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Attention network functioning in children with anxiety disorders, attention-deficit/hyperactivity disorder and non-clinical anxiety

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Abstract

Background.—Research with adults suggests that anxiety is associated with poor control of executive attention. However, in children, it is unclear (*a*) whether anxiety disorders and non-clinical anxiety are associated with deficits in executive attention, (*b*) whether such deficits are specific to anxiety *versus* other psychiatric disorders, and (*c*) whether there is heterogeneity among anxiety disorders (in particular, specific phobia *versus* other anxiety disorders).

Method.—We examined executive attention in 860 children classified into three groups: anxiety disorders ($n = 67$), attention-deficit/hyperactivity disorder (ADHD; $n = 67$) and no psychiatric disorder ($n = 726$). Anxiety disorders were subdivided into: anxiety disorders excluding specific phobia ($n = 43$) and specific phobia ($n = 21$). The Attention Network Task was used to assess executive attention, alerting and orienting.

Results.—Findings indicated heterogeneity among anxiety disorders, as children with anxiety disorders (excluding specific phobia) showed impaired executive attention, compared with disorder-free children, whereas children with specific phobia showed no executive attention deficit. Among disorder-free children, executive attention was less efficient in those with high,

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Declaration of Interest

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relative to low, levels of anxiety. There were no anxiety-related deficits in orienting or alerting. Children with ADHD not only had poorer executive attention than disorder-free children, but also higher orienting scores, less accurate responses and more variable response times.

Conclusions.—Impaired executive attention in children (reflected by difficulty inhibiting processing of task-irrelevant information) was not fully explained by general psychopathology, but instead showed specific associations with anxiety disorders (other than specific phobia) and ADHD, as well as with high levels of anxiety symptoms in disorder-free children.

Keywords

Anxiety; attention-deficit/hyperactivity disorder; Attention Network Task; Children; executive attention

Introduction

Theories based on cognitive and neuroscience research in adults relate deficient attention control to anxiety (Eysenck *et al.* 2007; Bishop, 2008). According to attention control theory (Eysenck *et al.* 2007), high anxiety impairs one's ability to inhibit processing of task-irrelevant information and switch attention between different tasks. Moreover, poor attention control may contribute to anxiety through difficulty inhibiting processing of task-irrelevant information impairing cognitive and emotional responses to stress (Rueda *et al.* 2005; Posner & Rothbart, 2007).

Studies in adults using objective measures of attention control (e.g. effect of distracting stimuli on primary task performance) relate high non-clinical anxiety to reduced efficiency of executive attention (Eysenck *et al.* 2007; Eysenck & Derakshan, 2011). However, evidence of executive attention deficits in adults with anxiety disorders is mixed (Airaksinen *et al.* 2005; Castaneda *et al.* 2008), with some studies failing to find anxiety-related deficits (Castaneda *et al.* 2011). Inconclusive findings may be partly explained by confounding effects of medication use and type of anxiety disorder included in the studies (Castaneda *et al.* 2008). In one investigation, adults with mixed anxiety disorders showed impaired visual attention and task switching, whereas those with 'pure' specific phobia showed no deficits (Airaksinen *et al.* 2005). Specific phobia is commonly regarded as distinct from other anxiety disorders, since it is more circumscribed, less persistent across childhood, and less likely to be characterized by general anxiousness (Pine *et al.* 1998; Costello *et al.* 2003; Craske & Waters, 2005). Consequently, it did not seem surprising that adults with specific phobias have similar executive functioning to healthy controls (Airaksinen *et al.* 2005).

Few studies extend this research to children. In a non-clinical sample of 8- to 12-year-old children, high anxiety was negatively associated with self-reported attention control, but not with a behavioral performance-based measure of attention control, after accounting for age and gender (Muris *et al.* 2008). A clinical study using neuropsychological tests found no attention deficits in youths with anxiety disorders compared with healthy controls (Günther *et al.* 2004). Another investigation found that youths with anxiety disorders had better sustained attention and attention shifting than those with attention-deficit/hyperactivity disorder (ADHD) (Weissman *et al.* 2012), but this study did not include a disorder-free

comparison group. Comparison of results across studies is further complicated by heterogeneity in measures of attention. Posner parses attention into three dissociable networks: 'executive attention', which monitors and resolves conflict in processing competing stimuli and responses; 'alerting', which controls readiness to respond to incoming stimuli; and 'orienting', which prioritizes the source of sensory information (Posner & Rothbart, 2007; Petersen & Posner, 2012).

The Attention Network Task (ANT) has been widely used to assess these networks in adults and children (Fan *et al.* 2002; Posner & Rothbart, 2007), although few studies have examined relationships with anxiety. In a non-clinical study, adults with high trait anxiety showed greater ANT conflict scores (poorer executive attention) than those with low trait anxiety (Pacheco-Unguetti *et al.* 2010). Two other studies failed to replicate this finding, possibly due to differences in sampling (Moriya & Tanno, 2009; Reinholdt-Dunne *et al.* 2013). A clinical study suggested that executive attention is impaired in adults with mixed anxiety disorders (Pacheco-Unguetti *et al.* 2011). The main aim of the present study was to extend such research to children with anxiety disorders and high levels of non-clinical anxiety.

Research in developmental psychopathology often finds non-specific associations between information-processing deficits and a range of disorders. Therefore another aim of the study was to examine the specificity of the putative executive attention deficit to anxiety disorders, relative to ADHD, in which impaired executive attention has been implicated (Sergeant *et al.* 2002; Millan *et al.* 2012). Some studies using the ANT reported higher conflict scores (i.e. impaired executive attention) in ADHD children relative to controls (Konrad *et al.* 2006; Johnson *et al.* 2008), although this is not always found (Booth *et al.* 2007; Adólfssdóttir *et al.* 2008; Kratz *et al.* 2011).

The current study tested four hypotheses: in comparison with disorder-free children, executive attention is impaired in children with anxiety disorders (hypothesis 1) and children with ADHD (hypothesis 2). We also examined whether there is heterogeneity among anxiety disorders (Airaksinen *et al.* 2005); specifically, whether impaired executive attention is limited to anxiety disorders other than specific phobias (hypothesis 3). Regarding children without psychiatric disorders, we predicted that executive attention is less efficient in those with high, relative to low, levels of anxiety symptoms (hypothesis 4). Supplementary analyses explored whether anxiety and ADHD were associated with deficits in the two other attention networks: alerting and orienting.

Method

Participants

Participants were drawn from a community sample of 9937 Brazilian children, aged 6–12 years at screening. From these 9937 children, a subset of 2512 was selected for further evaluation (38% randomly selected; 62% selected as high risk according to screening child and family psychiatric symptoms; for details of recruitment and selection, see Salum *et al.* 2015). From these 2512 children, 1015 completed the ANT^{†1} (37% randomly selected; 63% high risk). To address the hypotheses, participants were eligible for inclusion for this study if

they had ANT data and one of the following: diagnosis of anxiety disorder, ADHD or no disorder. Of those eligible ($n = 937$), participants were excluded if they were currently using medication ($n = 20$); did not have complete ANT scores due to excessive errors ($n = 19$) or extreme outliers ($n = 5$) described later; or had a co-morbid diagnosis of pervasive developmental disorders, tics, eating disorders, psychosis or attachment disorder ($n = 8$). There were no cases of manic episodes, stereotypies or selective mutism. To select diagnostically homogeneous groups, children with anxiety or ADHD who had co-morbid depressive disorders ($n = 8$) or co-morbid post-traumatic stress disorder ($n = 3$) were excluded (there were too few cases to examine effects of these co-morbidities). Children with co-morbid ADHD and disruptive behavioral disorders (oppositional defiant disorder and conduct disorder; ODD/CD) were not excluded from the ADHD group given high co-morbidity between these behavioral disorders. To prevent overlap in diagnoses between the two main diagnostic groups, children were excluded if they had co-morbid anxiety and ADHD ($n = 12$) or co-morbid anxiety and ODD/CD ($n = 2$). There were no cases of panic disorder or obsessive-compulsive disorder after these exclusions.

