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Trait Mechanisms in Youth with and without Attention-Deficit/Hyperactivity Disorder

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Abstract

Relations of temperament and personality traits within children and adolescents with ADHD and non-ADHD controls were examined. A two-process structure was hypothesized involving top-down effortful and bottom-up reactive response tendencies. Top-down processes were hypothesized to relate to inattentive ADHD symptoms, whereas bottom-up processes were hypothesized to relate to hyperactive-impulsive ADHD symptoms. Each hypothesis was tested in a sample of 179 children age 7 to 13 (113 boys; 107 ADHD) and then replicated in 184 adolescents age 14 to 17 (109 boys; 87 ADHD). All families completed a multistage diagnostic process. Youth completed laboratory measures of cognitive control, and parents completed trait ratings. Traits examined in the current study included effortful control, reactive control, resiliency, negative emotionality, neuroticism, extraversion, openness, agreeableness, and conscientiousness. Correlational relations among traits were inconclusive, but external correlations with cognitive tasks and ADHD symptoms were interpretable within the hypothesized two-process framework. Results provide partial support for a distinction between effortful and reactive traits and suggest this distinction is useful in relation to understanding ADHD.

Keywords

Traits; Temperament; Personality; ADHD; children; adolescents

Temperament and personality applications to psychopathology have been increasingly emphasized. Complicating that linkage is that temperament and personality have historically been treated as distinct concepts, despite using similar behavioral descriptors. More recently, at least at the level of superordinate behavioral traits, temperament and personality appear to be converging. Several theorists have suggested that major dimensions of temperament in children and personality in adults may be isomorphic (e.g., Digman, 1997; Markon, Krueger, & Watson, 2005). If so, better empirical linkage of temperament and personality models in children will simplify the field and help to clarify developmental pathways. Yet, the development of an appropriate structure for such integration is not as straightforward as one might wish. Temperament dimensions among children do not always map cleanly onto corresponding personality dimensions among adults. The first goal for the current study was

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to use a multimethod approach to evaluate hypotheses about basic processes that may provide linkages between specific temperament and personality dimensions.

At the same time, we evaluated the associated pattern of these basic traits with psychopathology in order to provide cross validation of our hypothesis. Several forms of psychopathology might arguably be related to personality or temperament traits (Nigg, 2006a). Here we focus on one common disorder, Attention-Deficit/Hyperactivity Disorder (ADHD). ADHD is made up of two symptom domains that are typically correlated at about .5 to .7. Inattention-disorganization includes behaviors like “often fails to give close attention to details” or “makes careless mistakes in schoolwork, work, or other activities” (APA, 2000). Hyperactivity/impulsivity includes behaviors like “often fidgets with hands or feet,” “squirms in seat,” or “often has difficulty awaiting turn” (APA, 2000). ADHD is important as a very common, highly impairing, and trait-like (chronic) behavioral syndrome originating in childhood (APA, 2000). It thus provides an excellent case study for examining the structure of traits and their relation with psychopathology. Indeed, initial evidence suggests that individuals with ADHD are often characterized by extreme temperament or personality traits (Martel & Nigg, 2007; Nigg et al., 2002a; 2002b).

The translational effort in this paper entails both (a) clarifying the structural relation between two trait models, one developed for children and one developed for adult personality and (b) exploring their joint mechanisms through the lens of two external validation strategies: cognitive neuropsychological function and ADHD symptoms. In order to gain some purchase on replication and on potential developmental differences in findings, we conducted the study in a primary sample of children and a replication sample of adolescents. The examination of these relations in a sample of children and adolescents may also shed some light on developmental processes affecting trait structure and relations with psychopathology, especially since it is unclear at what point in development adult-like trait structure emerges (John et al., 1994).

Operational Models of Temperament and Personality

The terms temperament and personality have several different possible definitions and connotations. As used herein, temperament is defined as constitutionally-based differences in emotional reactivity and regulation. To operationalize temperament traits for children, we focus on Eisenberg et al.’s (1996; 2003) model of control and emotionality. This model describes four higher-order traits, which by childhood or adolescence doubtless include aspects of both temperament and personality. Effortful control is defined as the relatively deliberate, “top-down” modulation of behavior and mental life in the service of more distal goals held in working memory (Eisenberg et al., 2000). Reactive control, in contrast, is defined as a relatively automatic, “bottom-up” modulation of behavior in response to immediate incentive (Eisenberg et al., 2000). Resiliency refers to the flexible modulation of control in response to context demands. This trait is thought to relate to moderate levels of reactive control, exhibiting a curvilinear relation, and is correlated with high levels of effortful control. Negative emotionality connotes the propensity to experience a variety of negative affects, particularly anxiety, sadness, and -- to some extent -- anger.

Personality, as used here, is defined as cognitive structures and adaptive strategies developed across time through socialization and the further expression of temperament within an individual (Rothbart, Ahadi, & Evans, 2000). To operationalize personality, we selected the Five Factor Model (McCrae & Costa, 1987), one of the most widely-validated summaries of human personality traits (Eysenck, 1992; Goldberg, 1993), though it is not without its critics (Block, 1995).

