Research Article

Greater Attention Problems During Childhood Predict Poorer Executive Functioning in Late Adolescence

Naomi P. Friedman,[1] Brett C. Haberstick,[1] Erik G. Willcutt,[2] Akira Miyake,[2] Susan E. Young,[1] Robin P. Corley,[1] and John K. Hewitt[1]

[1]Institute for Behavioral Genetics, University of Colorado at Boulder, and [2]Department of Psychology, University of Colorado at Boulder

ABSTRACT—*Attention problems (behavior problems including inattention, disorganization, impulsivity, and hyperactivity) are widely thought to reflect deficits in executive functions (EFs). However, it is unclear whether attention problems differentially relate to distinct EFs and how developmental stability and change predict levels of EFs in late adolescence. We investigated, in an unselected sample, how teacher-rated attention problems from ages 7 to 14 years related to three correlated but separable EFs, measured as latent variables at age 17. Attention problems at all ages significantly predicted later levels of response inhibition and working memory updating, and to some extent set shifting; the relation to inhibiting was stronger than the relations to the other EFs or IQ. Growth models indicated that attention problems were quite stable in this age range, and it was the initial levels of problems, rather than their changes across time, that predicted later EFs. These results support the hypothesis that attention problems primarily reflect difficulties with response inhibition.*

"Attention problems" is a broad term often used to describe a collection of behavioral problems that include inattentiveness, distractibility, poor concentration, impulsivity, and, in some cases, hyperactivity. Such problems appear to be an important dimension of many psychological, social, and cognitive problems. Individual differences in childhood and adolescent attention problems are nearly ubiquitous correlates of psychopathological symptoms in normal and clinical populations (e.g., Gadow & Sprafkin, 1999; Leech, Larkby, Day, & Day, 2006; Mick, Biederman, Pandina, & Faraone, 2003; Pennington, 2002). Attention problems are also associated with learning disabilities (e.g., Snowling, Bishop, Stothard, Chipcase, & Kaplan, 2006; Willcutt & Pennington, 2000) and with psychosocial outcomes such as social skills, academic and occupational performance, and global adaptive functioning (Biederman et al., 2004; Lahey & Willcutt, 2002; Reynolds & Kamphaus, 2004).

Attention problems are widely thought to reflect deficits in executive functions (EFs), a family of cognitive control processes that operate on lower-level processes to regulate and shape behavior (Barkley, 1997; Nigg, 2000, 2001; Pennington, 2002; Pennington & Ozonoff, 1996), but the question of whether attention problems are differentially related to distinct EFs remains unresolved. Moreover, it is unclear how stability and change in childhood attention problems relate to eventual levels of EF abilities. We investigated, in a normal population, how teacher-rated attention problems from ages 7 to 14 years related to three correlated but separable EFs, measured with laboratory-based tasks in late adolescence. We focused on three primary questions: (a) Do attention problems differentially relate to distinct EFs? (b) How stable are the correlations of attention problems from age 7 through age 14 with later EFs? and (c) How do developmental stability and change in attention problems (i.e., developmental trajectories) relate to later EFs?

Much of the evidence for a link between everyday attention problems and EFs comes from clinical studies of individuals diagnosed with attention-deficit/hyperactivity disorder (ADHD),

Address correspondence to Naomi Friedman, Institute for Behavioral Genetics, 447 UCB, University of Colorado, Boulder, CO 80309, e-mail: naomi.friedman@colorado.edu.

who can be considered to be at the extreme of a continuous dimension of individual differences in attentional control and behavioral self-regulation (Fergusson & Horwood, 1995; Levy, Hay, McStephen, Wood, & Waldman, 1997). A recent meta-analysis of 83 studies found that groups with ADHD were impaired on a variety of EF measures (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005), though the correlations between ADHD symptoms and scores on EF tasks were typically modest (rs = .15−.35). The few studies that have examined attention problems in unselected, general-population samples have found similar results (e.g., Kuntsi, Andereou, Ma, Borger, & van der Meere, 2006), suggesting that the relation between attention problems and EFs is not confined to clinical populations.

Although executive control has long been treated as a unitary construct and measured with single complex "frontal lobe" tasks such as the Wisconsin Card Sorting Test (WCST), recent research supports the alternative characterization of executive control as a collection of behaviorally and neuropsychologically correlated but separable abilities (Collette et al., 2005; Miyake et al., 2000; Willcutt et al., 2001). For example, in previous work (Miyake et al., 2000), we found that three commonly discussed EFs—inhibiting prepotent or automatic responses (inhibiting), updating working memory by adding new relevant information as it appears and deleting no-longer-relevant information (updating), and shifting between tasks or mental sets (shifting)—were moderately correlated but separable (i.e., the correlations were significantly larger than zero, but significantly smaller than 1.0). Moreover, these three EFs showed differential involvement in complex neuropsychological tasks such as the WCST (associated most strongly with shifting; Miyake et al., 2000) and other cognitive constructs such as intelligence (associated most strongly with updating; Friedman et al., 2006).