Thus, the final sample comprised 860 children in three main diagnostic groups used to test hypotheses 1 and 2: (1) anxiety disorders, including social phobia, agoraphobia, separation anxiety, generalized anxiety disorder (GAD), specific phobia and other anxiety disorder ($n = 67$); (2) ADHD with or without co-morbid ODD/CD ($n = 67$); and (3) no psychiatric disorder ($n = 726$). Differences among diagnostic subgroups were examined in secondary analyses, in which anxiety disorders were divided into two groups to test hypothesis 3: (i) anxiety disorders other than specific phobia ($n = 43$); and (ii) specific phobia ($n = 21$), in the absence of another anxiety disorder; three children were excluded from these groups due to co-morbidity between specific phobias and other anxiety disorders. Additionally, ADHD was divided into two diagnostic subgroups to evaluate potential effects of co-morbidity with ODD/CD: (i) non-co-morbid ADHD ($n = 45$); and (ii) co-morbid ADHD + ODD/CD ($n = 22$).

To test hypothesis 4 and allow comparison with results from high-*versus* low-anxious adults (Pacheco-Unguetti *et al.* 2010), the disorder-free sample was stratified according to Child Behavior Checklist (CBCL) anxiety tertile scores into high-anxiety (score > 5 , $n = 223$) and low-anxiety (score < 2 , $n = 207$) groups (75th, 67th, 50th, 33rd, 25th percentiles were 6, 5, 3, 2 and 1, respectively).

The ethics committee of the University of São Paulo approved the study. Written consent was obtained from parents, and verbal assent from children (with additional written consent where appropriate). Assessments were home-based for parents, and school-based for children.

[†]The notes appear after the main text.

¹ANT data were not obtained for over half the sample largely due to technical problems in task administration. Participants with ANT scores did not significantly differ from those who also met diagnostic selection criteria but lacked ANT scores on measures of psychopathology (proportions in diagnostic categories; CBCL anxiety or ADHD symptom scores) or demographic variables, except age as those with ANT scores were on average 3 months older (mean difference = 0.26 years, S.E. difference = 0.08, $p < 0.05$).

Measures

Diagnoses—The Development and Well-Being Assessment (DAWBA) was used to assess psychiatric diagnoses (Goodman *et al.* 2000). The DAWBA is widely used, reliable and well suited to epidemiological research (e.g. Ford *et al.* 2003; Fleitlich-Bilyk & Goodman, 2004; Heiervang *et al.* 2007; Aebi *et al.* 2012; see also <http://www.dawba.info>). This structured interview using Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV) criteria was administered to biological parents (95% mothers) by trained lay interviewers and rated by nine psychiatrists, who were trained and supervised by a senior child psychiatrist. To assess reliability, another child psychiatrist rated 200 interviews and κ was 0.70 for anxiety disorders (agreement 93.7%; expected agreement 78.4%; $p < 0.001$) and 0.72 for ADHD (agreement 92.4%; expected agreement 72.6%; $p < 0.001$). For details of training and administration, see Salum *et al.* (in press).

Psychopathology symptoms—These were assessed using the 120-item parent-report CBCL (Achenbach *et al.* 2003), which was completed by the biological mother for 95% of children. Anxiety scores were obtained from the 16-item anxiety scale, which has better psychometric properties than the six-item DSM-oriented anxiety scale (Kendall *et al.* 2007), and ADHD scores from the 13-item DSM-oriented ADHD scale (Achenbach *et al.* 2003). General psychopathology was indexed by total scores. Cronbach's α was 0.80, 0.83 and 0.95 for anxiety, ADHD and total scores, respectively ($n = 860$).

Intelligence quotient (IQ)—IQ was estimated using vocabulary and block-design subtests of the Wechsler Intelligence Scale for Children, 3rd edition (Wechsler, 2002) using Tellegen & Briggs' (1967) method and Brazilian norms (Figueiredo, 2001). It was obtained for 93% of the sample.

Attention Network Task (ANT)—The version used here was designed to assess executive attention, alerting and orienting in children (for task details, see Rueda *et al.* 2004) (https://www.sacklerinstitute.org/cornell/assays_and_tools/). Participants indicate whether a central target (drawing of a fish) points right or left; and the target appears under differing warning cue and flanker conditions (Fig. 1). Each trial starts with a central fixation cross (randomly varying 400–1600 ms). Next, one of four types of warning cue appears (150 ms): (i) 'no-cue': only the fixation-cross appears; (ii) 'central-cue': an asterisk replaces the central fixation cross; (iii) 'double-cue': two asterisks appear, one above and one below the fixation cross; (iv) 'spatial-cue': one asterisk appears, either above or below the fixation cross, indicating where the target will appear. Next, the central fixation cross appears alone again (450 ms).

The target array then appears above or below the central fixation cross (1700 ms) and is either a row of five fish (two flanker fish each side of the central target fish) or the central fish alone. On 'congruent' trials, the flanker and central fish point in the same direction; on 'incongruent' trials, the flanker fish point in the opposite direction to the central fish; and on 'no-flanker' trials the central fish appears alone. Participants are instructed to press one of two keys to indicate as quickly and accurately as possible the direction of the central fish. Feedback is given on each trial: a 'whoohoo' sound on correct trials, and a single tone on

incorrect trials. There were 24 practice and 96 experimental trials (Rueda *et al.* 2004, experiment 2), with an equal number of trials per condition, appearing in a fully random order.

Preparation of ANT data—Three attention network scores are indexed by differences in median correct reaction times (RTs) between the following trial types: conflict = RT incongruent – RT congruent flankers; alerting = RT no cue – RT double cue; orienting = RT central cue – RT spatial cue. Higher conflict scores reflect poorer distracter inhibition (poorer executive attention). The alerting score reflects a beneficial effect on RT of the cue indicating temporal imminence of the target; and orienting indicates a benefit of the cue indicating target location. ANT scores were not calculated if RTs were missing from >40% of trials ($n = 19$, 2% of sample), as in Rueda *et al.* (2004). Five children (0.2% of sample) were excluded due to extreme outlying ANT scores shown on box-and-whisker plots. The error rate was log-transformed before analyses to reduce skewness. RT variability was indexed by the S.D. of correct RTs.

Statistical analysis—Hypotheses were tested using analyses of variance (ANOVAs) of ANT conflict scores with custom hypothesis tests in general linear model procedures. Effect sizes relating to hypotheses were indexed by Cohen's d (standardized difference between group means in S.D. units, with 0.2, 0.5 and 0.8 reflecting small, medium and large effects, respectively; Cohen, 1988). Analysis of covariance (ANCOVA) examined (i) whether similar results were obtained when controlling potential confounds (i.e. age, gender, IQ, overall error rate, overall mean correct RT, and RT variability), and (ii) whether executive attention deficits in specific disorder groups were independent of other symptoms of psychopathology. Planned analyses of diagnostic subgroups compared the two anxiety subgroups (specific phobia *versus* other anxiety disorders), and two ADHD subgroups (ADHD *versus* ADHD + ODD/CD), and significant differences were followed by comparisons with other groups. To compare groups on other variables, χ^2 and ANOVA were used. The level of α was 0.05, two-tailed, throughout.

