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The interplay among temperament, neuropsychological abilities, and global functioning in young hyperactive/inattentive children

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Abstract

Cognition and emotion have been shown to interact and to influence psychological functioning. However, to date these interactions have only been examined cross-sectionally among inattentive and/or hyperactive/impulsive children. This study investigated the moderating effects of neuropsychological functioning at age 3–4 years on the relation between negative emotionality at age 3–4 years and global functioning one year later, at age 4–5 years. Hyperactive/inattentive (H/I; N=114) preschoolers entered the study (BL: baseline) and were seen again one year later (F1). Children's BL scores on a neuropsychological test (NEPSY) and their temperament as rated by parents (Child Behavior Questionnaire) and teachers (Temperament Assessment Battery for Children-Revised) were obtained, as were clinicians' ratings of their global functioning (Children's Global Assessment Scale) at F1. Hierarchical Linear Regression analyses revealed that BL temperament variables accounted for significant variance in F1 Global Functioning. Significant interactions indicated that higher Verbal Executive abilities were associated with better child functioning when parent-rated Effortful Control was high, but not when Effortful Control was low. Additionally, high levels of Nonverbal Executive skills were associated with higher child global functioning when both parent and teacher rated negative affect was low, but not when negative affect was high.

Keywords

Preschool; Adaptive functioning; Neuropsychological functioning; Temperament; ADHD

Attention-Deficit/Hyperactivity Disorder (ADHD) is a common, oftentimes chronic, disorder characterised by difficulties in regulating activity levels, impulse control, and/or

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attention (American Psychiatric Association, 2013). For many individuals, these symptoms first become apparent during the preschool years (Lahey et al., 2004).

To receive a diagnosis of ADHD the presence of the core symptoms of ADHD alone is insufficient. These symptoms must also negatively affect adaptive functioning – that is, they must be impairing (American Psychiatric Association, 2013). It is well established that at the group level, children and adolescents with ADHD experience significant difficulties in a number of areas of adaptive functioning (Stein, Szumowski, Blondis, & Roizen, 1995), including, but not limited to peer relationships, parent-child interactions, school achievement, and they are at greater risk for psychiatric comorbidity (e.g., Cuffe et al., 2015; Johnston & Mash, 2001; Murray-Close et al., 2010). Therefore, there is a need to study impairment in functioning among children who exhibit symptoms of ADHD.

Efforts to develop an integrative understanding of early behavioral problems have led researchers to posit that more emotional, spontaneous, stimulus-driven, and “bottom-up” responses may work in consonance with the more cognitive, planned self-regulatory, and “top-down” processes to promote behavioral regulation (Casey, 2005; Martel, Nigg, Von Eye, 2009; Rabinovitz, O’Neill, Rajendran, & Halperin, *in press*). A multiple pathways model which integrates both temperamental, reactive traits with higher-order cognitive abilities may better explain the course of ADHD (Nigg, 2000) and its associated impairment. From a developmental perspective, Halperin and Schulz (2006) proposed that ADHD is characterised by early and enduring subcortical dysfunction, while symptom remission may reflect later-emerging executive control processes. Given that difficulties in temperament or reactive “bottom-up” processes may also hinder the development of cortical control (Nigg, 2000), research needs to explore the interplay of emotional and neuropsychological characteristics on child functioning over time.

Few studies have examined the moderating effect of cognition on relations between negative emotionality and behavior in children at risk of ADHD, and none have examined the interaction in relation to adaptive functioning. Martel and Nigg (2006) found that the interaction between the temperament traits of negative emotionality and effortful control (an indicator of executive functioning) predicted ADHD symptom severity. In their sample of 6- to 9-year-olds, low negative emotionality was associated with higher symptom severity when coupled with low effortful control. These findings suggest that when negative affect was high, effortful control did not seem to alleviate symptom severity. In contrast, when negative emotionality was low, the effect of poor effortful control became apparent. Healey, Marks and Halperin (2011) also looked at the moderating effect of neuropsychological functioning on the relation between negative emotionality and ADHD symptom severity, but in a younger sample. Similar to Martel and Nigg (2006), Healey et al. (2011) found that among hyperactive/inattentive preschoolers, when negative emotionality was low, but not high, poorer neurocognitive performance was associated with greater ADHD symptom severity.

