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Neuropsychological Predictors of ODD Symptom Dimensions in Young Children

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Abstract

Objective: Oppositional defiant disorder (ODD) is a commonly diagnosed childhood behavior disorder, yet knowledge of relations between ODD and early neuropsychological functions, particularly independent of attention deficit hyperactivity disorder (ADHD), is still limited. Additionally, studies have not examined neuropsychological functioning as it relates to the different ODD symptom dimensions.

Method: Structural equation modeling (SEM) was used to investigate how preschool neuropsychological functioning predicted negative affect, oppositional behavior, and antagonistic behavior symptom dimensions of ODD in 224 6-year-old children, oversampled for early behavior problems.

Results: Working memory, inhibition, and sustained attention predicted negative affect symptoms of ODD, controlling for ADHD, whereas delay aversion uniquely predicted oppositional behavior, controlling for ADHD. Delay aversion also marginally predicted antagonistic behavior, controlling for ADHD.

Conclusion: Results demonstrate that different ODD symptom dimensions may be differentially predicted by different neuropsychological functions. The findings further underscore the importance of future research on ODD to take into account the possible heterogeneity of both symptoms and underlying neuropsychological functioning.

Keywords

ODD symptoms; neuropsychological functions; ADHD; preschoolers; symptom dimensions

Neuropsychological Predictors of Dimensions of ODD Symptoms in Young Children

Oppositional defiant disorder (ODD) is defined by a pattern of angry/irritable mood, argumentative/defiant behavior, or vindictiveness, which lasts at least 6 months and causes significant impairment in functioning (American Psychiatric Association [APA], 2013). Lifetime prevalence of ODD is estimated between 3 and 10% in nationally representative samples, with initial symptom onset usually occurring in the preschool years (APA, 2013; Dickstein, 2010; Nock, Kazdin, Hirpi, & Kessler, 2007). Angry/irritable mood and argumentative/defiant behavior have recently been recognized as distinct symptom dimensions of ODD in the newest edition of the Diagnostic and Statistical Manual for Mental Disorders (DSM-5; APA, 2013), reflecting findings that behavioral symptoms of ODD are most predictive of future attention deficit hyperactivity disorder (ADHD), whereas affective symptoms predict depression and anxiety (Aebi, Plattner, Metzke, Bessler, & Steinhausen, 2013; APA, 2013; Rowe, Costello, Angold, Copeland, & Maughan, 2010). A third dimension, vindictiveness, is also recognized in the DSM-5, and is linked to future conduct disorder (CD; Burke, Hipwell, & Loeber, 2010; Stringaris & Goodman, 2009). There is some empirical support for these three dimensions (Stringaris & Goodman, 2009) though others have identified slightly different structures. For example, Burke et al. (2010) identified dimensions of negative affect, oppositional behavior, and antagonistic behavior.

Neuropsychological functioning has been frequently linked to childhood behavior disorders. Most commonly, ADHD has been linked to poorer performance in a variety of neuropsychological domains, including attention, response inhibition, working memory, and delay aversion (Martel, Roberts, & Gremillion, 2013; Pauli-Pott & Becker, 2011; Sjöwall, Bohlin, Rydell, & Thorell, 2015). However, at present we lack a solid understanding of the neuropsychological functions associated with ODD, as studies in the area have yielded widely mixed results (e.g., Allan & Lonigan, 2015; Hobson, Scott, & Rubia, 2011; Schoemaker et al., 2012; Thorell & Wahlstedt, 2006). This may be due in part to significant comorbidity between ODD and ADHD; comorbidity rates between them have been estimated at 35% in a nationally representative sample (Nock et al., 2007) and 40% in a clinical sample of children with ADHD (Elia, Ambrosini, & Berrettini, 2008). Studies of neuropsychological functions and ODD have inconsistently controlled for comorbid ADHD symptoms, but even among the studies that do control for ADHD, there have been mixed results. Studies have also frequently combined ODD and CD into a broader disruptive behavior group (which will be referred to as ODD/CD), which may further contribute to mixed findings. Another possible contributor to the lack of consensus is that no studies of ODD and neuropsychological functions thus far have accounted for the heterogeneity in ODD symptoms. Although most children with negative affect symptoms of ODD also have oppositional behavior, it is also common for children to present with oppositional behavior alone (APA, 2013). Given this heterogeneous presentation, and differential outcomes for children who display negative affect and oppositional behavior symptoms, it is important to

move beyond studying ODD as a unitary disorder, and investigate neuropsychological functions that predict the different ODD dimensions.

Are Neuropsychological Functions Related to ODD Independently of ADHD?

Significant relations have been found most consistently between ODD and neuropsychological tasks involving a motivational or reward component, such as delay-of-gratification or delay aversion tasks (e.g., Hobson, Scott, & Rubia, 2011; Matthys, Vanderschuren, & Schutter, 2013; van Goozen, 2004). For example, a study of 7–12-year-old children with ODD or comorbid ODD and ADHD found that performance on tasks requiring inhibition of a response to gain a reward was impaired in both groups compared to controls (van Goozen et al., 2004). Similarly, Schoemaker et al. (2012) found that preschoolers with ODD/CD¹, as well as those with comorbid ADHD and ODD/CD, had deficits in inhibiting responses when the task involved motivational components in the form of tangible rewards. Studies have also found significant relations between ODD and other neuropsychological functions, including response inhibition (with no reward component; e.g., Hobson et al., 2011; Morgan & Lilienfeld, 2000; Schoemaker et al., 2012; van Goozen et al., 2004), attention (Allan & Lonigan, 2015), and working memory (Saarinen, Fontell, Vuontela, Carlson, & Aronen, 2014; Séguin et al., 1999).

