (c^2=.42) homework behaviors indicated significant shared environmental influences. Additionally, results suggested significant shared environmental influences for the FAIR (c^2=.14) and FCAT (c^2=.20) reading comprehension measures. All measures indicated significant non-shared environmental influences (including error; e^2=.08–.57).

Multivariate Analysis

Prior to conducting the genetically sensitive analyses, phenotypic confirmatory factor analysis (CFA) was conducted on the three-factor structure (with ADHD represented as full ADHD, Inattention only and Hyperactivity only) to test the measurement models. Models were estimated using Mpus 7.11 with all available age and sex standardized raw data using only one member of each twin pair (Muthén & Muthén, 1998–2012). Model fit indices indicated the full ADHD model was the best fitting model to the data and that the hypothesized three-factor structure was a good fit to the data (χ^2=24.51 df=13; CFI=.99; AIC= 30604.89; RMSEA=.02). Although, non-significant chi-square values are preferred, this statistic is highly sensitive to large sample sizes and should be evaluated with caution (Kline, 2011). Fit statistics and chi-square difference tests for the phenotypic models are presented in Table 4. Following phenotypic model testing, the three separate Cholesky models, each representing a different definition of ADHD (full ADHD, Inattention only, and Hyperactivity/Impulsivity only), were conducted in Mx. Although the full ADHD model was the best fitting phenotypic model, all three models were analyzed in keeping with the

ADHD literature suggesting differences between the Inattention and Hyperactivity factors. Results from the three models showed similar patterns of results (see Table 5 and Figures 1–3). Given this and the results of the phenotypic model testing, for brevity and clarity, only the results from the full ADHD model, where ADHD was defined as both Inattention and Hyperactivity/Impulsivity, will be described here. Differences from this model and the two other models will then be summarized.

Within the full ADHD model, factor loadings were significant and moderate to high, indicating a relatively well fitting factor model (−2LL= 20888.57, *df*= 8946; AIC= 2996.57; BIC= −21685.77). One exception was the ECS child-reported factor loading on homework behavior, which was low but significant. Results for the first set of genetic and environmental factors (A_1, C_1 and E_1) indicated significant shared genetic influences between ADHD (estimate of .72), Homework Behavior (estimate of .40) and Reading Comprehension (estimate of .42; see Table 5). In addition, although there was a significant shared environmental influence on ADHD (estimate of .42), there was non-significant shared environmental overlap with Homework Behavior (estimate of .00) and Reading Comprehension (estimate of .17). Significant overlap of non-shared environmental influences was present between ADHD (estimate of .14) and Homework Behavior (estimate of .37), but this overlap did not include Reading Comprehension (nonsignificant estimate of .11).

Looking at the second set of genetic and environmental factors (A_2, C_2 and E_2), results indicated significant genetic influences on Homework Behavior (estimate of .61) that did not overlap with Reading Comprehension (estimate of .00) above and beyond the first set of overlapping genetic influences (i.e., A_1). There were significant shared environmental influences between Homework Behavior (estimate of .58) and Reading Comprehension (estimate of .19). Non-shared environmental influences were negligible and insignificant between Homework Behavior (estimate of .00) and Reading Comprehension (estimate of . 07). Finally, the third set of genetic and environmental factors (A_3, C_3 and E_3), representing variance unique to Reading Comprehension outside of the overlap with ADHD and Homework Behavior, showed a significant genetic effect (estimate of .66) and shared environmental influence (estimate of .46) only.

As indicated above, there were only slight differences between the models where ADHD was defined as either Inattention only or Hyperactivity/Impulsivity only versus ADHD as a whole. For the model where ADHD was defined as Inattention, results indicated overlapping non-shared environmental influence between all three factors, rather than just between ADHD and Homework Behavior (E_1 estimates of .39, .17 and .10, respectively; −2LL= 17573.73, *df*= 7507; AIC= 2559.73; BIC= −18174.94). When ADHD was defined as Hyperactivity/Impulsivity only, there were again differences in the non-shared environmental overlap, but this time there were overlapping non-shared environmental influences between Homework Behavior and Reading Comprehension only (E_2 estimates of .35 and .13, respectively; −2LL= 17574.07, *df*= 7516; AIC= 2542.07; BIC= −18207.10). For both of these models, the shared environmental influence on Reading Comprehension alone was nonsignificant, although it was similar in magnitude to the full ADHD model (C_3 estimate of .43).

