Psychological Medicine (2008), **38**, 1057–1066. © 2007 Cambridge University Press
doi:10.1017/S0033291707001584 Printed in the United Kingdom

ORIGINAL ARTICLE

Genetic and environmental contributions to retrospectively reported DSM-IV childhood attention deficit hyperactivity disorder

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Background. A variety of methodologies and techniques converge on the notion that adults and children with attention deficit hyperactivity disorder (ADHD) have similar deficits, but there is limited knowledge about whether adult retrospective reports reflect similar genetic and environmental influences implicated in childhood ADHD.

Method. DSM-IV ADHD symptoms were collected retrospectively from 3896 young adults participating in the National Longitudinal Study of Adolescent Health. Responses from this genetically informative sample of same- and opposite-sex twins and siblings were used to determine the magnitude of genetic and environmental influences. Possible gender differences in these effects were also examined. The degree of familial specificity of the genetic and environmental influences on the Inattentive and Hyperactive-Impulsive symptom dimensions was also determined.

Results. Additive genetic effects contributed moderately to DSM-IV Inattentive, Hyperactive-Impulsive and Combined ADHD subtypes (heritability estimates of 0.30–0.38). Individual-specific influences accounted for the remaining proportion of the variance. Both genetic and individual-specific environmental effects contributed to the covariation of Inattentive and Hyperactive-Impulsive symptomologies.

Conclusions. Results from our genetic analyses agree with previous findings based on self-assessment of current and retrospectively reported ADHD symptoms in adolescents and adults. Large individual-specific environmental influences as identified here suggest that current questionnaires used for retrospective diagnoses may not provide the most accurate reconstruction of the etiological influences on childhood ADHD in general population samples.

Received 29 August 2006; Revised 10 July 2007; Accepted 17 July 2007; First published online 25 September 2007

Key words: Add Health, adult attention deficit hyperactivity disorder (ADHD), genetics, retrospective.

Introduction

Without a documented history of childhood attention deficit hyperactivity disorder (ADHD), clinicians need to establish a diagnosis in adulthood based on retrospective reports. As a diagnosis other than adult ADHD has been encouraged in the absence of a positive childhood history, it is important that such retrospective reports reflect similar etiological influences identified during childhood. To this end, different techniques and methodologies have been used to demonstrate that childhood and adult ADHD have etiological similarities (Murphy & Barkley, 1996; Seidman *et al*. 1998; Barkley *et al*. 2004; Hervey *et al*. 2004; Spencer *et al*. 2005; Turner *et al*. 2005; Biederman *et al*. 2006). Despite this, however, there has been limited research into whether adult self-reports of childhood ADHD evidence similar genetic and environmental influences as implicated during childhood.

Personal histories of childhood ADHD symptoms have primarily been collected using rating scales. One of the earliest and best known is the Wender Utah Rating Scale (WURS; Wender *et al*. 1981). This self-completed, 61-item questionnaire assesses cognitive and behavioral ADHD symptoms and includes affective measures such as mood, temper and irritability. Adults retrospectively report about childhood symptoms, their medical histories, and how they behaved at school, using descriptors such as 'slightly or not at all', 'moderately', 'mildly', 'quite a bit' and 'very much'. A shorter, 25-item scale (WURS-S) has been suggested to be more closely related to the clinical criteria for ADHD and has been shown to have acceptable psychometric qualities (Ward *et al*. 1993; Stein *et al*. 1995). Utah criteria have been used to

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describe ADHD symptoms in a variety of clinical and treatment studies (Wender *et al*. 2001; McGough & Barkley, 2004) as well as candidate gene association studies (Muglia *et al*. 2000, 2002; Retz *et al*. 2002).

Strengths of the WURS include its emphasis on the dual assessment of childhood and adult ADHD symptoms and inclusion of third-party observations. Weaknesses of the Utah criteria include their heterogeneity and divergence from current conceptualizations of ADHD (Mancini *et al*. 1999; McGough & Barkley, 2004). For example, factor analyses have identified three factors for the WURS that appear to cluster as measuring oppositional-defiant behaviors, mood disorders and school/work problems (Mancini *et al*. 1999; McCann *et al*. 2000). Although useful in characterizing broad levels of functioning for clinical purposes, such complexity may not permit a focused investigation of ADHD symptomologies.

