Bifactor Latent Structure of Attention-Deficit/Hyperactivity Disorder (ADHD)/Oppositional Defiant Disorder (ODD) Symptoms and First-Order Latent Structure of Sluggish Cognitive Tempo Symptoms

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The objective was to determine if the latent structure of attention-deficit/hyperactivity disorder (ADHD) and oppositional defiant disorder (ODD) symptoms is best explained by a general disruptive behavior factor along with specific inattention (IN), hyperactivity/impulsivity (HI), and ODD factors (a bifactor model) whereas the latent structure of sluggish cognitive tempo (SCT) symptoms is best explained by a first-order factor independent of the bifactor model of ADHD/ODD. Parents’ (n = 703) and teachers’ (n = 366) ratings of SCT, ADHD-IN, ADHD-HI, and ODD symptoms on the Child and Adolescent Disruptive Behavior Inventory (CADBI) in a community sample of children (ages 5–13; 55% girls) were used to evaluate 4 models of symptom organization. Results indicated that a bifactor model of ADHD/ODD symptoms, in conjunction with a separate first-order SCT factor, was the best model for both parent and teacher ratings. The first-order SCT factor showed discriminant validity with the general disruptive behavior and specific IN factors in the bifactor model. In addition, higher scores on the SCT factor predicted greater academic and social impairment, even after controlling for the general disruptive behavior and 3 specific factors. Consistent with predictions from the trait-impulsivity etiological model of externalizing liability, a single, general disruptive behavior factor accounted for nearly all common variance in ADHD/ODD symptoms, whereas SCT symptoms represented a factor different from the general disruptive behavior and specific IN factor. These results provide additional support for distinguishing between SCT and ADHD-IN. The study also demonstrates how etiological models can be used to predict specific latent structures of symptom organization.

Keywords: attention-deficit/hyperactivity disorder, sluggish cognitive tempo, oppositional defiant disorder, bifactor models, trait-impulsivity etiological model of ADHD

Recent studies have applied a bifactor latent model to attention-deficit/hyperactivity disorder (ADHD) symptoms. This model includes a general ADHD factor, along with specific inattention (IN) and hyperactivity/impulsivity (HI) factors. The general ADHD factor accounts for common variance among ADHD symptoms, and is independent of specific IN and HI factors, whereas specific IN and HI factors account for common variance in their respective symptoms independent of the general ADHD factor. The bifactor model consistently yields better fit than the two correlated factors (IN and HI) model (e.g., Dumenci, McConaughy, & Achenbach, 2004; Gibbins, Toplak, Flora, Weiss, & Tannock, 2012; Gomez, 2014; Martel, von Eye, & Nigg, 2012; Normand, Flora, Toplak, & Tannock, 2012; Toplak et al., 2012; Wagner et al., 2015; Willsoughby, Blanton, & the Family Life Project Investigators, 2015).

Although the bifactor model always fit better than the correlated two-factor model, the specific IN and HI dimensions from the bifactor model accounted for little true score variance, over-and-above the general ADHD factor. For example, omega-hierarchical (ωh) values for the specific IN and HI factors in Wagner et al. (2015) were .33 and .08, respectively, with the values from Willsoughby et al. (2015) being .25 and .10, respectively. In contrast, ωh values for the general ADHD factor were .86 and .83 in these two studies, respectively. These results suggest that the specific IN and HI factors contain too little true score variance to be useful as specific measures of the IN and HI dimensions independent of the
general ADHD dimension (Burns, Moura, Beauchaine, & McBurnett, 2014; Wagner et al., 2015).

Findings of better fit for a bifactor structural model are consistent with the trait-impulsivity etiological theory of ADHD (Beauchaine, 2015; Beauchaine, Hinshaw, & Pang, 2010; Beauchaine & McNulty, 2013). This etiological model predicts that a general impulsivity factor should account for most of the variance in ADHD symptoms but has much broader implications for bifactor models of externalizing symptom structure than simple application to ADHD. The trait-impulsivity etiological model hypothesizes that common behavioral genetic and neural vulnerabilities underlie all externalizing syndromes, including ADHD, oppositional defiant disorder (ODD), and conduct disorder (CD) symptoms. At the neurobiological level, trait impulsivity is conferred by mesolimbic dopamine (DA) dysfunction, as manifested in blunted striatal responding to incentives among those with externalizing behavior disorders (Beauchaine & McNulty, 2013; Gatzke-Kopp et al., 2009; Pflichta & Scheres, 2014). Affected individuals likely engage in impulsive, reward-seeking behaviors to upregulate their underresponsive mesolimbic DA systems (Beauchaine & Gatzke-Kopp, 2012), which give rise to negative affectivity, reduced hedonic capacity, and trait irritability (Laakso et al., 2003)—core characteristics of externalizing behavior disorders. However, although several studies have examined the bifactor structure of ADHD (see above), only one study to date has applied a bifactor latent model to ADHD and ODD symptoms simultaneously (Burns, Moura et al., 2014, described in more detail below).