These findings raise the question of whether attention problems may be differentially related to distinct EFs. Indeed, several theoretical proposals suggest that attention problems may be particularly related to response-inhibition abilities (Barkley, 1997; Nigg, 2000, 2001). For example, Barkley (1997) proposed that ADHD is primarily a deficit in behavioral inhibition, which leads to secondary deficits in other control processes such as working memory. Although there is considerable evidence that attention problems are related to inhibitory and other executive deficits (for reviews, see Barkley, 1997, and Nigg, 2001), few studies have systematically tested for differential relations between attention problems and specific EFs. Such a test is important, because delineation of the particular profile of executive deficits associated with general attention problems would provide an empirical basis for more targeted research that could lead to substantial theoretical advances in understanding attention problems and related disorders.

Another area of interest concerns developmental patterns of attention problems and the relations of these developmental patterns to EFs. Attention problems consistent with symptoms of ADHD begin in childhood and often persist into adulthood (Barkley, Fischer, Smallish, & Fletcher, 2002; Bongers, Koot, van der Ende, & Verhulst, 2003). Cross-sectional studies suggest that attention problems show similar relations to EFs in childhood (Chhabildas, Pennington, & Willcutt, 2001; Willcutt et al., 2005) and adulthood (Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005; Hervey, Epstein, & Curry, 2004; Nigg, Butler, Huang-Pollock, & Henderson, 2002). However, such cross-sectional studies cannot shed light on how developmental stability and change (i.e., developmental trajectories) in attention problems over time relate to later levels of EFs. Though this relation is an important piece of the overall picture of how everyday attention problems relate to executive control, to our knowledge no studies have yet examined it.

In the current study, we investigated whether attention problems show differential relations to multiple, separable EFs, and how developmental stability and change in attention problems relate to later EFs. Specifically, we examined how attention problems, measured with the Teacher Report Form of the Child Behavior Checklist (TRF; Achenbach, 1991) at ages 7 to 14 years, relate to inhibiting, updating, and shifting abilities, measured with laboratory tasks at age 17 years, and IQ at age 16.

Following our previous work, we measured these EFs with latent variables, an approach that circumvents the "task impurity" problem: Because EFs are conceptualized as control processes that operate on lower-level processes, individual differences in performance on any one task necessarily include variance that is unrelated to the EF. Hence, correlations (or lack thereof) with individual EF tasks, as well as differential correlations with various individual EF measures, may be due to the non-EF aspects of the tasks. A latent variable is a statistical extraction of the reliable variance common to multiple measures that tap the same underlying construct. When tasks are selected to tap the same EF, but with different lower-level processing requirements, this common latent-variable variance should not include variance unrelated to the target EF (e.g., variance in word recognition ability). Hence, compared with individual EF tasks, latent variables provide purer measures of EFs that are also free of measurement error (Bollen, 1989). This increased purity and decreased measurement error of the EF variables enhances power and interpretability when examining their associations with other constructs of interest, such as attention problems.

METHOD

Subjects

The subjects were 866 individual twins (422 male, 444 female) from the Colorado Longitudinal Twin Study, an ongoing study of child and adolescent behavioral development at the Institute for Behavioral Genetics (University of Colorado, Boulder). The total sample in the current analyses consisted of all individuals (out of 966 enrolled in the longitudinal study) with data for teacher-rated attention problems, IQ, or EFs. There were 798 individuals with data on attention problems and 582 individuals with data for the IQ and EF measures (those who had reached the age range for testing on the EF battery); of these latter 582 subjects, 86 were missing data for one or more EF measures because of color blindness or subject, experimenter, or equipment error. All research protocols were reviewed and approved by the University of Colorado's institutional review board. Parental permission and informed consent or assent were obtained from each subject at each assessment. The subjects received monetary compensation for participation.

Materials, Design, and Procedure

Attention Problems

We measured attention problems with ratings from the TRF (Achenbach, 1991), a questionnaire for assessing childhood attention problems outside the home. The 20-item Attention Problems scale reflects the child's responses to the demands of a structured classroom. The majority of the items on the scale assess attention and organization (e.g., *inattentive*, *easily distracted*, *can't concentrate*, *daydreams*). Subsets of items measure related constructs such as impulsivity (*impulsive*), overactivity (*can't sit still*, *restless*, *hyperactive*), and learning (*poor school work*, *has difficulty learning*). Teachers rated each item using a 3-point Likert scale (0 = *not true*, 1 = *somewhat or sometimes true*, and 2 = *very true or often true*). The dependent measure at each age was the sum of the ratings (maximum possible score of 40). Teachers' observations were collected annually at ages 7 to 14, with different teachers rating each individual across the years.