An alternative approach available to establishing childhood ADHD retrospectively has been the use of rating scales based on DSM criteria. The DSM-IV assesses ADHD symptoms using 18 items that adults report as present or absent. Although alternatives have been proposed, childhood ADHD is diagnosed in the presence of six or more symptoms, with onset before the age of 7, and evidence of impairment in two or more settings. Two symptom dimensions are recognized in DSM-IV: inattention and hyperactive-impulsive. From these, three subtypes have been distinguished. The predominantly Inattentive (I) type is characterized by lack of organization, difficulties sustaining attention at work or play, and finishing work or following directions. General feelings of restlessness, talking too much or out of turn, and fidgeting portray the predominantly Hyperactive-Impulsive (H) subtype. High levels of both inattention and hyperactivity-impulsivity characterize a Combined (C) subtype. Although originally based on children from clinical samples, this organization of ADHD symptoms has been shown to be feasible in adult samples from the general population (Kooij *et al*. 2004).

To date, there has been only one genetically informative study of adult retrospective reports of childhood ADHD symptoms in a general population sample (Schultz *et al*. 2006). In that study, DSM-III-R ADHD symptoms during childhood were reported retrospectively by middle-aged adult twins ($n = 692$) participating in the Vietnam Era Twin Registry. Responses were found to evidence small heritable (0.29) effects, and large individual-specific influences (0.71). Slightly higher estimates were reported for each of the two ADHD symptom dimensions, where it was also shown that heritable and individual-specific environmental effects accounted for their covariation. Whether the magnitude of these risk factors varied as a function of sex or whether interactions between different alleles within the same gene (e.g. non-additive genetic) were an etiological factor was not reported.

The current study reports findings from a genetic study of retrospectively reported DSM-IV childhood ADHD symptoms. Reports were collected from young adult participants, ages 18–24 years, in the National Longitudinal Study of Adolescent Health. Our study was designed to determine: (1) the nature of genetic (additive and non-additive or dominant) and environmental influences, the extent that these risk factors contributed to observed variation in each of these three ADHD symptom dimensions, and whether these risk factors differed for males and females, and (2) the specificity of familial risk factors for the predominantly Inattentive and Hyperactive-Impulsive ADHD symptom dimensions.

Method

Subjects

Our sample for these analyses was composed of twins and siblings participating in the National Longitudinal Study of Adolescent Health at wave III. A detailed explanation of the Add Health study design and sampling strategy used for both the full and this genetically informative subsample are available elsewhere (Harris *et al*. 2006). At wave III, 4356 twins and siblings participated. Of those, 52.1% were male. The ethnic composition, based on self-nomination, was 23.7% Black, 6.9% Asian, 1.7% Native American and 67.7% White. Response rates varied across sibling type, but was above 85% at wave III (Harris *et al*. 2006). The current analyses are based on reports from 563 same-sex (M 284, F 279) monozygotic (MZ) twins, 492 (M 260, F 232) dizygotic (DZ) twins, 1283 (M 635, F 648) full-siblings (FS) and 380 (M 184, F 196) half-siblings (HS). Responses from opposite-sex (OS) siblings were also examined and totaled 1178 (OSDZ 381, OSFS 454, OSHS 343). The mean age of males and females was 22.5 ± 1.76 and 22.4 ± 1.76 years respectively. Zygosity status of the sibling pairs sample was initially determined by self-report at wave I and subsequently at wave III using molecular markers as detailed elsewhere (http://www.cpc.unc.edu/projects/addhealth/files/biomark.pdf).

Assessment

Retrospective reports of childhood ADHD symptoms were collected at wave III only using the Childhood ADHD Symptom Scale, Self-Report (Barkley & Murphy, 1998). This scale includes nine DSM-IV ADHD inattention (ADHD-I) symptoms and eight DSM-IV ADHD hyperactive-impulsive (ADHD-H)

symptoms. Inattentive and ADHD-H items were alternated in their order of appearance. One impulsive DSM-IV ADHD symptom ('often interrupts or intrudes on others') was not collected where respondents were asked to indicate how spiteful or vindictive they had been. Symptom frequency and severity were scored using a four-point Likert scale that ranged between 0 (rarely or never), 1 (sometimes), 2 (often) and 3 (very often). Participants were asked which answer best described their behavior when they 'were between 5 and 12 years of age'. Data concerning whether ADHD symptoms occurred prior to the age of 7 or whether levels of functioning were across different settings were not collected. Total scores for the ADHD-I and ADHD-H subtypes were calculated separately by summing across their respective items. Scores for a Combined (C) scale were calculated by summing across the ADHD-I and ADHD-H scales. Total scores could range between 0 and 27 on the ADHD-I scale and 0 and 24 for the ADHD-H scale. For the Combined scale, total scores could range between 0 and 51.