As investigators have examined whether ADHD best fits within a bifactor structure, a largely separate line of research has examined whether sluggish cognitive tempo (SCT) symptoms are distinct from ADHD-IN symptoms. SCT is characterized by inconsistent alertness (e.g., absentmindedness, reduced attention, daydreams, loses train of thought, easily confused) and slowness (e.g., thinking is slow, behavior is slow, and drouniness). Recent psychometric studies have identified a core group of SCT symptoms (i.e., substantial loadings on the SCT factor) that also have discriminant validity with ADHD-IN symptoms, anxiety, and depression factors (Barkley, 2013; Lee, Burns, Snell, & McBurnett, 2014; Willcutt et al., 2014). Research also shows that the SCT dimension is associated with other symptom and impairment dimensions even after controlling for ADHD-IN. For example, higher levels of SCT predict higher levels of depression, academic impairment, and social impairment over-and-above ADHD-IN. In addition, SCT shows a negative (or a nonsignificant) relationship with externalizing problem after controlling for ADHD-IN, whereas ADHD-IN shows a positive relationship with externalizing problems after controlling for SCT (see Barkley, 2013; Becker, Luebbe, Fite, Stoppelbein, & Greening, 2014; Bernad, Servera, Grases, Collado, & Burns, 2014; Burns, Servera, Bernad, Carrillo, & Cardo, 2013; Lee et al., 2014; Penny, Waschbusch, Klein, Corkum, & Eskes, 2009; Servera, Bernad, Carrillo, & Burns, 2015; Willcutt et al., 2014). Finally, although mixed findings have been reported in terms of SCT’s relation to IQ (e.g., Willcutt et al., 2014), some studies have found SCT to be unassociated with intelligence (Becker & Langberg, 2014) or even associated with higher levels of intelligence in children with ADHD (Marshall, Evans, Eiraldi, Becker, & Power, 2014). SCT symptoms appear not attributable to low intelligence. These various findings point to the importance of evaluating the SCT construct in its own right.

Although one study has applied the trait-impulsivity model to predict bifactor latent structure of ADHD/ODD symptoms, no study has applied this etiological model of externalizing liability to model the latent structure of ADHD, ODD, and SCT symptoms. The trait-impulsivity model posits that SCT arises from different neural substrates from ADHD and ODD, and therefore should not load on the general disruptive behavior factor with ADHD/ODD symptoms. In contrast to the fronto-striatal dysfunction and reward seeking associated with these disorders, SCT may be characterized by fronto-parietal dysfunction and problems with motivation (Beauchaine, 2015).

Below we provide further details on the trait-impulsivity etiological model of ADHD-IN, ADHD-HI, ODD, CD, and SCT symptoms, followed by predictions from this model for the latent structure of these symptoms. We then introduce a study to test these predictions. Our purposes are to provide a more sophisticated evaluation of the independence of ADHD-IN and SCT symptom dimensions, and test a series of specific predictions from the trait-impulsivity etiological model for the latent structure of ADHD, ODD, and SCT symptoms.

### Trait-Impulsivity Etiological Model of ADHD/ODD

The trait-impulsivity etiological model of ADHD (Beauchaine, 2015; Beauchaine et al., 2010; Beauchaine & McNulty, 2013) assumes that low tonic and low phasic responding in primarily one neural system—the mesolimbic reward system, or “bottom-up” pathway—results in development of HI symptoms early in life (Gatzke-Kopp et al., 2009), with IN symptoms arising secondarily. This neurodevelopmental vulnerability—expressed behaviorally as ADHD-HI or ADHD combined presentations—increases the likelihood of developing of ODD and CD in high-risk environments characterized by coercive family processes, deviant peer group affiliations, and neighborhood violence and criminality (Beauchaine & McNulty, 2013). This model extends early dopaminergic theories of impulsivity, including those articulated by Gray (e.g., Gray, 1987), Quay (1993), and others (e.g., Beauchaine, 2001). A second “top-down” pathway involves dysfunction in parietal and frontal structures (i.e., the prefrontal cortex, anterior cingulate). This dysfunction results in the direct development of IN symptoms with a much lower likelihood of developing HI, ODD, and CD symptoms, and low levels of trait-impulsivity.

Burns, Moura et al. (2014) tested predictions derived from trait-impulsivity theory by applying a bifactor model to ADHD/ODD symptoms. Predictions were that the general disruptive behavior factor would explain most of the common variance in ADHD/ODD symptoms, with the specific HI factor accounting for no common variance in HI symptoms above-and-beyond the general disruptive behavior factor. It was further predicted that specific IN and ODD factors would account for only a small amount of common variance above-and-beyond the general disruptive behavior factor. Results were consistent with these predictions, with the general disruptive behavior factor accounting for 69% to 71% of common variance, the specific HI factor accounting for 4%–6%, the specific IN factor accounting for 14%, and the specific ODD factor accounting for 11%. The same results were found for mothers’ and fathers’ ratings, for the total sample, for boys and girls, and for younger and older children (Burns, Moura et al., 2014).
Because vulnerability to development of SCT symptoms is believed to be associated with different neural mechanisms than vulnerability to ADHD-HI and ADHD-IN symptoms (IN symptoms secondary to HI symptoms), a model that includes SCT as a separate factor that does not load on a general disruptive behavior factor should provide a better fit than a model that assumes the general disruptive behavior factor underlies SCT symptoms. Thus, predictions from trait-impulsivity theory have implications for the latent structure of the SCT, ADHD, and ODD symptoms. In the next section we present four different measurement models for the structure of these symptoms, along with a rationale for why one of these models best matches predictions afforded by trait-impulsivity theory.

**Alternative Measurement Models of ADHD, ODD, and SCT Symptoms**

Figure 1 shows four models for the latent structure of ADHD-IN, ADHD-HI, ODD, and SCT symptoms. Model 1 represents a SCT, IN, HI, and ODD correlated first-order model with separate factors for each dimension. With the exception of Garner et al. (2014) described in more detail below, this correlated first-order model is the model used in all previous studies evaluating the independence of the SCT and ADHD-IN factors (e.g., Barkley, 2013; Becker, Langberg, Luebbe, Dvorsky, & Flannery, 2014; Bernad et al., 2014; Burns et al., 2013; Lee et al., 2014; Penny et al., 2009; Severa et al., 2015; Willcutt et al., 2014). These studies find support for distinct SCT and ADHD-IN first-order correlated factors with different external correlates.

