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The Effects of Co-Occuring Anxiety on Executive Functions in Children with ADHD

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Ingrid Arnestad
Linn Løkeland Krebs

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Veileder

Lin Sørensen

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Abstract

Objective: Children with Attention-Deficit/Hyperactivity Disorder (ADHD) are known to have deficits in executive functioning. There is an ongoing debate whether anxiety has an ameliorating effect on executive functions in these children or not. The purpose of the present study was to investigate the effect of high anxiety on executive functioning in children with ADHD and in a group of typically developing children. Based on the Attentional Control Theory we hypothesized that higher levels of anxiety would lead to longer response times (RT's) on inhibition and set-shifting as measured by the Color Word Interference Test (CWIT) from the Delis-Kaplan Executive Function System (D-KEFS). Methods: 74 children, divided into two groups (ADHD: n=40; controls: n= 34) performed D-KEFS CWIT. Results: Higher levels of trait-anxiety decreased the RT significantly on the measure of inhibition in children with ADHD and in the typically developing children. The children with ADHD had higher error scores of inhibition and set-shifting, but showed shorter set-shifting RT's than the controls. Conclusion: The study showed a significant positive association between trait anxiety and RT in inhibition in children with ADHD, and the children with ADHD showed a profile of predominantly inhibitory problems, and not set-shifting problems.

Sammendrag

Barn med ADHD er kjent for å ha vansker med eksekutiv fungering, og det er en pågående debatt om angst har en modererende effekt på slike vansker eller ikke. Målet med denne studien var å undersøke hvordan trekk- og tilstandsangst påvirker eksekutiv fingering hos barn med ADHD og normalfungerende barn. Basert på "Attentional Control Theory" (ACT) var hypotesen vår at høyere grad av angst ville føre til lengre reaksjonstid på inhibisjon og kognitiv fleksibilitet (set-shifting) målt ved "Color Word Interference Test" (CWIT) fra "Delis-Kaplan Executive Function System" (D-KEFS). Metode: 74 barn delt i to grupper (ADHD: n=40; kontrollgruppe: n=34) utførte D-KEFS CWIT, en nyere versjon av Stroop-testen som registrerer responstid og antall feil. Resultater: Resultatene viste at høy grad av trekk-angst hos både barn med ADHD og kontrollbarna påvirket responstiden positivt, motsatt fra hva som ble forventet, ved at høy grad av trekkangst korrelerte med en raskere inhibisjons-responstid. Barna med ADHD hadde flere feilskårer på målene av både inhibisjon og kognitiv fleksibilitet, men viste kortere responstid på kognitiv fleksibilitet. Konklusjon: Denne studien viser at høy trekk-angst har en statistisk signifikant positiv effekt på responstiden på inhibisjon hos barn med ADHD.

The Effects of Co-Occurring Anxiety on Executive Functions in Children With ADHD

The present study investigates the influence of state- and trait anxiety on the executive control functions of inhibition and set-shifting in children with Attention-Deficit/Hyperactivity Disorder (ADHD). There is an ongoing debate whether co-occurring symptoms of anxiety have an ameliorative effect on cognitive control in these children (Bloemsma et al., 2013; Manassis, Tannock, & Barbosa, 2000; Pliszka, 1992; Pliszka, Carlson, & Swanson, 1999; Pliszka, Hatch, Borcherding, & Rogeness, 1993) or not (Abikoff et al., 2002; Newcorn et al., 2001; Oosterlaan, Logan, & Sergeant, 1998). The results seem to depend on the test paradigm and on the difficulty level of the test paradigm used (Newcorn et al., 2001; Nigg, 2001). Previous research tends to concentrate on anxiety as a clinical disorder; however, self-reported symptoms of anxiety may detect associations with neurocognitive functions that will not be observed with the use of categorical diagnoses in the statistical analyses (Bloemsma et al., 2013). Thus, rather than focusing on clinical symptoms that predict the presence of a clinical anxiety disorder, the effect of anxiety can be studied as a personality trait dimension or as a situationally induced state dimension (Eysenck & Byrne, 1992). Individuals differ in anxiousness without higher levels of anxiety necessarily implying a clinical diagnosis (Eysenck, Derakshan, Santos, & Calvo, 2007). State and trait anxiety are often associated with performance impairment on cognitive tasks in both children and adults (Bishop, 2008; Eysenck & Byrne, 1992; Wetherell, Reynolds, Gatz, & Pedersen, 2002). We therefore hypothesize that the same effect might emerge in children with ADHD.

In the present study, the effect of anxiety on a newer version of the Stroop task, the Delis-Kaplan Executive Function System´s (D-KEFS) Color Word Interference Test (CWIT), was studied in children with ADHD. The CWIT includes measures of the executive functions inhibition and set-shifting.

The characteristics of ADHD

The prevalence of ADHD is 3-5% in childhood (American Psychiatric Association, 1994), and about 50 % of diagnosed children continue to fulfill the diagnostic criteria into adulthood (Okie, 2006). Children with ADHD have problems with attention, hyperactivity and/or impulsivity. According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) the children must have at least six symptoms of inattention and/or hyperactivity and impulsivity (American Psychiatric Association, 1994). The patterns of behavior have to be present in at least two settings (e.g., school and home), and they have to be manifest prior to 7 years. DSM-IV differentiates between predominantly inattentive subtype, predominantly hyperactive/impulsive subtype and a combination of these (American Psychiatric Association, 1994).

Children with ADHD have impairments across multiple domains of functioning. They appear to have lower academic achievement and more difficulties in social relationships (Barkley, 2002). They are also more prone to emotional problems (Wolraich et al., 2005). In addition to causing problems on an individual level, ADHD also represents an economic challenge on a societal level. For instance, it is estimated that children with ADHD add an annual cost of approximately $13 billion to the US Education System (Robb et al., 2011).