Scale scores based on symptom counts were also examined. In those analyses, each item was scored as either present or absent and summed within symptom dimension. Total scores could range between 0 and 9 on the ADHD-I symptom dimension scale, and between 0 and 8 for the ADHD-H symptom dimension scale. For the Combined symptom dimension scale, scores could range between 0 and 17.

Statistical analyses

For each ADHD symptom cluster, means, variances and sibling correlations were estimated taking into account the non-independence within our data. Sex differences in sample means and variances were tested using the χ^2 likelihood ratio test as implemented in the statistical software Mx (Neale & Cardon, 1992). Sibling correlations were calculated on residual scores that controlled for the differences in sex, age and ethnicity. Cronbach's α was calculated to determine the internal reliability for the I, H and C subtypes.

Genetic analyses were conducted on residual scores. Two genetic models were used for the current analyses: sex-limitation and bivariate Cholesky decomposition (Neale *et al*. 1999, 2006). When based on data from same-sex sibling pairs, the sex-limitation model examines whether the magnitudes of heritable and environmental influences on ADHD are different in males than in females. When data are available from OS sibling pairs, two additional sex-specific parameters can be included to examine whether different genetic and environmental risk factors influence ADHD in one sex but not the other. This specification is illustrated in Fig. 1 and includes the sex-specific

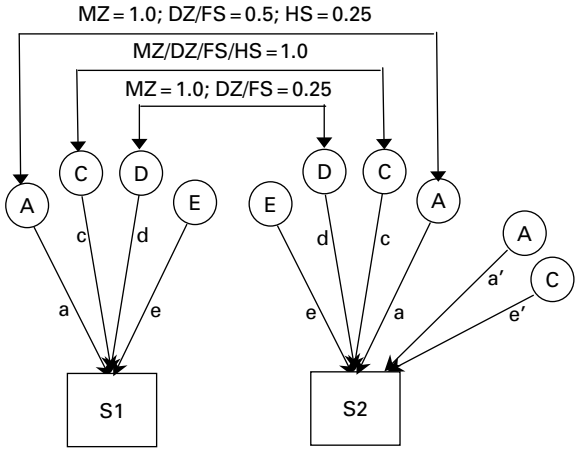

Fig. 1. Univariate model of genetic, environmental, sex-specific risk factors for retrospectively reported DSM-IV childhood attention deficit hyperactivity disorder (ADHD). MZ, monozygotic twins; DZ, dizygotic twins; FS, full siblings; HS, half-siblings; S1, sibling 1; S2, sibling 2. For each model, latent variables are depicted in circles, and observed variables (ADHD subtypes) are depicted in rectangles. Each latent variable has a variance of 1.00. Partial regression paths of the observed variable on the latent genetic and environmental risk factors are represented by single-headed arrows and included the a and d paths and c and e paths respectively. Sex-specific partial regression paths for additive genetic and shared environmental influences are denoted by a′ and e′ respectively.

additive genetic and shared environmental effects. The bivariate Cholesky decomposition model examines the extent to which genetic and environmental effects contribute to the covariation of two observed variables and is a simple restatement of the latent factor structure designated in our univariate model. Latent genetic and environmental influences are stratified into factors that are common to both ADHD-I and ADHD-H, and those that are specific or residual to ADHD-H. From this model it is possible to obtain two indices: the genetic correlation, which indexes the extent that genetic influences on ADHD-I overlap with those genetic influences on ADHD-H, and the bivariate heritability, which indicates the extent to which genetic effects shared between ADHD-I and ADHD-H contribute to the phenotypic correlation between the two symptom clusters. The extent that genetic and environmental effects contribute to the covariation of ADHD-I and ADHD-H is suggested by higher cross-sibling cross-trait correlations for more genetically related pairs.