Discussion

The main aim of the present study was to investigate the genetic and environmental influences between ADHD, homework behavior and reading comprehension. Past phenotypic and genetically sensitive investigations have provided evidence for a positive association between ADHD symptoms and difficulties in reading comprehension, however, the association is not fully understood (Ghelani et al., 2004; Willcutt et al., 2000). Homework behavior has also been linked with ADHD (Power et al., 2006) and reading comprehension (Ghelani et al., 2004), although the nature of the relation amoung the three was unknown prior to this study. Existing research has found a differential influence of Inattention symptoms versus Hyperactivity/Impulsivity symptoms of ADHD on reading comprehension, although not for homework behavior. Therefore, increasing understanding about the underlying influences on these associations may lead to better methods of adapting to the effects of ADHD symptoms on achievement, specifically reading comprehension (Stern & Shalev, 2013; Willcutt et al., 2007).

Prior investigations have found high heritability for ADHD and the current univariate results supported this (Hart, Petrill, et al., 2010; Willcutt et al., 2007). Of the ADHD measures, DBD Hyperactivity/Impulsivity was the only measure to indicate significant shared environmental influences. Turning towards the univariate results for homework behavior, shared environmental influences were found across both parent-reported and self-reported homework behavior. No previous behavioral genetic analyses on homework behavior could be found. However, previous hypotheses have suggested a relation between environmental conditions such as chaos in the home and homework behavior, suggesting that home environment may contribute to children's ability to concentrate on and complete homework effectively (Hanscombe, Haworth, Davis, Jaffee, & Plomin, 2011; Hart, Petrill, Deckard, & Thompson, 2007). The current results provide evidence of environmental influences on homework behavior which lends support to this hypothesis, however, the etiology of these influences is still unknown. Lastly, univariate estimates of reading comprehension indicated significant genetic and shared environmental influences. The finding of moderate genetic influences on reading comprehension is in keeping with the previous literature, but the low and significant shared environmental influences are a departure from some previous findings (Keenan et al., 2006). However, this pattern is consistent with other reports from this same sample, which find significant shared environmental influences on reading achievement across measures (e.g., Hart et al., 2013; Soden-Hensler, Schatschneider & Taylor, 2012; Taylor et al., 2010).

Multivariate analyses of ADHD, homework behavior and reading comprehension provide further insight into the associations between these factors. In keeping with the literature indicating a differential association between Inattention symptoms of ADHD with reading achievement versus Hyperactivity/Impulsivity symptoms of ADHD with reading achievement (e.g., Willcutt et al., 2007), three models were examined. Interestingly, all three models produced very similar results, supporting prior evidence that a constellation of ADHD symptoms, not just inattention, influences academic outcomes (Hart, Petrill, et al., 2010). First, there were significant genetic influences overlapping between ADHD, homework behavior and reading comprehension. Although this model cannot identify the

source of this effect, it is plausible that the common influence of executive functions such as working memory on ADHD, homework behaviors and reading comprehension may at least partially explain this result (e.g., Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005). Evidence has accumulated indicating that deficits in working memory are an integral aspect of ADHD (e.g., Rapport et al., 1999; Miller et al., 2013) and academic achievement (Gathercole, Pickering, Knight & Stegman, 2004). Although not directly tested in the literature, behaviors related to good homework behavior such as properly recording the assignment, concentrating on the details of the assignment, remaining on task, and lower prevalence of careless mistakes also likely rely on executive functions such as working memory (Langberg et al., 2010; Power et al., 2006). However, it is also possible that the etiology of this shared genetic influence is due to a number of processes other than working memory.

Interestingly, the shared environmental influences on the three factors showed a different pattern from the genetic influences. ADHD, homework behavior and reading comprehension did not have overlapping shared environmental influences. However, there was an overlap of shared environmental influences between homework behavior and reading comprehension only. Broader aspects of the home, such as quiet and organized spaces (e.g., Hanscombe et al., 2011; Hart et al., 2007), or literacy-supportive home environments (e.g., many books in the home; Griffin & Morrison, 1997), may underlie the overlap of shared environmental influences measured between homework behavior and reading comprehension. It may also be the case that parental influences towards creating environments supporting homework practices and literacy are also at work. Further investigation of this association may be important to determine which characteristics of homework environments differentially influence reading comprehension skills in elementary and middle school-aged children. Interventions on homework behavior which have targeted the home environment have shown some success when children and parents are encouraged to designate a quiet study area, a consistent time to work on homework each day, and organized assignment tracking (Toney, Kelley, & Lanclos, 2003). However, these interventions have focused on older middle school and high school student populations, therefore, research focusing on the homework environments of early elementary students may be a beneficial addition to the literature.