However, other studies have concluded that relations between ODD and neuropsychological functions are solely a result of comorbid ADHD (e.g., Berlin & Bohlin, 2002; Munkvold, Manger, & Lundervold, 2014; Oosterlan, Scheres, & Sargeant, 2005; Thorell & Wahlstedt, 2006). Oosterlan et al. (2005) examined performance on working memory, verbal fluency, and planning tasks in children 6–12 years old and reported that deficits were present in children with ADHD, and children with comorbid ADHD and ODD/CD, but not in children with only ODD/CD. Likewise, Thorell and Wahlstedt (2006) found that inhibition, working memory, and verbal fluency in preschoolers were related to ADHD, but not ODD, in both categorical and dimensional analyses.

Only one study was identified that examined neuropsychological functions in young children and how these predicted later ODD symptoms (Brocki, Nyberg, Thorell, & Bohlin, 2007). Preschool response inhibition predicted school-aged ADHD symptoms, but not ODD symptoms, when comorbidity was controlled for dimensionally. Examining early predictors of ODD symptoms may be important for understanding the developmental course of the disorder, and for finding possible avenues for intervention. For ODD in particular, which is often diagnosed at school age, identification of early neuropsychological predictors may be important for improving our ability to distinguish transient problem behaviors that arise as a typical part of early development from those that are indicative of risk for future psychopathology.

¹The term ODD/CD indicates that the study combined children with ODD and CD into a broader disruptive behavior group.

Do Different ODD Symptom Dimensions Have Different Neuropsychological Predictors?

Research has recently shown the utility of distinguishing between ODD symptoms that reflect angry/irritable mood, defiant and argumentative behavior, and spiteful or vindictive behavior, which is reflected in the DSM-5 reconceptualization of ODD (APA, 2013). Although there has been some lack of consensus about the best factor structure for ODD, the most commonly proposed models (reviewed below) reflect these basic distinctions (Burke et al., 2010; Rowe et al., 2010; Stringaris & Goodman, 2009). The DSM-5 has adopted the model proposed by Stringaris and Goodman (2009), which groups the symptoms *is often angry or resentful, often loses temper* and *is often touchy or easily annoyed by others* into an angry/irritable mood dimension, the symptoms *often argues with adults, often actively defies or refuses to comply with adults' requests or rules, often deliberately annoys other people, and often blames others for his or her mistakes or misbehavior* into an argumentative/defiant symptoms dimension, and the symptom *is spiteful* as the single item on a spiteful/vindictive dimension (APA, 2013). This factor structure has been replicated in samples of adolescents and school-aged children. Another commonly cited factor structure is the Burke et al. (2010) model, which groups the symptoms *is spiteful, is often angry or resentful, and is often touchy or easily annoyed by others* into a negative affect dimension, the symptoms *often argues with adults, often actively defies or refuses to comply with adults' requests or rules, and often loses temper* into an oppositional behavior dimension, and the symptoms *often deliberately annoys other people, and often blames others for his or her mistakes or misbehavior* into an antagonistic behavior dimension. This factor structure has been replicated in samples of preschool and school-aged children, and one study found that this model fit a sample of preschoolers better than the Stringaris and Goodman (2009) model (Ezpeleta, Granero, de al Osa, Pabelo, & Domenech, 2012).

Although no studies have previously examined neuropsychological predictors of different dimensions of ODD symptoms separately, there are theoretical arguments for distinct links between these symptom dimensions and specific neuropsychological functions. Matthys and colleagues (2012) have suggested that ODD, a disorder of both behavior and emotion, is also a disorder of multiple neurocognitive dysfunctions, in which social learning processes are impaired by deficits in both cognitive control and reward and punishment processing. They hypothesize that difficulties with neuropsychological functions involving cognitive control, such as attention and inhibition, can result in poor problem solving, and an inability to adapt behavior to different circumstances, which can manifest in poor emotion regulation. Consistent with this, links between working memory, attention, and inhibition, and experiences of negative affect have been hypothesized to reflect the importance of these neuropsychological functions in antecedent emotion regulation strategies such as redirecting attention and cognitive reappraisal (Hofmann, Friese, Schmeichel, & Baddeley, 2011; Moriya & Tanno, 2007; Schmeichel, Volokhov, & Demaree, 2008). Indeed, deficits in working memory, attentional control, and inhibition have been linked empirically to the ability to regulate emotion, and particularly experiences and displays of negative emotion (Carlson & Wang, 2007; Moriya & Tanno, 2007; Schmeichel et al., 2008). For example, Carlson and Wang (2007) found that children with better inhibition had less intense

expressions of negative affect in response to receiving a disappointing gift. Thus, theory and research suggests that neuropsychological functions involving cognitive control may be linked to the negative affect (or angry-irritable) dimension of ODD.