Despite a vast amount of research on ADHD has been published (Barkley, 1997a; Gaub & Carlson, 1997; Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007), its etiology remains somewhat unclear. One of the most important findings is that symptoms of ADHD are similar to those produced by injuries or lesions to the prefrontal cortex, suggesting that the cause of the disorder is linked to the frontal lobes of the brain (Benton, 1991; Heilman, Voeller, & Nadeau, 1991). Based on this “frontal hypothesis”, some researchers have claimed that the hyperactive, impulsive and inattentive symptoms that children with ADHD display are linked to deficits in executive functioning (Barkley, 1997b; Pennington & Ozonoff, 1996).

ADHD and executive functions

Cognitive executive functions are associated with activity in the frontal lobes and include higher-order cognitive processes that are linked to the regulation of goal directed behavior. In the everyday life, inhibition and cognitive flexibility are important features of executive functions (Miyake et al., 2000); also for individuals with ADHD (Barkley, 1997b; Halleland, Haavik, & Lundervold, 2012; Nigg, 2006). Inhibition can be defined as "*the ability to deliberately inhibit dominant, automatic or prepotent responses when necessary"* (Miyake et al., 2000, p. 57). Cognitive and behavioral inhibition is a fundamental aspect in understanding the pathophysiology of children with ADHD's cognitive functioning, especially in settings with competing responses (Barkley, 1997a; Oosterlaan et al., 1998; Scheres et al., 2004). Deficits in inhibition have been proposed to underlie ADHD and the symptoms of inattention, hyperactivity and impulsiveness (Barkley, 1997b; Sonuga-Barke, 2005). Some theories even state that the inhibition deficits are unique to ADHD (Barkley, 1997b; Douglas, 1989; Pennington & Ozonoff, 1996; Wender, 1972). Set-shifting is another central aspect of executive functioning. It can be defined as *"the ability to shift back and forth between multiple tasks, operations or mental sets"* (Miyake et al., 2000, p. 55). Adults with ADHD are shown to struggle with the combination of inhibition and set-shifting (Halleland et al., 2012). However, the few studies focusing on ADHD and difficulties in set-shifting have lead to inclusive results using standard neuropsychological tests (Piek, Dyck, Francis, & Conwell, 2007; Rohlf et al., 2012). The high level of task difficulty and the need to include contrast measures that control for basic functions have partly explained these results. A task that includes contrast measures for more basic functions in measuring the executive functions inhibition and set-shifting is the D-KEFS CWIT (Delis, Kaplan, & Kramer, 2001; Halleland et al., 2012).

A vast amount of research shows that children and adults with ADHD display deficits in executive functioning (Pennington & Ozonoff, 1996; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). However, these cognitive control problems are not unique for ADHD as a symptom disorder. Deficits in executive functions are also observable in other mental health diagnosis such as higher functioning autism, oppositional defiant disorder, conduct disorder, depression, and anxiety (Sergeant, Geurts, & Oosterlaan, 2002). Anxiety is however a symptom disorder that is both associated with better (Oosterlaan et al., 1998) and poorer (Tucker & Derryberry, 1992) executive functions than control groups, and is frequently discussed to have a differential effect on the executive functioning in children with ADHD (Bloemsma et al., 2013; Nigg, 2001).

ADHD and anxiety

Kadesjø & Gilberg (2001) found that 87 % of a sample of Swedish children that met the criteria for ADHD had one or more comorbid diagnosis, and 67 % had at least two. The high prevalence of a comorbid diagnosis also highlights the fact that the prevalence of a "pure" ADHD is rather low (Kadesjö & Gillberg, 2001). The high prevalence of clinical anxiety of 25 % (Tannock, 2000) among children diagnosed with ADHD represents a conundrum. ADHD and anxiety disorders might seem to be opposite disorders, in that ADHD is commonly associated with externalizing symptoms such as inattention, hyperactivity and impulsivity (Cosgrove et al., 2011), while anxiety disorders are characterized by an inward expression of distress such as excessive worry and tension, which however, may also lead to inattention (Eysenck, Derakshan, Santos, & Calvo, 2007). Despite this distinction, these disorders also overlap in symptomatology (Bloemsma et al., 2013). It is hypothesized that anxiety can ameliorate the inhibition dysfunction seen in children with ADHD because of contrary mechanisms working together, and thus compensating each other's effect.

Anxiety and executive functions

Gray (1970) suggests that behavioral regulation depends on the "balance" between the Behavioral Inhibition System (BIS) and the Behavioral Activating System (BAS) respectively responsible for inhibition and activation. This theory predicts that children with anxiety are more sensitive for signals of punishment, which leads to an overactive BIS system (Biederman et al., 1993). At the contrary, children with ADHD are characterized by impulsive behavior and an underactive BIS. Based on Gray´s work, Quay (1988) suggests that when both ADHD and anxiety are present simultaneously, and thus have opposing effects on BIS, it is thought that the systems balance each other out, leading to a compensatory effect on inhibition.

Contradictory to this theory, a body of research suggests that high levels of anxiety has a negative effect, rather than an enhancing effect, on cognitive test performance in children and adults (Ackerman & Heggestad, 1997; Derakshan & Eysenck, 2009; Hembree, 1988; Ma, 1999; Owens, Stevenson, Norgate, & Hadwin, 2008). This is for instance explained in an Attentional Control Theory (ACT; Eysenck et al., 2007). The ACT comprises an assumption that high levels of anxiety direct the attention to threat-related stimuli, which then limits the attentional resources available to allocate for processing of stimuli requiring attentional control (Eysenck et al., 2007). The ACT postulates that this conflict between task-related processing and threat-related processing will slow down the resources available for attentional control processing, and thereby affect the efficiency, but not necessarily the effectiveness of the processing. Effectiveness is measured by the level of accuracy, and refers to the quality of performance, whereas efficiency is measured by time to process (i.e., RT) and refers to the relationship between the quality of performance and the effort invested to attain the performance (Eysenck et al., 2007). Eysenck et al. (2007) assume that anxiety predominantly has an effect on time to process stimuli requiring attentional control, and that the slowing down in attentional control processing compensate for the limited attentional

control, and this use of additional effort hinders errors to occur. Based on these assumptions, anxiety is expected to lead to a slower RT in tasks measuring inhibition and set-shifting, but is not expected to be associated with a higher level of errors.