Finally, the results from the child-specific, non-shared environmental modeling indicated differential findings depending on which model was examined. Non-shared environmental influences were significant between ADHD and homework behavior for the full ADHD model and the ADHD Hyperactivity/Impulsivity model only. For the ADHD Inattention model, there were non-shared environmental influences overlapping across the three latent factors. This suggests that there may be non-shared environmental influences between ADHD, homework behavior and reading comprehension that are impacted by attentional mechanisms rather than mechanisms of hyperactivity. In general, these non-shared environmental influences could be features such as the room each twin choses to do homework or times of day during which the twins work on homework. Different times of day may be more chaotic in the home and a twin who works on homework during potentially more active and distractive times may be less able to effectively attend to homework tasks or read homework materials than his or her co-twin.

Although all three models suggested very similar general genetic and environmental trends, the literature suggests that the ADHD Inattention and ADHD Hyperactivity/Impulsivity factors would have influenced reading comprehension differentially at the very least (e.g., Rabiner, Coie, & The Conduct Problems Prevention Research Group, 2000; Willcutt et al., 2007). For example, it has been indicated that the inattentive symptoms of ADHD only are attributable to lower academic achievement (Massetti, et al., 2008). The phenotypic correlations did indeed indicate that Inattention behaviors were slightly more negatively associated with reading comprehension than Hyperactivity/Impulsivity behaviors, supporting the previous behavioral literature. Despite this, the present results suggest that the extent to which various ADHD symptoms covary with homework behavior and reading comprehension, there are similar influences due to common genetic and environmental influences. Findings from other twin samples exploring similar research questions have been mixed, with one finding very similar results examining Inattention versus Hyperactivity/Impulsivity related to mathematics and reading (Hart et al., 2010), but another finding differential results based on Inattention versus Hyperactivity/Impulsivity related to reading (Willcutt et al., 2007).

As with all studies, the current study has limitations. First, this study included a very limited measure of homework behavior, with only a single item across two reporters concerning completion of homework used as a proxy for a wider range of homework behaviors. With only two indicators for the Homework Behavior factor and ADHD and Reading Comprehension represented with more rigorous measures, the latent factors within the models represented different levels of measurement. Future investigations may benefit from including a more in depth, standardized measure of homework behavior such as the Homework Problem Checklist (Anesko, Schoiock, Ramirez, & Levine, 1987), which would allow a richer description of the homework environment as well as improving the measurement model. Additionally, model fit indices from the two phenotypic submodels which represented ADHD as either Inattention only or Hyperactivity only indicated that these models were a poorer representation of the data compared with the full ADHD model. However, these submodels were included in the genetically sensitive analyses in order to align with existing literature on the differential relation between Inattention and Hyperactivity symptoms of ADHD and reading comprehension. Also, the current sample is limited by reading comprehension measures from state measures of achievement only. A large body of reading comprehension measures has been developed, but they are not all equal in their accuracy and reliability in measuring the construct of reading comprehension (Keenan, Betjemann, & Olson, 2008). The current findings are likely limited in generalizability to the similar measures of reading comprehension. A final important limitation to consider is that the direction of influence between ADHD, homework behavior and reading comprehension cannot be determined from the current results and, indeed, even bi-directional influences such as gene-environment correlations may also be present. For example, students with greater reading comprehension skills and less ADHD symptoms may be more likely to select quiet and organized spaces to work on homework assignments or, alternatively, students with poor reading comprehension skills or greater ADHD symptoms may evoke less attention from parents regarding their homework environments.