EFs and IQ

Subjects completed the third edition of the Wechsler Adult Intelligence Scale (WAIS-III; Wechsler, 1997) at approximately age 16 (M = 16.6, SD = 0.8, range = 15.8–20.0). They completed the nine tasks used to tap the three target EFs (three tasks per EF) at approximately age 17 (M = 17.4, SD = 0.6, range = 16.1–20.1). Because the methods are described in more detail elsewhere (Friedman et al., 2006, 2007), only the primary requirements of the individual tasks are summarized in Table 1.

Statistical Procedures

To reduce the influence of outliers and improve normality, we used transformations (square root and arcsine) and trimming when appropriate (see Table 2 for details and descriptive statistics). These procedures resulted in acceptable skewness and kurtosis for all variables.

We used Mplus 4.1 (Muthén & Muthén, 2006) for the confirmatory factor analyses (CFAs) and latent growth-curve models, including subjects with missing data for one or more measures. To correct for the nonindependence of the twin pairs, we used

TABLE 1

Descriptions and Factor Loadings of the Executive Function Tasks

Measure	Description[a]	Factor loading[b]
Inhibiting		
Antisaccade	Suppress the reflexive tendency to look at a cue and instead look in the opposite direction to identify a briefly appearing target (DM = proportion correct)	.41
Stop-signal	Withhold a prepotent categorization response on trials with an auditory signal (DM = stop-signal RT, calculated according to Logan, 1994)	.53
Stroop	Resist a dominant tendency to read color words, instead naming the incongruent font color; on neutral trials, name the color of a string of asterisks (DM = incongruent-trial RTs – neutral-trial RTs)	.46
Updating		
Keep-track	Given a series of 15 words from 6 categories, recall the last presented word belonging to each of 2 to 4 target categories (DM = proportion correct)	.71
Letter-memory	Continuously say the last 3 letters presented in a running series of unpredictable length, then recall the final 3 letters (DM = proportion correct)	.61
Spatial 2-back	Given 10 boxes that are randomly distributed on a screen and highlighted in an unpredictable sequence, indicate whether each highlighted box is the same as the box highlighted 2 trials before (DM = proportion correct)	.45
Shifting		
Number-letter	Depending on the location of a number-letter pair, switch between classifying numbers as odd/even or letters as consonant/vowel (DM = switch-trial RTs − no-switch-trial RTs)	.66
Color-shape	Depending on a cue letter presented with a colored shape, switch between classifying the shape as circle/triangle or the color as red/green (DM = switch-trial RTs − no-switch-trial RTs)	.64
Category-switch	Depending on a cue symbol, switch between classifying the referent of a word as living/nonliving or small/big (DM = switch-trial RTs − no-switch-trial RTs)	.74

Note. DM = dependent measure; RT = reaction time.
[a]For RT DMs, directionality was reversed so that higher numbers indicated better performance. [b]This column presents standardized factor loadings of the tasks on their respective latent variables from the final growth-curve model.

TABLE 2
Descriptive Statistics

Task	*n*	Mean	*SD*	Min	Max	Skewness	Kurtosis	Reliability
EF tasks[a]								
Antisaccade[b]	562	1.04	0.20	0.47	1.57	−0.14	−0.32	.89[e]
Stop-signal	540	284 ms	65	151	500	1.18	1.67	.76[e]
Stroop[c]	548	212 ms	89	0	483	0.51	0.06	.91[e]
Keep-track[b]	559	0.93	0.18	0.37	1.50	0.25	0.59	.66[f]
Letter-memory[b]	568	1.09	0.24	0.38	1.57	0.29	−0.01	.61[f]
Spatial 2-back[b]	564	1.17	0.18	0.63	1.57	−0.96	1.57	.91[f]
Number-letter[c]	562	336 ms	190	−14	953	1.12	1.28	.86[e]
Color-shape[c]	551	333 ms	192	−196	930	0.83	0.97	.86[e]
Category-switch[c]	553	343 ms	193	−34	941	1.05	1.01	.85[e]
WAIS-III IQ	582	102	11	70	142	0.16	0.37	.97[g]
Attention problems[d]								
Age 7	571	5.47	7.13	0	37	0.52	−0.75	.91[f]
Age 8	529	5.25	7.17	0	38	0.62	−0.59	.94[f]
Age 9	507	5.78	7.46	0	33	0.49	−0.89	.94[f]
Age 10	505	5.28	6.85	0	34	0.50	−0.88	.93[f]
Age 11	497	5.12	7.29	0	35	0.68	−0.58	.94[f]
Age 12	435	4.23	6.40	0	32	0.82	−0.31	.94[f]
Age 13	355	3.93	6.13	0	29	0.87	−0.32	.93[f]
Age 14	263	4.27	6.54	0	31	0.82	−0.43	.94[f]