The five traits of the Big Five are Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness. Neuroticism is characterized by vulnerability to anxiety, depression, and other negative emotions, including anger. Extraversion is characterized for our purposes by interpersonal activity that is directed outward, as well as by positive emotions and approach. Openness to Experience can be thought of as the active appreciation of life experiences. Agreeableness is defined by altruism, trust, compliance, and concern (with hostility at its opposite pole). Conscientiousness is characterized by planfulness, goal-directed behavior, and organization (McCrae & Costa, 1999). These traits have been replicated in a wide range of adult samples. A few studies in the past decade have suggested that very similar traits can be reproduced in samples of children and adolescents (Huey & Weisz, 1997; John et al., 1994; Measelle, John, Ablow, Cowan, & Cowan, 2005).

Proposed Integrative Framework

To render trait models informative with regard to developmental psychopathology, a process or mechanism model is needed. Herein, a two-process perspective is adopted that is related broadly to that suggested by John (1990) and Eisenberg (1996; and thus similar to that advocated by Block & Block, 1980) and recent findings in neuroscience. This perspective emphasizes a distinction between what we label heuristically as “top-down” and “bottom-up” response processing. These terms are used in many ways, but have specific meanings here derived from cognitive neuroscience. In this context, the speculated neural implementation of top-down processing reflects frontal cortical activation that tends to suppress limbic, subcortical, and posterior cortical activation (Casey, Jones, & Hare, in press). Behavioral forms of top-down control refer to the deliberate allocation of effort, attention, and behavior toward goals represented in working memory (Eisenberg et al., 2000; Rothbart & Bates, 1998). The neural underpinnings of bottom-up control involve the interruption of behavior sequences by activation of limbic networks (Holroyd & Coles, 2002). Behavioral forms of bottom-up control typically occur in response to immediate incentives (e.g., strong signals of danger or opportunity that activate anticipatory excitement, anxiety, or fear; Holroyd & Coles, 2002).

Developmentally, it is important to recognize that these two types of operation (effortful control of behavior versus stimulus-response strength) both develop dramatically during adolescence, with the bottom-up processes appearing to mature earlier than the top-down processes (Casey, Tottenham, Liston, & Durston, 2005). Top-down style of processing matures across development, particularly during adolescence, asserting increased control over bottom-up circuitry during late adolescence (Casey, Jones, & Hare, in press; Halperin & Schulz, 2006). Bottom-up processing is thought to come online much earlier in development, potentially exhibiting its strongest impact on behavior during early adolescence when the neural circuitry that underpins top-down control is still not fully developed (Casey, Jones, & Hare, in press). Therefore, it is not clear that the pattern of associations of behavioral traits with external validation markers will be the same across these periods of development.

The major traits of the Eisenberg model and the Big Five can be organized within this type of framework both by examination of the behaviors that characterize them and by initial experimental findings that we attempt to extend here. Because multiple neural response systems are involved in incentive response (beginning with avoidance versus approach at the most basic level; Nigg, 2006a), all theories posit that more traits are characterized as bottom-up versus top-down.

Following Ahadi and Rothbart (1994) and Nigg (2006a), we hypothesized that effortful control and resiliency from the Eisenberg et al (1996) model, and Conscientiousness from the Big Five reflect primarily top-down processes. Both effortful control and conscientiousness clearly reflect the deliberate, controlled allocation of attention and behavior so their assignment to this

domain was straightforward. Resiliency is more controversial, as it has also been linked to affective stability. However, Valiente, Eisenberg and colleagues (2003) suggest it is related to top-down processing, and we therefore followed that hypothesis here. If this hypothesis is correct, then these three traits should cluster together in correlational structure and should have similar external correlates, at least at the most abstract (two-factor) level. They should be uniquely correlated with laboratory measures of cognitive control that are known to depend on activation of prefrontal cortex.

The remaining traits in both models were viewed as bottom-up in nature. However, bottom-up processes are not expected to be unitary once one moves beyond an abstract two-component model. Low reactive control and high Extraversion were hypothesized to relate to a reactive response system based on approach tendencies. Early in life, this system may appear as reactive control, but later in life it develops into Extraversion. Negative emotionality and Neuroticism were hypothesized to share similar neural propensity to avoidance-related affect and behavior (note that avoidance response to potential loss of reward is conceptually and empirically distinct from social avoidance or affiliation).

In the present study, we use factor analytic techniques to examine the evidence for these models. After evaluating the two, three, and four-factor solutions, we followed up with external validation using a single bottom-up factor to emphasize the communalities between reactive, or affectively-based, forms of control as compared to top-down forms of control. We further acknowledge that different traits may be more or less prominent at different levels of abstraction with more traits being clustered together under fewer traits at higher levels of abstraction (e.g., at a two-trait level) and fewer traits being clustered together under more factors at lower levels of abstraction (e.g., at a five-factor level; Digman, 1997; Markon, Krueger, & Watson, 2005). The present study emphasizes a higher-order model with two factors.

External validation via cognitive control

By way of external validation, we obtained laboratory measures of cognitive control/executive function and ADHD symptoms. The laboratory measures of cognitive control were selected from among several that are validated with regard to top-down control processing and its neural correlates in functional imaging studies (i.e., prefrontal activation at the expense of subcortical or posterior activation). Effortful traits, the relatively deliberate modulation of emotional states, attention, and ensuing behavior have been conceptually related to cognitive control (Eisenberg et al., 1996; Olson et al., 2005).