The fit of our genetic models was evaluated using maximum-likelihood estimation. Our baseline model included the additive genetic (A) and non-shared environmental (E) latent factors and either a non-additive genetic (D) or shared environment (C) factor,

https://doi.org/10.1017/S0033291707001584 Published online by Cambridge University Press

Table 1. *Endorsement rates of DSM attention deficit hyperactivity disorder (ADHD) items*

ADHD items	Endorsement rate (%)			
	Never or rarely	Sometimes	Often	Very often
1. Failed to pay attention/careless mistakes	24.4	54.6	16.5	4.4
2. Fidget with hands/squirm in seat	24.8	40.7	22.5	12.0
3. Difficulty sustaining attention in tasks	53.5	33.1	9.7	3.7
4. Left seat without permission	67.7	22.7	6.7	2.8
5. Didn't listen when spoken to directly	55.2	34.5	7.5	2.8
6. Felt restless	40.4	44.3	10.5	4.5
7. Failed to finish work or follow instructions	51.0	39.1	6.7	3.2
8. Difficulty doing fun things quietly	54.3	31.2	10.6	3.9
9. Difficulty organizing tasks or activities	52.0	38.0	7.6	2.4
10. Felt 'on the go' or 'driven by a motor'	38.2	37.2	16.4	8.3
11. Avoided, disliked or reluctant to engage in tasks requiring sustained mental effort	58.8	31.2	7.4	1.8
12. Talked too much	37.3	31.1	17.3	14.2
13. Lost things necessary for tasks or activities	45.9	42.1	8.8	3.2
14. Blurted out answers	38.7	41.4	14.4	5.4
15. Easily distracted	31.9	43.8	16.1	8.3
16. Difficulty awaiting your turn	51.5	34.9	9.7	3.8
17. Forgetful	39.9	45.5	10.4	4.2
18. Were spiteful or vindictive	63.1	30.2	4.7	2.0

as both are confounded in sibling-based models. The significance of model parameters was evaluated by a comparison of the twice log-likelihood (−2LL) for models with or without the parameters, with the difference distributed as a χ^2 distribution and the degrees of freedom being equal to the difference between the number of parameters estimated. A non-significant difference χ^2 ($\Delta\chi^2$) between two models indicates that the parameters dropped from the more parsimonious model were not significantly different from zero. Models were accepted on the basis of the Akaike Information Criterion (AIC; Akaike, 1987), as calculated by subtracting twice the difference in the degrees of freedom from the difference χ^2 between any particular model and the fullest (i.e. least parsimonious model) considered. The AIC indexes the extent that a given model offers the most parsimonious, but adequate, explanation to the data.

Results

For descriptive purposes, Table 1 presents item endorsement rates as a function of frequency and severity. As could be expected from a general population sample, the majority reported having little to no difficulty between 5 and 12 years of age. Among respondents, a total of 25 (1.2%) indicated that they had taken medication for ADHD within the past 12 months. χ^2 tests based on dichotomous item scores indicated that participants taking medication endorsed all but three items (nos 10, 16 and 18) more frequently ($p<0.05$) than those not taking medication at wave III. Four inattention items (nos 3, 5, 7 and 11) were endorsed at a substantially higher rate ($p<0.0001$), suggesting their potential usefulness in differentiating groups.

Internal reliability coefficients were in the range 0.84–0.85 for the ADHD-I scale, 0.78–0.80 for the ADHD-H scale and 0.89–0.90 for the ADHD-C scale. The distribution of raw scores for each of the three retrospectively reported DSM-IV ADHD scales approximated to normality. Across both sexes, the coefficients of skewness across each of the three ADHD symptom dimensions ranged between 0.77 and 1.22. Kurtosis for these three distributions of scores ranged between 0.24 and 2.03. Means for the raw scores on the ADHD-I, ADHD-H and ADHD-C scales were higher in males than in females across all three ADHD symptom dimensions (Table 2). Tests of the homogeneity of variance identified no significant differences between males and females. Means and standard deviations did not differ as a function of sibling type.

Sibling correlations for ADHD-I, ADHD-H and ADHD-C are shown in Table 3. Cross-trait within-individual correlations (0.58–0.73) were substantial and consistent with the idea that inattentive and

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Table 2. *Retrospective scores of DSM-IV subtypes for 3896 young-adult sibling pairs*