Despite a social push towards classroom-based indicators of success in high stakes testing, this work suggests that aspects of the home environment, as well as behavioral aspects, could play an important role in standardized reading outcomes. Preparation for high stakes testing is increasingly important as the frequency of standardized test administration increases due to national and state implementation of common core standards (Carmichael, Martino, Porter-Magee, & Wilson, 2010). This work adds to the building literature that aspects outside of the classroom are important to consider for aspects of academic achievement such as reading comprehension. The current study revealed evidence of overlapping genetic influences between ADHD, homework and reading comprehension as well as environmental influences shared between homework, ADHD and reading comprehension. This work might suggest that focusing on aspects of homework (time, quality etc.) which are related to reading comprehension may be an important direction for future work. Further investigation of the environments in which children do homework is warranted to better understand the relations between ADHD, homework behavior, reading comprehension and other achievement measures.

Acknowledgements

The first author was supported by Predoctoral Interdisciplinary Fellowship (funded by the Institute of Education Sciences, US Department of Education (186000-520-025833)). The research project was supported, in part, by a grant from the National Institute of Child Health and Human Development (P50 HD052120). Views expressed herein are those of the authors and have neither been reviewed nor approved by the granting agencies.

The authors wish to thank the twins and their families for their participation in making this research possible.

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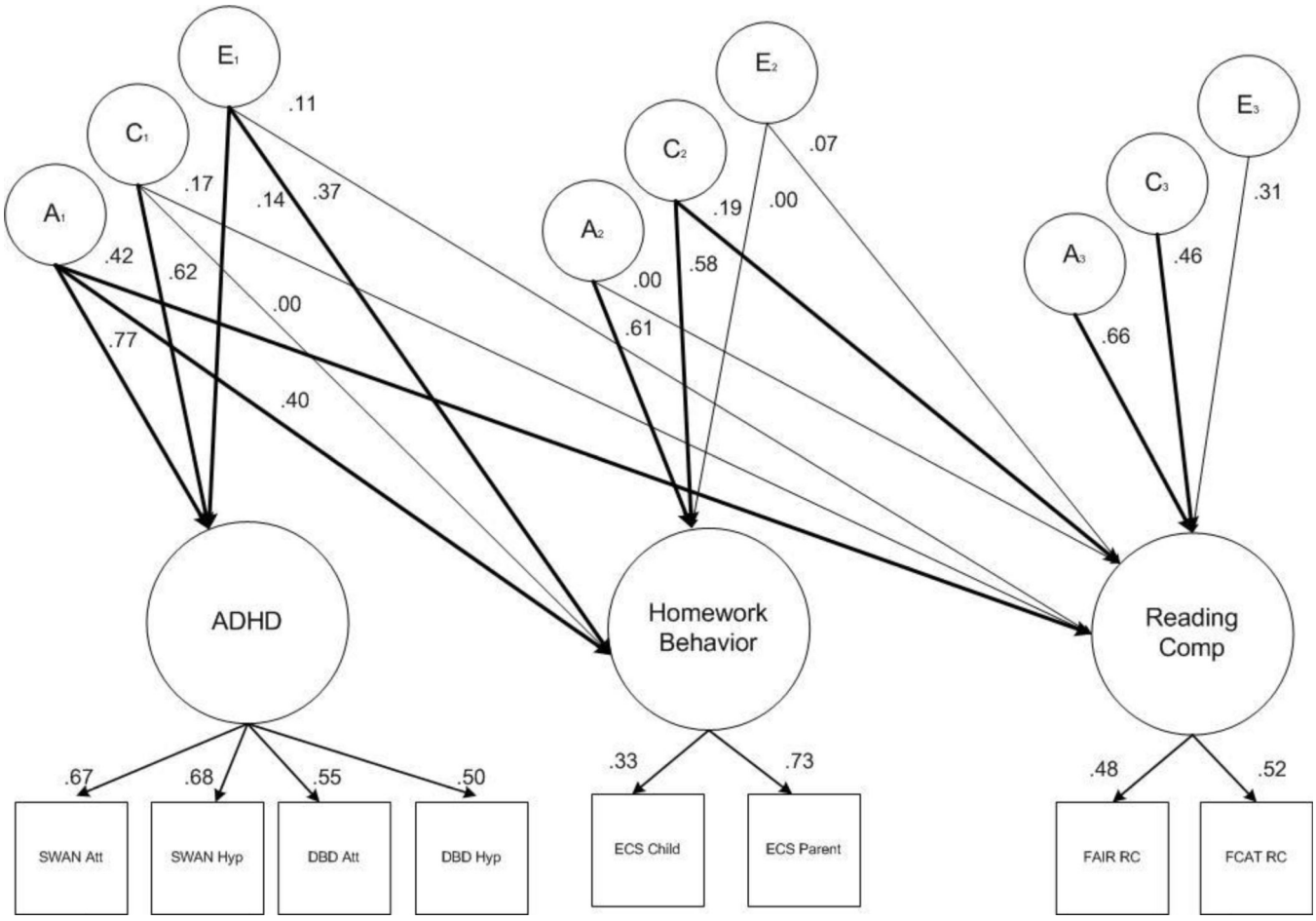

Figure 1.