External validation via relations with ADHD

In previous work examining children with behavior problems, low levels of both effortful and reactive control and high levels of negative emotionality were related to externalizing problems (Eisenberg et al., 1996; 2000). Earlier work by our group using a subset of the children reported on here, found that resiliency and effortful control were related to inattention, whereas reactive control was related to hyperactivity-impulsivity (Martel & Nigg, 2006). High levels of Extraversion and high levels of Neuroticism, Conscientiousness, and Agreeableness also appear to be related to externalizing disorders (Huey & Weisz, 1997; White, 1999). Nigg et al (2002a; 2002b) showed that in multiple samples of adults, ADHD symptoms of inattention-disorganization were closely related to low Conscientiousness, whereas ADHD symptoms of hyperactivity-impulsivity were related to low Agreeableness and, in some samples, high Extraversion. The relation to low Agreeableness appears to be accounted for by the overlap of hyperactivity-impulsivity with antisocial behaviors (Nigg et al., 2002b). If similar patterns of relation could be shown in children and adolescents, it would bridge this prior work on adults and children.

A parallel to our model of top-down and bottom-up control is readily available in regard to ADHD. ADHD's two symptom domains may emanate from breakdowns in top-down control mechanisms (inattention) versus bottom-up response mechanisms (hyperactivity/impulsivity; Nigg, 2006b; Nigg, Goldsmith, & Sachek, 2004; Sonuga-Barke, 2003; 2005). It therefore was hypothesized that inattention-disorganization would be related to the top-down factor and that hyperactivity-impulsivity would be related to the bottom-up component. Individual differences in relative number of symptoms in these two domains lead to subtyping of ADHD into "primarily inattentive" (ADHD-PI) and "combined" (both hyperactive and inattentive; ADHD-C). Primarily hyperactive children are also specified but are rare in the age range studied here and not included.

Summary: Aims and Hypotheses

Linkages between different trait models developed for children versus adults are not well-studied, particularly in regard to external correlates like cognitive control and ADHD symptom domains. Therefore, the current study sought to clarify the relationship of temperament and personality traits within a sample of children with ADHD and controls. We hypothesized that we could fit a two-process model to the personality traits, utilizing a distinction between top-down and bottom-up response tendencies borrowed from the temperament and cognitive neuroscience literatures. We tested whether we could validate this distinction with experimental measures of cognitive control, hypothesized to be related to top-down control and thus effortful traits. We further predicted that ADHD symptoms of inattention would differentially relate to top-down forms of control, while ADHD symptoms of hyperactivity-impulsivity would relate to bottom-up forms of control.

METHOD

Participants--Overview

The current study examines two samples: a child sample and an adolescent replication sample. In the child sample, participants were 179 children (113 boys, 66 girls) age 6 through 12 years. This was the same sample reported on in Martel & Nigg (2006). Twenty-eight percent of the child sample identified themselves as ethnic minorities. Children were initially included in one of two groups: those diagnosed with ADHD ($n = 107$) and controls ($n = 72$). Children with ADHD included 24 primarily Inattentive type (i.e., met criteria for 6 or more inattentive symptoms) and 68 Combined subtype (i.e., met criteria for 6 or more inattentive symptoms and 6 or more hyperactive-impulsive symptoms). Fifteen children had five symptoms of ADHD, falling just slightly below diagnostic threshold and were considered as part of the ADHD group. In the adolescent sample, participants were 184 adolescents (109 boys, 75 girls) age 13 to 18 years. This was the same sample reported on in Martel, Nikolas, & Nigg (2007). Twenty-two percent of the adolescent sample identified themselves as ethnic minorities. Adolescents were initially included in one of two groups: those diagnosed with ADHD, any type ($n = 87$) and controls ($n = 97$). Adolescents with ADHD included 48 primarily Inattentive type and 39 Combined type.

Participants—Recruitment and Identification

A broad community recruitment strategy was used, with mass mailings to parents in local school districts and public advertisements, in order to obtain as broadly representative of a sample as possible. Families initially recruited then passed through a standard multi-gate screening process to establish diagnostic groupings. At Stage 1, all families ($N = 969$ for children and $N = 672$ for adolescents) were screened by phone to rule out children and adolescents prescribed long-acting psychotropic medication (e.g. antidepressants), neurological impairments, seizure history, head injury with loss of consciousness, other major

medical conditions, uncorrectable vision problems or any hearing loss, or a prior diagnosis of mental retardation or autistic disorder, as reported by the parent.

At Stage 2, parents and teachers of participants not screened out at stage 1 ($N = 301$ for children and $N = 469$ for adolescents) completed rating scales (CBCL, Achenbach, 1991; Conners Rating Scale, Conners, 1997; ADHD Rating Scale, DuPaul et al. 1998). Youth who exceeded empirically-validated cutoffs on at least one parent (at the 80th percentile) and one teacher (at the 90th percentile) rating scale were eligible as possible ADHD; the others were eligible as controls.