Results

Anxiety, ADHD and no-disorder groups

Demographic and symptom measures—For means and ANOVA results, see Table 1. The three groups did not differ significantly in age, gender [$\chi^2 = 3.44$, degrees of freedom (df) = 2, $p = 0.18$], socio-economic status score or IQ. Groups differed significantly as expected in CBCL anxiety (anxiety disorders > ADHD > no disorder) and ADHD scores (ADHD > anxiety disorders > no disorder). The anxiety and ADHD groups had similar CBCL total scores ($p > 0.2$), which were significantly higher than those of disorder-free children (p 's < 0.01).

Overall errors and RTs—The ADHD group had significantly more variable RTs and more errors than the no-disorder and anxiety disorders groups; and slower RTs than the no-disorder group (all p 's < 0.05) (see Table 1). Anxiety and no-disorder groups did not significantly differ in errors, overall RT or RT variability (p 's > 0.2).

Executive attention—Hypothesis-driven tests showed that the anxiety disorder group as a whole did not differ significantly from the no-disorder group in conflict scores ($F_{1,857} = 2.38$, $p = 0.123$, $\eta_p^2 = 0.003$, $d = 0.20$) (hypothesis 1 was not confirmed). However, conflict scores were significantly higher in the ADHD than no-disorder group ($F_{1,857} = 7.15$, $p = 0.008$, $\eta_p^2 = 0.008$, $d = 0.35$), which supports hypothesis 2 (see Table 1 for means). The latter result remained significant when potential confounds were controlled (age, gender, IQ, overall errors, mean RT, RT variability) ($F_{1,790} = 4.21$, $p = 0.041$, $\eta_p^2 = 0.005$).

Alerting and orienting—The groups did not differ significantly in alerting (Table 1), but differed in orienting scores ($F_{2,857} = 3.43$, $p = 0.033$, $\eta_p^2 = 0.008$). Children with ADHD had higher orienting scores than the anxiety and no-disorder groups (p 's < 0.05), with no significant difference between the anxiety and no-disorder groups ($p > 0.3$). The difference in orienting scores between the ADHD and other groups remained significant after controlling potential confounds (as above) ($F_{2,790} = 3.26$, $p = 0.039$, $\eta_p^2 = 0.008$).

Diagnostic subgroups

Demographic and symptom measures—For means and ANOVA results, see Table 2. Comparison of the four diagnostic subgroups (anxiety disorders excluding specific phobia; specific phobia; non-co-morbid ADHD; ADHD + ODD/CD) and the no-disorder group showed no significant difference in gender ratio ($\chi^2 = 5.75$, $df = 4$, $p = 0.22$), age, socio-economic status or IQ. Children with anxiety disorders (excluding specific phobia) had significantly higher CBCL anxiety, ADHD and total scores than those with specific phobia (p 's < 0.05). The ADHD subgroups did not differ significantly from each other in anxiety or ADHD scores (p 's > 0.4), although total scores were higher in ADHD + ODD/CD than ADHD alone ($p < 0.05$). Disorder-free children had significantly lower symptom scores than each disorder subgroup (p 's < 0.05), except for similar ADHD scores to specific phobics ($p > 0.6$).

Overall errors and RTs—These did not significantly differ across the five groups, which may reflect reduced sensitivity of analyses using a larger number of smaller groups (Table 2).

Executive attention—Custom hypothesis tests (addressing hypothesis 3) showed that after excluding specific phobia, children with anxiety disorders did have significantly higher conflict scores compared with no-disorder ($F_{1,852} = 7.41$, $p = 0.007$, $\eta_p^2 = 0.009$, $d = 0.43$) and specific phobia ($F_{1,852} = 6.35$, $p = 0.012$, $\eta_p^2 = 0.007$, $d = 0.68$) groups (Fig. 2A, left). These group differences remained significant when potential confounds (age, gender, IQ, overall errors, mean RT, RT variability) were controlled ($F_{1,785} = 6.49$, $p = 0.011$, $\eta_p^2 = 0.008$; $F = 4.62$, $p = 0.032$, $\eta_p^2 = 0.006$, respectively). There were no significant group differences in conflict scores between specific phobia *versus* no disorder; non-co-morbid ADHD *versus*

ADHD + ODD/CD; or anxiety disorders (excluding specific phobia) *versus* ADHD (all p 's > 0.2).

Alerting and orienting—The five groups did not differ significantly in alerting or orienting (Table 2).

Disorder-free children: high versus low anxiety

Demographic and symptom measures—For means and ANOVA results comparing high- and low-anxious disorder-free children, see Table 3. These groups did not differ significantly in socio-economic status, but differed in gender (50% *v.* 40% female, respectively, $\chi^2 = 4.44$, $df = 1$, $p = 0.04$). High-anxious children also tended to be older and have significantly lower IQ scores than low-anxious children (Table 3). High-anxious children not only had higher CBCL anxiety scores (due to selection criteria), but also significantly higher general psychopathology and ADHD scores than low-anxious children.

Overall errors and RTs—Responses were significantly slower and tended to be more variable in the high- than low-anxious group (Table 3), but not when CBCL ADHD scores were controlled (F 's < 1). Accuracy was similar across groups.

Executive attention—As predicted (hypothesis 4), high-anxious children had higher conflict scores than low-anxious children significant group differences, reported earlier, were independent of co-morbid psychopathology symptoms. ($F_{1,723} = 4.37$, $p = 0.037$, $\eta_p^2 = 0.006$, $d = 0.20$) (Fig. 2A, right). This group difference remained significant when potential confounds (age, gender, IQ, overall error, mean RT, RT variability) were controlled ($F_{1,664} = 6.57$, $p = 0.011$, $\eta_p^2 = 0.010$).

Alerting and orienting—The groups did not differ significantly in alerting or orienting (Table 3).

Supplementary analyses of ANT conflict scores

Controlling effects of co-morbid psychopathology symptoms—ANCOVA of conflict scores from the four diagnostic subgroups and no-disorder group showed that the significant group differences, reported earlier, were independent of co-morbid psychopathology symptoms. Specifically, the difference between the anxiety disorders (excluding specific phobia) and no-disorder groups remained significant when CBCL ADHD and total problems scores were used as covariates, as well as potential confounds described earlier ($F_{1,783} = 5.64$, $p = 0.018$, $\eta_p^2 = 0.007$). Also, the difference between the combined ADHD and no-disorder groups was significant when CBCL anxiety and total problems scores were covariates ($F_{1,783} = 6.85$, $p = 0.009$, $\eta_p^2 = 0.009$).

A separate ANCOVA of conflict scores from disorder-free children confirmed the significant difference between the high- *versus* low-anxiety groups when CBCL ADHD and total problems scores were controlled in addition to potential confounds ($F_{1,662} = 6.83$, $p = 0.009$,

$\eta_p^2 = 0.010$) (anxiety items were excluded from the total problems score because the independent variable of anxiety group is based on these items).