Model 2 represents a bifactor model with a general disruptive behavior factor along with specific IN/SCT, HI, and ODD factors. This model assumes that a general disruptive behavior factor underlies all symptoms, with IN/SCT symptoms best represented by a single specific attention factor (i.e., SCT and IN do not represent separate specific attention factors in this model). Model 3 again represents the application of a bifactor model to all symptoms. Although this model assumes that a general disruptive behavior factor underlies all symptoms, here SCT and IN represent different specific attention factors.

Model 4 includes a general disruptive behavior factor underlying ADHD/ODD symptoms, along with specific IN, HI, and ODD factors, and a first-order SCT factor. In this model, the general disruptive behavior factor does not underlie SCT symptoms. The model includes a correlation between the first-order SCT factor and the general disruptive behavior and the specific IN factors to evaluate the discriminant validity of the SCT factor from the general disruptive behavior and specific IN factors. If the correlation of the SCT factor with either of these two factors is too large (> .85; Brown, 2006, p. 131), it would argue against Model 4 even if Model 4 had better fit than the other three models. If Model 4 has the best fit and these correlations are moderate, SCT would appear to represent a different factor from the general disruptive behavior and specific IN factors.

**Predictions From Trait-Impulsivity Etiological Model for Symptom Structure**

The trait-impulsivity etiological model of externalizing behavior (ADHD/ODD) predicts that Model 4 will provide the best fit, and also hypothesizes seven more specific outcomes:

![Figure 1](image-url)
Hypothesis 1

The first prediction concerns common variance associated with the general disruptive behavior and specific HI, IN, and ODD factors. Most of the common variance in ADHD/ODD symptoms should be accounted for by a general disruptive behavior factor (>$70\%$) with the specific HI factor accounting for no common variance above that accounted for by the general disruptive behavior factor (<$5\%$), and the specific IN and specific ODD factors accounting for only a small amount of common variance above the general disruptive behavior factor (<$15\%$) (Burns, Moura et al., 2014). Such results would indicate that nearly all-common variance in ADHD/ODD symptoms is accounted for by the general disruptive behavior factor.

Hypothesis 2

The second prediction concerns latent factor reliability coefficients for factors in the bifactor part of Model 4, more specifically the omega-hierarchical ($\omega_h$) values for the total ADHD/ODD scores, along with scores on the IN, HI, and ODD scales (McDonald, 1999; Zinbarg et al., 2006). The $\omega_h$ value for the total disruptive behavior score is expected to remain high ($\geq .85$), even after accounting for true score variance associated with HI, IN, and ODD scores. In contrast, HI scores are expected to contain nearly no true score variance, over-and-above the general disruptive behavior factor, with IN and ODD scores containing only a modest amount of true score variance over-and-above the general disruptive behavior factor ($\approx .30\%$) (Burns, Moura et al., 2014). Such results would indicate that all the content of HI scores, along with most of the content of IN and ODD scores, reflects the general disruptive behavior factor and not specific content of the three individual scales. SCT scale scores are expected to contain approximately 90% true score variance.

Hypothesis 3

ADHD/ODD symptoms are predicted to have substantial loadings ($>.70$) on the general disruptive behavior factor, with HI symptoms predicted to have low loadings (<.30) on the specific HI factor. ADHD-IN and ODD symptoms are expected to have moderate loading on their respective specific factors ($\approx .50$). SCT symptoms are expected to have substantial loadings on the first-order SCT factor ($>.70$).

Hypothesis 4

The fourth prediction concerns the correlation of the SCT factor with the general disruptive behavior and specific IN factors. The magnitude of these correlations will indicate that SCT is disso-

ciable from the general disruptive behavior and specific IN factors (correlations <$.85$). As noted earlier, if either of these correlations is greater than $.85$, this would indicate that the SCT factor failed to show discriminant validity with the other factor, suggesting it is not a separate construct from the general disruptive behavior or specific IN factor.

Hypothesis 5

Even if bifactor Model 4 provides a better fit than bifactor Models 2 and 3 at the global level (larger CFI and TLI values in conjunction with smaller AIC, BIC, and RMSEA values), a comparison of the loadings of SCT and IN symptoms on the general disruptive behavior in Models 2 and 3 allows an additional test of predictions from trait-impulsivity theory. Trait-impulsivity theory predicts that loadings of IN symptoms on the general disruptive behavior factor will be substantially larger than loadings of SCT symptoms on the general disruptive behavior factor in Models 2 and 3.

Hypothesis 6

A sixth prediction involves SCT’s ability to predict academic and social impairment, after controlling for the general disruptive behavior and specific IN, HI, and ODD factors. If SCT represents an important clinical dimension, then higher scores on SCT should predict higher levels of academic and social impairment, even after controlling for the general and specific factors.

Hypothesis 7

The seventh prediction is that Model 4 will be the best model for boys and girls in separate analyses and that this model will show measurement invariance (i.e., like-item loadings and like-item thresholds) across boys and girls.