Stage 3 diverged slightly for the initial child sample versus the subsequent adolescent sample. In the child sample, at Stage 3 eligible primary caretakers ($N=218$) completed the Diagnostic Interview Schedule for Children (DISC-IV; Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000) by telephone or during on-campus visits. The DISC-IV, a computer-guided, structured interview designed for use by non-clinicians, assessed symptomatology, as well as onset, duration, and impairment criterion for disorders in the *DSM-IV*. A 3-subtest short form of the WISC-III, comprised of the Block Design, Vocabulary, and Information subtests was also administered at this stage. This composite has a reliability coefficient of .93 and a validity coefficient of .88 (Sattler, 2001). Estimated full scale IQ over 75 was required for inclusion. For the adolescent sample at Stage 3, youth and their primary caregiver ($N = 368$) completed a semi-structured clinical interview (i.e., KSADS-E; Puig-Antich & Ryan, 1986), rather than the *DISC-IV*.

Final ADHD Classification and Data Combination

Final ADHD classification procedures were similar for children and adolescents. For children, the DISC-IV supplement with an “or” algorithm was used to confirm the diagnosis. If children met criteria regarding age of onset, duration, impairment, and cross-situational manifestation, the diagnostic assignment was determined by adding the endorsed symptoms of the DISC-IV with the teacher-reported symptoms on the ADHD Rating Scale to get the total number of symptoms. Children failing to meet cut-offs for all parent and teacher ADHD rating scales at the 80th percentile and having 4 or fewer symptoms of ADHD with the “or” algorithm were considered Controls. For adolescents, a “best estimate” diagnostic process was implemented, in which the psychiatrist and psychologist independently arrived at a clinical decision regarding ADHD diagnosis, subtype, and presence of comorbid disorders. To do so, they employed the generally accepted “or” algorithm across parent structured interview and teacher ratings to count symptoms and reviewed evidence of onset, duration, impairment, and cross-situational manifestation in the interview and ratings data. Their agreement rates all exceeded kappa = .88.

Clinical Symptom Counts—Evidence suggests that ADHD represents an arbitrary cut point on a continuous dimension of behavior (a trait), which favors the statistically more powerful dimensional approach over the categorical approach (Levy et al., 1997; Sherman et al., 1997). In order to create a quasi-continuous variable of total ADHD symptomatology, inattentive and hyperactive ADHD symptoms were added together. This sum was created from the teacher + parent-rated symptom count described above. To test key hypotheses, however, the effects of the two ADHD symptom domains needed to be isolated. This was done by creating residual scores after regressing each symptom domain on the other. Symptoms or diagnosis of Oppositional Defiant Disorder and Conduct Disorder were based on parent-report on the DISC-IV or KSADS-E.

Temperament and Personality Traits- California Q-Sort

To assess traits from the two models using the same methods, as many traits as possible were assessed with a parent-completed California Child Q-Sort (CCQ), a common language version of this personality inventory (Caspi et al., 1992). The CCQ is a typical Q-Sort consisting of 100 cards which must be placed in a forced-choice, 9-category, rectangular distribution. The rater (in this case, the mother) described the child by placing descriptive cards in one of the categories, ranging from 1 (least descriptive) to 9 (most descriptive). The CCQ was selected because it has previously been used to assess the Eisenberg and Big Five traits in children. Instructions given were derived from the standard instruction set provided by Jack Block (personal communication to J. Nigg, 1996). To measure *reactive control*, *resiliency*, and *negative emotionality*, scales developed by Eisenberg et al (1996; 2003; personal communication to J. Nigg, 2006) were used. To measure the Big Five, scales developed by John and colleagues (1994) were used. The scales for these trait measures have been well-validated in school-age children and adolescents, using a Q-sort format (Caspi et al., 1992; Eisenberg et al., 1996; John et al., 1994); thus, the items appear to be developmentally appropriate.

Handling of item overlap—Item overlap among personality and temperament trait scales was noted. Procedures were followed to eliminate overlapping items and reexamine the results. The correlational results were not substantially different or more meaningful with non-overlapping items. Therefore, because our primary concern was not to compromise the construct validity of these scales as devised by independent research experts (the temperament and Big Five investigators), we retained the raw scales with all items in the analyses reported here. Alpha reliability of all scales was acceptable (above .72). However, Openness has been poorly validated in children (Caspi, Roberts, & Shiner, 2005; John et al., 1994), so it was excluded from analyses.

Early Adolescent Temperament Questionnaire

Effortful control was not included in the Q-sort constructs provided in the literature. Therefore, in the child sample, mothers completed a short form of the Early Adolescent Temperament Questionnaire (EATQ; Capaldi & Rothbart, 1992). The EATQ Parent Report-Revised consists of 62 items describing child temperament characteristics. The questionnaire instructions consist of asking the parent to rate how well the statements describe her child on a scale from 1 (almost always untrue of the child) to 5 (almost always true of the child), yielding 10 scales. In the current study, a scale of *effortful control* was created by using a scale from the EATQ (Eisenberg et al., 1996). Alpha reliability was acceptable (.84). The measure was not obtained in the replication sample.

Laboratory Measures of Top Down Control

Four variables were obtained from three tasks, each with prior extensive literature as potential laboratory indices of cognitive control.