In children with ADHD, a comorbid anxiety disorder appears to be associated with longer RT's and with a lower level of inhibition errors, compared to children with ADHD with no comorbid anxiety (Bloemsma et al., 2013). The longer RT's are in accordance with the ACT of Eysenck and colleagues (2007), though few studies have investigated the effect of anxiety on RT's directly linked to inhibitory processes. Most of the time, the longer RT's may be a result of a slower psychomotor speed, which is not reckoned as an executive function, but as a more basic cognitive function that is important for executive functioning (Miyake et al., 2000). Furthermore, the positive effect of anxiety on inhibitory efficacy (i.e., accuracy) is not in line with the ACT, but more with the theory of Quay (1988). Quay does not make specific predictions on whether anxiety ameliorates executive functioning, inhibitory control processing, on RT or accuracy. It seems more like both of these behavioral measures are expected to be positively modulated in children with ADHD with higher levels of anxiety. It is important to note, though, that not all studies confirm the ameliorate effect of anxiety in reducing inhibition errors in children with ADHD (Newcorn et al., 2001; Oosterlaan & Sergeant, 1998). These contradictions in the literature highlight a need for studies to investigate the effect of anxiety on executive functioning in children with ADHD on both process measures of RT and accuracy.

According to Nigg (2001), the inconsistent findings might be explained by the diversity in the nature of the tasks. For instance, when children with ADHD and anxiety are given tasks measuring another executive function, working memory, their executive functioning is decreased (Bedard & Tannock, 2007). Working memory assess the ability to hold complex information in mind while performing a task, whereas inhibitory and set-

shifting control relates to solving conflicts and to shifting between different conditions, respectively. Thus, these different executive functions overlap (Miyake et al., 2000). In performing more complex tasks, whether it predominantly assesses inhibition or set-shifting, it may also load on working memory where slowing down the attention control processing in children with ADHD and anxiety may not compensate for the limited attention capacity.

The theory of the balance between BIS and BAS and the effect anxiety has on this balance in children with ADHD (Quay, 1988) focus on the effect on inhibitory control, but does not specifically predict the effect of anxiety on the two other executive functions of set-shifting and working memory. The ACT on the other hand, describes the same effect of anxiety on inhibitory control, set-shifting and working memory. In relation to set-shifting, it predicts that anxiety will reduce the ability to flexibly shift attention between relevant task demands (Eysenck et al., 2007). In accordance with this, Derakshan, Smyth and Eysenck (2009) found a significant interaction between state anxiety and a task that involved the shifting function. Anxious individuals performed slower compared with non-anxious individuals, but only when the measure involved shifting between tasks. This indicates that anxiety affects the shifting function under certain conditions. The same tendency is also found when using the Wisconsin Card Sorting Test, where a high score on trait anxiety is associated with more errors (Caselli, Reiman, Hentz, Osborne, & Alexander, 2004; Goodwin & Sher, 1992) and longer reaction times (Goodwin & Sher, 1992). This is also confirmed in a study of children with ADHD and anxiety by Sørensen, Plessen, Nicholas, and Lundervold (2011). Parents reported here that anxious children with ADHD had significantly more difficulties with set-shifting in everyday life, compared to children with “pure” ADHD or a “pure” anxiety diagnosis. This research is further supported by one of the few studies that have examined the neural correlates of the shifting function and anxiety (Ansari & Derakshan, 2011).

Previous studies concerned with ADHD and anxiety have focused on anxiety as a clinical disorder. This focus in research differs from the ACT, which focuses on trait and state anxiety. Both set-shifting and response inhibition are important parts of executive functioning, and executive functioning is found to be affected by both state- and trait anxiety (Eysenck & Derakshan, 2011; Eysenck et al., 2007), as well as ADHD (Barkley, 1997b). As anxiety disorders consists of a group of disorders, a growing need for additional studies with adequate power to examine ADHD comorbidity on separate anxiety disorders has evolved. Furthermore, research suggests that children might experience anxiety without fulfilling the criteria for an anxiety diagnosis (Bloemsma et al., 2013), indicating that other measures are also needed, in order to further our understanding of the ADHD-anxiety overlap. A large study by Bloemsma et al. (2013) found that self-reported anxiety assessments on the Multidimensional Anxiety Scale for Children (MASC; March, Parker, Sullivan, Stallings, & Conners, 1997) predicted neurocognitive dysfunctions better than other measures such as parent and teacher reported anxiety, indicating that self-reported anxiety might detect associations that will not be identified by using categorical diagnosis as between-group effects. Accordingly, rather than focusing on anxiety as a clinical disorder, the effect of anxiety on cognitive tasks might be investigated more accurately by observing anxiety as a personality trait- or state dimension (Eysenck et al., 2007).

Trait- and state-anxiety

In the current study, anxiety is measured as a personality dimension (i.e. trait) and as a reaction to a specific situation (i.e. state), assessed by Spielberger's State-Trait Anxiety Inventory (STAI; Spielberger, 1983). Anxiety as a personality trait measured dimensionally seems to be closely related to pathological anxiety measured categorically (Chambers, Power, & Durham, 2004; Naragon-Gainey, 2010; Schmidt, Mitchell, & Richey, 2008). For instance,

high scores on the STAI is linked to being prone to experience anxiety across a range of situations, and hence being more vulnerable to anxiety disorders (Chambers et al., 2004).