While understanding symptom severity is important, it is unknown whether these relations hold true in influencing child functioning. Recently, researchers have started the process of creating a standardized profile of the functioning of youngsters with ADHD using the World Health Organisation (WHO) International Classification of Functioning, Disability and

Health – Child and Youth version (ICF-CY) (de Schipper et al., 2015). This is based on a biopsychosocial model whereby a person's level of functioning is considered to the end result of a complex interaction of the respective health condition, personal and environmental factors. Experts from 11 different professions across 45 countries responded to a survey asking them to identify aspects of Body Functions (e.g., sleep; memory), Activities and Participation (e.g., school education; carrying out daily routine), Environmental Factors (e.g., immediate family), and Body Structures (e.g., brain; upper and lower extremities) affected by ADHD. Results showed that across these four broad domains, 83 different categories of impairment were identified by at least 5% of respondents. Experts also identified Personal and Environmental factors that may confer resilience or support for individuals with ADHD, such as their creativity and energy. Given the wide-ranging impairment related to ADHD in young people, global measures of functioning may be helpful in that they provide a snapshot at a point in time of overall severity of impairment, having taken into account a child's various strengths (Shaffer et al., 1983).

The need to study adaptive functioning on its own, outside of symptom severity, is important for other reasons. Although it is clear that wide ranging impairment is observed at the group level, at the individual level it is not universal. When community samples are used to classify a group as meeting symptom criteria for ADHD, only around a third of them are significantly impaired by their symptoms (Gathje, Lewandowski, & Gordon, 2008; Gordon et al., 2006; Healey, Miller, Castelli, Marks & Halperin, 2008). Similarly, Faraone and colleagues showed in their review of 50 epidemiological studies, that when symptoms *plus* impairment was used to make diagnoses rather than just symptoms alone, prevalence rates fell dramatically (Faraone, Sergeant, Gillberg, & Biederman, 2003). These studies suggest that symptoms and impairment are distinct constructs. Further evidence for the dissociation of symptoms and impairment can be seen from studies showing only moderate correlations between ADHD symptom severity and child functioning (Brammer & Lee, 2012; Gathje et al., 2008). Finally, it is also clear that across development, even if symptom severity decreases, functioning tends not to improve at the same rate, if at all (O'Connor, Garner, Peugh, Simon, & Epstein, 2015). This suggests that understanding predictors of adaptive functioning among children with elevated symptoms of inattention and/or hyperactivity/impulsivity is essential.

A key aim of the present study is to examine whether deficits in neuropsychological functioning, such as attentional control, inhibitory control, language and motor functioning, along with difficulties in regulating emotions increase the level of dysfunction experienced in children with symptoms of inattention and/or hyperactivity. Specifically, we hope to understand the interaction of reactive, "bottom-up" temperamental factors with the more trained and self-regulatory neuropsychological abilities on child global functioning. Given the wide-ranging impairment experienced by children with ADHD, and the dissociation between symptoms and impairment, better understanding of the predictors of children's adaptive functioning has important treatment implications. Using the same sample of preschoolers with elevated symptoms of ADHD as employed in Healey et al. (2011), this study examined the degree to which interactions between temperament and neuropsychological performance predict later child functioning.

Method

Participants

Three- and 4-year-old children with elevated levels of hyperactivity/impulsivity and/or inattention (H/I) were recruited into a longitudinal study through local preschools. Parents and teachers completed home and school versions of the Attention-Deficit/Hyperactivity Disorder Rating Scale, Fourth Edition (ADHD-RS-IV; DuPaul, Power, Anastopoulos, & Reid, 1998). To be included in the Hyperactive/Impulsive or Inattentive (H/I) group, children needed 6 or more symptoms rated as *Often* or *Very Often* on the Hyperactivity/Impulsivity and/or Inattention subscale(s) by either parent or teacher. Children who had fewer than 3 symptoms as rated by both parent and teacher were also recruited as TD but are not included in the present study, which focuses on children with elevated symptoms of inattention and hyperactivity. If the parent was fluent in English and the child was not on systemic medications, they were invited into the study. At the baseline (BL) assessment, the Wechsler Preschool and Primary Scale of Intelligence, 3rd Edition (WPPSI-III; Wechsler, 2002) was administered and children who had IQ below 80 or had a previous diagnosis of Pervasive developmental disorder, were excluded from the study.

Among those who were screened as either TD or H/I and did not enter the study, 87 did not meet criteria for either the H/I or TD group. An additional 29 refused participation; 12 aged-out of the study (were >5 years-old when we began bringing them in for assessment); 6 had parents who were not fluent in English; 3 were no longer in the school where they were recruited or had moved; 2 were taking medication; and 3 had IQ below 80 or had a previous diagnosis of pervasive developmental disorder. Further, after we reached the predetermined number of TD children (N=76) to be recruited into the study, children who were found to have <3 symptoms of inattention and hyperactivity after screening were not further pursued.