Note. EF = executive function; Min = minimum; Max = maximum; WAIS-III = Wechsler Adult Intelligence Scale, 3rd ed.
[a]Observations more than 3 *SD*s from the group mean for each EF task were replaced with values 3 *SD*s from the mean. This procedure affected no more than 2.1% of the observations for any task. [b]Accuracy scores were arcsine transformed. [c]Means used for reaction time (RT) differences were obtained by averaging the RTs remaining after excluding errors and extreme RTs (those deviating from the median by more than 3.32 times the median absolute deviation in each condition; Wilcox & Keselman, 2003). [d]Means and standard deviations were calculated for raw summed scores. All analyses used square-root-transformed attention-problem scores; skewness and kurtosis reflect the distributions of the transformed scores. [e]Internal reliability was calculated by adjusting split-half correlations with the Spearman-Brown prophecy formula. [f]Internal reliability was calculated using Cronbach's alpha. [g]Internal reliability was taken from Wechsler (1997).

Mplus's TYPE = COMPLEX option to obtain corrected standard errors and a scaled chi-square robust to nonindependence. To assess model fit, we supplemented the chi-square statistic with the confirmatory fit index (CFI) and root-mean-square error of approximation (RMSEA). Because the chi-square is sensitive to sample size, we used $CFI > .95$ and $RMSEA < .06$ as indicators of good fit (Hu & Bentler, 1998). To test whether parameters of interest were significant or whether two parameters could be constrained to be equal, we used scaled chi-square difference tests ($\Delta\chi^2$; Satorra & Bentler, 2001) for nested model comparisons; significant chi-square differences indicate that the model constraints significantly worsened model fit.

RESULTS AND DISCUSSION

As shown in Table 2, the average attention-problems scores were low, as might be expected given the unselected sample. The intercorrelations among the attention-problems scores at different ages ranged from .39 to .65, with a correlation of .40 between ratings at age 7 and those at age 14. These correlations are remarkably high considering that different teachers rated each individual across the 8-year span of time and suggest that attention problems exhibited in school are quite stable.

Relations Between Attention Problems at Each Age and Later EFs

We used CFAs to examine how attention problems at each year related to the three EFs and IQ, measured in late adolescence. CFA is a procedure that estimates the parameters and fits of a factor structure that is specified a priori. The base CFA model consisted of three EF latent variables (constructed from their respective tasks, described in Table 1) and IQ. As in our previous analyses (Friedman et al., 2006) on a subset of the current sample (the first 234 individuals with data available at that time), the fit of the model was good, $\chi^2(30) = 63.01, p < .001$, $CFI = .963$, $RMSEA = .043$. All of the EF tasks loaded significantly on their respective constructs (see Table 1 for the loadings from the growth model we present later, which were essentially identical to those in the CFAs), and all the interfactor correlations (also essentially the same as those in the growth model) were significant and within the 95% confidence intervals of the interfactor correlations obtained for the earlier subset of the sample (Friedman et al., 2006). To this base model we added the attention-problems scores for each year (each year added in a separate analysis, resulting in eight separate CFA models) to obtain the correlations between attention problems and the later EFs and IQ. The fits of the resulting models were good, all χ^2s$(36) < 83.30$, ps $< .001$, CFIs $> .948$, $RMSEA$s $< .044$.

TABLE 3
Correlations of Attention Problems With Later Executive Functions and IQ

	Attention-problems measure							
Measure	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14
Inhibiting	**−.44**	**−.41**	**−.38**	**−.39**	**−.31**	**−.42**	**−.44**	**−.48**
Updating	**−.34**	**−.27**	**−.22**	**−.27**	**−.19**	**−.17**	**−.20**	**−.27**
Shifting	**−.17**	−.14	**−.19**	**−.19**	**−.24**	−.07	−.11	−.08
WAIS-III IQ	**−.28**	**−.27**	**−.24**	**−.26**	**−.21**	**−.23**	**−.24**	**−.25**

Note. Boldface indicates $p < .05$, determined with chi-square difference tests. WAIS-III = Wechsler Adult Intelligence Scale, 3rd ed.

As shown in Table 3, lower levels of attention problems at all ages significantly predicted better later Inhibiting and Updating abilities, as well as IQ. Ratings for half the ages also significantly predicted Shifting abilities. The patterns of correlations were remarkably consistent across years, with attention problems showing the highest correlations with Inhibiting (M correlation = −.41), and lower correlations with Updating (M = −.24) and Shifting (M = −.15). The correlations with IQ were similar to those for Updating (M = −.25), a finding consistent with our previous findings that IQ and Updating abilities are closely related (Friedman et al., 2006).