Matthys and colleagues (2012) theorize that deficits in the processing of rewards and punishments also play a role in ODD symptoms, as they result in an inability to delay gratification to gain or avoid later rewards or punishments. They suggest that for children with ODD, behavior is not shaped by consequences as it is with typical children, resulting in defiant and oppositional behavior (Matthys et al., 2012). Likewise, Stringaris and Goodman (2009) have suggested that deficits in the ability to delay gratification may play an important role in the oppositional behavior symptoms of ODD, in that argumentativeness and failure to follow rules/requests represent an “I want it now” attitude. Empirically, aggressive and antisocial behavior has been linked fairly consistently with impairment in neuropsychological tasks involving a reward or motivational component (e.g., Dolan & Lennox, 2013; Krueger, Caspi, Moffitt, White, & Stouthamer-Loeber, 1996; Morgan & Lilienfeld, 2000; Rubia, 2011). For example, Dolan and Lennox (2013) found that children with externalizing behaviors had deficits in inhibition tasks that involved rewards as a motivator. Thus, theory and research also suggest that neuropsychological functions involving a motivational component, such as delay aversion, may be linked especially to behavioral (i.e., oppositional or antagonistic) symptoms of ODD.

The Present Study

The present study investigated how neuropsychological functions at preschool age predict three symptoms dimensions of ODD (negative affect, oppositional behavior, and antagonistic behavior) at age 6, in children identified as having had early behavior problems.

Specifically, the present study addressed the following questions:

1. Do working memory, response inhibition, sustained attention, and delay aversion at preschool age differentially predict later ODD symptoms of negative affect, oppositional behavior, and antagonistic behavior?
2. Do these relations between neuropsychological functions and ODD symptom dimensions remain after controlling for ADHD?

Although few previous studies exist to directly inform our hypotheses, our preliminary hypotheses based on these studies and existing theory are that working memory, response inhibition, and attention will predict future negative affect symptoms of ODD, whereas delay aversion will predict future oppositional and antagonistic behavior symptoms of ODD. We further hypothesized that these neuropsychological functions will significantly predict negative affect and oppositional symptoms, even controlling for ADHD symptoms.

Method

Participants

Participants were 224 children (121 boys; 103 girls) who were drawn from a larger sample of 259 children who participated in a 3-year longitudinal study investigating the

development of behavior problems in the preschool and early school years (see Authors, 2011 for a more detailed description of this study). Data was collected in four visits, each approximately 1 year apart. Data from the first, second, and fourth visits were used in this study. Children were 3 years old at the first visit ($M = 44.25$ months, $SD = 3.35$ months), 4 years old at the second visit ($M = 56.57$ months, $SD = 3.65$ months), and 6 years old at the fourth visit ($M = 80.37$ months, $SD = 4.93$ months). The larger sample consisted of two groups of children: (a) 199 children who were identified as having externalizing problems at age 3, and (b) 59 children who were identified as not having significant externalizing problems at age 3. Children who had complete data for at least one of the neuropsychological assessment time points (at age 3 or 4) and completed the follow-up at age 6 were included in this study (168 children with externalizing behavior problems and 56 typically developing children). Participants had a median annual family income of \$50,000. Number of years of maternal education ranged from 8 to 20 ($M = 13.54$, $SD = 2.76$). Most (58.5%) of children in the present sample were identified by their parents as European American/White, 18.3% as Latino (predominantly Puerto Rican), 10.3% as African American/Black, and another 12.9% of children were identified by their parents as bi/multiracial.

Procedure

Participants were recruited from 3-year-old children ($n = 1752$) whose parents completed a screening packet received through the mail (via state birth records), pediatrician offices, child care centers, and community centers throughout western Massachusetts. The packet contained a consent form; a Behavior Assessment System for Children-Parent Rating Scale (BASC-PRS; Reynolds & Kamphaus, 1992); and a questionnaire assessing exclusion criteria, parental concern about externalizing symptoms, and demographic information. Criteria for all participants included no evidence of intellectual disability, deafness, blindness, language delay, cerebral palsy, epilepsy, autism, or psychosis. Criteria for children with externalizing behaviors were: (a) parent responded “yes” or “possibly” to the question, “Are you concerned about your child’s activity level, defiance, aggression, or impulse control?” and (b) BASC-PRS hyperactivity and/or aggression T scores fell at or above 65 (1.5 SD s above the mean). Criteria for the typically developing children were: (a) parent responded “no” to the question above and (b) BASC-PRS hyperactivity, aggression, inattention, anxiety, and depression T scores fell at or below 60. Fifty-nine percent of externalizing problem children and 72% of typically developing children whom we sought to recruit participated. Written informed consent was obtained from all parents who participated and verbal assent was obtained from children. The study was conducted in compliance with the authors’ Institutional Review Board.

The 224 children who were included in the present study did not differ significantly from the 35 children who were not included on gender, age, age 3 ADHD or ODD symptoms on the DISC-IV, income, maternal education, or paternal education. However, the 35 children who did not complete a visit at age 6 were more likely to be African American or multi-ethnic and less likely to be Latino or European American, compared to the 224 children included in the study, $\chi^2(3) = 12.69$, $p = .01$.

Measures

A Developmental Neuropsychological Assessment (NEPSY; Korkman, Kirk, & Kemp, 1998).—Working memory and response inhibition were assessed at age 4 with the Sentence Repetition and Statue subtests from the first edition of the NEPSY, a frequently used test of neuropsychological abilities (Korkman et al., 1998). Sentence Repetition requires children to repeat sentences of increasing lengths to assess working memory. The Statue subtest assesses motor response inhibition. Children are required to remain still with their eyes closed, and refrain from responding to various sound distracters for 75 seconds. Raw scores from each subtest were converted to scaled scores comparing performance to an age-based reference group. Scaled scores are normed with a mean of 10 and standard deviation of 2. Test-retest reliability for Sentence Repetition has been found to be good for 4-year-olds (.84), though relatively low for the Statue subtest (.50; Korkman et al., 1988). Children with neurological impairment have been found to have lower scores on the NEPSY than controls (Schmitt & Woodrich, 2004).