Summary

At this time only one study has applied a bifactor model to ADHD and SCT symptoms (Garner et al., 2014). Although Garner et al. provided preliminary support for an SCT factor that was not part of the bifactor structure of ADHD symptoms; there were several limitations that the current study addresses. First, Garner et al. used a small set of items (three items for parents ratings, four items for teacher ratings) drawn from the Child Behavior Checklist/Teacher’s Report Form. In the current study, we used a recently validated parent- and teacher-report rating scale developed to assess SCT specifically (Lee et al., 2014). Second, Garner et al. evaluated only ADHD and SCT symptoms. In the current study, we examine SCT and ADHD as well as ODD symptoms to more thoroughly evaluate ADHD and ODD as part of a more general externalizing liability. Third, Garner et al. used an ADHD-referred sample (168 children, with 92% meeting diagnostic criteria for ADHD). Because examining SCT within ADHD-defined samples may obscure findings in studies that examine how SCT and ADHD are differentiated (Barkley, 2014), we tested our hypotheses in a community sample. If Model 4 results in the best fit, and support is obtained for the seven hypotheses, it would indicate that although a general disruptive behavior factor underlies ADHD/ODD symptoms, this factor does not underlie SCT symptoms, providing evidence that the SCT dimension is different from a general disruptive behavior dimension and a specific IN dimension. Such findings would have important implications for the Research Domain Criteria (RDoC) initiative, which seeks to identify both transdiagnostic and unique contributions to different forms of psychopathology across all relevant levels of analysis, from genes to behavior. Studies such as ours, which dovetail neuroscience-informed theoretical models of psychopathology with factor analytic accounts of symptoms, will likely advance our understanding of etiology, which often facilitates advances in treatment (see
Beauchaine, Neuhaus, Brenner, & Gatzke-Kopp, 2008), and it has been posited that SCT may itself be conceptualized as transdiagnostic in nature (Becker, Ciesielski et al., 2014; Becker, Marshall, & McBurnett, 2014).

Method

Participants and Procedures

Parent ratings. With approval from the school district and Washington State University’s IRB, all 1,356 children from the four elementary schools in the district were given the cover letter and rating scale to give to their parents. Participation was voluntary and anonymous. Scales were returned from 703 children (55.2% girls), ages 5–13 years (M = 8.29, SD = 2.04). Mothers completed 81.6% of the scales, fathers 11.7%, and other family members 6.7%. The race of the children in the four elementary schools was 2% American Indian or Alaskan Native, 1% Asian or Pacific Islander, 2% Black, 6% Hispanic, and 89% White. Sixty-three percent of children in the four schools received free/reduced priced meals, thus indicating many low-income families in the district. Ethnicity and free/reduced meal information were not available for individual children.

Teacher ratings. The teacher ratings were collected in the same four elementary schools the year prior to the parent ratings. With school district and IRB approval, 58 teachers were invited to participate, with 46 participating teachers each rating eight students randomly selected from their class list by the researchers (one teacher rated six students). Teachers provided ratings for a total of 366 children (56% girls; M_age = 8.23, SD = 2.08). Given that teachers and parents completed the measures in different years, and the ratings were anonymous, it was not possible to link ratings.

Measure

Parents and teachers completed the Child and Adolescent Disruptive Behavior Inventory (CADBI; Burns & Lee, 2011). The SCT (eight items), ADHD-IN (nine items), ADHD-HI (nine items), ODD toward adults (eight items; e.g., argues with adults), ODD toward peers (eight items; e.g., argues with peers), academic impairment (four items; homework, reading, arithmetic, and writing skills), and social impairment (teacher scale only, two items: quality of interactions with adults and peers at school) scales were used in this study. The eight SCT symptoms were daydreams, alertness fluctuates, absent-minded, loses train of thought, easily confused, drowsy, slow thinking, and slow behavior (Burns et al., 2013, Table 1, shows the complete wording of the eight SCT symptoms). These eight SCT symptoms showed convergent validity (substantial loadings on the SCT factor) along with discriminant validity (significantly higher loadings on the SCT factor than the ADHD-IN factor, Lee et al., 2014). Earlier studies provide a more detailed description of the CADBI SCT scale (Burns et al., 2013; Lee et al., 2014). The ADHD symptoms included examples specific to the home and school settings. The two ODD scales (i.e., oppositionality toward adults and peers) were combined into a single ODD scale for this study. Wording of ADHD and ODD symptoms was consistent with DSM-IV.

The eight SCT items were rated on a 6-point duration of occurrence scale for the past month ranging from 1 (nearly none of the time) to 6 (nearly all of the time) on parent and teacher scales. For the teacher scale, the ADHD and ODD items were rated on an 8-point frequency of occurrence scale for the past month ranging from 1 (never in the past month) to 8 (10 or more times per day). For the parent scale, ADHD and ODD items were rated on a 6-point frequency of occurrence scale for the past month ranging from 1 (nearly occurs none of the time; e.g., 2 or fewer times in the past month) to 6 (nearly occurs all the time; e.g., many times per day). For the parent and teacher scales, academic and social impairment items were rated on a 7-point scale ranging from 1 (severe difficulty) to 7 (excellent performance). All of the teachers had been interacting with the students for a minimum of 6 months.

Parents were asked to rate their child’s behaviors in the home/community and to not consider behavior at school since parents could not directly observe such behavior in the classroom. Teachers were asked to rate each child’s behaviors in the classroom. Earlier studies provide support for the reliability (true score variance, test-retest, and interrater) and validity of scores from the symptom and impairment scales of the CADBI (e.g., Bernad et al., 2014; Burns et al., 2008, 2013, 2014; Lee et al., 2014; Servera et al., 2015). For example, for mothers and fathers, interrater factor correlations were .71, .83, .79, .70, and .86 for SCT, ADHD-IN, ADHD-HI, ODD, respectively, and academic impairment with similar interrater factor correlations for teachers. The parent–teacher factor correlation for academic impairment varied from .55 to .67 in earlier studies. Twelve-month stability coefficients (test-retest) varied from .52 (social impairment) to .78 (ADHD-IN).