Biases in processing threat-related information have been associated with the etiology and the maintenance of anxiety (Eysenck et al., 2007). In accordance with this, trait anxiety is defined as a generalized and enduring predisposition to react to different situations in a fearful matter (Allport, 1937), hence representing a personality trait. State anxiety on the other hand, refers to the currently and subjectively experienced level of anxiety and might be affected by both trait anxiety and by fear provoking stimuli (Eysenck & Byrne, 1992). State anxiety is often associated with adverse performance on cognitive tasks (Eysenck & Byrne, 1992). This finding highlights the importance of investigating both state- and trait anxiety in relation to cognitive performance, for instance with a clinical assessment like STAI, which provides evaluation of both present and trait anxiety levels (Segenreich, Fortes, Coutinho, Pastura, & Mattos, 2009).

To the best of our knowledge, no study has investigated the effect of state- and trait anxiety on children with ADHD measured by the STAI. Previous research has used STAI as an additional measure when individuals already fulfill the criteria of an anxiety diagnosis (Epstein, Johnson, Varia, & Conners, 2001). Because of this, the benefit of STAI being more sensitive as an anxiety measure in relation to neurocognitive functioning might disappear. Moreover, STAI measures have been used to identify improvement in anxiety symptoms before and after methylphenidate treatment in children with ADHD. Research indicates that there is a significant decrease in trait anxiety measured after three months of treatment (Gurkan et al., 2009). Besides the positive effect of treatment, this illustrates that STAI might be a helpful and constructive measure that might quantify symptoms in a way that changes will be detected. As research suggests that the occurrence of comorbid diagnosis reduces the level of cognitive functioning in both children and adults with ADHD (Schatz & Rostain,

2006), it is reasonable to believe that the presence of high trait and state-anxiety might affect inhibition and set-shifting measured by the CWIT.

The Stroop-test and D-KEFS CWIT

The Stroop Color-word task is a widely used measure of inhibition (i.e., interference control) in studies with ADHD groups, and is recommended as a part of a neuropsychological test battery in clinical settings (Sorensen, Plessen, Adolfsdottir, & Lundervold, 2014). Children with ADHD are known to have a decreased performance on this test (Klingberg, Forssberg, & Westerberg, 2002). This is further supported by neuroimaging studies indicating that the anterior cingulate cortex, a region of the frontal cortex associated with the executive functions, are active while individuals perform Stroop-like tasks (Adleman et al., 2002; Bush, Luu, & Posner, 2000).

However, the validity of the Stroop test to measure inhibition has been doubted (Nigg, 2005). Sørensen et al. (2014) suggest that the inconsistent findings might be due to the use of Stroop interference scores depending on RT's instead of error scores, and found that using errors as a measure of inhibition were more sensitive for ADHD than using RT as a measure of inhibition. It was therefore concluded that errors should be recorded independent of RT. The D-KEFS CWIT version has exactly this advantage; the RT's is recorded independently from self-corrected errors. RT is a measure of the efficiency of the ability to inhibit the automatic response of word reading, whereas recording of errors is a measure of the failure to inhibit the automatic reading process (Sorensen et al., 2014). Different from the original version of the Stroop task and version typically being used, the CWIT includes a measure of set-shifting in addition to measuring inhibition. The few studies that have been accomplished using CWIT indicate promising results when it comes to separate children with ADHD from controls (Wodka et al., 2008).

The aims of the current study

In the current study we investigated the effect of high levels of trait- and state anxiety on measures of the executive functions of inhibition and set-shifting in a group of children with ADHD and in a control group of typically developing children. In line with Eysenck's ACT, we expected that higher levels of symptoms of anxiety would lead to longer RT's, and not increased level of errors, on measures of inhibition and set-shifting calculated from CWIT scores in both the children with ADHD and in the control group. The inhibition and set-shifting scores were calculated as residual scores where the influence of basic functions such a psychomotor speed (i.e., the color naming condition) and reading (i.e., the color word condition) were controlled for. The calculations of the residual scores were done in accordance to how the contrast scores of inhibition and set-shifting is being calculated in the D-KEFS algoritm. In previous studies of the effect of high levels of anxiety on inhibition in children with ADHD have used tasks (i.e., go/no-go and stop signal paradigms) that predominantly measures what Nigg (2001) refers to as behavioral inhibition, in that the tasks assesses the behavioral ability to inhibit automatic motoric responses. Nigg (2001) suggests, on the other hand, that the Stroop task is constituting a conflict between task relevant stimuli and distracting stimuli in accordance with the ACT, and expects therefore the Stroop task to be more cognitive demanding to perform than go/no-go and stop signal paradigms. Based on this, we hypothesized that higher levels of anxiety in children with ADHD and in typically developing children would associate with poorer inhibitory control and set-shifting abilities as measured with RT's. In relation to the diagnosis of ADHD, we expected a significant difference between the children with ADHD and the typical developing children on all the CWIT scores except for on the inhibition RT score, since previous research has shown this tendency (Sorensen et al., 2014).

Methods

Participants

The participants in this study were referred from outpatient child and adolescent psychiatric clinics in the municipality of Bergen on the grounds of a suspected ADHD diagnosis. Exclusion criterions were a current ADHD diagnosis, former or current use of psychostimulant medicine, suspicion of an autism spectrum diagnosis, or former head trauma. The control group consisted of typically developing children that was recruited from schools in geographical areas overlapping with the areas served by the outpatient clinics that the children with ADHD were referred from. In the current study 74 children were included consisting of 40 children fulfilling an ADHD diagnosis and 34 typically developing children. The children were in the age range of 8 to 13 years old (M: 10.10 and SD: 1.18), with a majority of boys (64.9 %).