McCarthy Scales of Children's Abilities (MCSA; McCarthy, 1972).—Working memory was further assessed using two subtests from the MSCA, a test of cognitive abilities for children aged 2.5 to 8.5 (McCarthy, 1972): Numerical Memory I, which requires children to repeat a series of digits forwards, and Numerical Memory II, which requires children to repeat a series of digits backwards. The subtests were administered at age 3. Since these subtests were two of four included on the overall memory scale, raw scores were used. Test-retest reliability for the memory scale for children 3 to 3.5 years old has been found to be good (.78; McCarthy, 1972). The MSCA has been found to have adequate convergent and predictive validity with other cognitive and achievement tests (McCarthy, 1972).

Conners' Kiddie Continuous Performance Test (K-CPT; Conners, 2001).—The K-CPT is a computerized test of sustained attention, designed as a screener for attention problems (Conners, 2001). The K-CPT is adapted for preschoolers from the original CPT, designed for persons over the age of 8. The K-CPT was administered to participants at age 4. During the 7.5 minute task, pictures of common objects appear on a computer screen at either 1.5s or 3s stimulus intervals. Children are required to press the spacebar every time a picture appears on the screen, but refrain from pressing the spacebar when that picture is a ball. Split-half reliability of the K-CPT has been found to be good (.72 to .88), and performance on the K-CPT improves with age, as expected (Conners, 2001). Children with ADHD score significantly worse on the K-CPT (Conners, 2001). Three scores from the K-CPT were used in this study: omission errors (the number of times the child did not respond to a target object), hit rate standard error (the overall consistency in a child's reaction time), and variability (the extent to which the consistency of the child's reaction time varies across the task). These three components have been shown to factor together to form a measure of sustained attention (see Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001). Barkley et al. (2001) found that ADHD and control groups in their study significantly differed on this factor, with the ADHD group exhibiting poorer sustained attention.

Snack delay task.—A snack delay task (adapted from Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996) was administered at age 3 to assess children's delay aversion. In this task, the experimenter placed two M&Ms® under one of three identical transparent cups that were placed in front of the child, within arm's length. The child was instructed to wait to "find" the M&Ms® until the experimenter rang a bell. Six trials were conducted, with the following delay periods: 15 seconds, 35 seconds, 10 seconds, 45 seconds, 25 seconds, and 30 seconds. Children were given a point for each trial in which they waited until the bell rang before finding the M&M®. Total scores for this task were out of 6, with lower scores indicating greater delay aversion. Kochanska et al. (1996) found that internal consistency for a battery of snack delay and similar tasks in 3–4 year-olds was good (.79). Performance on this task at age 3 predicts children's later behavior problems (Gadow & Sprafkin, 2002; Kim, Nordling, Yoon, Bolt, & Konchaska, 2013), and differentiates between hard-to-manage preschoolers and controls (Campbell, Pierce, March, Ewing, & Szumowski, 1994).

ODD Symptoms.—ODD symptoms were measured using the ODD items from the Disruptive Behavior Rating Scale (DBRS; Barkley & Murphy, 1998). The DBRS consists of eight items assessing ODD symptoms as defined in the DSM-5. At age 6, mothers rated the presence of symptoms on a 4-point Likert scale ranging from 0 ("not at all") to 3 ("very often"). Ratings of individual items on this 0–3 scale were used in study analyses. This scale has been validated for use in preschool and school-aged children (Friedman-Weieneth, Doctoroff, Harvey, & Goldstein, 2009). Alpha for the full eight item ODD scale in this sample was .91.

ADHD Symptoms.—A count of ADHD hyperactive and inattention symptoms as measured by the Diagnostic Interview Schedule for Children- 4th Edition (DISC-IV; Shaffer et al., 2000), was used as the measure of ADHD symptoms. The DISC-IV was administered at age 6 by trained graduate students of psychology to the primary caregivers of participants. The DISC-IV ADHD items were used instead of the ADHD items from the DBRS to reduce method variance. The parent-report version of the DISC has been validated for use in diagnosing ADHD in school aged children (Schwab-Stone et al, 1996). Alpha for the hyperactivity/impulsivity and inattention symptoms scales in this sample were .81 and .87 respectively.

Data Analytic Plan

Analyses were performed using structural equation modeling (SEM) in LISREL 8.8. (Jöreskog & Sörbom, 2006). First, to determine which of the two commonly proposed models of ODD symptom dimensions fit the data best, the Stringaris and Goodman (2009) model and the Burke et al. (2010) model were each tested using confirmatory factor analysis. In order to confirm the suitability of a multidimensional model, a unidimensional ODD model was also fit for comparison. Confirmatory factor analyses were also performed to confirm the fit of the measures of neuropsychological functions to their proposed latent factors. Goodness of fit for the structural equation models was evaluated using five indicators: χ^2/df (< 2 indicates good model fit), Root Mean Square Error of Approximation (RMSEA; values of .08 and lower represent acceptable model fit and values between .08 and