To examine whether attention problems at each year differentially correlated with the three EFs, we used chi-square difference tests to determine whether models that set these correlations to be equal resulted in significantly worse fits to the data. Equating the correlations between attention problems and the three EFs significantly worsened model fit at ages 7, 8, 12, 13, and 14, all $\Delta\chi^2$s(2) $\geq$ 7.83, ps $<$ .020. The chi-square differences were marginally significant for ages 9 and 10, both $\Delta\chi^2$s(2) $>$ 4.67, ps $<$ .097, but not significant for age 11, $\Delta\chi^2(2) = 1.65$, $p = .438$. Pair-wise comparisons (i.e., constraining two correlations to be equal) indicated that the correlations of attention problems with Inhibiting were significantly larger than the correlations of attention problems with Shifting at every age, all $\Delta\chi^2$s(1) $>$ 4.68, ps $<$ .031, except age 11. The correlation with Inhibiting was significantly higher than the correlation with Updating at age 12, $\Delta\chi^2(1) = 7.14$, p = .008, and age 14, $\Delta\chi^2(1) = 4.42$, $p = .036$, and the correlation with Updating was significantly higher than the correlation with Shifting at age 7, $\Delta\chi^2(1) = 4.25$, $p = .039$. Taken together, these results confirm that attention problems are differentially related to the three EFs, showing the highest correlation with Inhibiting and the lowest correlation with Shifting. In the next section, we revisit this issue of differential relations in the context of growth trajectories, which provide an efficient and informative way to combine the developmental data.

Relations Between Growth Trajectories and Later EFs

The strength of the correlations between attention problems at age 7 and later EFs and IQ, as well as the consistency of the correlations between attention problems and later EFs and IQ across years (Table 3), raises the possibility that it is one's initial level of attention problems, rather than how they change, that is related to later EFs and IQ. To examine this issue, we evaluated how individual differences in growth trajectories of attention problems across time predicted later EFs and IQ.

We first estimated a latent growth-curve model (Bollen & Curran, 2006) of attention problems across time. As is evident from the means for the attention-problems ratings from age 7 to age 14 (see Table 2), attention problems overall showed small (nonlinear) decreases across time. In growth models, one can parsimoniously represent trajectories with an intercept variable and a slope variable[1]; in standard parameterizations such as the one we used, the intercept variable can be interpreted as the initial level of the measured variable (here, attention problems),[2] and the slope variable can be interpreted as the change across time. For the current study, an important feature of these models is that they allow for individual differences in the trajectories (in the intercept and slope values) that can be used to examine how individual differences in these growth parameters predict individual differences in later EFs.

The growth model showed a good fit to the data, $\chi^2(25)$ = 49.59, $p = .002$, $CFI = .979$, $RMSEA = .035$. Both the intercept and the slope factors showed significant variance, indicating individual differences in both the initial level of attention problems and the degree of change in attention problems. The small but significant correlation (.26) between the intercept and slope resulted from a tendency for higher levels of initial attention problems to be generally associated with more arched (small increases followed by decreases) growth trajectories.

To examine how individual differences in these trajectories predicted later EFs, we added the three EF latent variables (and IQ, for comparison) simultaneously to the growth model and allowed them to correlate with the intercept and the slope latent variables. The model fit was good, $\chi^2(127) = 195.35$, $p < .001$,

[1]We modeled the shape of the trajectories using a single nonlinear slope variable (obtained by setting the age-7 loading on the slope variable to zero, setting the age-14 loading to 1.0, and freeing the remaining loadings for ages 8 to 13). This method provides a more parsimonious way of modeling trajectories than modeling several polynomial (e.g., linear, quadratic) slope factors (Bollen & Curran, 2006).

[2]In general, the intercept can be interpreted as the initial (age 7) level of attention problems, but because it is a latent variable that loads on all ages and incorporates subjects with missing data, its correlations with the EFs and IQ are not necessarily exactly the same as those presented in Table 3.

TABLE 4
Correlations Among Growth-Model Intercept and Slope and Later Executive Functions and IQ

Measure	1	2	3	4	5	6
1. Intercept	—					
2. Slope	**.26**	—				
3. Inhibiting	**−.54**	.04	—			
4. Updating	**−.33**	−.13	**.75**	—		
5. Shifting	**−.21**	**−.22**	**.74**	**.39**	—	
6. WAIS-III IQ	**−.35**	−.05	**.55**	**.70**	**.20**	—

Note. Boldface indicates $p < .05$, determined with chi-square difference tests. WAIS-III = Wechsler Adult Intelligence Scale, 3rd ed.

$CFI = .970$, $RMSEA = .025$. As Table 4 shows, it was primarily the intercept that predicted later EFs and IQ, which suggests that it is indeed the initial level of attention problems, rather than the degree of subsequent change, that predicts these cognitive abilities in late adolescence. The direction of the intercept's correlations with the cognitive variables indicated that higher levels of early attention problems predicted poorer Inhibiting, Updating, Shifting, and IQ. The only significant correlation between the slope variable and the cognitive variables was with Shifting. This correlation is difficult to interpret, however, as its direction reflects a tendency for flatter trajectories of attention problems across time to be associated with better Shifting abilities.