Diagnostic Evaluation and Procedure

"Schedule for Affective Disorders and Schizophrenia for School-Age Children – Present and Lifetime Version" (K-SADS-PL; Kaufman et al., 1997) was used for the diagnostic assessment. K-SADS-PL is a semi-structured interview that uses the diagnostic criteria from the DSM-IV and was administered by clinical professionals with the participating children and their parents. K-SADS-PL has been shown to generate reliable and valid child psychiatric diagnoses (Kaufman et al., 1997). A board consisting of an experienced child psychiatrist and a clinical psychologist finally decided the diagnostics evaluations. The DSM-IV presents ADHD with three subtypes: predominantly inattentive type, predominantly hyperactive/impulsive and combined type. There were 12 children that fulfilled the criteria for the inattentive type, a subtype that is used when sufficient inattentive but insufficient hyperactive/impulsive symptoms are present. Further, 3 children met the criteria for the hyperactive-impulsive type, which is used when sufficient hyperactive/impulsive symptoms were present, but insufficient inattention symptoms. Finally, there were 25 children that were classified as the combined type, for children who

showed at least six inattentive and six hyperactive/impulsive symptoms, in addition to meeting all the other criteria. However, these subtypes were not included in the statistical analysis.

Color-word Interference Test (CWIT) from D-KEFS

The test includes four conditions: 1) Color Naming, 2) Word Reading, 3) Inhibition and 4) Inhibition/switching. In the Color Naming condition, the task is to name color patches as fast as possible. In the Word Reading condition, the task is to read color words as fast as possible. These two conditions measure basic lower-level cognitive skills, processing tempo and reading tempo respectively, as opposite to the third and forth conditions that measure EF as higher level cognitive functioning. The third condition measures inhibition, the task is to inhibit reading color words while naming the incongruent color the color word is printed in. In the fourth condition, the test person has to alternate between inhibiting an automatic response of reading color words while naming the incongruent color the color word is printed in, and reading the color word when the word is framed. The fourth condition requires both inhibition and set-shifting skills (Delis et al., 2001).

Instead of using the contrast scores that is generated with the D-KEFS algorithm, which comprise difference scores between the basic (color naming and color reading) and the more complex conditions (naming the incongruent color of color words and switching between naming the incongruent color of color words and reading color words) on the CWIT, we calculated residual scores of inhibition and set-shifting. We based these residual scores on the calculation of the contrast scores in CWIT, where the Inhibition score is controlled for the basic condition of color naming, and the Set-Shifting score is controlled for the third condition of naming the incongruent color of color words – namely inhibition. This means that the residual score based on the fourth condition is to mainly measure set-shifting. The residual scores where calculated by running linear regression analyses, where the third and

fourth conditions on the CWIT were included as outcome variables in separate analyses, and the color naming was included as an independent variable in relation to the calculation of the Inhibition score, and the naming of the incongruent color of color words was included as an independent variable in the calculation of the Set-Shifting score.

State-Trait Anxiety Inventory for children (STAIC)

The state- and trait version of State-Trait Anxiety Inventory for children (STAIC), "How I feel Questionnaire" was included as measures of anxiety symptoms (Spielberger & Edwards, 1973). The STAI consists of two forms with 20 items in each, one designed to measuring state-anxiety in the test situation and the other one trait-anxiety. In these forms, children are asked to decide whether statements are hardly ever, sometimes or often true.

Intellectual function – Full scale IQ (FSIQ)

FSIQ was assessed using a Norwegian translation of the Wechsler Intelligence scale for children, fourth edition (WISC-IV; Wechsler, 2003). See table 1 for mean and standard deviations for all groups.

Statistical Analysis

All statistical analyses were carried out using the IBM SPSS, version 20. An independent-samples t-test was run using group membership (i.e. ADHD and no ADHD) as the independent variable, and age and full-scale IQ (FISQ) as the dependent variables.

An analysis of bivariate correlations was conducted for the following variables: age, gender, FSIQ, scores of RT's and errors from inhibition and set-shifting of the D-KEFS CWIT, and State and Trait anxiety assessed by STAI. The results are presented in table 2. This was followed up by a Multivariate analysis of covariates (MANCOVA). Group membership was included as a between-group factor, with age and anxiety symptom scores as covariates. CWIT scores (set-shifting and inhibition) were used as dependent variables.

Results

A chi-square test was performed to test for gender difference between the groups of children with ADHD and the control children. The results showed that there were no significant differences between the groups in gender distribution.

An independent-samples t-test was conducted to compare age and FISQ scores for children with and without ADHD. As expected, the children with ADHD had significantly lower FSIQ than the control group. There was no significant difference in age between the ADHD group and the control group. The magnitude of the differences in the means was very small (eta squared=.003). For additional descriptive statistics see table 1.

Please insert table 1 about here

Bivariate Correlations of cognitive control functions scores

The relationship between age, FISQ, gender, state anxiety, trait anxiety, inhibition scores and set-shifting scores were investigated using Pearson product-moment correlation coefficient. Preliminary analysis was performed to ensure no violation of the assumptions of normality, linearity and homoscedasticity. A lower FISQ was significantly correlated with longer set-shifting RT and with higher error scores of inhibition and set-shifting. The FSIQ did, however, not correlate significantly with the inhibition RT score. Further, a lower FISQ correlated significantly with higher levels of trait anxiety. State and trait anxiety correlated also positively with each other. For a complete overview of the correlations, see table 2.

Please insert table 2 about here

Between-Group Comparison on the Measures of control functions

A MANCOVA was performed using ADHD as a between-group factor. Age and anxiety scores were used as covariates, and the inhibition RT, inhibition Error, set-shifting RT and set-shifting Error as dependent variables (vectors). The results showed a significant multivariate group-effect (Wilks'Lambda = .768; F (4.68) = 5.148, p = .001) of the ADHD factor in terms of their overall performance on CWIT. In the univariate analyses, the ADHD factor showed a significant between-group effect on the test measures (Set-shifting RT: F (1.71) = 12.00, p <.05; Set-shifting Error: F (1.71) = 8.02, p <.05; Inhibition Error: F (1.71) = 5.77, p <.05), except for on the inhibition RT score. The children with ADHD showed shorter set-shifting RT's and higher error scores on the measures of inhibition and set-shifting than the group of typically developing children (see Figure 1). Further, age covaried overall with the CWIT performance (Wilks' Lambda = .865; F (4,68) = 3.657, p = .040) and with the CWIT score of inhibition RT (F (1.71) = 7.35, p <.01).