1.0 indicate mediocre model fit), Bentler's Comparative Fit Index (CFI; values higher than .90 indicate acceptable model fit), Normative Fit Index (NFI; values higher than .90 indicate acceptable model fit) and Standardized Root Mean Square Residual (SRMR; values lower than .08 indicate adequate model fit; Hu & Bentler, 1998)

SEM was used to determine the best fitting model of the relations between neuropsychological functions and negative affect, oppositional behavior, and antagonistic behavior symptoms, controlling for ADHD. To address our first question, a model was fit with paths from each of the neuropsychological factors to each of the ODD symptom dimensions. Non-significant paths were trimmed, as described below, to obtain a final model. To address our second question, the same model was estimated with ADHD as a covariate in the regression paths. The sums of ADHD hyperactivity/impulsivity and inattentive symptoms, respectively, on the DISC-IV were used to estimate a latent measure of ADHD. Since ADHD was used solely as a covariate in the structural model, to reduce model complexity the item-level bifactor method of modelling heterogeneity of ADHD symptoms was not used.

Missing data for neuropsychological variables ranged from 10% to 37%. Sample sizes for each measure were as follows: NEPSY Sentence Repetition: $n = 200$; NEPSY Statue: $n = 198$; McCarthy Numerical Memory I: $n = 197$; McCarthy Numerical Memory II: $n = 179$; M&M® task: $n = 164$; and the K-CPT: $n = 140$. Missing data for the neuropsychological variables were due to test refusal or invalid administrations. A subset of children were missing data on the K-CPT measures due to technical difficulties encountered during the computer administration. Missing data for ODD and ADHD symptom variables ranged from 1 to 2 %. The minimal missing data for ODD and ADHD variables was due to incomplete data on the DISC or the DBRS. Missing data were accounted for by multiple imputation using the Expectation-Maximization (EM) algorithm in LISREL 8.8 (see Enders, 2001; Enders & Peugh, 2004).

Results

Preliminary Analyses

Factor structure of ODD symptoms.—The Stringaris and Goodman (2009; Model 1) Burke et al. (2010; Model 2) model, and a unidimensional ODD model (Model 3) were compared for goodness of fit in this sample. Model 1 evidenced adequate fit on some indices (CFI = 0.96; NFI = 0.96; SRMR = 0.04), and poor fit on others (Chi-square/df = 4; RMSEA = 0.12). Model 3 likewise evidenced adequate fit on some indices (CFI = .97; NFI = .96; SRMR = .04), and poor fit on others (Chi-square/df = 3.35; RMSEA = 0.11). Model 2 evidenced better overall fit, with all measures suggesting at least adequate fit (Chi-square/df = 2.5; RMSEA = .09; SRMR = .03; CFI = .98; NFI = .97). The factor structure from Model 2 was used in subsequent analyses.

Factor structure of neuropsychological measures.—A confirmatory factor analysis was performed to confirm the relations of the neuropsychological measures to their proposed latent factors. In this model, NEPSY Sentence Repetition, and McCarthy Numerical Memory I and II were used as measures of working memory. CPT Omission Errors,

Variability, and Hit Rate Standard Error were used as measures of sustained attention. The NEPSY Statue subtest was used as the measure of response inhibition, while the snack delay task was used as the measure of delay aversion. Each indicator loaded onto its respective factor, and the model showed adequate overall fit (Chi-square/df = 2.4; RMSEA = .08; SRMR = .04; CFI = .97; NFI = .96).

Descriptive Statistics—Descriptive statistics and bivariate correlations among observed variables are presented in Table 1. Means and *SDs* were similar to national norms on the neuropsychological measures. Bivariate correlations among the latent factors are presented in Table 2. The negative affect, oppositional behavior, and antagonistic behavior latent factors were very highly correlated in this sample (r s between .83 and .94, all p s < .001). The ADHD symptoms latent factor was significantly correlated with the negative affect, oppositional behavior, and antagonistic behavior factors ($r = .51, p < .001, r = .43, p < .001$, and .66, $p < .001$, respectively).

Neuropsychological Functions and ODD Symptom Dimensions—Although there were *a priori* hypotheses about the relations between neuropsychological functions and ODD symptom dimensions, a full model was first fit with paths from each neuropsychological latent factor to each ODD latent factor, in order to rule out the possibility of other patterns of relations among the variables. The fit of the full model was good (Chi-square/df = 1.87; RMSEA = .06; SRMR = .04; CFI = .97; NFI = .95). Model trimming was then used whereby paths that were non-significant above the .10 level were trimmed one-by-one, beginning with the paths with the highest p values. In the trimmed model, paths to negative affect from working memory, response inhibition, and sustained attention were significant at the .05 level. The paths to oppositional behavior from sustained attention and delay aversion were also significant. The path from sustained attention to antagonistic behavior was significant, and the path from delay aversion to antagonistic behavior was marginally significant (Figure 1). Path coefficients indicated relations were in the expected direction (i.e., better neuropsychological functioning was related to fewer ODD symptoms) except for the path between response inhibition and negative affect, which indicated that better response inhibition was related to more negative affect symptoms. Fit indices for the trimmed model also indicated good fit (Chi-square/df = 1.81; RMSEA = .06; SRMR = .04; CFI = .97; NFI = .95). Neuropsychological factors accounted for 11% of the variance in the negative affect factor, 12% of the variance in the oppositional behavior factor, and 7% of the variance in the antagonistic behavior factor.