The magnitudes of the correlations between the intercept variable and the EFs (Table 4), like the correlations in Table 3, suggest that attention problems are most closely related to Inhibiting. Indeed, the intercept's correlation with Inhibiting was significantly larger than its correlation with Updating, $\Delta\chi^2(1) = 5.72, p = .017$; Shifting, $\Delta\chi^2(1) = 10.93$, $p = .001$; and IQ, $\Delta\chi^2(1) = 5.05$, $p = .025$. In contrast, the intercept's correlations with Updating, Shifting, and IQ did not differ significantly from each other, all $\Delta\chi^2\text{s}(1) < 2.53$, $ps > .112$. These results indicate that, as was generally the case with the models examining each age separately, attention problems are differentially related to the three EFs.

GENERAL DISCUSSION

The goals of this study were to (a) determine whether normal individual differences in school-age attention problems differentially relate to three EFs, (b) evaluate the stability of the relation between childhood attention problems and EFs in late adolescence, and (c) specify how developmental trajectories in attention problems predict later EFs. We found that attention problems at all eight ages significantly predicted individual differences in later Inhibiting, Updating, and IQ, and that attention problems at some of the ages also predicted Shifting. Model comparisons indicated that attention problems were differentially related to the three EFs. In particular, attention problems were more closely related to Inhibiting than to Updating and Shifting.

We also found that attention problems were more strongly related to Inhibiting than to IQ, which suggests that the link between attention problems and Inhibiting is not simply due to lower levels of general cognitive ability associated with attention problems. A supplementary analysis supported this conclusion: We found that the intercept variable of the attention-problems growth curve correlated significantly (−.40) with the variance in Inhibiting that was unrelated to IQ (i.e., the residual variance in Inhibiting that remained after partialing out WAIS-III IQ).

Though several other research groups have suggested that specific aspects of executive control may be differentially related to attention problems (e.g., Barkley, 1997; Nigg, 2001; Pennington & Ozonoff, 1996), to date there has not been much strong evidence for these hypotheses. The current results are consistent with theoretical predictions that attention problems arise primarily from a deficit in response inhibition (e.g., Barkley, 1997; Nigg, 2000, 2001). Although there may be separable EFs other than those measured here (for discussions of this issue, see Friedman & Miyake, 2004, and Miyake et al., 2000), the three EFs we included in this study are perhaps the most frequently discussed and well studied in the literature (e.g., Willcutt et al., 2005), and as such are arguably the critical EFs to examine in an attempt to specify the nature of the relation between attention problems and EFs. The facts that the EF latent variables' correlations with attention problems were considerably higher (up to −.48) than those reported in previous studies using single EF tasks (*r*s = .15−.35; see Willcutt et al., 2005) and that these correlations were precise enough to show statistically significant differences demonstrate the value of the latent-variable approach for EF research.

The correlations between childhood attention problems at each year and EFs in late adolescence were surprisingly similar across years, considering that the ratings for a given child came from different teachers at different time points. These results suggest substantial stability in the relations of attention problems across time to later EFs and IQ. Remarkably, the correlations between attention problems at age 7 and later EFs and IQ were among the highest, despite the approximately 10-year age gap between the school attention-problem ratings and the later laboratory-based cognitive measures. Indeed, the results from our latent growth-curve models indicated that the initial levels of attention problems, rather than changes across time, related to later executive control. Although speculative, one interpretation of these results is that even early everyday attentional and behavioral problems reflect stable EF deficits that continue into late adolescence and early adulthood. However, because we did not have EF data at each year with which to test whether attention problems were associated with lower EFs at each time point, we cannot rule out the alternative interpretation that persistent attention problems in childhood lead to lower EF abilities later in adolescence.

The fact that we obtained these results in a normal population, who on average showed low levels of attention problems, indicates that individual differences in EF abilities are important for understanding even normal variation in attention problems, not just clinical extremes. These results are consistent with the characterization of variation in attention problems as an underlying continuum of risk for psychopathology (e.g., Fergusson & Horwood, 1995; Levy et al., 1997). The similarity of our results to those from clinical studies, particularly studies of ADHD (conceptually the psychopathology most closely related to attention problems), suggests that our findings may generalize to more extreme clinical populations. Although no ADHD studies have incorporated EF latent variables, and few have tested for differential relations between ADHD and EFs, meta-analyses suggest that ADHD is associated with lower performance on individual tasks thought to tap response inhibition, including some of the tasks used in the current study (Frazier, Demaree, & Youngstrom, 2004; Willcutt et al., 2005).