Executive attention in non-co-morbid anxiety disorders, other than specific phobia—With the exception of specific phobia, hypotheses had not been formulated for other individual non-co-morbid anxiety diagnoses (e.g. separation anxiety, GAD) because these samples were small, and differences between these disorders were not expected. Mean conflict score was 133 (s.d. = 104) ms for non-co-morbid separation anxiety ($n = 10$), 129 (s.d. = 85) ms for non-co-morbid GAD ($n = 11$) and 92 (s.d. = 74) ms for other anxiety disorders ($n = 13$). ANOVA of conflict scores comparing these groups with no-disorder children (mean = 77 ms, s.d. = 76, $n = 726$) showed a significant overall group difference ($F_{3,756} = 3.58$, $p = 0.014$, $\eta_p^2 = 0.014$). Relative to no-disorder children, conflict scores were higher in those with separation anxiety ($d = 0.74$, $p = 0.020$) and GAD ($d = 0.69$, $p = 0.025$) (results were similar with potential confounds as covariates).

Effects of potential confounds—ANCOVA of conflict scores with age, gender, IQ, overall errors, mean RT, and RT variability as covariates showed significant effects of two covariates, which were independent of the significant group effect (anxiety disorders, ADHD, no disorder) reported earlier: i.e. higher conflict scores were also associated with younger age ($F_{1,790} = 14.32$, $p < 0.01$, $\eta_p^2 = 0.018$) and greater RT variability ($F_{1,790} = 6.89$, $p = 0.009$, $\eta_p^2 = 0.009$). Similar effects of age and RT variability were found in ANCOVAs comparing the diagnostic subgroups, and low- *versus* high-anxiety disorder-free subgroups.

Discussion

Results summary

Anxiety disorders—Overall, children with anxiety disorders did not differ significantly from disorder-free children in ANT conflict scores assessing executive attention (hypothesis 1 was not supported). However, there was heterogeneity among anxiety disorders. As predicted (hypothesis 3), children with anxiety disorders, excluding specific phobias, did have higher conflict scores compared not only with disorder-free children, but also with children with specific phobias, who showed no deficit in executive attention. There was no evidence of anxiety-related deficits in alerting or orienting.

ADHD—Children with ADHD had higher conflict scores than disorder-free children (supporting hypothesis 2). There was no significant difference in conflict scores between non-co-morbid ADHD and co-morbid ADHD + ODD/CD, or between the anxiety disorders (excluding specific phobia) and ADHD groups. That is, anxiety disorders (excluding specific phobia) and ADHD were each associated with impaired executive attention. The ADHD group also had higher orienting scores, less accurate responses and more variable RTs than the anxiety disorders and no-disorder groups.

Non-clinical anxiety—Disorder-free children with high anxiety showed poorer executive attention than those with low anxiety (hypothesis 4 was supported). There were no anxiety-related deficits in alerting or orienting.

Contribution of findings to previous research

Anxiety-related deficits in executive attention—As noted earlier, past studies using the ANT investigated executive attention in adults with clinical and non-clinical anxiety. The present study not only extends this work, but also reveals notable similarities between children and adults. First, the finding of impaired executive attention in anxiety disorders (excluding specific phobia), relative to disorder-free individuals, resembles results from a small sample of adults with anxiety disorders (12 patients, most having GAD or agoraphobia; none with pure specific phobia; Pacheco-Unguetti *et al.* 2011). The present study shows this effect in a larger medication-free sample of children. Second, the finding of heterogeneity in executive attention among anxiety disorders (i.e. between specific phobias *versus* other anxiety disorders) is similar to that observed in adults on other executive attention tasks (Airaksinen *et al.* 2005). Third, the present finding of impaired executive attention in high- *versus* low-anxious disorder-free children complements results from non-clinical high- *versus* low-anxious adults (Pacheco-Unguetti *et al.* 2010). Together, these results indicate that children and adults share a similar pattern of anxiety-related deficits in executive attention.

Moreover, the present results extend previous research by providing further evidence of anxiety-specific deficits in executive attention. Anxiety-related group differences in conflict scores remained significant in supplementary analyses that took account of the effects of other psychopathology and potential confounds (including age and IQ). Specifically, differences in conflict scores between: (i) anxiety disorders (excluding specific phobia) *versus* no-disorder groups; and (ii) high- *versus* low-anxious groups of disorder-free children were independent of co-morbid ADHD symptoms or general psychopathology scores. Hence, anxiety appears to be the primary variable underlying these group differences in executive attention functioning.

ADHD-related deficits in executive attention—Children with ADHD had higher conflict scores than disorder-free children. This is consistent with two previous ANT studies of ADHD (Konrad *et al.* 2006; Johnson *et al.* 2008), although this effect has not always been found, perhaps because RTs tend to be highly variable in ADHD, which may increase noise in the ANT data (Booth *et al.* 2007; Adólfssdóttir *et al.* 2008; Kratz *et al.* 2011). Furthermore, in the present study, the difference between the ADHD and no-disorder groups in conflict scores remained significant when effects of anxiety symptoms and general psychopathology were controlled. Thus, impairment in executive attention function in ADHD was not accounted for by co-morbid psychopathology.

The ADHD group differed from both anxiety disorders and no-disorder groups on other ANT measures. The ADHD group had higher orienting scores, which may indicate that they benefited more from the spatial warning cue (indicating where the target will appear), possibly due to lower intrinsic efficiency of the orienting network (Brunyé *et al.* 2010). This

finding was not predicted; it has not been found in previous ANT studies (Adólfssdóttir *et al.* 2008; Johnson *et al.* 2008), and the reason for these mixed orienting results across studies is unclear.

The ADHD group showed additional deficits which have been proposed to be robust markers of cognitive dysfunction in ADHD (Adólfssdóttir *et al.* 2008): i.e. less accurate responses and more variable RTs, compared with both anxiety and no-disorder groups. These results suggest an elevated level of basic cognitive dysfunction in ADHD that is not shared by children with anxiety disorders (for further evidence of basic information processing deficits in ADHD, see Salum *et al.* 2014a, b).

Are executive attention deficits disorder-specific?

In the present study, the pattern of conflict scores appears to more closely resemble the pattern of general psychopathology (reflected by CBCL total problems score) than anxiety symptoms (Fig. 2A, B and C), respectively. For example, the specific phobia group had the lowest levels of general psychopathology and conflict scores of the four diagnostic subgroups, while the anxiety disorders (excluding specific phobia) and ADHD groups had the highest levels of both general psychopathology and conflict scores. Closer similarity between the patterns of conflict scores and general psychopathology, rather than anxiety, would not be explained by cognitive models such as attention control theory, which focus on the effect of non-clinical anxiety on executive attention function, with anxiety viewed as a continuous dimension (Eysenck *et al.* 2007).