As part of the multi-year follow up study, BL and 1-year follow-up (F1) assessments were completed by 114 preschoolers [M (SD) age at BL= 4.36 (.48)]. The majority of the participants were boys [n (%) = 86 (75.4)], and the sample was ethnically and racially diverse: 47 (41.2%) identified as White, Not Hispanic; 25 (21.9%) identified as White, Hispanic; 14 (12.3%) identified as Black, Not Hispanic; 2 (1.8%) identified as Black, Hispanic; 4 (3.5%) identified as Asian, and 22 (19.3%) identified as 'other/mixed race and/or ethnicity.' Socioeconomic status was measured using the Nakao-Treas Socioeconomic Prestige Index (Nakao & Treas, 1994). The mean (SD) socioeconomic status (SES) of children's families at baseline was 60.81 (18.95), consistent with a moderate-level SES, although the sample included families from a wide range of socioeconomic backgrounds (range = 20 – 97).

Given the inclusion criteria, all children had clinically significant ADHD symptoms as rated by a parent [M (SD) total score = 28.14 (10.56)] and/or a teacher [M (SD) total score = 29.12 (13.20)]. Although children did not have to meet DSM-IV criteria for ADHD to be included in the study, 88 of the 114 preschoolers did, as determined by a parent interview using the K-SADS-PL (Kaufman et al., 1997): 40 (35.1%) Combined Type; 40 (35.1%) Predominantly Hyperactive/Impulsive subtype; 8 (7.0%) Predominantly Inattentive subtype. The Hyperactive group and Combined group were not significantly different from each other

or from Inattentive or No diagnosis group on IQ, age or gender (p for all $>.05$). Mean (SD) full-scale IQ for the sample, as measured by WPPSI-III (Wechsler, 2002), fell in the Average range [103.04 (13.25); range=80 to 138]. See Table 1 for a summary of the sample's descriptive statistics.

No differences in gender [$\chi^2(1) = .03, p = .55$], age [$F(1, 138) = .91, p = .34$], SES [$F(1, 138) = .01, p = .91$], ADHD severity [$F(1, 138) = 2.56, p = .11$], or ADHD diagnosis [$\chi^2(1) = 1.52, p = .36$] were observed between children who did ($N=114$), and did not return ($N=26$) for their F1 evaluation. Participants identifying as Asian were significantly less likely to return for the follow-up evaluation [$\chi^2(1) = 4.35, p = .04$]. At BL 8 participants identified as Asian, but only 4 of them returned for their F1 assessment. No other differences were observed as a function of race/ethnicity.

Measures

A Developmental Neuropsychological Assessment (NEPSY; Korkman, Kirk, & Kemp, 1998)—The NEPSY is a standardized neuropsychological test battery for children aged 3 to 12 years of age. The 3- and 4-year-olds in the present study were administered 11 subtests that yielded five domain scores: Attention/Executive Functioning (including the ability to plan, monitor performance, inhibit responses and manipulate information); Visuospatial Processing (including the ability to synthesize elements into a meaningful whole, represent objects mentally, discriminate between objects, judge orientation of lines and angles and understand relationship between objects in space); Sensorimotor Functions (e.g., motor coordination); Language (including phonological processing, comprehension, articulation); and Memory and Learning (including the ability to conceptualize, categorize, recall and make associations). In the normative sample, the test-retest reliability for the 5 domains ranged from .68 to .90 for the 3- to 4-year-old sample.

Research on the NEPSY has failed to validate the five-factor model proposed by the test developers (c.f. Mosconi, Nelson, & Hooper, 2008; Stinnett, Oehler-Stinnett, Fuqua & Palmer, 2002; Visu-Petra, Cheie, Benga, & Miclea, 2012). Visu-Petra and her colleagues (2012) and Stinnett and colleagues (2002) found evidence for a single factor model in preschool and school-aged children respectively. On the other hand, Mosconi and colleagues found that the number of factors extracted varied by age, though the five-factor model did not fit any age group. Further, the revised NEPSY-II recommends against using the 5 domain scores separately (Korkman, Kirk, & Kemp, 2007). Therefore, we conducted a factor analysis based on maximum likelihood estimation with oblique rotation to assess the relations among the five domains of neuropsychological performance. A two-factor solution emerged with Sensorimotor and Visuospatial Domains loading on one factor and Language and Memory Domains loading on the other. The Attention/Executive Domain split its variance, loading on both factors. The pattern matrix and factor matrix were very similar and the pattern matrix was interpreted. The first factor with loadings of Sensorimotor, Visuospatial, and Executive functioning was termed as the “Nonverbal Executive” factor and it explained 30.92% of the variance in neuropsychological performance. The second factor, which included loadings of Language, Memory, and Attention/Executive function, was termed as the “Verbal Executive” factor, and it explained 25.27% of the variance in

neuropsychological performance. These factor scores were saved as variables for use in subsequent analyses.