Considering that the attention-problems ratings were teachers' observations of classroom behavior and the later EF latent variables were based on cognitive tasks, the magnitudes of their correlations were strikingly high. These findings illustrate the external validity of current cognitive models of executive control, developed through laboratory-based research, for understanding everyday "real-world" problems. In particular, the differential relations of the three EFs to everyday attention problems highlights the value of considering the distinctions made in the cognitive literature for refining current understanding of attention problems, and has implications for a number of psychopathologies and neuropsychiatric disorders that are associated with attention problems—for example, ADHD, anxiety, depression, and bipolar disorder (Gadow & Sprafkin, 1999; Leech et al., 2006; Mick et al., 2003); conduct disorder, schizophrenia, and Asperger's disorder (Gadow & Sprafkin, 1999); and Tourette's disorder (Termine et al., 2006). The success of this approach in investigating the relations between EFs and attention problems suggests that it may provide a useful framework for future research investigating the relations between EFs and other dimensions of psychopathologies and neuropsychiatric disorders.

Acknowledgments—Data collection was supported by National Institutes of Health (NIH) Grants MH63207 and HD010333. N.P. Friedman was supported by NIH Grant MH075814, B.C. Haberstick by National Institute on Alcohol Abuse and Alcoholism Grant AA07464, and S.E. Young by NIH Grant MH01865. We thank Sally Ann Rhea and Scott Sabella for project coordination and data collection.

REFERENCES

Achenbach, T.M. (1991). *Manual for the Teacher Report Form and 1991 profile*. Burlington: University of Vermont, Department of Psychiatry.

Barkley, R.A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*, *121*, 65–94.

Barkley, R.A., Fischer, M., Smallish, L., & Fletcher, K. (2002). The persistence of attention-deficit/hyperactivity disorder into young adulthood as a function of reporting source and definition of disorder. *Journal of Abnormal Psychology*, *111*, 279–289.

Biederman, J., Monuteaux, M.C., Seidman, L.J., Wilens, T.E., Ferrero, F., Morgan, C.L., & Faraone, S.V. (2004). Impact of executive function deficits and attention-deficit/hyperactivity disorder (ADHD) on academic outcomes in children. *Journal of Consulting and Clinical Psychology*, *72*, 757–766.

Bollen, K.A. (1989). *Structural equations with latent variables*. New York: Wiley.

Bollen, K.A., & Curran, P.J. (2006). *Latent curve models: A structural equation perspective*. New York: Wiley.

Bongers, I.L., Koot, H.M., van der Ende, J., & Verhulst, F.C. (2003). The normative development of child and adolescent problem behavior. *Journal of Abnormal Psychology*, *112*, 179–192.

Boonstra, A.M., Oosterlaan, J., Sergeant, J.A., & Buitelaar, J.K. (2005). Executive functioning in adult ADHD: A meta-analytic review. *Psychological Medicine*, *35*, 1–12.

Chhabildas, N., Pennington, B.F., & Willcutt, E.G. (2001). A comparison of the neuropsychological profiles of the DSM-IV subtypes of ADHD. *Journal of Abnormal Child Psychology*, *29*, 529–540.

Collette, F., Van der Linden, M., Laureys, S., Delfiore, G., Degueldre, C., Luxen, A., & Salmon, E. (2005). Exploring the unity and diversity of the neural substrates of executive functioning. *Human Brain Mapping*, *25*, 409–423.

Fergusson, D.M., & Horwood, L.J. (1995). Predictive validity of categorically and dimensionally scored measures of disruptive childhood behaviors. *Journal of the American Academy of Child & Adolescent Psychiatry*, *34*, 477–485.

Frazier, T.W., Demaree, H.A., & Youngstrom, E.A. (2004). Meta-analysis of intellectual and neuropsychological test performance in attention-deficit/hyperactivity disorder. *Neuropsychology*, *18*, 543–555.

Friedman, N.P., & Miyake, A. (2004). The relations among inhibition and interference control processes: A latent variable analysis. *Journal of Experimental Psychology: General*, *133*, 101–135.

Friedman, N.P., Miyake, A., Corley, R.P., Young, S.E., DeFries, J.C., & Hewitt, J.K. (2006). Not all executive functions are related to intelligence. *Psychological Science*, *17*, 172–179.

Friedman, N.P., Miyake, A., Young, S.E., DeFries, J.C., Corley, R.P., & Hewitt, J.K. (2007). *The unity and diversity of executive function are genetic in origin*. Manuscript submitted for publication.

Gadow, K.D., & Sprafkin, J. (1999). *1999 revised norms and scoring guide for the Child Symptom Inventory–V 4*. Stony Brook, NY: Checkmate Plus.

Hervey, A.S., Epstein, J.N., & Curry, J.F. (2004). Neuropsychology of adults with attention-deficit/hyperactivity disorder: A meta-analytic review. *Neuropsychology*, *18*, 485–503.