Adding trait- and state anxiety as a dimensional covariate did not change the group differences. The results still showed a significant multivariate group-effect (Wilks' Lamba = .796; F (4.66) = 4.237, p =.004) of the ADHD factor in their overall performance on CWIT. And further, that the ADHD factor led to shorter RT's and higher error scores on all CWIT measures (Set-shifting RT condition: F (1.69) = 9.15, p <. 05; Set-shifting Error: F (1.69) = 5.65, p <.02; Inhibition Error: F (1.69) = 4.69, p <.05), except for on the Inhibition RT score. Higher levels of trait anxiety covaried significantly with the Inhibition RT score (F (1.69) = 5,5, p <. 05), but not on a multivariate level with the CWIT scores. Higher levels of state anxiety did not covary significantly with any of the CWIT scores. Additionally, age covaried again on a multivariate level with the CWIT scores (Wilks' Lambda = .842; F (4.66) = 3.087, p = .022) and with the inhibition RT score (F (1.69) = 9.31, p < .01).

Interaction effects between the ADHD factor and symptom level of trait anxiety were tested on the CWIT scores. The results showed that the effect of trait anxiety on the inhibition

RT score was not specific to one of the subgroups, but was a main effect across the total sample. See figure 1 for the estimated marginal means of interaction effects and the main effect of ADHD.

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Discussion

The present study predicted in accordance with the ACT that higher levels of state and trait anxiety in children with ADHD would slow down the RT's, but not affect the level of accuracy, on tasks measuring the executive functions inhibition and set-shifting. In relation to the diagnosis of ADHD, we expected a significant difference between the children with ADHD and the typical developing children on all the CWIT scores except for on the inhibition RT score. There were several findings of note. High trait anxiety associated with shorter inhibition RT, and not longer as expected, in both the children with ADHD. Furthermore, independent of level of trait anxiety, the children with ADHD showed a higher level of errors on the inhibition and set-shifting scores; however, they showed shorter set-shifting RT's compared to the controls, and not longer as expected.

The results showed that higher levels of trait anxiety, but not higher levels of state anxiety, affected the RT of the inhibition score from the CWIT. Higher levels of trait anxiety had a positive effect on the inhibition score, and not a negative effect as expected, in that the ADHD group with higher levels of trait anxiety was quicker than those with a lower level of trait anxiety. There was, as expected, no interaction effect between having an ADHD diagnosis and higher levels of trait anxiety on the outcome score of inhibition RT. This means that both in the children with ADHD and in the group of typically developing

children, a higher level of trait anxiety led to a more efficient executive functioning in relation to inhibitory control.

The association between high anxiety and enhanced inhibitory control seen in the current study is not in accordance with the ACT, which predicts higher levels of anxiety to have detrimental effects on inhibitory control and on set-shifting. The ACT (Eysenck et al., 2007) assumes that higher levels of state and trait anxiety should slow down the performance on a Stroop task like CWIT. The theory describes an attentional conflict between task relevant stimuli, and distracting information in the Stroop paradigm, but also an attentional conflict between task relevant stimuli and possible threat-related stimuli in the environment or in the thoughts of an individual with high levels of anxiety. The finding that higher levels of trait anxiety in children with ADHD displayed a better inhibitory control function overlaps with previous findings of a positive effect of high anxiety on behavioral inhibition in children with ADHD (Bloesma et al., 2013). The association between higher levels of anxiety and more efficient inhibitory control in the children with ADHD in the current study fits therefore with Quay's (1988) theoretical framework. His motivational theory suggests that ADHD and anxiety might lead to better inhibitory control than ADHD alone. Thus, when children display higher symptom levels of anxiety and ADHD both the BIS and BAS systems reach a better balance, resulting in improved inhibition in a task like CWIT. Yet, not all of the results in the current study are explained sufficiently by Quay's theory. Higher levels of anxiety did not affect the error scores of inhibitory control, a finding that does not support Quay's theory. Instead, the lack of an association between anxiety and the error scores can be seen in support of the ACT. It is though important to mention that ACT is not a theory designed for ADHD, and does not claim any specific effects of anxiety in this group of children on executive function tasks. Thus, the positive association between high anxiety and inhibition RT was also shown in the group of typically developing children in the current study. This shows that

the lack of support for the ACT in the ADHD group is not due to clinical characteristics that the ACT has not taken into account in the postulations of the effect of high anxiety on executive functions.

It may be the approach in calculating the scores of inhibition and set-shifting on the basis of performance on the CWIT that can explain the finding in the present study of high anxiety to positively affect inhibitory control, and not slow down the inhibitory control function as expected. The previous findings of slower RT's is associated with higher anxiety on inhibition tasks in children with ADHD (Bloesma et al., 2013) may result of anxiety leading to a generally lower psychomotor speed, and not leading specifically to slower speed in processing tasks requiring attentional control; inhibitory control and set-shifting. In the current study, the effects of a general slower psychomotor speed are controlled for when calculating the response time scores of inhibition and set-shifting. This control of slower psychomotoric speed can explain the positive effect of anxiety appearing on the inhibition RT score. Future studies should compare the effect of higher levels of anxiety on psychomotor speed to the effect anxiety has on speed specifically associated with inhibitory control and set-shifting.