Full Cholesky Decomposition model. Bolded pathways represent significance based on 95% confidence intervals.

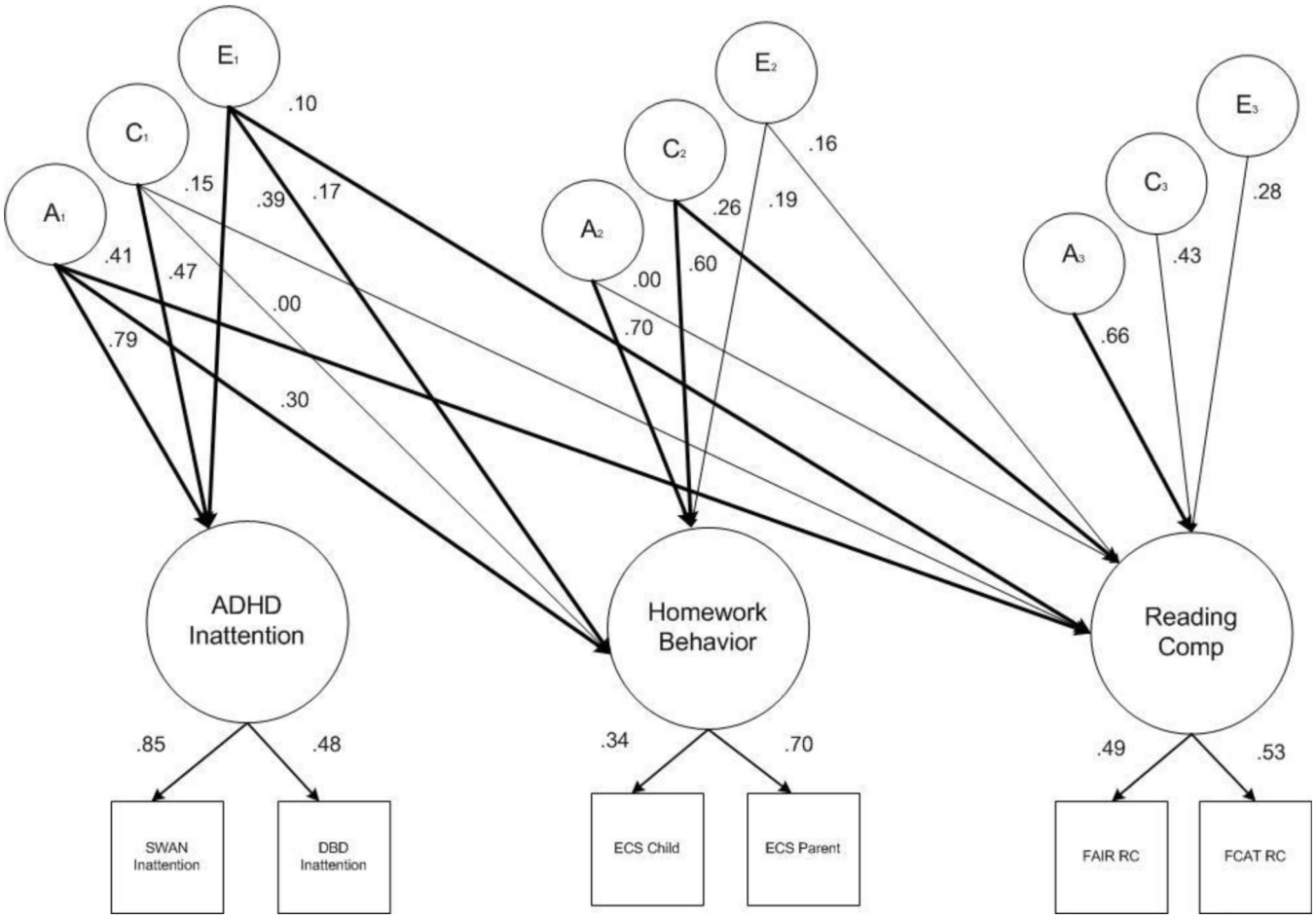

Figure 2.