Hu, L., & Bentler, P.M. (1998). Fit indices in covariance structure modeling: Sensitivity to underparameterized model misspecification. *Psychological Methods*, *3*, 424–453.

Kuntsi, J., Andereou, P., Ma, J., Borger, N.A., & van der Meere, J.J. (2006). Testing assumptions for endophenotype studies in ADHD: Reliability and validity of tasks in a general population sample. *BMC Psychiatry*, *5*, 1–11.

Lahey, B.B., & Willcutt, E.G. (2002). The validity of attention-deficit/hyperactivity disorder among children and adolescents. In P.S. Jensen & J.R. Cooper (Eds.), *Diagnosis and treatment of attention deficit hyperactivity disorder: An evidence-based approach* (pp. 1-1–1-23). New York: Civic Research Institute.

Leech, S.L., Larkby, C.A., Day, R., & Day, N. (2006). Predictors and correlates of high levels of depression and anxiety symptoms among children at age 10. *Journal of the American Academy of Child & Adolescent Psychiatry*, *45*, 223–230.

Levy, F., Hay, D.A., McStephen, M., Wood, C., & Waldman, I. (1997). Attention-deficit hyperactivity disorder: A category or a continuum? Genetic analysis of a large-scale twin study. *Journal of the American Academy of Child & Adolescent Psychiatry*, *36*, 737–744.

Logan, G.D. (1994). On the ability to inhibit thought and action: A user's guide to the stop signal paradigm. In D. Dagenbach & T.H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 189–239). San Diego, CA: Academic Press.

Mick, E., Biederman, J., Pandina, G., & Faraone, S.V. (2003). A preliminary meta-analysis of the Child Behavior Checklist in pediatric bipolar disorder. *Biological Psychiatry*, *53*, 1021–1027.

Miyake, A., Friedman, N.P., Emerson, M.J., Witzki, A.H., Howerter, A., & Wager, T.D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*, 49–100.

Muthén, L.K., & Muthén, B.O. (2006). *Mplus users guide* (4th ed.). Los Angeles: Muthén & Muthén.

Nigg, J.T. (2000). On inhibition/disinhibition in developmental psychopathology: Views from cognitive and personality psychology and a working inhibition taxonomy. *Psychological Bulletin*, *126*, 220–246.

Nigg, J.T. (2001). Is ADHD a disinhibitory disorder? *Psychological Bulletin*, *127*, 571–598.

Nigg, J.T., Butler, K.M., Huang-Pollock, C.L., & Henderson, J.M. (2002). Inhibitory processes in adults with persistent childhood onset ADHD. *Journal of Consulting and Clinical Psychology*, *70*, 153–157.

Pennington, B.F. (2002). *The development of psychopathology*. New York: Guilford.

Pennington, B.F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *37*, 51–87.

Reynolds, C.R., & Kamphaus, R.W. (2004). *Behavior assessment system for children* (2nd ed.). Circle Pines, MN: AGS.

Satorra, A., & Bentler, P.M. (2001). A scaled difference chi-square test statistic for moment structure analysis. *Psychometrika*, *66*, 507–514.

Snowling, M.J., Bishop, D.V.M., Stothard, S.E., Chipcase, B., & Kaplan, C. (2006). Psychosocial outcomes at 15 years of children with a preschool history of speech-language impairment. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *47*, 759–765.

Termine, C., Balottin, U., Rossi, G., Maisano, F., Salinia, S., Di Nardo, R., & Lanzi, G. (2006). Psychopathology in children and adolescents with Tourette's syndrome: A controlled study. *Brain & Development*, *28*, 69–75.

Wechsler, D. (1997). *Wechsler Adult Intelligence Scale* (3rd ed.). San Antonio, TX: Psychological Corp.

Wilcox, R.R., & Keselman, H.J. (2003). Modern robust data analysis methods: Measures of central tendency. *Psychological Methods*, *8*, 254–274.

Willcutt, E.G., Doyle, A.E., Nigg, J.T., Faraone, S.V., & Pennington, B.F. (2005). Validity of the executive function theory of attention-deficit/hyperactivity disorder: A meta-analytic review. *Biological Psychiatry*, *57*, 1336–1346.

Willcutt, E.G., & Pennington, B.F. (2000). Comorbidity of reading disability and attention-deficit/hyperactivity disorder: Differences by gender and subtype. *Journal of Learning Disabilities*, *33*, 179–191.

Willcutt, E.G., Pennington, B.F., Boada, R., Ogline, J.S., Tunick, R.A., Chhabildas, N.A., & Olson, R.K. (2001). A comparison of the cognitive deficits in reading disability and attention-deficit/hyperactivity disorder. *Journal of Abnormal Psychology*, *110*, 157–172.

(Received 9/21/06; Revision accepted 12/12/06;
Final materials received 12/17/06)