The non-significant association between high trait- and state anxiety and the set-shifting condition are not in accordance with neither the ACT nor Quay's (1988) theory. The results indicate that trait-anxiety did not affect the children's ability to perform this measure of set-shifting in accuracy or RT's. In an extension of the ACT, Owens, Stevenson, Hadwin, and Norgate (2014) suggest that individuals high in trait-anxiety will be motivated to do well on a test to avoid negative evaluation, yet this advantage is only possible if there are enough cognitive resources to offset. According to this extension of the ACT, it might seem that the children had available cognitive resources to perform this task. This is in contrast to Nigg (2001) who suggested that the Stroop task would prove more cognitive demanding to perform

than go/no-go and stop signal paradigms, and that anxiety would have a negative effect on a Stroop-like task. Another possible explanation might be that the high trait anxious individuals have an inefficient use of the shifting function even though there are non-significant effects of trait or state anxiety on this condition. A body of research indicates that high anxiety individuals have higher brain activation in areas associated with the shifting function compared to low-anxious individuals (Ansari, Derakshan, & Richards, 2008; Hajcak, McDonald, & Simons, 2003; Righi, Mecacci, & Viggiano, 2009; Wager, Jonides, & Reading, 2004). For instance, Righi, Mecacci & Viggiano (2009) found that subjects high or low in anxiety may exhibit similar performance on a cognitive test, but differences in anxiety are still revealed by different patterns of cortical activity. Thus, one cannot preclude that high-anxious individuals have an inefficient use of the shifting function at a cortical level, although not visible on the performance of measures of set-shifting used in the present study.

As expected, the CWIT score of errors distinguished children with ADHD from children without ADHD on both the inhibition and the set-shifting measures. This is in line with previous research that has recorded the error scores independently from the response time (Sørensen et al., 2014). Previous meta-analyses have not applied this independent recording, and relied on response time in assessing inhibition on the Stroop (Lansbergen, Kenemans, & van Engeland, 2007; Van Mourik, Oosterlaan, & Sergeant, 2005). They have reached divergent conclusions depending on the statistical approach used to calculate the classical Stroop effect of inhibition (Lansbergen, Kenemans, & van Engeland, 2007; Van Mourik, Oosterlaan, & Sergeant, 2005). This highlights two important effects: Firstly, that the results may differ based on which statistical approach being used, an effect that has been pointed out in previous research (Halleland et al., 2012; Sørensen et al., 2014). In the current study, the classical difference score was used to calculate the inhibition scores of RT and errors, and then only a significant effect of ADHD was expected in relation to the inhibition

error score (Sørensen et al., 2014). Secondly, it highlights D-KEFS benefit of recording both these scores separately and use contrast scores to standardize the difference between the variables (Delis et al., 2001). Furthermore, the results revealed that children with ADHD had, unexpectedly from previous findings in adults with ADHD (Halleland et al., 2012), shorter set-shifting RT's, and not longer, compared to controls. Since these children did perform better in the set-shifting trial than the preceding inhibition trial, the results might be related to a practice effect. The participants may have improved their ability to inhibit the word reading response after the inhibition trial is completed, leading patients to perform faster at the forth trial, the set-shifting condition. It may also be that children with ADHD do not have specific difficulties with set-shifting as measured with the CWIT, and when we have controlled out the effect of inhibition and psychomotor tempo in the calculation of the set-shifting score, they seem to be better than the typically developing children in shifting between conditions. The combination of a shorter RT and higher error scores on the set-shifting measures in the current study may thus indicate an impulsive style in children with ADHD where they act before they reflect, leading to a low accuracy in their performance.

FSIQ is known to affect executive functions, and children with ADHD have on average lower FSIQ scores than normally developing children (Dennis et al., 2009). Therefore, the effect of FSIQ was expected to overlap with the effect of ADHD (see Sørensen, et al. 2014). This was also shown in the current study in that FSIQ associated with the same CWIT scores that ADHD affected. For example, the FSIQ did not significantly correlate with the inhibition RT score, which ADHD did not show to affect. However, the current study also shows that FSIQ correlated significantly with the set-shifting RT score, where the children with ADHD had faster RT's than the controls. This may relate to this effect being a result of less inhibitory control than the typically developing children, in a quick response style where the children with ADHD do not use time to reflect before they

act, and therefore do high levels of errors (i.e. a poorer set-shifting error score than controls). A poorer inhibitory control and lower levels of intelligence typically associate in children with ADHD (Barkley, 2008).

Strengths and limitations

One of the strengths in the present study is that all the participants were diagnosed as a part of the procedure, and were therefore not using any psychostimulant medication at the time the data was obtained. Additionally, the children in the current study had low numbers of comorbid disorders, other than anxiety. This might be a strength since it reduces the chance that the results being influenced by other disorders. Nevertheless, anxiety can have some overlap in the symptomatology with for instance depression and oppositional defiant disorder, which are often comorbid to ADHD (Kadesjö & Gillberg, 2001; Murphy, Barkley, & Bush, 2002). On this basis, it is important to note that the K-SADS-PL might not have been sensitive enough to discover potential comorbidity and that this could have affected the results in the study.

Some limitations should be noted. These include uneven gender distribution, size of the sample, theory used and impact of FSIQ. These limitations will be addressed individually:

Uneven gender distribution. In the current study gender was not controlled for, besides the testing for significant differences between the gender compositions of each group. Uneven gender distribution is known to be a risk factor that might have influenced the results (Kasper, Alderson, & Hudec, 2012).

Size of the sample. The selection in the current study can be regarded as relatively small, and therefore the statistical power of the analyses conducted might have been limited. Additionally, the size of the sample made it difficult to take the ADHD subgroups into account. For instance, a child with an ADHD predominantly inattentive type might be affected differently by anxiety than a child a predominantly impulsive type of ADHD. It may

also be the case that anxiety has a differential effect on the various subtypes (Hartman, Willcutt, Rhee, & Pennington, 2004). Future studies with larger samples will allow for these eventualities to be explored.