Table 1

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
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<tr>
<td>1. SCT</td>
<td>—</td>
<td>.75</td>
<td>.53</td>
<td>.44</td>
<td>.41</td>
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<tr>
<td>2. ADHD-IN</td>
<td>.74</td>
<td>—</td>
<td>.74</td>
<td>.61</td>
<td>.43</td>
<td>a</td>
</tr>
<tr>
<td>3. ADHD-HI</td>
<td>.35</td>
<td>.71</td>
<td>—</td>
<td>.69</td>
<td>.32</td>
<td>a</td>
</tr>
<tr>
<td>4. ODD</td>
<td>.25</td>
<td>.57</td>
<td>.75</td>
<td>—</td>
<td>.24</td>
<td>a</td>
</tr>
<tr>
<td>5. AI</td>
<td>.65</td>
<td>.67</td>
<td>.35</td>
<td>.30</td>
<td>—</td>
<td>a</td>
</tr>
<tr>
<td>6. SI</td>
<td>.45</td>
<td>.53</td>
<td>.44</td>
<td>.53</td>
<td>.52</td>
<td>a</td>
</tr>
</tbody>
</table>

Table 1: Correlations Among the SCT, ADHD-IN, ADHD-HI, ODD, Academic Impairment, and Social Impairment CADBI Subscales for Parent (Above the Diagonal) and Teacher (Below the Diagonal) Ratings

Note. SCT = sluggish cognitive tempo; ADHD = attention-deficit/hyperactivity disorder; IN = inattention; HI = hyperactivity/impulsivity; ODD = oppositional defiant disorder; AI = academic impairment; SI = social impairment. All correlations significant at p < .001.

a The social impairment subscale was not administered to parents.
Table 2
Fit Statistics for Alternative Models of SCT, ADHD, and ODD Symptoms

<table>
<thead>
<tr>
<th>Models</th>
<th>df</th>
<th>$\chi^2$</th>
<th>CFI</th>
<th>TLI</th>
<th>RMSEA (90% CI)</th>
<th>AIC</th>
<th>BIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parents’ ratings ($n = 703$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 1</td>
<td>521</td>
<td>1,859</td>
<td>.963</td>
<td>.961</td>
<td>.060 [.057, .063]</td>
<td>50,617</td>
<td>51,465</td>
</tr>
<tr>
<td>Model 2</td>
<td>493</td>
<td>2,467</td>
<td>.946</td>
<td>.938</td>
<td>.075 [.073, .078]</td>
<td>50,628</td>
<td>51,603</td>
</tr>
<tr>
<td>Model 3</td>
<td>493</td>
<td>2,400</td>
<td>.948</td>
<td>.941</td>
<td>.074 [.071, .077]</td>
<td>50,491</td>
<td>51,701</td>
</tr>
<tr>
<td>Model 4</td>
<td>499</td>
<td>1,512</td>
<td>.972</td>
<td>.969</td>
<td>.054 [.051, .057]</td>
<td>50,246</td>
<td>51,194</td>
</tr>
</tbody>
</table>

Teachers’ ratings ($n = 366$) |
| Model 1 | 521 | 1,216    | .979 | .978 | .060 [.056, .065] | 26,978 | 27,844 |
| Model 2 | 493 | 964      | .986 | .984 | .051 [.046, .056] | 26,596 | 27,571 |
| Model 3 | 493 | 1,933    | .957 | .951 | .089 [.085, .094] | 26,351 | 27,327 |
| Model 4 | 499 | 928      | .987 | .986 | .048 [.044, .053] | 26,134 | 27,086 |

Note. Figure 1 shows the path diagrams for the four models. Bold entries indicate the best-fit value for each column. SCT = sluggish cognitive tempo; ADHD = attention-deficit/hyperactivity disorder; ODD = oppositional defiant disorder; CFI = comparative fit index; TLI = Tucker-Lewis Index; RMSEA = root mean square error of approximation; CI = confidence interval; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion.

Analytic Strategy

Items were treated as categorical indicators and robust weighted least squares estimation was used to evaluate the four models (WLSMV estimator in Mplus v.7.3, Muthén & Muthén, 1998–2012). Global model fit was evaluated with the comparative fit index (CFI; ideal study criterion ≥ .95), Tucker-Lewis index (TLI; ideal study criterion ≥ .95), and root mean square error of approximation (RMSEA; ideal study criterion ≤ .05). Covariance coverage was approximately 99% for parent and teachers. In addition, because the WLSMV estimator does not provide information criteria, all analyses were repeated with the MLR estimator (items still treated as categorical, thus a logit link) to obtain Akaike information criterion (AIC) and Bayesian information criterion (BIC). The model with the smallest AIC and BIC values was considered to have the best global fit.

The four models (see Figure 1) do not represent nested models so it is not appropriate to use the chi-square difference test to determine if one model provides a better fit than another (Little, 2013, pp. 339–341). If Model 4 has the best global fit (i.e., best CFI, TLI, RMSEA, AIC, and BIC values) and support occurs for the seven hypotheses, then such outcomes would suggest that Model 4 was the best of the four models.

Results

Model Fit

Table 2 shows fit measures for the four models. Model 1 estimated 186 parameters, Model 2 estimated 214, Model 3 estimated 213, and Model 4 estimated 208. As predicted, for both parent and teacher ratings, Model 4 was the best model (i.e., smaller chi-square values, larger CFI and TLI values, and smaller RMSEA, AIC, and BIC values than the other models). We now evaluate the seven predictions for Model 4.1

Hypothesis 1: Common Variance for the General and Specific Factors in Model 4

Expected common variance (ECV) is the percent of explained variance accounted for by the general disruptive behavior factor and the three specific factors (i.e., “for each factor the ECV is the sum of the squared loadings for that factor divided by the sum of all squared factor loadings (the common variance) for the model;” Brouwer, Meijer, & Zevalkink, 2013, p. 139). Consistent with predictions from the trait-impulsivity etiological model of ADHD/ODD, for parents (teachers), common variance accounted for by the general disruptive behavior factor was 70% (69%). The specific HI factor accounted for 2% (3%), the specific IN factor for 12% (13%), and the specific ODD factor for 16% (15%). Table 3 shows these values. These results are almost identical to the first study that examined ADHD and ODD symptoms with bifactor modeling (Burns, Moura et al., 2014).