	Male–male siblings			Female–female siblings			Opposite-sex siblings		
ADHD subtype	*n*	Mean	S.D.	*n*	Mean	S.D.	*n*	Mean	S.D.
Inattentive									
MZ	240	6.32	4.83	253	5.29	4.39	–	–	–
DZ	209	6.88	4.87	185	5.61	4.87	197	6.26	4.82
FS	477	7.46	5.01	524	5.64	4.38	722	6.77	4.73
HS	123	7.13	4.82	146	5.83	4.80	244	7.20	5.43
Hyperactive-Impulsive									
MZ	240	6.59	4.43	251	5.32	3.99	–	–	–
DZ	210	7.34	4.62	188	5.91	4.56	298	6.46	4.82
FS	479	7.43	4.74	523	5.83	3.97	728	6.92	4.73
HS	123	7.40	4.64	148	6.27	4.50	244	7.20	5.43
Combined									
MZ	239	13.32	8.75	248	10.89	7.83	–	–	–
DZ	206	14.71	9.16	184	11.87	8.95	294	13.09	8.62
FS	475	15.42	9.30	520	11.87	7.94	719	14.15	8.85
HS	122	15.09	9.25	144	12.65	8.90	242	14.91	9.87

ADHD, Attention deficit hyperactivity disorder; S.D., standard deviation; MZ, monozygotic twins; DZ, dizygotic twins; FS, full siblings; HS, half-siblings.

hyperactive-impulsive behaviors covary in the general population. Higher within-pair ADHD-I, ADHD-H and ADHD-C correlations for more genetically related sibling-pairs are consistent with genetic effects on ADHD. Genetic effects appear to be smaller in magnitude than those reported in twin and adoption studies, although possibly larger for males than females. The pattern of within-pair correlations for OS sibling pairs was mixed in comparison to same-sex siblings, suggesting possible sex-limited effects. However, the observation that the within-pair correlation is roughly the same between OSDZ twins, who are the same age, and same-sex DZ twins does not support the role of sex-limited effects. A small to moderate genetic contribution to the covariation between ADHD-I and ADHD-H is suggested by the differences in the cross-sibling cross-trait correlations because MZ twins correlated more strongly than DZ twins, and FS who were correlated more highly than HS. None of the differences in correlations between siblings indicated non-additive genetic contributions and therefore they were not examined further.

Univariate modeling

Table 4 summarizes the results from our univariate models. Model 1 allowed each latent factor to be estimated separately for males and females and included sex-specific A and C factors. The overall fit of this model for ADHD-I was $-2LL = 19920.01$ (df = 3345), $-2LL = 19460.93$ (df = 3357) for ADHD-H, and $-2LL = 23791.85$ (df = 3318) for ADHD-C. Sex differences in each ADHD subtype were examined in models 2 and 3. Model 2 tested whether the magnitudes of A, C and E risk factors were different in males and females. Model 3 investigated whether there were A or C sex-specific risk factors limited to males. The results from both models indicated that the genetic and environmental factors contributed equally in males and females and that there were no sex-limited influences on any of the three DSM-IV subtypes. This was further supported by the improvement in fit of a model that did not specify any sex differences (model 4). Our final model examined the significance of shared environmental influences on individual differences in ADHD scores (model 5). Judging by AIC, model 5 represented the most parsimonious explanation and implicated moderate genetic and large individual-specific environmental effects on ADHD-I, ADHD-H and ADHD-C subtypes. The magnitudes of heritable contributions were 0.31 (0.23–0.40), 0.36 (0.27–0.43) and 0.37 (0.28–0.44) respectively. Individual-specific environmental influences on ADHD-I were 0.69 (0.61–0.77), and 0.64 (0.57–0.73) for ADHD-H and 0.63 (0.56–0.72) for ADHD-C. Similar, but slightly lower, estimates were obtained for the genetic and environmental effects on ADHD symptom count scores.

Bivariate modeling

We next examined the extent of familial specificity in the genetic and environmental influences on

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Table 3. *Sibling correlations for DSM-IV Inattentive, Hyperactive-Impulsive and Combined subtypes*[a]