Children's Behaviour Questionnaire (CBQ; Rothbart, Ahadi, Hershey, & Fisher, 2001)—The CBQ is a caregiver-rated measure of children's temperament. The 94-item short-form was used when children were aged 3 to 4 years. Caregivers indicated on a 7-point Likert scale the extent to which each item reflected their child's behaviour (1 = 'extremely untrue'; 7 = 'extremely true'). Items fall across 15 scales, each representing a different aspect of temperament: Positive Anticipation; High Intensity Pleasure; Smiling/Laughter; Activity Level; Impulsivity; Shyness; Discomfort; Fear; Anger/Frustration; Sadness; Soothability; Inhibitory Control; Attentional Focusing; Low Intensity Pleasure; and Perceptual Sensitivity. In this age range, these scales load onto three factors representing broader dimensions of temperament: Negative Affectivity comprised of the sub-scales of discomfort, sadness, anger and soothability (reverse coded). Surgency/Extraversion reflects positive affectivity and approach and included the sub-scales of impulsivity, high intensity pleasure, activity, approach, smiling and shyness (reverse coded); and Effortful Control which reflects a child's capacity to self-regulate attention and inhibit a prepotent response included the sub-scales of low intensity pleasure, inhibitory control, perceptual sensitivity and attentional focusing (Rothbart et al., 2001).

The CBQ shows adequate reliability with coefficient α ranging from .64 to .92 ($M = .73$ across 15 scales) for 4- and 5-year-olds (Rothbart et al., 2001). In the present sample, the coefficient alphas for the Negative Affectivity, Surgency, and Effortful Control were .70, .70 and .62 respectively.

Temperament Assessment Battery for Children - Revised (TABC-R; Martin & Bridger, 1998)—The TABC-R, a teacher-rated measure of temperament normed for 3- to 7-year-old children, was completed at BL. The scale comprises 29 items that fall across four scales: Negative Emotionality (frustration tolerance); Inhibition (shyness in novel situations), Activity, and Lack of Task Persistence (effortful control). Behaviours reflected in the items are rated on a scale from 1 (Hardly Ever) to 7 (Almost Always). The TABC-R shows good internal consistency with coefficient α ranging from .86 to .95. In our sample, the coefficient alphas were: Negative Emotionality .89; Inhibition .81; Activity .80; and Lack of Task Persistence .88.

Children's Global Assessment Scale (CGAS; Schaffer et al., 1983)—The CGAS is a clinician-rated measure of the severity of children's disturbance, which served as the primary outcome variable at F1. Raters integrate their knowledge of the child's behavioural, emotional, and adaptive functioning and generate a single summary score from 1 to 100 that represents the child's lowest level of functioning over a specified time period. Lower CGAS scores reflect poorer overall functioning. Scores above 70 represent a child who is functioning within the normal range (Schaffer et al., 1983). For the present study, CGAS scores were generated by clinically-trained graduate students and doctoral-level psychologists who attended regular case-conferences. Following a presentation of the case, raters generated CGAS scores and the median value across raters was used in the analyses. The number of raters in the present sample ranged from 3 to 10 with most cases (91.2%)

being rated by 5 to 10 raters. Intra-class correlations (ICC) were excellent ranging from .95 to .99 when there were 5 to 10 raters. The ICC was .79 when there were 3 raters and .85 when there were 4 raters. The median for this sample ranged from 35 to 90, with a Mean (SD) of 52.32 ($SD = 12.12$). Within-subject standard deviations ranged from 0.58 to 12.33 with a mean of 4.12.

Procedure

Children who met inclusion criteria for the study, based on parent and teacher ADHD-RS-IV ratings, were invited to take part in the study. At BL, children and parents visited the laboratory on two occasions. Each session lasted approximately 3 hours, during which time children completed a battery of cognitive and neuropsychological tasks, including the WPPSI-III (Wechsler, 2002) and NEPSY (Korkman et al., 1998). Along with ADHD-RS-IV ratings, parents and teachers completed the CBQ short form (Rothbart et al., 2001) and TABC-R (Martin & Bridger, 1998), respectively, to provide measures of preschoolers' temperament.

One year later (F1), children and their parents returned to the laboratory for a single 3-hour session. Similar to their BL evaluation, children completed several tests of neuropsychological performance. Evaluators completed observations of the children's behaviour during the testing session, particularly noting their attentional capacity, activity and impulsivity levels, as well as their affect and sociability.

Child evaluators were blind to all parent and teacher ratings and interview data, including diagnoses and sub-types, when completing their behavioural observations following the child neuropsychological testing session.