Hypothesis 2: Latent Factor Reliability Coefficients for Model 4

Table 3 shows latent factor reliability coefficients (amount of true score variance) for the total disruptive behavior (nine IN + nine HI + eight ODD symptoms), IN (nine IN symptoms), HI (nine HI symptoms), ODD (eight ODD symptoms), and SCT (eight SCT symptoms) scores. The $\omega$ values for IN, HI, and ODD scores represent the amount of variance the IN, HI, and ODD scores accounted for by a blend of the general disruptive behavior factor and the relevant specific factor (e.g., because the $\omega$ values conflate the variance of the general and specific factors, the $\omega_{\text{hierarchical}}$ values are more relevant for evaluating the subscale

1 Although a second-order model (i.e., the SCT, ADHD-IN, ADHD-HI, and ODD first-order factors and a disruptive behavior second-order factor) was not central to our evaluation of the trait-impulsivity model of externalizing liability, we also evaluated such a model—that is, parents: $\chi^2(523) = 2351$, CFI = .950, TLI = .946, RMSEA = .071 (.068-.073), AIC = 50702, and BIC = 51540; teachers: $\chi^2(523) = 1869$, CFI = .960, TLI = .958, RMSEA = .084 (.080-.088), AIC = 27292, and BIC = 28138). The second-order model fit significantly worse ($p < .001$) than the first-order model, thus indicating that the second-order disruptive behavior factor did not account for the covariation among the first-order factors. Research on a general (higher order) factor underlying all psycho-pathology represents a different research question than the current study’s use of a bifactor model to test predictions from the trait-impulsivity etiological model of externalizing liability (see Caspi et al., 2014).
scores, see next paragraph). For parents (teachers), \( \omega \) values for IN, HI, and ODD scores were .96 (.98), .96 (.98), and .97 (.98), respectively. The \( \omega \) values for the total disruptive behavior scale scores (blend of the general and three specific factors) were .98 for parents and .99 for teachers. The \( \omega \) coefficient for the SCT scores was .90 for parents and .93 for teachers.

The \( \omega_{\text{hierarchical}} \) values indicate the unique amount of variance in scores that was due to the general or specific factor. These values are more relevant for evaluation of factors in the bifactor part of Model 4 than the \( \omega \) values. For total disruptive behavior scores for parents (teachers), the general disruptive behavior factor accounted for 87% (87%) of the variance after controlling for the three specific factors. For parents (teachers) \( \omega_{\text{hierarchical}} \) values for IN, HI, and ODD scores (after controlling for the general disruptive behavior factor) were .38 (.46), .02 (.00), and .46 (.39), respectively. These results are consistent with predictions from trait impulsivity theory and are almost identical to the first application of the bifactor model to ADHD/ODD symptoms (Burns, Moura et al., 2014).

**Hypothesis 3: Symptom Factor Loadings for Model 4**

Table 3 shows loadings from Model 4. All eight SCT symptoms had substantial loadings on the first-order SCT factor (> .70).
Loadings of IN, HI, and ODD symptoms on the specific and general factors were consistent with predictions from the trait-impulsivity model. For example, loadings of these 52 symptoms on the general disruptive behavior factor were substantial (all but four > .60 for parents and teachers) with loadings of the HI symptoms on the specific HI factor being low (all less than .47 with most close to zero). IN symptoms had moderate loading on the specific IN factor (.42–.58 for parents and .48–.65 for teachers) with the ODD symptoms also having moderate loading on the specific ODD factor (.54–.71 for parents and .50–.74 for teachers).

**Hypothesis 4: Correlation of SCT Factor With General Disruptive Behavior and Specific ADHD-IN Factors From Model 4**

For parents, the first-order SCT factor correlated .59 (SE = .03) with the general disruptive behavior factor and .52 (SE = .03) with the specific IN factor. For teachers, the first-order SCT factor correlated .44 (SE = .05) with the general disruptive behavior and .72 (SE = .04) with the specific IN factor. These correlations indicate that first-order SCT showed discriminant validity with the general disruptive behavior and specific ADHD-IN factors.

**Hypothesis 5: Loading of the SCT and ADHD-IN Symptoms on the General Disruptive Behavior Factor in Models 2 and 3**

The average loading of SCT symptoms on the general disruptive behavior factor in Model 2 was much lower than the loadings of the IN symptoms on the general disruptive behavior factor (Parents: SCT—M = .46, SD = .06, range = .37–.53; IN—M = .81, SD = .04, range = .74–.86; Teachers: SCT—M = .32, SD = .12, range = .13–.44; IN—M = .76, SD = .03, range = .73–.81). Similar results occurred for Model 3. These results indicate the general disruptive behavior factor underlies IN symptoms more than SCT symptoms.

**Hypothesis 6: First-Order and Unique Relationships of Factors From Model 4 With Academic and Social Impairment**

Higher scores on the SCT factor were associated with higher scores on the academic impairment factor (parents: r = .46, SE = .03, p < .001; teachers: r = .73, SE = .03, p < .001) with significant results occurring for general disruptive behavior (parents: r = .35, SE = .04, p < .001; teachers: r = .45, SE = .05, p < .001), specific IN (parents: r = .35, SE = .04, p < .001; teachers: r = .66, SE = .04, p < .001), and specific HI (parents: r = .12, SE = .05, p < .01; teachers: r = .19, SE = .05, p < .001). The specific ODD factor was not related to academic impairment (parents: r = .02, SE = .04, ns; teachers: r = .01, SE = .04, ns).