Thus, the pattern of results in Fig. 2 raises the question of whether executive function deficits are primarily a function of general psychopathology, rather than specific disorders. Recent models of the structure of psychiatric disorders highlight the role of general psychopathology ('p') as a common higher-order factor underlying both internalizing and externalizing disorders, including anxiety and ADHD (Lahey *et al.* 2012; Caspi *et al.* 2013). The factor p is described as being conceptually similar to the g factor of general intelligence, in that it is a higher-order factor that accounts for much variation in lower-order factors. Factor p underlies psychopathology severity across disorders, such that individuals with a high p have more persistent and co-morbid problems, greater life impairments as children and adults, and greater emotional dysregulation and executive deficits (Caspi *et al.* 2013). This view would explain why it may be difficult to identify disorder-specific markers (e.g. in cognitive function, or neuroimaging indices), but it does not rule out their existence. An association between executive attention dysfunction and general psychopathology would seem compatible not only with a p-factor model, but also with the view, from developmental and personality research, that executive attention plays a key role in supporting effective regulation of thoughts, behavior and emotion; i.e. self-regulation, which is compromised across a wide range of psychopathologies (Posner & Rothbart, 2000, 2007; Muris & Ollendick, 2005; Rueda *et al.* 2005; Hofmann *et al.* 2012).

In relation to the p-factor model, the present results suggest the following conclusions. First, the presence of any psychiatric disorder is not sufficient in itself to account for impaired executive attention, given that such impairment was not found in specific phobias. Second, while the pattern of executive attention function across the different disorder groups appears

to parallel that of general psychopathology (Fig. 2), the latter does not seem sufficient to account for the results given that supplementary analyses indicated anxiety-specific and ADHD-specific deficits in executive attention; i.e. associations were found between impaired executive attention and diagnoses of anxiety disorders (not specific phobia) and ADHD after controlling the effect of general psychopathology symptoms. Third, the difference in executive attention between specific phobias and other anxiety disorders may relate to differences in specific symptom profiles (rather than general psychopathology), such as severity of cognitive *versus* behavioral symptoms of anxiety (e.g. worry *versus* behavioral avoidance). Thus, it would seem useful to investigate further the extent to which executive attention deficits relate to different classes of anxiety symptoms in anxiety disorders. Finally, neuroimaging research may help clarify other issues, such as whether common neural mechanisms underlie executive attention dysfunction associated with non-clinical anxiety, anxiety disorders (other than specific phobia) and ADHD.

Strengths and limitations

A strength of the study is the use of a large community sample of medication-free children. However, a limitation was the small number of children with specific non-co-morbid anxiety disorders, such as GAD and separation anxiety, so examination of these disorders was curtailed. Another strength is the use of a theoretically grounded task, specifically designed to assess function of the executive attention network, indexed by distracter interference (Fan *et al.* 2002; Posner & Rothbart, 2007; Posner & Fan, 2008). However, a limitation of the ANT is that it does not assess cognitive flexibility, reflected by task switching, which is another aspect of executive attention that may be impaired by high anxiety (Eysenck *et al.* 2007). Resistance to distraction is also distinct from other cognitive functions related to child psychopathology such as motor response inhibition and attention bias to threat. The children studied here were a subsample of those participating in separate investigations of ADHD-related impairment in response inhibition (using Go/No-Go and Conflict Control tasks; Salum *et al.* 2014a, b) and anxiety-related threat attention bias (visual probe task; Salum *et al.* 2013). There was some evidence suggesting ADHD-related impairment in response inhibition, but this was explained by basic information-processing deficits; and no response inhibition deficits were associated with other psychopathology including anxiety and depressive disorders. Threat attention bias was associated with high internalizing symptoms in disorder-free children and distress disorders (GAD, depressive disorders), but not externalizing disorders (ADHD, ODD/CD; Salum *et al.* 2013). Given that resistance to distraction, motor response inhibition and threat attention bias are separable constructs (Nigg, 2000; Bunge *et al.* 2002; Brydges *et al.* 2013; Diamond, 2013), their specific contributions to child psychopathology warrant further clarification.

Effect sizes for hypothesis-related significant group differences in conflict scores were in the moderate-to-low range: d was 0.43 for anxiety disorders (excluding specific phobia); 0.35 for ADHD (each *versus* no-disorder); and 0.20 for high *versus* low anxiety in disorder-free children. Previous research suggests large effects of adult anxiety on conflict scores ($d = \sim 1.0$, Pacheco-Unguetti *et al.* 2010, 2011); and null-to-large effects of ADHD (e.g. $d = \sim 0.1$, 0.4 and 1.0 in Adólfssdóttir *et al.* 2008, Johnson *et al.* 2008, and Konrad *et al.* 2006, respectively). Methodological variables may contribute to variation in effect sizes, e.g. larger

effects may be found with adult participants (whose RT data may be less ‘noisy’ than children’s), homogeneous samples and strictly controlled experimental testing conditions (e.g. laboratory *versus* school settings).

Conclusion

This study contributes to previous research by demonstrating that executive attention is impaired in children with anxiety disorders (excluding specific phobias), as well as in children with ADHD, relative to disorder-free children. Furthermore, executive attention was less efficient in disorder-free children who have high, relative to low, levels of anxiety symptoms. Such findings have potential clinical and educational implications, as poor executive attention is linked not only with psychopathology, such as anxiety and ADHD, but also with lower educational attainment (St Clair-Thompson & Gathercole, 2006). If executive attention promotes self-regulation, as discussed earlier, cognitive and behavioral interventions that improve children’s executive attention (Diamond & Lee, 2011) may help reduce non-clinical and clinical manifestations of psychopathology, and increase educational success (Posner & Rothbart, 2005; Diamond, 2012).

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References

- Achenbach TM, Dumenci L, Rescorla LA (2003). DSM-oriented and empirically based approaches to constructing scales from the same item pools. *Journal of Clinical Child Adolescent Psychology* 32, 328–340. [PubMed: 12881022]
- Adólfssdóttir S, Sørensen L, Lundervold AJ (2008). The Attention Network Test: characteristic pattern of deficits in children with ADHD. *Behavioral and Brain Functions* 12, 1–9.
- Aebi M, Kuhn C, Metzke CW, Stringaris A, Goodman R, Steinhausen H-C (2012). The use of the Development and Well-Being Assessment (DAWBA) in clinical practice: a randomized trial. *European Child and Adolescent Psychiatry* 21, 559–567. [PubMed: 22722664]
- Airaksinen E, Larsson M, Forsell Y (2005). Neuropsychological functions in anxiety disorders in population-based samples: evidence of episodic memory dysfunction. *Journal of Psychiatric Research* 39, 207–214. [PubMed: 15589570]
- Bishop S (2008). Trait anxiety and impoverished prefrontal control of attention. *Nature Neuroscience* 12, 92–98. [PubMed: 19079249]
- Booth JE, Carlson CL, Tucker DM (2007). Performance on a neurocognitive measure of alerting differentiates ADHD combined and inattentive subtypes: a preliminary report. *Archives of Clinical Neuropsychology* 22, 423–432. [PubMed: 17339094]
- Brunyé TT, Mahoney CR, Lieberman HR, Taylor HA (2010). Caffeine modulates attention network function. *Brain Cognition* 72, 181–188. [PubMed: 19733954]
- Brydges CR, Anderson M, Reid CL, Fox AM (2013). Maturation of cognitive control: delineating response inhibition and interference suppression. *PLOS ONE* 8, e69826. [PubMed: 23894548]