Cholesky Decomposition model with ADHD represented by Inattention factor. Bolded pathways represent significance based on 95% confidence intervals.

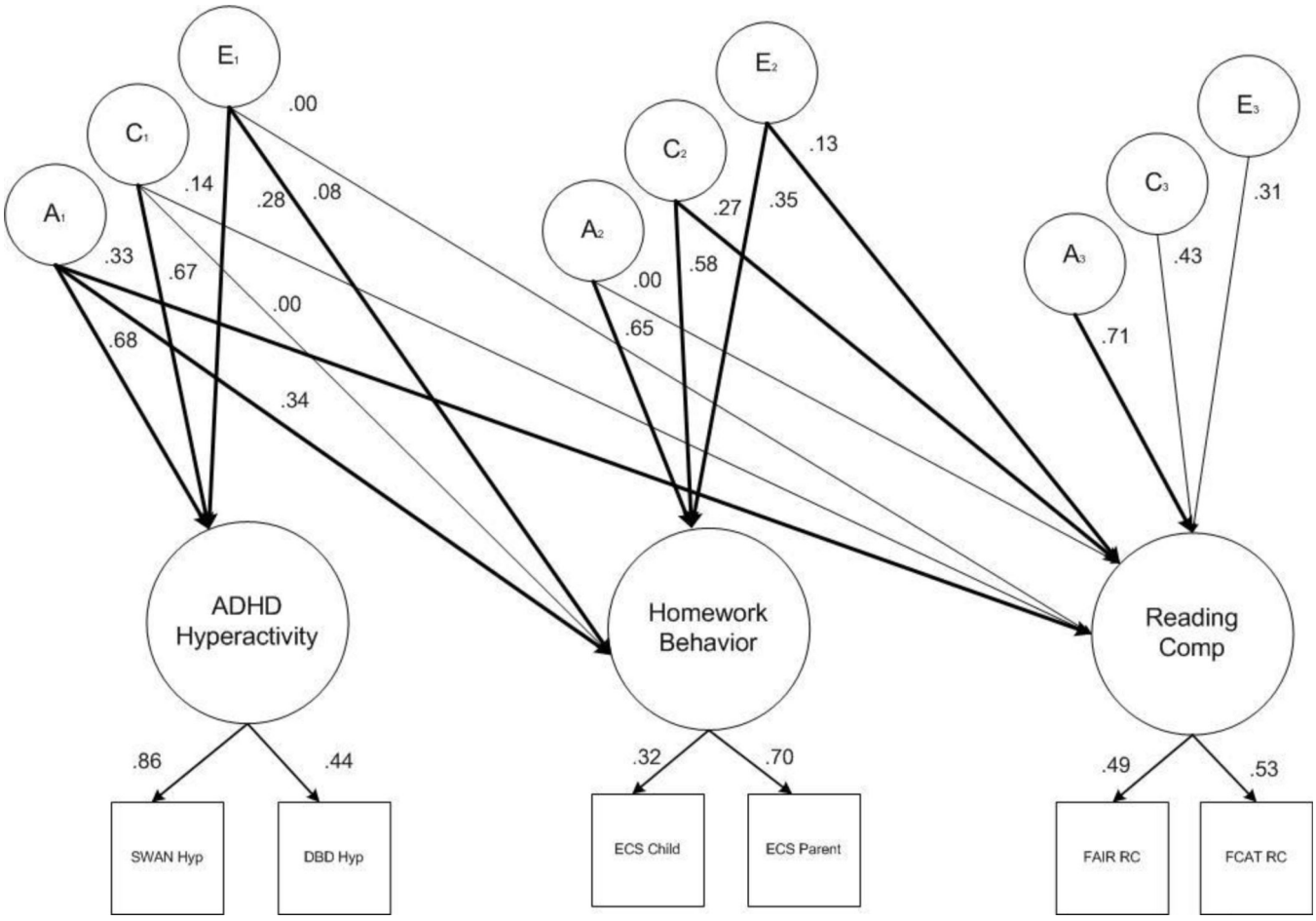

Figure 3.