Higher scores on the social impairment factor (only available for teacher ratings) were associated with higher scores on the SCT, r = .51, SE = .04, p < .001, general disruptive behavior, r = .52, SE = .04, p < .001, specific IN, r = .28, SE = .05, p < .001, and specific ODD factor, r = .31, SE = .04, p < .001. The social impairment factor was not associated with the specific HI factor (r = .08, SE = .05, ns).

**Figure 2.** Structural regression model. Each latent variable was defined by manifest variables (not shown in the path diagram). The same structural regression model was used to regress social impairment on the four factors from Model 4: The SCT factor is a first-order factor with the G-DB, S-IN, S-HI, and S-ODD being part of the bifactor model. G = general; S = specific; SCT = sluggish cognitive tempo; IN = inattention; HI = hyperactivity/impulsivity; ODD = oppositional defiant disorder; DB = disruptive behavior.

A structural regression analysis was used to regress the academic impairment factor on the first-order SCT factor, the general disruptive behavior factor and specific IN, HI, and ODD factors from Model 4 to determine each factor’s unique effect on academic impairment (see Figure 2). For parents and teachers, higher scores on SCT predicted higher levels of academic impairment, even after controlling for the other factors (ps < .05). The general disruptive behavior factor, and the specific IN and specific HI factors also uniquely predicted academic impairment (ps < .01). Table 4 shows these partial standardized regression coefficients. For teachers’ ratings, the social impairment factor was regressed on the first-order SCT factor, the general disruptive behavior factor, and specific IN, HI, and ODD factors to determine each factor’s unique effect on social impairment. Higher levels of SCT predicted higher levels of social impairment, even after controlling for all the other factors (p = .001). Higher scores on the general disruptive behavior factor and the specific ODD factor also predicted higher levels of social impairment, controlling for the other factors (ps < .001).

**Hypothesis 7: Sex Effects**

The analyses for Models 1, 2, 3, and 4 were repeated for parents’ ratings of boys and girls. The sample size for teacher ratings was too small for a separate evaluation of the models for boys and girls. ECV and reliability values for boys and girls for were almost identical to values reported for the total sample for Model 4, and regression results yielded the same results as the total sample with one exception: For parent ratings of girls, the general disruptive behavior factor did not predict academic impairment after controlling for the first-order SCT factor and the three specific factors, β = .66, SE = .09, ns.
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Cohen’s $r = 0.21$ (specific HI, specific ODD factors were $0.21$) general disruptive behavior factor and, importantly, the specific IN that a general disruptive behavior factor does not underlie SCT predictions from the trait-impulsivity etiological model of ADHD comes replicate findings of Burns, Moura et al. (2014) with par-
counted for by the general disruptive behavior factor. These out-
most of the true score variance in these three subscales is ac-

ting behavior; DB = disruptive behavior. All coefficients were significant ($p < .01$) unless noted as nonsignificant (ns).

Model 4 was also invariant across boys and girls for like-item loadings and like-item thresholds (i.e., the CFI, TLI, and RMSEA values all indicated improvement in fit going from the model with no constraints to the model with the constraints on the loadings and thresholds). Fit of the model with constraints was good, $\chi^2(1,159) = 1,844$, $CFI = .981$, $TLI = .982$, and $RMSEA = .030$ ($p = .025$–.034). With girls coded 0 and boys coded 1, the latent Cohen’s $d$ values for the SCT, general disruptive behavior, specific IN, specific HI, and specific ODD factors were 0.21 ($p < .05$), 0.21 ($p < .01$), 0.00 (ns), 0.30 ($p < .05$), and $-0.12$ ($p = .26$), respectively.

Discussion

A bifactor model applied to ADHD-HI, ADHD-IN, and ODD symptoms, in conjunction with a separate first-order SCT factor, provided the best model for the latent structure of these symptoms. Of note, results were remarkably similar across parent and teacher ratings. The general disruptive behavior factor accounted for nearly all of the common variance in ADHD-HI symptoms, and most of the common variance in ADHD-IN and ODD symptoms. Our results also suggest that the ADHD-HI, ADHD-IN, and ODD subscale scores contain too little true score variance to be viewed as specific measures of these constructs, independent of the general disruptive behavior factor (e.g., Reise et al., 2013, recommend a minimum $w_3$ of .50 for specific factors in the bifactor model to be useful with our values for specific HI, IN and ODD being much lower than .50). In other words, clinical interpretations of ADHD-
HI, ADHD-IN, and ODD subscale scores must keep in mind that most of the true score variance in the first subscales is ac-
counted for by the general disruptive behavior factor. These out-
comes replicate findings of Burns, Moura et al. (2014) with par-
ents, extend findings to teachers, and are consistent with predictions from the trait-impulsivity etiological model of ADHD and ODD (Beauchaine, 2015; Beauchaine et al., 2010; Beauchaine & McNulty, 2013).

Another important contribution of this study is demonstration that a general disruptive behavior factor does not underlie SCT symptoms. The SCT factor showed discriminant validity with the general disruptive behavior factor and, importantly, the specific IN factor. In addition, higher levels of SCT predicted higher levels of academic and social impairment, even after controlling for the general disruptive behavior along with three specific factors, align-
ing with other recent studies linking SCT to impairment (Becker, 2013; Bernad et al., 2014; Severa et al., 2015). These results provide additional support that SCT and ADHD-IN represent different dimensions, suggesting that SCT symptoms do not align with the externalizing spectrum of psychopathology (Becker et al., 2013), and are consistent with the trait-impulsivity model that SCT and ADHD/ODD symptoms develop from different neural sub-
strates. As outlined above, externalizing spectrum disorders, in-
cluding ADHD, ODD, and CD, share a common neural sub-
strate—dysfunction on mesolimbic DA responding, whereas SCT may be linked to fronto-parietal dysfunction (see, e.g., Beauchaine & McNulty, 2013; Zisner & Beauchaine, in press).