Neuropsychological Functions and ODD Symptom Dimensions, Controlling for ADHD^{2,3}—To answer the second research question, the process above was repeated with an ADHD symptoms factor added as a control variable. The fit of the full model was good (Chi-square/df = 1.94; RMSEA = .07; SRMR = .03; CFI = .98; NFI = .97). Model

²The final model was also run controlling for gender. Results did not change with gender as a control variable, and model fit was worse. This model was therefore not presented as it was not central to the aims of this paper.

³The final model was also run controlling for CD symptoms, to ensure that relations between neuropsychological functions and ODD symptoms were not due solely to overlap with CD. The pattern of results when controlling for CD symptoms did not change, and all paths in the final model remained significant, except the path from working memory to negative affect, which was marginally significant at $p = .058$, when controlling for CD symptoms.

trimming was again used as described above. In the final model, paths to negative affect from working memory, response inhibition, and sustained attention were significant at the .05 level. The path from delay aversion to oppositional behavior was also significant. The path between delay aversion and antagonistic behavior was marginally significant (see Figure 2). Path coefficients indicated relations were in the expected direction except for the path between response inhibition and negative affect, which again indicated that better response inhibition was related to greater negative affect symptoms. Conversely, the bivariate correlation between response inhibition and the negative affect dimension was in the expected negative direction. After adding ADHD as a control variable, the paths from sustained attention to oppositional behavior and antagonistic behavior were no longer significant. Fit indices for this final model also indicated good fit (Chi-square/df = 1.84; RMSEA = .06; SRMR = .04; CFI = .97; NFI = .94). Neuropsychological factors and ADHD together accounted for 30% of the variance in the negative affect factor, 36% of the variance in the oppositional behavior factor, and 44% of the variance in the antagonistic behavior factor.

Discussion

This study examined neuropsychological functions in children measured at ages 3 and 4 as predictors of three symptom dimensions of ODD at school age. Neuropsychological functions differentially predicted later negative affect versus oppositional and antagonistic behavior dimensions. More delay aversion uniquely predicted more oppositional behavior symptoms, and marginally predicted more antagonistic symptoms, controlling for ADHD. Better working memory and sustained attention predicted fewer negative affect symptoms, controlling for ADHD. Contrary to prediction, greater response inhibition predicted *more* ODD negative affect symptoms, controlling for ADHD. Finally, relations between sustained attention and oppositional and antagonistic symptoms of ODD were accounted for by comorbid ADHD symptoms.

Neuropsychological Functions Differentially Predict ODD Symptoms

The finding that delay aversion predicted oppositional and antagonistic symptoms of ODD, but not negative affect, is consistent with previous studies that have linked deficits on neuropsychological tasks with a motivational component to aggressive and antisocial behaviors (Dolan & Lennox, 2010; Hobson et al., 2011; Rubia, 2011; van Goozen et al., 2004). One theory for this link is that children who have difficulty processing reward stimuli to delay gratification for later gain also have difficulty with rules for behavior that prevent immediate reward (Matthys et al., 2013; Stringaris & Goodman, 2009). Additionally, sensitivity to reinforcement is essential for social learning. Social learning theory suggests that children's behavior is typically shaped by environmental contingencies. Children with deficits in processing reward information have difficulty learning appropriate behavior (Matthys et al., 2012). Consistent with this theory, children with ODD have been found to have functional deficits in the orbitofrontal cortex and amygdala associated with hyposensitivity to rewards (see Matthys et al., 2013).

The finding that working memory and sustained attention are related to negative affect symptoms of ODD, but not to oppositional and antagonistic behavior, is also consistent with previous research suggesting that neuropsychological functions play an important role in regulation of negative emotions. Working memory, for example, may help with regulation strategies such as the reframing of negative situations, while attentional control can help with mitigating attentional bias (Hofmann, Friese, Schmeichel, & Baddeley, 2011; Moriya & Tanno, 2007; Schmeichel, Volokhov, & Demaree, 2008). Working memory has also been hypothesized to be important in recalling effective emotion regulation strategies (Barkley, 2015).

Response inhibition was significantly related to negative affect symptoms, but not in the expected direction. When controlling for ADHD, better response inhibition was related to more negative affect symptoms. Examination of the bivariate correlation between these two variables, which is in the expected negative direction, shows that the coefficient is positive only when the oppositional and antagonistic behavior dimensions are controlled for. Negative affect states, particularly related to anxiety, have been linked to over-inhibition of response, providing a possible explanation for this finding (e.g., Fox, Henderson, Rubin, Calkins, & Schmidt, 2001; Park, Belsky, Putnam, & Crnic, 1997). With the variance accounted for by behavioral difficulties removed, the negative affect dimension of ODD may therefore be reflecting primarily affective, rather than behavioral symptoms, which could account for this finding.

Differential relations between neuropsychological functions and ODD symptom dimensions may help explain previous mixed results. Since past studies did not account for the different dimensions of symptoms, relations between, for example, working memory, response inhibition, and sustained attention and ODD may have depended on the extent to which children in the samples experienced negative affect versus oppositional or antagonistic behavior symptoms. This problem would have been compounded by the fact that many past studies did not differentiate between ODD and CD, instead examining combined “disruptive behavior disorder” groups. Utilizing ODD/CD samples may have obscured variability in ODD with regard to negative affect symptoms. The present results could indicate that the relations between neuropsychological functions and ODD depend on the ODD symptom dimension in question.