1. The ability to suppress a prepotent motor response, or response inhibition, was measured in the laboratory with the *Stopping Task* (Logan, 1994; Nigg, 1999). This function entails activation of areas in the prefrontal cortex, particularly the right inferior frontal gyrus (Aron et al., 2003) and associated regions in the striatum, particularly the caudate (Casey et al., 1997). During this two-alternative choice reaction time task with four blocks of 64 trials, participants see an X or an O on a computer screen and respond rapidly with one of two keys. On 25% of trials a tone sounds shortly after the X or O is displayed, indicating that participants are to withhold their response. We used a tracking methodology which provides the most reliable estimates of stop signal reaction time (Band, van der Molen, & Logan, 2003),

averaging the final three blocks unless data quality checks suggested otherwise (see Nigg, 1999). A quantitative model of RT processes enables calculation of each participant's speed of stopping or inhibiting a response (the stop signal RT or SSRT) by subtracting average stop signal delay from average RT (Logan, 1994). This SSRT score thus indicates how much warning time was needed in order for the participant to interrupt a response to meet the goals of the task.

2. Reaction time variability was evaluated from the “go” trials of the stop task; this was the within-child standard deviation of reaction time on correct “go” trials. It was conceptualized as reflecting degree of interference between “hot” and “cool” executive function processes, energetic deficits, and temporal instability of responding (Castellanos et al., 2006; Russell et al., 2006).
3. Participants completed the Trail-making B task which served as an index of set-shifting (Spree & Strauss, 1991). Participants were asked to draw a line between alternating numbers and letters in numerical and alphabetical order as quickly as possible (e.g., 1-A-2-B-3-C...25). Number of errors and time served as indices of set-shifting and working memory.
4. To assess interference control, children completed the *Stroop Color-Word Interference Test* (Golden, 1978). The ability to monitor response conflict and suppress a competing response in order to carry out a primary response is part of top-down control. The test activates the anterior cingulate and dorsolateral prefrontal cortex (Cabeza & Nyberg, 1997). A widely-used clinical and cognitive measure (MacLeod, 1991), the paper and pencil version of the Stroop was administered with 45 seconds per trial. Interference control was calculated by regressing the Color-word naming score on the Word-reading and Color-naming scores and saving the residual score.

Data analysis and data reduction

In the child sample, 2% of Q-Sort data and 20% of EATQ data was missing. EATQ data were missing because the instrument was added after new funding was obtained. Missingness on each variable was uncorrelated with scores on the available data for all the other variables (average $r = -.02$, only 1 out of 48 significant at $p < .05$, consistent with what would be expected by chance). Therefore, remaining missing data were imputed once using the expectation maximization (EM) algorithm, a form of maximum likelihood estimation (Shafer & Graham, 2002). The mean change in correlations between the trait variables and ADHD symptomatology due to imputation was less than $r = .01$, supporting the validity of the procedure. We report here results using the complete (imputed) data set. Data were complete on all adolescent participants.

RESULTS

Sample statistics for both samples can be seen in Table 1, broken down into children and adolescents with ADHD and a non-ADHD comparison group. Sex, ethnicity, age, and SES did not differ significantly between ADHD and control youth in either sample. In both samples, youth with ADHD had lower levels of Conscientiousness, Agreeableness, reactive control, effortful control (available only in child sample), and resiliency and higher levels of Neuroticism and negative emotionality than did typically developing control youth.

Question 1: Does the correlational structure among traits fit a two-process conception?

In order to explore the correlational structure and possible hierarchical nature of traits, we conducted exploratory principle component analyses, first separately by group (i.e., for

children with ADHD vs. controls and adolescents with ADHD vs. controls) and then among the combined samples (i.e., all children vs. all adolescents). Principle component analysis results conducted separately by group (i.e., ADHD vs. controls) yielded results conceptually similar to that conducted for the whole group (i.e., all children vs. adolescents), so for simplicity of reporting we provide complete results for the full (combined sample) groups only, with comments in text on any variation across the results for the two samples. We successively extracted two, three, and four components, using principle components analysis with varimax rotation, in order to evaluate a possible hierarchical structure among the traits related to the two-process conception and elucidate the trait clusterings (Eisenberg, 1996; Markon, Krueger, & Watson, 2005). The results from the factor analyses are displayed graphically in Figures 1 and 2; with the figures including principle component labels and correlations between principle component scores computed from each PCA analysis to show component interrelations.

The two-component result was similar in the child and adolescent samples. The first component, labeled Avoidance (following Nigg, 2006a), included low resiliency, negative emotionality, Neuroticism, Conscientiousness, effortful control, and Agreeableness. The second component, labeled Approach (Nigg, 2006a), included Extraversion and low reactive control. This two-component result was consistent with the model described by Nigg (2006a) and Markon et al (2005) at the highest order of abstraction.

The three-component model diverged slightly for children and adolescents. In children, the first component, labeled Control, included effortful control, Conscientiousness, low resiliency, and Neuroticism. In adolescents, the first component, labeled Avoidance, was comprised of low resiliency, negative emotionality, Conscientiousness, and Neuroticism. The second component in children included Agreeableness and negative emotionality; we viewed it as Avoidance. The second component in adolescents was comprised of Agreeableness; thus, we termed this component Agreeableness. The third component in both children and adolescents included Extraversion and low reactive control; we viewed it as Approach.