At F1, information collected from parents' and teachers' rating scales, the K-SADS-PL interview completed with the children's parent, child evaluators' behavioural observations, and children's test performance was then presented to a group of trained evaluators. Evaluators were blind to BL temperament ratings and NEPSY scores. These evaluators integrated all information to rate the each child's level of functioning on the CGAS (Shaffer et al., 1983).

This study was approved by the university's Institutional Review Board (IRB). All parents signed IRB-approved informed consent forms.

Data Analysis

Pearson product moment correlations were used to examine the relations among each of the BL parent- and teacher-rated temperament domains, BL neuropsychological performance and child global functioning. Hierarchical Linear Regression analyses were then run to investigate whether baseline neuropsychological performance moderated the relation between child temperament at baseline and child global functioning one year later. In the first step we included each domain of child temperament. Scores were centered by subtracting the sample mean from an individual's score (Jaccard, Wan & Turrissi, 1990). This was followed by adding a neuropsychological performance factor in the second step. Finally, at step 3, we added an interaction term, which was a product of the centered baseline

temperament and neuropsychological performance variables. We plotted significant interactions to clearly understand the direction of relations and differences in the magnitude of the relations between child neuropsychological performance and subsequent child global functioning at different levels of each temperament trait (Aiken & West, 1991; Jose & Huntsinger, 2005).

Results

As depicted in Table 2, children's temperament and neuropsychological performance scores at ages 3 to 4 years were correlated with their global functioning one-year later. In particular, higher parent ratings of Negative Affect and Surgency, and teacher ratings of Negative Emotionality, Activity, and Lack of Task Persistence were all significantly associated with lower global functioning; while higher parent ratings of Effortful Control were associated with higher global functioning. Teacher-reported Inhibition at baseline was not significantly associated with child global functioning and was therefore dropped from subsequent analyses. Lower Verbal and Nonverbal Executive scores were associated with poorer child global functioning one year later. Teacher ratings of Activity were negatively correlated with both Verbal and Nonverbal Executive skills, and teacher ratings of Inhibition were negatively correlated with Verbal Executive Skills.

Hierarchical linear regression analyses examined the effect of child temperament on later global functioning as moderated by Verbal Executive and Nonverbal Executive functioning. Child temperament was assessed using parent or teacher reports while global functioning was assessed by clinician ratings. Total sample sizes in these analyses varied from 106 to 114. All variables were normally distributed as defined by skewness (SE) between $-.76$ (.24) and 1.03 (.23) and kurtosis (SE) between $-.97$ (.47) and 56 (.44). Table 3 depicts the results for analyses examining the moderating effects of Verbal Executive functions. All of the temperament variables accounted for variance in global functioning, with Verbal Executive functioning accounting for additional unique variance in global functioning for all but one temperament variable (i.e., teacher-rated Lack of Task Persistence). There was only one significant interaction effect; that for parent-rated Effortful Control and Verbal Executive functioning. The plotted moderation effects revealed that higher Verbal Executive abilities were associated with better child functioning when Effortful Control was high but not when Effortful Control was low (see Figure 1). Simple slopes analyses indicated that the relation between Effortful Control and child functioning was significantly different from zero for high ($t = 4.68, p < .001$) but not for low ($t = -.10, p = .92$) Verbal Executive abilities.

Table 4 depicts the results for analyses examining the moderating effects of Nonverbal Executive functions. All of the temperament variables accounted for significant variance in child global functioning one year later. In the case of parent ratings of Negative Affect, and teacher ratings of Negative Emotionality and Activity level, Nonverbal Executive skills at baseline accounted for additional unique variance in child global functioning one year later, above and beyond the effects of temperament. However, it was only for ratings relating to negative affect/emotionality, by both parent and teacher, that significant interaction effects were found for temperament and Nonverbal Executive functioning. The plotted moderation effects revealed that high levels of Nonverbal Executive skills were associated with higher

child global functioning when negative affect (as per both parent and teacher reports) was low but not when negative affect was high (see Figures 2 & 3). Furthermore, high Nonverbal Executive skills did not lead to significantly higher functioning when negative affect was also high. Simple slope analyses indicated that the relation between parent reported Negative Affect and child global functioning was significantly different from zero for high ($t = -3.67$, $p < .001$) but not for low ($t = -.78$, $p = .44$) Nonverbal Executive functioning. Similarly, the relation between teacher reported Negative Emotionality and child functioning was significantly different from zero for high ($t = -3.15$, $p = .002$), but not for low ($t = -.13$, $p = .90$) Nonverbal Executive skills.