Clinical Implications

Our study demonstrates that it is possible to develop predictions about the latent structure of the SCT, ADHD, and ODD symptoms from a specific etiological model, the trait-impulsivity theory of externalizing liability. To date, almost no confirmatory factor analytic studies of externalizing behavior have used etiological models to predict latent structure of symptom sets in this manner. Continuation of such efforts might yield more useful diagnostic models that are grounded in both neurobiology and sound psychometrics (e.g., the connec-
tion of the trait-anxiety etiological model with the anxiety and depression dimension, Beauchaine, 2015).

As noted above, this approach is consistent with objectives of the National Institute of Mental Health RDoC initiative, which seeks to characterize how genetic and neural vulnerabilities map onto transdiagnostic symptom dimensions in efforts to better capture etiological substrates of psychopathology. It has been suggested that SCT might ultimately fit within the RDoC framework (Becker, Ciesielski et al., 2014), and while specu-
lative in the absence of data, it is possible that SCT and disruptive behavior both relate to the cognitive systems domain with different cognitive constructs being most relevant (e.g., working memory, cognitive control), and perhaps the arousal and regulatory system domain (although, again, different reg-
ulatory processes may be implicated). SCT and disruptive be-
havior may further part ways in that SCT may be more related to negative valence systems whereas disruptive behavior may be more related to positive valence systems. Research is needed to evaluate these hypotheses in a more formal manner, as well as by evaluating multiple constructs across the various units of analysis within the RDoC framework (e.g., genes, circuits, physiolo-
gy, behavior). Such research would not only advance our understanding of the structure and etiology of psychopa-
thology but would also be highly useful for informing our understanding of the heterogeneity within psychopathologies.

Our findings also have implications for the organization ADHD and ODD in the DSM–5 (American Psychiatric Association, 2013). In DSM–5, ADHD is in the general neurodevelopmental disorders category, whereas ODD is in the general disruptive, impulse-control, and conduct disorders category. Placement of ADHD and ODD in such different categories seems to imply different causal processes. However, as suggested by theoretical

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Table 4

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Academic impairment</th>
<th>Social impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parents β(SE)</td>
<td>Teachers β(SE)</td>
<td>Teachers β(SE)</td>
</tr>
<tr>
<td>First-Order SCT</td>
<td>.19 (.06)</td>
<td>.19 (.04)</td>
</tr>
<tr>
<td>General DB</td>
<td>.24 (.05)</td>
<td>.37 (.05)</td>
</tr>
<tr>
<td>Specific ADHD-IN</td>
<td>.25 (.05)</td>
<td>.52 (.09)</td>
</tr>
<tr>
<td>Specific ADHD-HI</td>
<td>.12 (.05)</td>
<td>-.19 (.05)</td>
</tr>
<tr>
<td>Specific ODD</td>
<td>.02 (.04)**</td>
<td>.01 (.04)**</td>
</tr>
</tbody>
</table>

Note. β = partial standardized regression coefficient; SE = standard error; SCT = sluggish cognitive tempo; ADHD = attention-deficit/hyperactivity disorder; IN = inattention; HI = hyperactivity/impulsivity; ODD = oppositional defiant disorder; DB = disruptive behavior. All coefficients were significant ($p < .01$) unless noted as nonsignificant (ns).
models (Beauchaine, 2015), behavioral genetics (e.g., Tuvblad et al., 2009), and the outcome of this study and the earlier one (Burns, Moura et al., 2014), creation of categories without careful consideration of etiological models may be problematic. Linkages of specific etiological models with specific symptom dimensions will likely prove more useful in furthering our understanding of psychopathology than the categorical approach.

Limitations

The use of a single rating scale and only two measures of impairment represent limitations. A multiple traits (general, specific, and first order factors) by multiple sources (mothers, fathers, teachers) by multiple methods (rating scales and interviews) by multiple occasions (repeated assessments) design would provide a stronger test of Model 4 in addition to a larger community sample with a wider age range. Such a design would allow for separation of trait effects from method and source effects, and would provide for a better identification of common and unique external correlates of factors (e.g., negative emotionality, executive functions, peer relationship problems) and how these correlates change across time. It would also be more ideal to have each teacher only rate a single child’s behavior.

Other studies are needed to further evaluate other domains of adjustment recently linked to SCT symptoms such as peer functioning (Becker, 2014), emotion dysregulation (Flannery et al., 2014), and internalizing symptoms (Becker, Luebbe et al., 2014; Bernad et al., 2014; Servera et al., 2015) within Model 4. Longitudinal studies should also evaluate the structure of disruptive behavior and SCT across time. Finally, inclusion of measures of anxiety and depression in addition to measures of SCT, ADHD, and ODD symptoms within the same study would allow simultaneously evaluation of the trait-impulsivity and trait-anxiety etiological models of youth psychopathology (Beauchaine, 2015). Such a study would provide an understanding of SCT’s relationship with the trait-anxiety etiological model in addition to the trait-impulsivity model, thus allowing a more sophisticated evaluation of the etiology of SCT than the current study.

Summary

Consistent with predictions from the trait-impulsivity etiological model of externalizing liability, a single, general disruptive behavior factor accounted for nearly all of the common variance in ADHD-HI symptoms and most of the common variance in ADHD-IN and ODD symptoms, whereas SCT symptoms represented a factor different from the general disruptive behavior and specific IN factors. These results provide additional support for SCT and ADHD-IN representing different symptom dimensions.

References


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