At the level of four components, in both samples Component 1 broke into a Control component (effortful control and Conscientiousness [and resiliency in adolescents]) and a Negative Emotion component (Neuroticism, low resiliency [only in children], and negative emotionality). This was generally consistent with our hypothesis that effortful control and Conscientiousness reflect the same or closely related underlying process, and also provides some empirical support for the disputes in the literature about whether resiliency is properly aligned with control or negative affect, suggesting this may depend on what other variables are analyzed or on age variation. Agreeableness separated into its own component. The Approach component remained the same as before in both samples. Thus, at the four-component level, results were similar for children and adolescents and generally consistent with the hypothesis regarding a single top-down control trait, and depending on the level of abstraction, one or more bottom-up response traits.

These results overall supported the primary hypothesis that reactive and effortful control have different personality correlates. Low reactive control was primarily related to Extraversion and seemed to form part of an Approach component at a more abstract level, while effortful control was related primarily to Conscientiousness. Effortful control was related secondarily to negative emotionality and Neuroticism, consistent with Rothbart and colleague's observations of early trait structure in children (Ahadi & Rothbart, 1994). It was also related to low Agreeableness under the umbrella of a broader Avoidance trait. Thus, there appeared to be some specificity of differential relations between reactive control, effortful control, and personality traits in children and adolescents. In addition, resiliency appeared to be related to effortful control and negative emotionality at different levels of abstraction.

Question 2: Are reactive and effortful traits differentially related to cognitive control?

If our hypothesis is correct, only the top-down traits should be related to neuropsychological measures of cognitive control. Bivariate correlations between individual traits and laboratory measures of cognitive control are displayed in Table 2. As predicted, cognitive control measures were significantly related to effortful control and Conscientiousness but not to most other traits. However, cognitive control measures were also related to reactive control. This may have been due to overlap among the personality traits.

Therefore, to isolate specific relations between cognitive control and traits, multivariate regressions were conducted with reactive control and Conscientiousness as predictors of each cognitive control measure. We used Conscientiousness in these analyses rather than effortful control because Conscientiousness was available in both samples, whereas effortful control was not. In both samples, using these controlled models, Conscientiousness but not reactive control, was a significant predictor of response inhibition ($\beta = -.26, p < .01$ for children; $\beta = -.38, p < .01$ for adolescents) and response variability ($\beta = -.30, p < .01$ for children; $\beta = -.35, p < .01$ for adolescents). For children, neither reactive control nor Conscientiousness was a significant predictor of set-shifting ($\beta = -.07, -.09, p > .05$), whereas in adolescents Conscientiousness ($\beta = -.23, p < .01$), but not reactive control ($\beta = -.00, p > .01$), was related to set-shifting. These regression results thus supported the hypothesis that top-down traits are related uniquely to neuropsychological executive function, but that bottom-up traits are not.

Question 3: Are reactive and effortful traits differentially related to the ADHD symptom domains of inattention and hyperactivity-impulsivity?

As shown in Table 3, bivariate correlations were computed between traits and the ADHD symptom domains of inattention and hyperactivity-impulsivity in children and adolescents. Correlations were computed separately for inattentive and hyperactive-impulsive symptom domains. Most traits were significantly correlated with both symptom domains, as seen in Table 3. This could be because the two symptom domains are correlated or because both are correlated with a common comorbid set of symptoms (such as disruptive or externalizing behavior).

Therefore, to clarify matters, a hierarchical regression was conducted with inattentive or hyperactive-impulsive symptoms as the criterion and the other symptom domain partialled. These results are shown in Tables 4 and 5 for the two samples, respectively. As the tables depict, at step 1, the alternate symptom domain (i.e., either inattention or hyperactivity-impulsivity) and ODD/CD symptoms were entered (these were entered in order to control for the most common comorbid symptoms). At step 2, effortful control and reactive control were entered. In children, effortful control (but not reactive control) was significantly related to inattentive ADHD symptoms, whereas reactive control (and, to a lesser extent, effortful control) was significantly related to hyperactive-impulsive ADHD symptoms, similar to the previous results of Martel and Nigg (2006; Table 3 on p.1180). In adolescents, Conscientiousness (and, to a lesser extent, reactive control) was significantly related to inattentive ADHD symptoms, whereas only reactive control was significantly related to hyperactive-impulsive ADHD symptoms.

DISCUSSION

This study examined temperament and personality trait structure in two samples (children and adolescents) enriched for presence of ADHD, a trait-like and common form of psychopathology in youth. Principal component analyses provided qualified support for the two-process trait conception. External correlations with cognitive control measures supported the assertion that effortful control and Conscientiousness are related to “top-down” control

processes. Correlations with ADHD symptoms were consistent with a double dissociation in which inattentive ADHD symptoms were more specifically related to top-down traits, while hyperactive-impulsive traits were more specifically related to bottom-up or reactive traits. Overall, these data provide partial support for an effortful versus reactive process distinction underlying a hierarchical model of temperament and personality in children and adolescents.