Discussion

The aim of this study was to prospectively examine both the unique and combined roles that temperament and neuropsychological abilities play in the global functioning of H/I preschoolers. In particular, we examined the relations between temperament and neurocognitive functioning at age 3 to 4 years, and child global functioning one year later. We began by examining the correlations among temperament, neuropsychological functioning, and global functioning and found, not surprisingly, that the three constructs were significantly related to one another. These results extend past research indicating that temperament and neuropsychological functioning are associated with ADHD symptom severity (Healey, Halperin & Marks, 2011; Martel & Nigg, 2006) by showing similar interactions affect children's global functioning.

The second set of analyses examined the additive and moderating effects of neuropsychological functioning on the relations between temperament and global functioning. Two sets of analyses examined Verbal and Nonverbal Executive skills, respectively. Verbal Executive Skills accounted for additional unique variance in global functioning, above and beyond temperament for all but one temperament measure, teacher-rated Lack of Task Persistence. This supported the notion that temperament and cognition are at least partially independent predictors of child functioning. The moderation analyses revealed a significant interaction between parent-rated Effortful Control and Verbal Executive abilities in predicting global functioning one year later. When high Effortful Control was coupled with high Verbal Executive abilities, global functioning was highest; however, when high Effortful Control was coupled with low Verbal Executive Skills, global functioning was significantly lower. Further, when Effortful Control was low, Verbal Executive skills had no significant effect on global functioning.

Nonverbal Executive skills, accounted for additional unique variance in global functioning, above and beyond temperament, for three of the six temperament measures assessed; namely, parent-rated Negative Affect and teacher-rated Negative Emotionality and Activity Level. The moderation analyses indicated two significant interactions, both relating to emotion regulation (i.e., parent-rated Negative Affect and teacher-rated Negative Emotionality) and Nonverbal Executive skills predicting global functioning. When Negative Affect/Emotionality was low, poor Nonverbal Executive skills were associated with lower global functioning; however, when Negative Affect/Emotionality was high, global functioning was low and Nonverbal Executive Skills did not significantly influence

functioning. These findings are in line with those of both Healey et al. (2011) and Martel and Nigg (2006) who found that in the context of severe negative emotionality, cognitive functioning/effortful control abilities do not seem to alter the relation between negative emotionality and ADHD symptom severity. Rather, it is only when negative affect scores are low that cognitive abilities appear to play a role in functioning.

The results of this study also have important theoretical implications. An extensive body of literature has shown that children with ADHD experience deficits across a wide array of cognitive functions including working memory (Martinussen & Tannock, 2006), inhibitory control (Nigg, 2001), language, and sensorimotor skills (Frazier, Demaree & Youngstrom, 2004). Additionally Barkley (2006) has stressed the important role of emotional impulsiveness and emotional control in ADHD. One might expect, as is the case in TD children, that strong neuropsychological performance would play a protective role in children with poor emotional control, given that executive functions are related to self-control (McClelland & Cameron, 2011). However, both Healey et al. (2011) and Martel and Nigg (2006) found that higher cognitive control, as assessed in very different ways, did not have a protective effect (i.e., was not linked to lower symptom severity) in those with high negative emotionality; such an effect was evident only in those where negative emotionality scores were low. These findings suggest that among some children with high levels of ADHD symptoms (perhaps those with comorbid ODD), strong bottom-up/emotional impulses may be driving the maladaptive behaviour patterns. Further, top-down control mechanisms, even when relatively well developed during the early years, cannot adequately compensate for these bottom-up influences. However, among preschoolers with ADHD symptoms who do not display high negative emotionality, the development of top-down cognitive control mechanisms can be protective. In other words, strong cognitive performance appears to be protective in those with low negative emotionality, but it cannot override the impact of high negative emotionality. Consideration should therefore be given to using negative emotionality as a subtyping factor within the ADHD population as it may be reflective of distinct neural underpinnings (i.e., frontostriatal versus more limbic involvement).

The findings also add to a small body of literature investigating impairment associated with ADHD. Better understanding of predictors of functional impairment are critical given that improvement in functioning does not necessarily follow a reduction in symptoms (O'Connor et al, 2015). Furthermore, impairment in functioning may last through early development. Lee, Lahey, Owens and Hinshaw (2007) followed a group of 4–6 year olds with ADHD over 7–8 years and found that at follow up years 7 and 8, only 17.7% of probands compared with 71.4% of controls were well-adjusted across three of five domains (Externalizing, Internalizing, Social Skills, Peers, and Academic) at both time points. Better understanding of predictors of functional impairment will help to inform treatment for youngsters with ADHD.