Differential relations between neuropsychological functions and ODD symptoms were found in this study despite very high correlations among the three ODD symptom dimensions. Although the three dimensional ODD model showed strong fit both in the present and previous studies (e.g., Burke et al., 2010; Ezpeleta et al., 2012), and the specificity of relations between these dimensions and neuropsychological functions lends further support to a multidimensional model of ODD, these high correlations are also potentially consistent with a unidimensional model of ODD. Replication of the differential relations observed in this study may help clarify this issue. In addition, the high correlations among ODD dimensions may explain why some neuropsychological dimensions did not show specificity (e.g., sustained attention). These issues all point to the importance of continuing to empirically evaluate the underlying factor structure of ODD.

Early Neuropsychological Functions Predict Later ODD Symptoms

Longitudinal studies of ODD are important for identifying early vulnerabilities that may contribute over time to the development of ODD symptoms. This study found that preschool neuropsychological functions predicted ODD symptoms at school age, and results suggest that these relations are not solely a result of comorbid ADHD. Further research is needed to determine whether results are specific to this particular developmental period. For example, the preschool period is critical for the development of frontal circuitry (Happaney, Zelazo, & Stuss, 2004; Kerr & Zelazo, 2004) which in turn plays an important role in the development of self-regulation. Structural and functional abnormalities in the amygdala, insula, striatum, and frontal gyrus have been found in children and adolescents with ODD. These areas are involved in emotion processing, the regulation of behavioral responses in emotion-salient situations, and reinforcement learning and response inhibition (Noordermeer, Loon, & Oosterlaan, 2016). Children with delays in the development of these brain regions may miss a critical opportunity for learning skills to regulate behavior and emotion. Neuropsychological deficits that emerge later in development may be less likely to lead to ODD symptoms if foundational self-regulation skills have already been established. Furthermore, preschool neuropsychological functions may exhibit a different predictive relation with ODD symptoms in later childhood and adolescents as ODD symptom expression shifts and other factors, such as peer influences, contribute to the development of ODD.

Limitations and Future Directions

First, the children in the present sample were not formally diagnosed with ODD when enrolled in the study, though they were oversampled for early behavior problems. Second, the measures of neuropsychological functions used in this study were collected over two years, when participants were 3 and 4 years old. Presumably, developmental changes in neuropsychological functioning could differentially predict later symptoms. However, given that the present study investigated how *early* neuropsychological functions predict *later* ODD symptoms, the one-year difference in data collection points likely would not have affected the investigation of the present study's hypotheses. Third, while the sample was relatively large, a number of children did not complete valid K-CPT assessments at age 4. Fourth, this study used ADHD symptoms ratings from the DISC and ODD symptoms ratings from the DBRS. Using multiple methods reduces method variance, which is an important strength, but may also attenuate actual relationships between ADHD and ODD. Fifth, this study did not control for IQ, which is a strong predictor of performance on neuropsychological tests. It should be noted, however, that some neuropsychological functions examined in this study, such as working memory, are often included as dimensions of IQ itself, further complicating the conceptual separation of neuropsychological functions and IQ. Sixth, two major models of the structure of ODD were evaluated, but extensive exploratory analyses of alternative structural models of ODD were not, and alternative models may exist that explain the data. The study also focused on heterogeneity in ODD symptoms as a first step, and did not also explore heterogeneity in ADHD symptoms. Lastly, the present study did not explore demographic (e.g., ethnicity and SES) differences in neuropsychological functions and ODD, as this was beyond the scope of the current study.

Future studies should investigate individual and family differences in the link between ODD and neuropsychological functions.

Effect sizes for the relations between neuropsychological factors and later ODD symptom dimensions in this study were generally small. This is not particularly surprising given the multiple factors that are hypothesized to influence the development of ODD (e.g., parent, peer, and environmental stress influences), and it highlights the need for continued research on multifaceted influences on the development of ODD symptoms. Future research should also investigate neuropsychological functions and ODD symptom dimensions in older children and adolescents. In addition to examining whether the present results are specific to young children, studies utilizing older child samples may better measure neuropsychological functions that are difficult to measure reliably in young children. Relatedly, future studies should continue to examine potential issues with reliability of neuropsychological measures in young children. Additionally, since the best factor structure for ODD is still being explored, future studies should continue to investigate the link between ODD and neuropsychological functions as knowledge about ODD symptom dimensions expands. Future studies might also further explore heterogeneity and overlap in ODD and ADHD symptoms, and how this may be related to neuropsychological functions.

Conclusion

Despite these limitations, the results have several theoretical and practical implications. First, these findings contribute to our theoretical understanding of ODD as a heterogeneous disorder, with multiple neuropsychological underpinnings. The findings underscore the importance of taking heterogeneity in ODD symptoms into account in future studies, as dissent in the literature about links between neuropsychological functions and ODD may have resulted at least partly from investigating ODD as a homogeneous disorder. Second, findings indicate that neuropsychological functioning predicts ODD symptoms independently of ADHD. Third, findings suggest that different early neuropsychological functions may underlie different ODD symptom dimensions, and that it may be important for interventions to differentiate between children with only behavioral symptoms, and those with mixed behavioral and affective symptoms. Interventions may be most effective if tailored to the particular symptom presentation of a child with ODD symptoms. As suggested by Matthys et al. (2012) for example, children with mostly behavioral symptoms may benefit most from increased attention to reward sensitivity, and inability to tolerate short term costs for longer term gains. Further research is needed to examine whether treatments that target specific neuropsychological functions associated with different dimensions of ODD may be effective.