- Bunge SA, Dudukovic NM, Thomason ME, Vaidya CJ, Gabrieli JD (2002). Immature frontal lobe contributions to cognitive control in children: evidence from fMRI. *Neuron* 33, 301–311. [PubMed: 11804576]
- Caspi A, Houts RM, Belsky DW, Goldman-Mellor SJ, Harrington H, Israel S, Meier MM, Ramrakha S, Shalev I, Poulton R, Moffitt TE (2013). The p factor: one general psychopathology factor in the structure of psychiatric disorders? *Clinical Psychological Science* 2, 119–137.
- Castaneda AE, Suvisaari J, Marttunen M, Perälä J, Saarni SI, Aalto-Setälä T, Lönnqvist J, Tuulio-Henriksson A (2011). Cognitive functioning in a population-based sample of young adults with anxiety disorders. *European Psychiatry* 26, 346–353. [PubMed: 20627469]
- Castaneda AE, Tuulio-Henriksson A, Marttunen M, Suvisaari J, Lönnqvist J (2008). A review on cognitive impairments in depressive and anxiety disorders with a focus on young adults. *Journal of Affective Disorders* 106, 1–27. [PubMed: 17707915]
- Cohen J (1988). *Statistical Power Analysis for the Behavioral Sciences* Routledge Academic: New York.
- Costello EJ, Mustillo S, Erkanli A, Keeler G, Angold A (2003). Prevalence and development of psychiatric disorders in childhood and adolescence. *Archives of General Psychiatry* 60, 837–844. [PubMed: 12912767]
- Craske MG, Waters AM (2005). Panic disorder, phobias, and generalized anxiety disorder. *Annual Review of Clinical Psychology* 1, 197–226.
- Diamond A (2012). Activities and programs that improve children's executive functions. *Current Directions in Psychological Science* 21, 335–341. [PubMed: 25328287]
- Diamond A (2013). Executive functions. *Annual Review of Psychology* 64, 135–168.
- Diamond A, Lee K (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science* 333, 959–966. [PubMed: 21852486]
- Eysenck MW, Derakshan N (2011). New perspectives in attentional control theory. *Personality and Individual Differences* 50, 955–960.
- Eysenck MW, Derakshan N, Santos R, Calvo MG (2007). Anxiety and cognitive performance: attentional control theory. *Emotion* 7, 336–353. [PubMed: 17516812]
- Fan J, McCandliss BD, Sommer T, Raz A, Posner MI (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience* 14, 340–347. [PubMed: 11970796]
- Figueiredo VLM (2001). Brazilian Version of WISC-III Intelligence Test Curso de Pós-Graduação em Psicologia, Instituto de Psicologia, Universidade de Brasília: Brasília, DF.
- Fleitch-Bilyk B, Goodman R (2004). The prevalence of child psychiatric disorders in Southeast Brazil. *Journal of the American Academy of Child and Adolescent Psychiatry* 43, 727–734. [PubMed: 15167089]
- Ford T, Goodman R, Meltzer H (2003). The British Child and Adolescent Mental Health Survey 1999: the prevalence of DSM-IV disorders. *Journal of the American Academy of Child and Adolescent Psychiatry* 42, 1203–1211. [PubMed: 14560170]
- Goodman R, Ford T, Richards H, Gatward R, Meltzer H (2000). The Development and Well-Being Assessment: description and initial validation of an integrated assessment of child and adolescent psychopathology. *Journal of Child Psychology and Psychiatry and Allied Disciplines* 41, 645–655.
- Günther T, Holtkamp K, Jolles J, Herpertz-Dahlmann B, Konrad K (2004). Verbal memory and aspects of attentional control in children and adolescents with anxiety disorders or depressive disorders. *Journal of Affective Disorders* 82, 265–269. [PubMed: 15488256]
- Heiervang E, Stormark KM, Lundervold AJ (2007). The Bergen Child Study of mental health in school-age children. Psychiatric disorders according to the Development and Well-Being Assessment: prevalence, risk factors and service use. *Journal of the American Academy of Child and Adolescent Psychiatry* 46, 438–447. [PubMed: 17420678]
- Hofmann W, Schmeichel BJ, Baddeley AD (2012). Executive functions and self-regulation. *Trends in Cognitive Sciences* 16, 174–180. [PubMed: 22336729]
- Johnson KA, Robertson IH, Barry E, Mulligan A, Daibhis A, Daly M, Watchorn A, Gill M, Bellgrove MA (2008). Impaired conflict resolution and alerting in children with ADHD: evidence from the Attention Network Task (ANT). *Journal of Child Psychology and Psychiatry, and Allied Disciplines* 49, 1339–1347.

- Kendall PC, Puliafico AC, Barmish AJ, Choudhury MS, Henin A, Treadwell KS (2007). Assessing anxiety disorders with the Child Behavior Checklist and the Teacher Report Form. *Journal of Anxiety Disorders* 21, 1004–1015. [PubMed: 17270388]
- Konrad K, Neufang S, Hanisch C, Fink GR, Herpertz-Dahlmann B (2006). Dysfunctional attentional networks in children with attention deficit/hyperactivity disorder: evidence from an event-related functional magnetic resonance imaging study. *Biological Psychiatry* 59, 643–651. [PubMed: 16197925]
- Kratz O, Studer P, Malcherek S, Erbe K, Moll GH, Heinrich H (2011). Attentional processes in children with ADHD: an event-related potential study using the attention network test. *International Journal of Psychophysiology* 81, 82–90. [PubMed: 21641942]
- Lahey BB, Applegate B, Hakes JK, Zald DH, Hariri AR, Rathouz PJ (2012). Is there a general factor of prevalent psychopathology during adulthood? *Journal of Abnormal Psychology* 121, 971–977. [PubMed: 22845652]
- Millan MJ, Agid Y, Brüne M, Bullmore ET, Carter CS, Clayton NS, Connor R, Davis S, Deakin B, DeRubeis RJ, Dubois B, Geyer MA, Goodwin GM, Gorwood P, Jay TM, Joëls M, Mansuy IM, Meyer-Lindenberg A, Murphy D, Rolls E, Saletu B, Spedding M, Sweeney J, Whittington M, Young LJ (2012). Cognitive dysfunction in psychiatric disorders: characteristics, causes and the quest for improved therapy. *Nature Reviews Drug Discovery* 11, 141–168. [PubMed: 22293568]
- Moriya J, Tanno Y (2009). Dysfunction of attentional networks for non-emotional processing in negative affect. *Cognition and Emotion* 23, 1090–1105.
- Muris P, Ollendick TH (2005). The role of temperament in the etiology of child psychopathology. *Clinical Child and Family Psychology Review* 8, 271–289. [PubMed: 16362256]
- Muris P, van der Pennen E, Sigmond R, Mayer B (2008). Symptoms of anxiety, depression, and aggression in nonclinical children: relationships with self-report and performance-based measures of attention and effortful control. *Child Psychiatry and Human Development* 39, 455–467. [PubMed: 18446435]
- Nigg JT (2000). On inhibition/disinhibition in developmental psychopathology: views from cognitive and personality psychology and a working inhibition taxonomy. *Psychological Bulletin* 126, 220–246. [PubMed: 10748641]
- Pacheco-Unguetti AP, Acosta A, Callejas A, Lupiáñez J (2010). Attention and anxiety: different attentional functioning under state and trait anxiety. *Psychological Science* 21, 298–304. [PubMed: 20424060]
- Pacheco-Unguetti AP, Acosta A, Marqués E, Lupiáñez J (2011). Alterations of the attentional networks in patients with anxiety disorders. *Journal of Anxiety Disorders* 25, 888–895. [PubMed: 21641180]
- Petersen SE, Posner MI (2012). The attention system of the human brain: 20 years after. *Annual Review of Neuroscience* 35, 73–89.
- Pine DS, Cohen P, Gurley D, Brook J, Ma Y (1998). The risk for early-adulthood anxiety and depressive disorders in adolescents with anxiety and depressive disorders. *Archives of General Psychiatry* 55, 56–64. [PubMed: 9435761]
- Posner MI, Fan J (2008). Attention as an organ system. In *Topics in Integrative Neuroscience* (ed. Pomerantz JR), pp. 31–61. Cambridge University Press: New York.
- Posner MI, Rothbart MK (2000). Developing mechanisms of self-regulation. *Development and Psychopathology* 12, 427–441. [PubMed: 11014746]
- Posner MI, Rothbart MK (2005). Influencing brain networks: implications for education. *Trends in Cognitive Science* 9, 99–103.
- Posner MI, Rothbart MK (2007). Research on attention networks as a model for the integration of psychological science. *Annual Review of Psychology* 58, 1–23.
- Reinholdt-Dunne ML, Mogg K, Bradley BP (2013). Attention control: relationships between self-report and behavioural measures, and symptoms of anxiety and depression. *Cognition and Emotion* 27, 430–440. [PubMed: 22917576]
- Rueda MR, Fan J, McCandliss BD, Halparin JD, Gruber DB, Lercari LP, Posner MI (2004). Development of attentional networks in childhood. *Neuropsychologia* 42, 1029–1040. [PubMed: 15093142]