	Sibling 1		Sibling 2		
	ADHD-I	ADHD-H	ADHD-I	ADHD-H	ADHD-C[b]
MZ					
S1 : I		0.69 (0.58–0.77)	0.40 (0.22–0.54)	0.21 (0.03–0.38)	
S1 : H	0.67 (0.56–0.76)		0.31 (0.14–0.47)	0.39 (0.23–0.54)	
S2 : I	0.36 (0.18–0.51)	0.16 (−0.03 to 0.34)		0.66 (0.54–0.75)	
S2 : H	0.22 (0.04–0.40)	0.34 (0.15–0.50)	0.70 (0.60–0.78)		
S2 : C					0.40/0.32
DZ					
S1 : I		0.66 (0.54–0.76)	0.25 (0.05–0.43)	0.31 (0.12–0.48)	
S1 : H	0.66 (0.53–0.76)		0.23 (0.04–0.41)	0.29 (0.11–0.46)	
S2 : I	0.08 (−0.13 to 0.29)	0.13 (−0.09 to 0.35)		0.70 (0.58–0.79)	
S2 : H	0.03 (−0.17 to 0.23)	0.12 (−0.08 to 0.32)	0.77 (0.67–0.85)		
S2 : C					0.30/0.15
FS					
S1 : I		0.63 (0.55–0.71)	0.15 (0.01–0.29)	0.16 (0.02–0.29)	
S1 : H	0.64 (0.53–0.76)		0.00 (−0.14 to 0.14)	0.02 (−0.12 to 0.16)	
S2 : I	0.09 (−0.04 to 0.21)	0.01 (−0.12 to 0.13)		0.70 (0.63–0.76)	
S2 : H	0.17 (0.04–0.28)	0.12 (0.00–0.24)	0.67 (0.60–0.74)		
S2 : C					0.10/0.12
HS					
S1 : I		0.67 (0.50–0.79)	0.08 (−0.09 to 0.35)	0.17 (−0.09 to 0.41)	
S1 : H	0.61 (0.44–0.74)		0.19 (−0.09 to 0.44)	0.22 (−0.04 to 0.45)	
S2 : I	0.05 (−0.20 to 0.30)	0.00 (−0.27 to 0.25)		0.73 (0.60–0.83)	
S2 : H	0.09 (−0.17 to 0.35)	−0.04 (−0.30 to 0.22)	0.68 (0.54–0.78)		
S2 : C					0.23/0.06
OS DZ/F[c]					
S1 : I		0.58 (0.47–0.68)	0.20 (0.04–0.35)	0.26 (0.10–0.41)	
S1 : H	0.67 (0.62–0.73)		0.23 (0.07–0.38)	0.33 (0.17–0.47)	
S2 : I	0.07 (−0.04 to 0.18)	0.10 (0.00–0.21)		0.70 (0.61–0.78)	
S2 : H	0.08 (−0.02 to 0.19)	0.13 (0.02–0.23)	0.68 (0.62–0.74)		
S2 : C					0.31/0.12
OSHS					
S1 : I		0.71 (0.61–0.79)	0.04 (−0.16 to 0.23)	0.28 (0.09–0.46)	
S1 : H			0.15 (−0.03 to 0.32)	0.29 (0.12–0.45)	
S2 : I				0.70 (0.60–0.78)	
S2 : H					
S2 : C					0.22

ADHD, Attention deficit hyperactivity disorder; I, Inattentive subtype; H, Hyperactive-Impulsive subtype; C, Combined subtype; MZ, monozygotic twins; DZ, dizygotic twins; FS, full siblings; HS, half-siblings; OS, opposite-sex sibling; S1, sibling 1; S2, sibling 2.

[a] Male sibling-pairs are within each shared area.

[b] Male–male/female–female sibling correlation.

[c] Opposite-sex DZ twin correlations are within the shaded area.

the Inattentive and Hyperactive-Impulsive subtypes. Based on our best-fitting univariate models, we investigated the extent that A and E risk factors mediated the covariation of ADHD-I and ADHD-H. The overall −2LL for this full model was 37372.05 (df = 6714). Dropping the shared A parameter from this model resulted in a worse fit as compared to the full model ($\Delta\chi^2 = 47.76$, $\Delta df = 1$, $p < 0.001$, AIC = 45.76) and indicated that the genetic risk factors for ADHD-I were important etiological factors for ADHD-H. Likewise, dropping the overlapping E parameter resulted in a deterioration in the model fit ($\Delta\chi^2 = 286.26$, $\Delta df = 1$, $p < 0.001$, AIC = 284.26) and suggested that non-shared environmental risk factors for ADHD-I

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Table 4. *Univariate model fit statistics on DSM-IV ADHD subtypes for 3896 young-adult pairs*