Cholesky Decomposition model with ADHD represented by Hyperactivity factor. Bolded pathways represent significance based on 95% confidence intervals.

J Learn Disabil. Author manuscript; available in PMC 2017 July 01.

Table 1

Means, standard deviations (SD), minimums, maximums and skew for 3rd through 7th grade SWAN, DBD, ECS, FAIR and FCAT scores.

Variable	Mean	SD	Minimum	Maximum	Skew	*n*
SWAN Inatt[a]	4.58	1.02	1.22	7.00	.13	687
SWAN Hyp[b]	4.64	1.07	1.11	7.00	.15	686
DBD Inatt[c]	.53	.53	−2.78	0.00	−1.29	691
DBD Hyp[d]	.51	.49	−3.00	0.00	−1.49	691
ECS Parent[e]	1.40	.61	1.00	5.00	1.25	678
ECS Self[f]	1.38	.64	1.00	5.00	1.60	425
FAIR[g]	93.27	14.62	62.00	158.00	.21	820
FCAT[h]	319.78	59.78	100.00	500.00	−.25	865

[a] SWAN Inattention.

[b] SWAN Hyperactivity/Impulsivity.

[c] DBD Inattention

[d] DBD Hyperactivity/Impulsivity

[e] Effortful Control Scale (ECS) Parent-report.

[f] Effortful Control Scale (ECS) Self-report.

[g] FAIR Reading Comprehension.

[h] FCAT Reading (FCAT).

Table 2

Phenotypic correlations between SWAN, DBD, ECS, FAIR and FCAT scores in grades 3 through 7.

Variable	SWAN Inatt[a]	SWAN Hyp[b]	DBD Inatt[c]	DBD Hyp[d]	ECS Parent[e]	ECS Self[f]	FAIR RC[g]	FCAT[h]
SWAN Inatt[a]	1.00							
SWAN Hyp[b]	.70*	1.00						
DBD Inatt[c]	.60*	.50*	1.00					
DBD Hyp[d]	.39*	.56*	.71*	1.00				
ECS Parent[e]	.24*	.22*	.31*	.19*	1.00			
ECS Self[f]	.24*	.18*	.24*	.15*	.42*	1.00		
FAIR[g]	.33*	.24*	.28*	.18*	.27*	.29*	1.00	
FCAT[h]	.40*	.30*	.32*	.17*	.26*	.28*	.77*	1.00

*p < .05

[a]SWAN Inattention.

[b]SWAN Hyperactivity/Impulsivity.

[c]DBD Inattention.

[d]DBD Hyperactivity/Impulsivity.

[e]Effortful Control Scale (ECS) Parent-report.

[f]Effortful Control Scale (ECS) Self-report.

[g]FAIR Reading Comprehension.

[h]FCAT Reading (FCAT).

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Table 3

Twin intraclass correlations and univariate h^2, c^2 and e^2 estimates for SWAN, DBD, ECS, FAIR and FCAT scores.

Variable	Twin intra-class correlations		Univariate estimates		
	MZ	DZ	h^2[C.I]	c^2[C.I]	e^2[C.I]
SWAN Inatt[a]	.86*	.57*	.63†[.45–.85]	.21[.00–.40]	.16†[.13–.19]
SWAN Hyp[b]	.94*	.68*	.49†[.37–.64]	.43†[.26–.60]	.08†[.06–.10]
DBD Inatt[c]	.81*	.48*	.83†[.61–.98]	.02[.00–.23]	.18†[.14–.22]
DBD Hyp[d]	.87*	.52*	.81†[.62–1.03]	.11[.00–.31]	.14†[.12–.18]
ECS Parent[e]	.86*	.68*	.57†[.41–.77]	.31†[.11–.51]	.14†[.11–.17]
ECS Self[f]	.39*	.48*	.01[.00–.40]	.42†[.10–.58]	.57†[.45–.69]
FAIR[g]	.67*	.45*	.52†[.37–.67]	.14†[.02–.27]	.34†[.29–.39]
FCAT[h]	.75*	.49*	.55†[.43–.68]	.20†[.09–.30]	.25†[.22–.29]

*p < .05 for intraclass correlations.

†significant univariate estimate based on 95% confidence intervals not bounding zero.

[a]SWAN Inattention.

[b]SWAN Hyperactivity/Impulsivity.