- Rueda MR, Posner MI, Rothbart MK (2005). The development of executive attention: contributions to the emergence of self-regulation. *Developmental Neuropsychology* 28, 573–594. [PubMed: 16144428]
- Salum GA, Gadelha A, Pan PM, Moriyama TS, Graeff-Martins AS, Tamanaha AC, Alvarenga P, Krieger FV, Fleitlich-Bilyk B, Jackowski A, Sato JR, Brietzke E, Polanczyk GV, Brentani H, de Jesus Mari J, do Rosário MC, Manfro GG, Affonseca-Bressan R, Mercadante MT, Miguel EC, Rohde LA (2015). High risk cohort study for psychiatric disorders in childhood: rationale, design, methods and preliminary results. *International Journal of Methods in Psychiatric Research* 24, 58–73. [PubMed: 25469819]
- Salum GA, Mogg K, Bradley BP, Gadelha A, Pan P, Tamanaha AC, Moriyama T, Graeff-Martins AS, Jarros RB, Polanczyk G, do Rosario MC, Leibenluft E, Rohde LA, Manfro GG, Pine DS (2013). Threat bias in attention orienting: evidence of specificity in a large community-based study. *Psychological Medicine* 43, 733–745. [PubMed: 22850475]
- Salum GA, Sergeant J, Sonuga-Barke E, Vandekerckhove J, Gadelha A, Pan PM, Moriyama TS, Graeff-Martins AS, de Alvarenga PG, do Rosario MC, Manfro GG, Polanczyk G, Rohde LA (2014a). Specificity of basic information processing and inhibitory control in attention deficit hyperactivity disorder. *Psychological Medicine* 44, 617–631. [PubMed: 23561016]
- Salum GA, Sonuga-Barke E, Sergeant J, Vandekerckhove J, Gadelha A, Moriyama TS, Graeff-Martins AS, Manfro GG, Polanczyk G, Rohde LA (2014b). Mechanisms underpinning inattention and hyperactivity: neurocognitive support for ADHD dimensionality. *Psychological Medicine* 44, 3189–3201. [PubMed: 25065454]
- Sergeant JA, Geurts H, Oosterlaan J (2002). How specific is a deficit of executive functioning for attention-deficit/hyperactivity disorder? *Behavioural Brain Research* 130, 3–28. [PubMed: 11864714]
- Clair-Thompson HL, St, Gathercole SE (2006). Executive functions and achievements on national curriculum tests: shifting, updating, inhibition, and working memory. *Quarterly Journal of Experimental Psychology* 59, 745–759.
- Tellegen A, Briggs PF (1967). Old wine in new skins: grouping Wechsler subtests into new scales. *Journal of Consulting Psychology* 31, 499–506. [PubMed: 6075979]
- Wechsler D (2002). Wechsler Intelligence Scale for Children Casa do Psicólogo: São Paulo, Brazil.
- Weissman AS, Chu BC, Reddy LA, Mohlman J (2012). Attention mechanisms in children with anxiety disorders and in children with attention deficit hyperactivity disorder: implications for research and practice. *Journal of Clinical Child and Adolescent Psychology* 41, 117–126. [PubMed: 22417186]

Fig. 1.

Illustration of main stimulus events on an experimental trial from the child version of the Attention Network Task (ANT) (upper panel). On each trial, participants press one of two keys to indicate the direction in which the central target fish is pointing. Spatial cues and target-flanker arrays (fish stimuli) are equally likely to appear above or below the fixation cross. The task is presented in color (yellow fish, turquoise background). RT, Reaction time. The figure has been adapted from Rueda *et al.* (2004) (Fig. 1; not drawn to scale).

Fig. 2.

(A) Executive attention dysfunction reflected by Attention Network Task (ANT) conflict score (ms). (B) General psychopathology reflected by Child Behavior Checklist (CBCL) total problems score. (C) Anxiety symptom severity reflected by CBCL anxiety score. Left panels: each score is shown as a function of the four diagnostic subgroups: anxiety disorders (excluding specific phobia); specific phobia; non-co-morbid attention-deficit/hyperactivity disorder (ADHD); and ADHD with co-morbid oppositional defiant disorder and conduct disorder (ODD/CD); and the no-disorder group. Right panels: each score is shown as a

function of low-, mid-range and high-anxiety groups in disorder-free children. Values are means, with standard errors are represented by vertical bars. ^{a,b,c,d} Mean values sharing the same letters do not differ significantly from each other ($p < 0.05$). ^{x,y,z} Mean values sharing the same letters do not differ significantly from each other ($p < 0.05$). Contrasts were planned to minimize the number of tests and address hypotheses as described earlier. The ADHD subgroups (ADHD and ADHD + ODD/CD) did not significantly differ in ANT conflict or CBCL anxiety scores, so were combined into an overall ADHD group in contrasts with other groups on these measures. The ADHD subgroups differed significantly in CBCL total

Table 1.
Characteristics and ANT scores of children with no disorder, anxiety disorders and ADHD

	No disorder	Anxiety disorders	ADHD	$F_{2,857}^a$	p	η_p^2
Age, years	9.9 (2.0)	9.9 (1.8)	9.5 (1.9)	1.20	0.301	0.003
SES score	20.1 (4.9)	19.3 (4.0)	20.8 (4.7)	1.72	0.180	0.004
IQ ^b	101.5 (15.8)	98.6 (14.1)	100.7 (17.9)	0.98	0.375	0.002
CBCL anxiety	4.3 (4.1)	9.9 (5.7)	6.0 (4.1)	57.17	<0.001	0.118
CBCL ADHD	3.1 (3.1)	4.4 (3.6)	8.3 (3.5)	88.58	<0.001	0.171
CBCL total problems	22.2 (19.9)	44.5 (26.3)	48.1 (25.6)	75.09	<0.001	0.149
Overall mean RT, ms	802.9 (134.8)	808.6 (130.9)	841.8 (120.6)	2.63	0.073	0.006
RT variability, S.D. of RTs	225.8 (52.6)	217.5 (45.7)	239.0 (49.7)	2.98	0.051	0.007
Overall error, % of trials	6.6 (6.9)	6.2 (7.1)	7.6 (6.1)	2.97	0.052	0.007
Attention network scores						
Alerting, ms	77.9 (88.0)	62.1 (67.3)	74.2 (70.9)	1.08	0.341	0.003
Orienting, ms	32.4 (73.0)	23.7 (63.6)	54.4 (80.6)	3.43	0.033	0.008
Conflict, ms	76.5 (76.0)	91.7 (80.0)	102.8 (84.3)	4.45	0.012	0.010
DSM-IV diagnoses, n						
Anxiety disorders	–	67	–			
SP	–	24	–			
Anxiety disorders (not SP)	–	43	–			
Separation anxiety	–	16	–			
GAD	–	14	–			
Social phobia	–	3	–			
Agoraphobia	–	1	–			
Other anxiety	–	17	–			
ADHD	–	–	67			
ADHD without ODD/CD	–	–	45			
ADHD with ODD/CD	–	–	22			
Male, n	391	29	39			
Female, n	335	38	28			
Total, n	726	67	67			