	Inattentive				Hyperactive-Impulsive				Combined			
Model	$\Delta\chi^2$	Δdf	p	AIC	$\Delta\chi^2$	Δdf	p	AIC	$\Delta\chi^2$	Δdf	p	AIC
1. ACE	–	–	–	–	–	–	–	–	–	–	–	–
2. ACE, m = f	2.64	3	0.45	−3.36	3.49	3	0.32	−2.51	3.24	3	0.36	−2.76
3. ACE, a′, e′ = 0	3.33	3	0.34	−2.68	1.16	3	0.76	−4.84	1.11	3	0.78	−4.89
4. ACE, m = f, a′, e′ = 0	7.58	6	0.27	−4.42	4.62	6	0.59	−7.38	4.45	6	0.62	−7.56
5. AE, m = f, a′, e′ = 0	7.58	7	0.37	−6.42	4.62	7	0.71	−9.38	4.45	7	0.73	−9.46

ADHD, Attention deficit hyperactivity disorder; df, degrees of freedom; AIC, Akaike Information Criteria; A, additive genetic; C, shared environment; E, non-shared environment; m, male; f, female, a′, sex-specific additive genetic path; e′, sex-specific non-shared environment path.

were also risk factors for ADHD-H. A final model that examined whether ADHD-I and ADHD-H had completely independent risk factors ($\Delta\chi^2 = 2858.68$, $\Delta df = 2$, $p < 0.001$, AIC = 2854.68) was not supported. Therefore, our full model was selected as the most parsimonious explanation for the covariation of ADHD-I and ADHD-H symptom dimensions. Similar conclusions were reached when symptom count scores were examined.

Parameter estimates for the genetic and environmental influences on ADHD-I and ADHD-H from our bivariate model were highly similar to those estimated from our univariate models. Although substantial in our best-fitting bivariate model, genetic risk factors correlated below 1.0 and indicated that there were independent genetic effects on ADHD-H that were not shared with ADHD-I. The genetic and environmental correlations between these two subtypes were 0.79 and 0.62 respectively. The bivariate heritability was 0.39 (confidence interval 0.29–0.49) and suggested that the genetic risk factors common to both ADHD-I and ADHD-H contributed moderately, but that their relationship was largely due to individual-specific environmental influences.

Discussion

Our goal was to determine, in a large population-based sample of same- and opposite-sex sibling pairs, the nature and extent of genetic and environmental influences on adult retrospective reports of childhood ADHD. Our results indicate that genetic influences contributed moderately to an individual's risk. Individual-specific environmental effects, however, contributed sizably. Furthermore, both types of risk factors account for the covariation of Inattentive and Hyperactive-Impulsive subtypes. The magnitudes of these effects appear to be the same for males and females.

Relationship to previous findings

Twin studies of childhood ADHD symptoms suggest that additive genetic effects contribute to an individual's risk for the disorder (Thapar *et al*. 1999). A few studies during childhood also suggest that interactions between different alleles within the same gene (e.g. non-additive genetic) could be an etiological risk factor (Hudziak *et al*. 2005), but could also reflect contrast effects (Rietveld *et al*. 2004; Knopik *et al*. 2006). Both types of genetic influences, along with individual-specific environmental experiences, are implicated in the stability of childhood ADHD symptoms (Rietveld *et al*. 2004), while evidence supporting differential effects among males and females is mixed (Rhee *et al*. 1999). Heritability estimates of DSM-IV-based measures of childhood ADHD have ranged between 0.60 and 0.94 (Hudziak *et al*. 2005). These estimates are similar to those based on quantitative measures rated by parents or teachers. Both additive genetic and individual-specific environmental experiences have been implicated in adolescent self-reported ADHD, with heritability estimates ranging from zero to 0.45 (Martin *et al*. 2002; Ehringer *et al*. 2006).

In contrast with studies of childhood ADHD, either diagnostically or quantitatively defined, genetic contributions to ADHD assessed at older ages appear to be lower. In a Dutch sample of young adults, aged 18–30, additive genetic effects accounted for 0.37 to 0.44 of the variance in current ADHD symptoms when measured at three ages across a 6-year period (van den Berg *et al*. 2006). Similar, albeit slightly lower, heritability estimates (0.29–0.35) were reported in the Vietnam Era Twin study, where retrospective reports of childhood ADHD were reported by twin pairs with the average age of 47.8 years (Schultz *et al*. 2006). Our results agree with these findings in a number of ways. First, our estimates of the genetic contribution to the ADHD-I, ADHD-H and ADHD-C subtypes ranged from 0.31 to 0.37. Second, similar to van den Berg *et al*.

https://doi.org/10.1017/S0033291707001584 Published online by Cambridge University Press

(2006), we did not obtain support for dominance contributions or find that the magnitude of genetic and environmental influences differed for males and females. Third, similar to Schultz *et al*. (2006), genetic influences common to the ADHD-I and ADHD-H subtypes accounted for a moderate proportion of their covariation.