The form of these results, furthermore, was partially consistent with the hierarchical structure reported in adults using different measures (Markon et al., 2005). At the highest level, an avoidance and an approach factor emerged that maintained a distinction between effortful and reactive control respectively, suggesting that these basic traits are at high levels of abstraction (Block & Block, 1980; Eisenberg et al., 2000). At lower, more specific, levels, the reactive control and effortful control distinction remained, while negative emotionality/Neuroticism separated out into an additional factor. Consistent with the concept of distinct types of control operations, effortful and reactive control appeared to have different personality correlates. Effortful control was related to negative emotionality, resiliency, Neuroticism, and Agreeableness and most primarily to Conscientiousness, while reactive control was related to Extraversion. Thus, at a higher level of abstraction, avoidance and control tendencies appear to be related, while approach remains a different system (Nigg, 2006a).

This top-down and bottom-up distinction was clarified when external validators like cognitive control and ADHD symptoms were examined. The exemplar top-down trait (Conscientiousness) was specifically related to laboratory measures of cognitive control, whereas the exemplar bottom-up trait, reactive control, was not. In addition, top-down traits (effortful control and Conscientiousness) were specifically related to inattentive ADHD symptoms, whereas the bottom-up trait (reactive control) was related to hyperactive-impulsive symptoms.

These last findings, in line with dual pathway models of ADHD (e.g., Nigg, 2006b; Sonuga-Barke, 2005), are consistent with the idea that cognitive control, ADHD symptoms, and particular personality traits may all share similar neural circuitry. Specifically, effortful control traits, related to cognitive control and inattentive ADHD symptoms, are suggested to be underpinned by frontal-striatal circuitry and dopaminergic disturbances (Nigg, 2006b; Rothbart & Bates, 1998; Sonuga-Barke, 2005). In contrast, at least some reactive traits may share specific relations with poor motivation or reward processes and hyperactive-impulsive symptoms that are more dependent on limbic circuitry (Sonuga-Barke, 2005). This pattern of relations is thus consistent with a perspective suggesting that relatively more top-down processes and prefrontal circuitry are implicated in effortful traits and mechanisms, while relatively more bottom-up processes and limbic circuitry are implicated in reactive traits.

In addition, however, the pattern of relations between top-down and bottom-up processes and ADHD symptoms appeared to differ somewhat between children and adolescents. For children, inattention appears to be related to top-down processes, while hyperactivity-impulsivity is related to top-down and bottom-up processes. In adolescents, inattention appears to be related to top-down and bottom-up processes, while hyperactivity-impulsivity is related only to bottom-up processing. This finding is consistent with the idea of the strong influence of bottom-up processing, or more reactive forms of control, during early adolescence (Casey, Jones, & Hare, in press). In contrast, breakdowns in top-down processing, or more effortful control, may be a more important factor in the development of ADHD symptoms during childhood. Thus, these findings may shed light on assessment and treatment of ADHD. Weakness in effortful control may be more important to assess and treat in childhood ADHD, while weakness in reactive control may be more influential in adolescent ADHD.

Admittedly, these cross-sectional relations do not shed light on longitudinal relations among temperament, personality, and psychopathology. Thus, it is unclear whether low levels of personality/temperamental control predispose individuals to psychopathology, interact with psychopathology, affect the expression of psychopathology, or are merely different manifestations of the same underlying cause or a milder part of the disorder spectrum (Watson, Kotov, & Gamez, 2006). Also, observational measures were not obtained; these are needed along with longitudinal studies to follow up this initial foray into a process-based integration of models. Additional limitations of the current study include missing data and, specifically, a measure of effortful control was missing in the adolescent sample, limiting the completeness of the cross-sample replication.

In conclusion, effortful and reactive processes appear to be distinct forms of behavioral control that can be externally validated by other personality/temperament traits, executive function, and ADHD symptoms. Effortful control shares specific relations with Conscientiousness, cognitive control, and inattentive ADHD symptoms, potentially mediated by prefrontal circuitry. In contrast, reactive control shares specific relations with Extraversion and hyperactive-impulsive symptoms, potentially mediated by limbic circuitry. Thus, temperament and personality traits may be able to be integrated using an effortful and reactive, or top-down and bottom-up, neural signaling framework and utilized to clarify relations of personality to psychopathology and other external correlates.

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Figure 1.

Relations between Two, Three, and Four Components of Personality/temperament in Children.

Note. Consc = Conscientiousness. EC = Effortful Control. Neur = Neuroticism. NE = Negative Emotionality. Resil = Resiliency. Agree = Agreeableness. Extr = Extraversion. RC = Reactive Control.

Figure 2.

Relations between Two, Three, and Four Components of Personality/temperament in Adolescents.

Note. Neur = Neuroticism. NE = Negative Emotionality. Consc = Conscientiousness. Resil = Resiliency. Agree = Agreeableness. Extr = Extraversion. RC = Reactive Control.