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Data are given as mean (S.D.) or as number of participants.

ANT, Attention Network Task; ADHD, attention-deficit/hyperactivity disorder; SES, socio-economic class score; IQ, intelligence quotient; CBCL, Child Behavior Checklist; RT, reaction time; S.D., standard deviation; DSM-IV, Diagnostic and Statistical Manual of Mental Disorders, 4th edition; SP, specific phobia; GAD, generalized anxiety disorder; ODD/CD, oppositional defiant disorder and conduct disorder.

^a *F*-values indicate overall main effect of group (three levels: no disorder, anxiety disorders, ADHD) on each dependent variable.

^b IQ scores were available for 799 children (93% of sample), degrees of freedom = 2, 796.

Table 2.

Sample characteristics and ANT scores as a function of diagnostic subgroups

	No disorder	Anxiety disorders (not SP)	SP	ADHD	ADHD+ ODD/CD	$F_{4,852}^a$	p	η_p^2
Age, years	9.9 (2.0)	9.7 (1.9)	10.1 (1.7)	9.5 (1.9)	9.4 (2.1)	0.81	0.519	0.004
SES score	20.1 (4.9)	19.0 (3.6)	19.6 (4.7)	21.4 (5.2)	19.6 (3.3)	1.52	0.196	0.007
IQ ^b	101.5 (15.8)	99.1 (16.2)	97.0 (9.7)	99.9 (18.8)	102.5 (16.2)	0.71	0.588	0.004
CBCL anxiety	4.3 (4.1)	10.6 (5.3)	8.1 (6.2)	6.3 (4.4)	5.5 (3.3)	27.56	<0.001	0.115
CBCL ADHD	3.1 (3.1)	5.2 (3.8)	2.8 (2.7)	8.2 (3.6)	8.7 (3.4)	46.80	<0.001	0.180
CBCL total problems	22.2 (19.9)	50.4 (27.7)	31.5 (20.2)	43.5 (23.8)	57.6 (27.0)	41.81	<0.001	0.164
Overall mean RT, ms	802.9 (134.8)	805.6 (131.2)	815.4 (135.6)	837.6 (121.9)	850.6 (120.2)	1.36	0.245	0.006
RT variability, S.D. of RTs	225.8 (52.6)	216.6 (46.0)	221.3 (45.1)	236.0 (52.2)	245.0 (44.9)	1.54	0.188	0.007
Overall error, % of trials	6.6 (6.9)	6.8 (7.6)	5.4 (6.5)	7.6 (6.4)	7.7 (5.6)	1.65	0.159	0.008
Attention network scores								
Alerting, ms	77.9 (88.0)	58.0 (76.6)	70.8 (48.5)	80.2 (69.5)	61.9 (73.8)	0.75	0.555	0.004
Orienting, ms	32.4 (73.0)	27.1 (71.3)	19.2 (49.9)	52.6 (85.3)	58.0 (71.8)	1.71	0.147	0.008
Conflict, ms	76.5 (76.0)	109.4 (82.8)	57.8 (68.8)	97.5 (72.3)	113.8 (105.7)	4.02	0.003	0.019
Male, <i>n</i>	391	21	7	24	15			
Female, <i>n</i>	335	22	14	21	7			
Total, <i>n</i>	726	43	21	45	22			

Data are given as mean (S.D.) or as number of participants.

ANT, Attention Network Task; SP, specific phobia; ADHD, attention-deficit/hyperactivity disorder; ODD/CD, oppositional defiant disorder and conduct disorder; SES, socio-economic class score; IQ, intelligence quotient; CBCL, Child Behavior Checklist; RT, reaction time; S.D., standard deviation.

^a *F*-values indicate overall main effect of group (five levels: no disorder, anxiety disorders excluding SP; SP; non-co-morbid ADHD; ADHD + ODD/CD) on each dependent variable.^b IQ scores were available for 796 children (93% of sample), degrees of freedom = 4, 791.

Table 3.
Sample characteristics and ANT scores in disorder-free children as a function of anxiety group

	Low anxiety (no disorder)	Mid-range anxiety (no disorder)	High anxiety (no disorder)	High v. low anxiety: $F_{1,723}^a$	p	η_p^2
Age, years	9.8 (1.9)	9.7 (2.0)	10.1 (1.9)	3.14	0.077	0.004
SES score	20.4 (4.9)	20.0 (4.8)	20.0 (5.0)	0.81	0.367	0.001
IQ ^b	102.5 (15.6)	102.5 (15.7)	99.3 (15.8)	4.15	0.042	0.006
CBCL anxiety	0.4 (0.5)	3.3 (1.1)	9.2 (3.4)	–		
CBCL ADHD	1.2 (1.7)	3.0 (3.0)	5.0 (3.0)	213.26	<0.001	0.228
CBCL total problems	6.1 (7.0)	19.3 (13.1)	41.1 (20.2)	627.49	<0.001	0.465
Overall mean RT, ms	791.8 (126.6)	796.8 (135.2)	821.1 (140.2)	5.10	0.024	0.007
RT variability, S.D. of RTs	224.2 (49.9)	221.3 (54.5)	233.3 (52.0)	3.24	0.072	0.004
Overall error, % of trials	6.0 (5.9)	6.8 (7.1)	6.8 (7.3)	0.27	0.762	0.001
Attention network scores						
Alerting	79.3 (85.9)	73.3 (87.0)	82.6 (91.3)	0.16	0.694	>0.001
Orienting	36.1 (67.7)	31.1 (73.0)	30.8 (77.8)	0.56	0.454	0.001
Conflict	67.9 (72.8)	77.6 (76.0)	83.1 (78.4)	4.37	0.037	0.006
Male, n	124	156	111			
Female, n	83	140	112			
Total, n	207	296	223			

Data are given as mean (S.D.) or as number of participants.

ANT, Attention Network Task; SES, socio-economic class score; IQ, intelligence quotient; CBCL, Child Behavior Checklist; ADHD, attention-deficit/hyperactivity disorder; RT, reaction time; S.D., standard deviation.

^a F -value was not calculated for CBCL anxiety, because the selection criteria resulted in no overlap in scores between groups. Data from all participants were used in total variance estimation. F -values relate to the comparison of high- versus low-anxiety groups for each dependent variable.

^b IQ scores were available for 673 children (93% of disorder-free children), degrees of freedom = 1, 670.