As compared with parent or teacher reports during childhood, individual-specific environments seem to contribute sizably to ADHD when assessed by self-reports. This observation appears to be independent of age as it has been reported in samples of adolescents and adults at differing ages (Murphy & Schachar, 2000; Martin *et al*. 2002; Ehringer *et al*. 2006; van den Berg *et al*. 2006). In these data, non-shared environmental effects accounted for over two-thirds of the variance for each ADHD subtype. There are several potential reasons for this. Estimates of non-shared environmental effects include measurement error. A source of error relevant to retrospective reports is the quality of recall. Despite being considered valid, retrospective reports may underestimate the severity of childhood ADHD symptoms (Faraone *et al*. 2000; Barkley *et al*. 2002). Moreover, reports may differ as a function of self-awareness or insight into the difficulties related to ADHD symptoms (Murphy & Barkley, 1996; Faraone *et al*. 2000; Weiss & Weiss, 2004). Non-shared environmental effects could also include child-specific experiences of salient environmental influences such as maternal lifestyle (Linnet *et al*. 2003; Knopik *et al*. 2006) or parenting. Finally, childhood ADHD symptoms do remit across time (Barkley *et al*. 2002; Faraone *et al*. 2005) for some, but not all, children. Differences in environmental experiences, longitudinal course and recall would contribute to sample heterogeneity and reduce the within-pair sibling correlation in family-based studies. This increased variation between siblings would consequently increase the proportion of variation apparently due to individual-specific influences.

Limitations

Although this is the largest study of adult retrospectively reported childhood ADHD symptoms, our results should be considered in the light of a number of limitations. While several studies suggest that adults can accurately recall childhood ADHD symptoms, the validity of retrospective reports remains a concern. Generally, recall accuracy increases as the probability of a sample having had childhood ADHD increases (Magnusson *et al*. 2006). Accordingly, it has been suggested that diagnoses based on retrospective reports in non-clinical samples would contribute to errors in clinical assessment (Mannuzza *et al*. 2002; Faraone *et al*. 2006). While we could not directly address this issue in these data, two features of retrospective reports in the Add Health sample do suggest some validity. First, in these data, endorsement rates of childhood symptoms were significantly higher among those have taken ADHD medication in the past 12 months. Second, retrospective reports significantly predict substance misuse, conduct problems, low educational achievement and low socio-economic status in young adulthood (Fletcher *et al*. unpublished observations). These patterns agree with reports from longitudinal follow-up studies of ADHD children (Murphy & Barkley, 1996; Barkley *et al*. 2002; Biederman *et al*. 2006). A related limitation is that retrospective reports may be biased by current levels of functioning (Retz *et al*. 2002). The relative similarity of findings between studies of current ADHD symptoms and those based on retrospective reports suggest this as a possibility. We were unable to address this possibility as current ADHD-related symptoms were not assessed. Finally, third-party observations, whether impairment occurred in multiple settings, and age of onset were not assessed. As with childhood ADHD, this information is important in establishing a diagnosis of ADHD. Accordingly, the magnitude of genetic and environmental effects on retrospective reports of childhood ADHD may differ between clinical and general population samples.

Conclusions

Our results support the notion that adult retrospective reports of childhood ADHD evidence familiality. Our data suggest that retrospective reports evidence genetic influences, albeit substantially lower than the magnitude implicated for childhood ADHD assessed contemporaneously. Moreover, our results are consistent with the idea that current assessments based on rating scales may not provide the most accurate characterization of the etiological contributions to ADHD in general population samples. Although findings from neuropsychological and psychopharmacological research on adult ADHD converge with results from studies of children, many of the studies in adulthood do not examine samples assessed using retrospective reports. As such, our results support calls for caution when making diagnoses using retrospective reports and encourage further research involving general population samples.

Acknowledgments

B. C. Haberstick and D. Timberlake were supported by grant AA07464, C. J. Hopfer by grant DA15522 and M. A. Ehringer by grant AA015336. This research used

data from the National Longitudinal Study of Adolescent Health funded by grant HD31921. Special thanks to Soo Hyun Rhee, Erik Willcutt and Julia R. Stennes for their helpful comments regarding this work.

Declaration of Interest

None.

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