In light of this study's findings, more targeted treatment interventions seem warranted. Research has suggested that emotional regulation during cognitive tasks may improve task performance (Keith & Frese, 2005). There is emerging evidence that interventions that promote mindful attention while improving emotional regulation and reducing negative

emotionality might be helpful to address both cognitive and emotional difficulties among adults (Chambers, Lo & Allen, 2008; Teper & Inzlicht, 2013). Feasibility studies also suggest that mindfulness is palatable to children (Burke, 2010), and may be helpful in reducing symptom severity in children with ADHD (van der Oord, Bogels, & Peijnenburg, 2012). Mindfulness may be a promising intervention for preschoolers too. Within the public school setting, 4-year-olds randomly assigned to a mindfulness-based “Kindness Curriculum” showed greater gains in teacher-rated social competence and higher grades for socio-emotional development compared to those in the control group (Flook, Goldberg, Pinger, & Davidson, 2015). Further, larger effect sizes for change in delay to gratification and cognitive switching were seen for preschoolers who completed the Kindness Curriculum than those in the control group (Flook et al., 2015). Further work now needs to be completed in very young children at risk for ADHD.

This study is not without limitations. The present study includes a preschool sample exhibiting elevated symptoms of ADHD affecting generalisation to the population. The coefficient alpha for effortful control (.62) was not high, suggesting that the components of effortful control for preschoolers in our sample may show moderate internal consistency. A possible reason for lower reliability may be the restricted range of scores given that we are studying children with high levels of hyperactivity/inattention. Further, we assessed temperament using parent and teacher reports rather than laboratory assessments which may have been less influenced by rater effects. However, the economy of parent ratings, their ease of administration, and their validity make parent reports a viable measure of child temperament (Rothbart, Chew & Gartstein, 2001).

A strength of this study is that all three constructs were assessed independently. Although the correlations between parent and teacher report of temperament were low, similar to other studies of children with ADHD (cf. Antrop, Roeyers, Oosterlaan, & Van Oost, 2002), the associations between children’s temperament and emotional control were consistent across parent and teacher reports. Additionally, neuropsychological performance was assessed using a standardized test battery, and global functioning was assessed using the median rating given by a group of trained clinicians following a comprehensive case presentation.

Conclusions

Overall the results of this study highlight the important interactive effects of cognition and emotion on the course of impairment in H/I preschoolers. A growing number of researchers have been examining the effects of cognitive training programs in children with ADHD, and results to date have been promising (e.g., Halperin et al., 2013; Healey & Halperin, 2015; Klingberg et al., 2005; Shalev et al., 2007; Tamm, Nakonezny, & Hughes, 2014). Our findings on the interplay between cognition and emotion in predicting both symptom severity and functioning would suggest the need to assess children’s emotional control. Randomised controlled trials of interventions that provide not only cognitive training but also emotional control, especially for children with high negative emotionality, may help test the clinical value of our findings.

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Figure 1.
Moderating effect of higher verbal-executive abilities on the relation between parent ratings of effortful control and child global functioning.

Figure 2.
Moderating effect of higher nonverbal & executive abilities on the relation between teacher report of negative emotionality and child global functioning.

Figure 3.
Moderating effect of higher nonverbal & executive abilities on the relation between parent ratings of negative affect and child global functioning.

Table 1

Descriptive Statistics of Continuous Variables for H/I Preschoolers

Variable	Mean (S.D.)	Range
Age BL (years)	4.36 (.48)	3.05–5.00
Family SES BL	60.81 (18.95)	20.00–97.00
FSIQ BL	103.04 (13.25)	80.00–138.00
Parent ADHD-RS-IV Total Score BL	28.14 (10.56)	0.00–48.00
Teacher ADHD-RS-IV Total Score BL	29.12 (13.20)	0.00–54.00
Extraversion/Surgency (P) BL	29.48 (3.86)	16.22–36.52
Effortful Control (P) BL	18.72 (2.58)	11.71–25.17
Negative Affectivity (P) BL	18.61 (3.85)	11.07–27.50
Inhibition (T) BL	27.97 (8.24)	15.00–49.00
Negative Emotionality (T) BL	31.98 (12.51)	8.00–56.00
Activity (T) BL	20.16 (5.84)	5.00–28.00
Lack of Task Persistence (T) BL	38.11 (11.36)	8.00–56.00
Global Functioning F1	52.32 (12.12)	35.00–90.00

(P) = Parent ratings; (T) = Teacher ratings

Table 2

Correlations among study variables

	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Child Global Functioning FI	.23*	.20*	-.27**	.31**	-.24**	-.16	-.23**	-.25*	-.31**
2. Nonverbal Executive factor BL	--	.33***	-.15	.14	.11	-.11	-.05	-.24**	-.36***
3. Verbal Executive factor BL		--	.08	.12	.04	-.27**	-.11	-.26**	-.37***
4. Surgency BL (P)			--	-.15	.12	-.10	.24**	.25**	.22*
5. Effortful control BL (P)				--	-.32***	-.05	-.04	-.12	-.16
6. Negative Affect BL (P)					--	.12	.04	-.17	-.10
7. Inhibition BL (T)						--	.29**	.06	.31**
8. Negative Emotionality BL (T)							--	.36***	.32***
9. Activity BL (T)								--	.75***
10. Lack of persistence BL (T)									--

Note: Higher scores on Child Global Functioning scale indicate higher functioning.