Table 1

Descriptive Statistics for ADHD and Control Groups of Children and Adolescents

	Children		Adolescents	
	ADHD(<i>n</i> = 107) <u>M</u> (SD)	Control(<i>n</i> = 72) <u>M</u> (SD)	ADHD(<i>n</i> = 87) <u>M</u> (SD)	Control(<i>n</i> = 97) <u>M</u> (SD)
<i>N</i> (%) Males	71(66.4)	42(58.3)	57(65.5)	52(53.6)
<i>N</i> (%) Ethnic Minority	34(31.8)	17(23.6)	18(20.7)	22(22.7)
African American	10(9.3)	6(8.3)	8(9.2)	15(15.5)
Hispanic/Latino	6(5.6)	5(6.9)	4(4.6)	2(2.1)
American Indian	1(.9)	1(1.4)	0(0)	2(2.1)
Other/Mixed	17(15.9)	5(6.9)	6(6.7)	3(3.1)
Child age in years	9.49(1.18)	9.44(1.18)	5.28(1.13)	5.58(1.07)
Inattentive Symptoms	8.17(1.26)	2.18(2.79) **	.25(2.59)	.02(1.42) **
Hyperactive-impulsive Symptoms	6.35(2.83)	1.97(2.86) **	.78(2.66)	46(.78) **
Reactive Control	3.93(1.05)	5.00(.93) **	4.50(1.20)	5.37(.97) **
Effortful Control	2.29(.53)	3.26(.74) **	--	--
Resiliency	5.40(1.11)	6.28(.90) **	5.26(1.06)	6.43(.76) **
Negative Emotionality	4.91(1.48)	3.65(1.21) **	4.15(1.36)	3.13(1.00) **
Neuroticism	4.76(1.10)	4.01(1.08) **	4.58(1.11)	3.70(.90) **
Extraversion	6.13(1.59)	5.81(1.34)	5.31(1.65)	5.18(1.59)
Agreeableness	5.71(1.21)	6.70(1.05) **	6.13(1.27)	6.64(1.01) **
Conscientiousness	3.99(1.02)	6.00(1.45) **	4.11(1.28)	6.68(1.15) **

Note. +*p* < .10.

*
p < .05.

**
p < .01. Significant differences between ADHD and control groups, measured by t-tests and chi-squares, indicated under total column.

Table 2
Bivariate Correlations between Cognitive Control and Traits in Children and Adolescents

	SSRT	SD	Trails B	Interference
Children				
Reactive Control	-.21 **	-.23 **	-.07	-.02
Effortful Control	-.18 *	-.28 **	-.18 *	-.09
Resiliency	-.13	-.16 *	-.14	.02
Negative Emotion	.13	.13	.05	-.11
Neuroticism	.09	.05	.12	.00
Extraversion	.03	.02	.01	.04
Agreeableness	-.06	.07	.12	.05
Conscientiousness	-.26 **	-.30 **	-.09	-.01
Adolescents				
Reactive Control	-.28 **	-.26 **	.00	.05
Resiliency	-.21 **	-.20 **	-.11	.20 **
Negative Emotion	.19 *	.23 **	.05	-.11
Neuroticism	.12	.06	.07	-.09
Extraversion	.04	.05	-.10	.02
Agreeableness	-.29 **	-.23 **	-.08	.02
Conscientiousness	-.38 **	-.35 **	-.15 *	.14

* *Note.* $p < .05$.

** $p < .01$. SSRT=response inhibition. SD = response variability. Trails B = set-shifting. Interference = interference control.

Table 3

Bivariate Correlations between ADHD Symptoms and Traits in Children and Adolescents

	Children		Adolescents	
	Inattentive Symptoms	Hyperactive Symptoms	Inattentive Symptoms	Hyperactive Symptoms
Reactive Control	-.62**	-.73**	-.57**	-.67**
Effortful Control	-.69**	-.52**	--	--
Resiliency	-.50**	-.36**	-.56**	-.45**
Negative Emotion	.49**	.45**	.43**	.45**
Neuroticism	.41**	.28**	.45**	.31**
Extraversion	.12	.32**	.03	.25**
Agreeableness	-.44**	-.54**	-.31**	-.38**
Conscientiousness	-.74**	-.59**	-.77**	-.64**

* *Note.* $p < .05$.**
 $p < .01$.

Table 4

Multivariate Associations among ADHD Symptom Domains and Effortful and Reactive Control in Children

Regression Model Predictor	Inattention		Hyper/Imp	
	β	β	β	β
<i>Step 1</i>	$R^2 = .55^{**}$		$R^2 = .64^{**}$	
Inattention	--	--	.57 ^{**}	.47 ^{**}
Hyperactivity	.71 ^{**}	.53 ^{**}	--	--
ODD/CD	.04	-.08	.35 ^{**}	.27 ^{**}
<i>Step 2</i>	$\Delta R^2 = .13^{**}$		$\Delta R^2 = .08^{**}$	
Effortful Control	--	-.43 ^{**}	--	.13 [*]
Reactive Control	--	-.04	--	-.37 ^{**}

* *Note.* $p < .05$.** $p < .01$.

Table 5

Multivariate Associations among ADHD Symptom Domains and Conscientiousness and Reactive Control in Adolescents

Regression Model Predictor	Inattention		Hyper/Imp	
	β	β	β	β
<i>Step 1</i>	$R^2 = .62^{**}$		$R^2 = .63^{**}$	
Inattention	--	--	.70 ^{**}	.65 ^{**}
Hyperactivity	.73 ^{**}	.55 ^{**}	--	--
ODD/CD	.11	.01	.17 ^{**}	.09
<i>Step 2</i>	$\Delta R^2 = .12^{**}$		$\Delta R^2 = .06^{**}$	
Conscientiousness	--	-.52 ^{**}	--	.15
Reactive Control	--	.16 ^{**}	--	-.36 ^{**}

* *Note.* $p < .05$.

** $p < .01$.