[c]DBD Inattention.

[d]DBD Hyperactivity/Impulsivity.

[e]Effortful Control Scale (ECS) Parent-report.

[f]Effortful Control Scale (ECS) Self-report.

[g]FAIR Reading Comprehension.

[h]FCAT Reading (FCAT).

Table 4

Goodness-of-fit indicators for phenotypic confirmatory factor analysis models of ADHD, Homework Behavior and Reading Comprehension.

Model	χ^2	*df*	χ^2*diff* (*df*)	AIC	CFI	RMSEA
Full ADHD	24.51	13		30604.89	.99	.02
ADHD Inattention	2224.46	19	2199.95 (6) *	32792.84	.59	.19
ADHD Hyperactivity	2439.40	19	2414.89 (6) *	33007.77	.55	.19

Note.

* = significant at p <.05.

Table 5

Multivariate modeling results of genetic and environmental influences on ADHD, Homework and Reading Comprehension [with 95% confidence intervals].

Full ADHD Model	**Shared Influences between ADHD, Homework and RC**	**Shared Influences between Homework and RC**	**Independent Influences on RC**
	A_1 [C.I.]	A_2[C.I.]	A_3[C.I.]
ADHD[a]	.77* [.66–.88]		
Homework[b]	.40* [.28–.50]	.61* [.49–.72]	
RC[c]	.42* [.23–.58]	.00 [.00–.10]	.66* [.52–.78]
	C_1	C_2	C_3
ADHD[a]	.62* [.45–.73]		
Homework[b]	.00 [.00–.15]	.58* [.43–.69]	
RC[c]	.17 [.00–.40]	.19* [.02–.37]	.46* [.11–.58]
	E_1	E_2	E_3
ADHD[a]	.14* [.08–.20]		
Homework[b]	.37* [.27–.41]	.00 [.00–.24]	
RC[c]	.11 [.00–.19]	.07 [.00–.38]	.31 [.00–.37]
ADHD Inattention			
	A_1 [C.I.]	A_2[C.I.]	A_3[C.I.]
Inattention[d]	.79* [.68–.94]		
Homework[b]	.30* [.16–.41]	.70* [.58–.82]	
RC[c]	.41* [.23–.57]	.00 [.00–.13]	.66* [.52–.78]
	C_1	C_2	C_3
Inattention[d]	.47* [.18–.62]		
Homework[b]	.00 [.00–.24]	.60* [.42–.72]	
RC[c]	.15 [.00–.45]	.26* [.07–.43]	.43 [.00–.56]
	E_1	E_2	E_3
Inattention[d]	.39* [.18–.44]		
Homework[b]	.17* [.11–.35]	.19 [.00–.37]	
RC[c]	.10* [.03–.24]	.16 [.00–.38]	.28 [.00–.37]
ADHD Hyperactivity			

Full ADHD Model	Shared Influences between ADHD, Homework and RC	Shared Influences between Homework and RC	Independent Influences on RC
	A_1 [C.I.]	A_2[C.I.]	A_3[C.I.]
Hyperactivity[e]	.68 * [.60–.78]		
Homework[b]	.34 * [.22–.44]	.65 * [.53–.78]	
RC[c]	.33 * [.14–.49]	.00 [.00–.16]	.71 * [.59–.81]
	C_1	C_2	C_3
Hyperactivity[e]	.67 * [.56–.75]		
Homework[b]	.00 [.00–.12]	.58 * [.41–.70]	
RC[c]	.14 [.00–.33]	.27 * [.06–.45]	.43 [.00–.56]
	E_1	E_2	E_3
Hyperactivity[e]	.28 * [.24–.32]		
Homework[b]	.08 * [.03–.14]	.35 * [.11–.40]	
RC[c]	.00 [.00–.08]	.13 * [.06–.37]	.31 [.00–.37]

Note.

* indicates significance based on confidence intervals not bounding zero.

[a] Latent factor of ADHD from SWAN and DBD Inattention and Hyperactivity/Impulsivity factors

[b] Latent factor of Homework Behavior from ECS Parent and ECS Child

[c] Latent factor of Reading Comprehension from FAIR and FCAT Reading Comprehension scores

[d] Latent factor of Inattention from SWAN and DBD Inattention factors

[e] Latent factor of Hyperactivity from SWAN and DBD Hyperactivity/Impulsivity factors