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Figure 1.

Structural model showing the relations between preschool executive functioning and age 6 ODD symptom dimensions. Note. CPT = Continuous performance test, DISC = Diagnostic Interview Schedule for Children. For sustained attention measures, higher scores indicate worse performance. For other neuropsychological measures, higher scores indicate better performance. For ADHD and ODD measures, higher scores indicate more symptomology. Standardized coefficients are presented. $*p < .05$, $**p < .01$, $***p < .001$

Figure 2.

Structural model showing the relations between preschool executive functioning and age 6 ODD symptom dimensions, controlling for symptoms of ADHD.

Note. CPT = Continuous performance test, DISC = Diagnostic Interview Schedule for Children. Standardized coefficients are presented. For sustained attention measures, higher scores indicate worse performance. For all other neuropsychological measures, higher scores indicate better performance. For ADHD and ODD measures, higher scores indicate more symptomology. * $p < .05$, ** $p < .01$, *** $p < .001$

Table 1.
Descriptive Statistics and Intercorrelations of ODD Symptoms, Neuropsychological Functioning (NF) Variables and ADHD

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
<u>NF Tasks</u>																		
1. Statue ^a	-																	
2. CPT - Variability ^d	-.38**	-																
3. CPT - Hit Rt Std Err. ^d	-.43**	.87**	-															
4. CPT - Omissions ^d	-.42**	.68**	.72**	-														
5. Sentence Memory ^a	.30**	-.34**	-.41**	-.33**	-													
6. Numerical Memory 1 ^b	.19**	-.08	-.19**	-.21**	.21**	-												
7. Numerical Memory 2 ^b	.26**	-.27**	-.34**	-.20**	.59**	.27**	-											
8. Snack Delay	.17*	-.23**	-.31**	-.16*	.33**	.11	.38**	-										
<u>ADHD</u>																		
9. DISC H/I	-.18*	.22**	.23**	.24**	-.22**	-.07	.04	-.16*	-									
10. DISC Inatt.	-.26**	.20*	.29**	.28**	-.23**	-.11	-.09	-.02	.68**	-								
<u>ODD^c</u>																		
11. Temper	-.16*	.16	.16	.13	-.22**	-.11	-.16*	-.19*	.41**	.28**	-							
12. Argues	-.14*	.13	.14	.07	-.14	-.02	-.17*	-.28*	.41**	.33**	.64**	-						
13. Defies	-.11	.25**	.25**	.20*	-.15*	-.05	-.18*	-.25**	.45**	.33**	.60**	.73**	-					
14. Annoys	-.18*	.23**	.23**	.23**	-.19**	-.06	-.10	-.13	.52**	.36**	.55**	.52**	.60**	-				
15. Blames	-.09	.16	.14	.16	-.08	-.04	.002	-.12	.38**	.28**	.48**	.53**	.52**	.55**	-			
16. Touchy	-.11	.22*	.24**	.26**	-.22**	-.04	-.10	-.10	.42**	.26**	.57**	.53**	.55**	.59**	.61**	-		
17. Angry	-.07	.23	.26**	.27**	-.19**	-.10	-.12	-.04	.39**	.26**	.56**	.51**	.63**	.56**	.50**	.66**	-	
18. Spiteful	-.06	.20*	.20*	.17*	-.18**	-.12	-.18*	-.10	.31**	.23**	.53**	.49**	.56**	.60**	.52**	.57**	.68**	-
<i>M</i>	10.45	50.67	50.58	50.31	10.62	4.62	.29	5.02	2.37	3.10	1.40	1.41	1.08	.96	1.11	1.05	.73	.49
<i>SD</i>	2.57	9.90	8.65	10.21	2.56	1.67	1.18	1.55	2.78	2.64	.95	1.01	.95	.94	.94	.99	.92	.80

* p < .05

p < .01.

Note. CPT = Continuous Performance Test, DISC = Diagnostic Interview Schedule for Children, H/I = Hyperactive/Impulsive, Inatt. = Inattention, Hit Rt Std Err. = Hit Rate Standard Error.

^aSubtest from A Developmental Neuropsychological Assessment.

^bSubtest from the McCarthy Scales of Children’s Abilities.

^cODD items from Disruptive Behavior Rating Scale.

^dLower scores indicate better performance on neuropsychological measures. Otherwise, higher scores indicate better performance.

For ADHD and ODD measures, higher scores indicate more symptomology.

Table 2.

Correlations among Latent Variables

	1.	2.	3.	4.	5.	6.	7.
1. Working Memory							
2. Sustained Attention	-.50**						
3. Response Inhibition	.38**	-.45**					
4. Delay Aversion	.45**	-.30**	.17*				
5. Negative Affect	-.26**	.30**	-.09	-.15**			
6. Oppositional Behavior	-.23**	.23**	-.18*	-.34**	.84**		
7. Antagonistic Behavior	-.18**	.26	-.20*	-.20**	.94**	.87**	
8. Attention Deficit Hyperactivity Disorder	-.24**	.36**	-.28**	-.17**	.51**	.54**	.66**

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

For the sustained attention measures, higher scores indicate worse performance. For other neuropsychological variables, higher scores indicate better performance. For ADHD and ODD variables, higher scores indicate more symptomatology.