* $p < .05$;** $p < .01$;*** $p < .001$

(P) = Parent ratings; (T) = Teacher ratings

Table 3

Hierarchical Regressions testing Verbal Executive abilities (BL) as a moderator of the relationship between Child Temperament (BL) and Global functioning (FI)

Variable	B	SE	Beta	T	Adjusted R ²	R ²	F	p
<i>Parent Ratings of Temperament</i>								
Surgency	-.85	.29	-.27	-2.97	.06	.05	7.76	.004
Verbal Executive	2.97	1.22	.22	2.44	.10	.05	5.80	.02
Interaction	-.30	.36	-.08	-0.85	.09	.01	0.72	.37
Negative affect	-0.72	.29	-.23	-2.42	.05	.06	7.26	.02
Verbal Executive	2.87	1.21	.21	2.36	.09	.05	5.70	.02
Interaction	-.41	.27	-.14	-1.50	.10	.02	2.24	.14
Effortful Control	1.13	.42	.24	2.71	.10	.11	12.90	.008
Verbal Executive	2.74	1.18	.20	2.33	.11	.02	3.08	.02
Interaction	1.32	.42	.28	3.12	.18	.07	9.74	.002
<i>Teacher Ratings of Temperament</i>								
Negative emotionality	-.19	.09	-.20	-2.15	.04	.05	5.36	.03
Verbal Executive	3.47	1.23	.26	2.80	.10	.07	7.85	.006
Interaction	-.06	.10	-.05	-.58	.09	.00	.34	.56
Activity level	-.42	.21	-.21	-1.97	.05	.06	6.98	.01
Verbal Executive	3.01	1.29	.23	2.33	.09	.05	5.48	.02
Interaction	.03	.23	.02	0.15	.08	.00	0.02	.88
Lack of persistence	-.27	.11	-.26	-2.44	.10	.10	12.02	.02
Verbal Executive	2.40	1.32	.18	1.81	.12	.03	3.37	.07
Interaction	.00	.11	.00	.04	.11	.00	0.00	.97

Table 4

Hierarchical Regressions testing Nonverbal Executive abilities (BL) as a moderator of the relationship between Child Temperament (BL) and Global functioning (FI).

Variable	B	SE	Beta	T	Adjusted R ²	R ²	F	p
<i>Parent Ratings of Temperament</i>								
Surgency	-.73	.29	-.23	-2.47	.06	.07	7.76	.01
Nonverbal Executive	1.95	1.14	.16	0.16	.07	.03	3.06	.09
Interaction	-.08	.27	.03	-.03	.07	.00	0.08	.77
Negative affect	-.77	.29	-.24	-2.67	.05	.06	7.26	.008
Nonverbal Executive	2.81	1.09	.23	2.57	.10	.05	6.68	.01
Interaction	-.47	.24	-.18	-1.98	.03	.04	3.90	.04
Effortful Control	1.34	.43	.29	3.13	.10	.11	12.90	.002
Nonverbal Executive	1.90	1.10	.16	1.73	.11	.02	2.85	.09
Interaction	0.47	.38	.11	1.21	.12	.01	1.47	.23
<i>Teacher Ratings of Temperament</i>								
Negative emotionality	-.21	.09	-.22	-2.43	.04	.05	5.37	.02
Nonverbal Executive	3.03	1.05	.26	2.88	.11	.07	8.61	.005
Interaction	-.20	.09	-.21	-2.28	.14	.04	5.20	.02
Activity level	-.45	.20	.22	-2.23	.05	.06	6.98	.01
Nonverbal Executive	2.75	1.12	.24	2.46	.09	.05	5.66	.02
Interaction	.17	.19	.09	.90	.09	.01	.80	.37
Lack of Persistence	-.26	.11	-.25	-2.41	.10	.10	12.02	.001
Nonverbal Executive	2.06	1.16	.18	1.78	.11	.03	3.28	.07
Interaction	-.02	.10	-.02	-.18	.11	.00	.03	.86