Impact of IQ: Children with ADHD in the current study were significantly lower in FSIQ than their peers in the control group. To avoid the problem of FSIQ as a confounding variable, we did not include FISQ as a covariate in between-group analyses. There are several statistical arguments for not including IQ as a covariate (Dennis et al., 2009); IQ does not meet the requirements for a covariate and using it as a covariate might produce overcorrected and counterintuitive findings (Dennis et al., 2009). Instead, we included FSIQ in the bivariate correlation analyses for transparency of the effect of FSIQ on ADHD.

Implications

The finding in the current study reveals that high levels of trait-anxiety in children with ADHD improves the children's performance on an inhibition-based test. However, anxiety seems to be characterized by emotional dysregulation that is associated with motivational aspects (Pennington, 2002), and earlier studies indicate that not all studies reveal this ameliorative effect (Abikoff et al., 2002). Since specific situational or environmental factors may increase or reduce this dysregulation, it is important to identify these situations or environmental factors, and adjust accordingly in test-situations for children. This might have important implications for the understanding of trait anxiety as an important factor that might influence children with ADHD in both positive and negative ways. Such adjustments may bring about findings that might broaden the understanding of children with ADHD and trait-anxiety. This will carry implications for how children with ADHD and anxiety are perceived by parents, teachers and peers.

ADHD with co-occurring anxiety is a complex phenomenon. Impulsive behavior is closely linked to ADHD, and it appears that anxiety at least under some conditions, alleviate

this effect. This may also have implications in form of difficulties in identifying a correct diagnose for these children. Some studies indicate that this group shows less hyperactivity and less conduct disorder symptoms compared to children with "pure" ADHD (Jensen, Martin, & Cantwell, 1997). Children with emotional symptoms are less frequently identified and referred to mental health services compared to children with more externalizing symptoms (Angold, Costello, Farmer, Burns, & Erkanli, 1999; Wu et al., 1999). The results in the current study suggest that children with high trait anxiety perform faster on a cognitive test than children with a "pure" ADHD-diagnosis. Considering 25 % of children with ADHD have a comorbid anxiety diagnosis (Tannock, 2000) it is reasonable to believe that even more children with ADHD display high-trait anxiety. This highlights the importance of a sufficient clinical screening when working with children with ADHD, even when they do not fulfill the criteria for a comorbid anxiety diagnosis.

Warrant for further research

The discrepancies in findings related to the effect of anxiety on ADHD highlight the need for further research on this topic. Future studies should include different measures of inhibition and set-shifting including motivational and emotional conditions, to investigate in which situations these effects differ. Inclusion of brain imaging techniques could strengthen such a study design, since it might investigate brain activity in the relationship between inattention and emotional problems when solving cognitive tasks.

Including more ecologically valid measures of the everyday life functioning might also give valuable insight in displaying how children with ADHD and anxiety differs from those with a "pure" diagnosis, and if their performance on measures of inhibition might predict other performance, for instance in test situations. We recommend that future studies include the D-KEFS CWIT, as the small amount of research that have used this measure have given promising results (Halleland et al., 2012; Yang et al., 2011).

Choice of measures. In this study we compared inhibition and set-shifting scores of ADHD-children with and without high trait- and state anxiety. To the best of our knowledge, this comparison has not been made before on the D-KEFS CWIT. Other measures of inhibition include the classical version of the Stroop test, the Continuous Performance Test (CPT), the go/no go task and the stop task. This illustrates the challenges in comparing different results when different measures are used. In accordance with this view, Kramer et. al. (2007) claims that the inconsistency in the literature concerning executive functioning in children with ADHD might be related to the diversity in defining, and measuring the concept.

Conclusions

The present study has demonstrated, using a variance analysis, the effect of anxiety on executive functions in children with ADHD. Moreover, the results imply that anxiety can have a mitigating effect on executive functions under certain conditions. However, only high trait anxiety correlated with the inhibition RT score, and not with the set-shifting RT scores or the error scores. The present study's contributions are the use of two different contrast measures to control for more basic functions, which may have led to high trait anxiety associating with a quicker inhibition response time score, and not a slower score, when the general basic, psychomotoric tempo was controlled for. Further studies should combine measures of neuropsychological function with more detailed clinical information as well as brain imaging techniques. Studies focusing on emotional problems (i.e. anxiety) within the ADHD literature are still lacking. Knowing more about the diagnosis and associated performance gives the opportunity to adjust the environment accordingly, perhaps preventing development of more complex problems with this group of children.

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Table 1 *Descriptive Statistics*

	Control (N=34)		ADHD (N=40)		T-value/ Chi Square	Df	P
	M	SD	M	SD			
Age	10.02	1.04	10.16	1.30	-.49	72	.11
FSIQ	109.15	16.30	88.27	10.91	6.35	56	.05
Inhibition RT	-.11	1.01	.07	.92	-.78	72	.44
Inhibition Error	-.28	.84	.23	.98	-2.35	72	.02
Set-shifting RT	.41	.65	-.28	.98	3.64	72	.00
Set-shifting Error	-.34	.89	.29	.98	-2.86	72	.01

Note. FSIQ= Full Scale IQ, RT= Response Time

Table 2 *Bivariate Correlations*

	Inhibition		Set-shifting	
	RT	Error	RT	Error
Total sample n=74				
Age	-.299**	-.092	-.169	.003
Gender	-.034	.054	-.012	-.083
FSIQ	-.106	-.381**	-345**	-.422**
Inhibition RT	1	.197	.022	-.091
Set-shifting RT	.022	-.045	1	-.543**
Inhibition Error	.197	1	-.045	.029
Set-shifting Error	-.91	.029	-.534**	1
State ANX	-.087	-.040	-.175	.139
Trait ANX	-.198	.139	-.194	.221

Note. FSIQ= Full scale intelligence quotient, RT= Response time, State ANX= State anxiety, Trait ANX= Trait anxiety, ** Correlation is significant at the 0.01 Level (2-tailed)

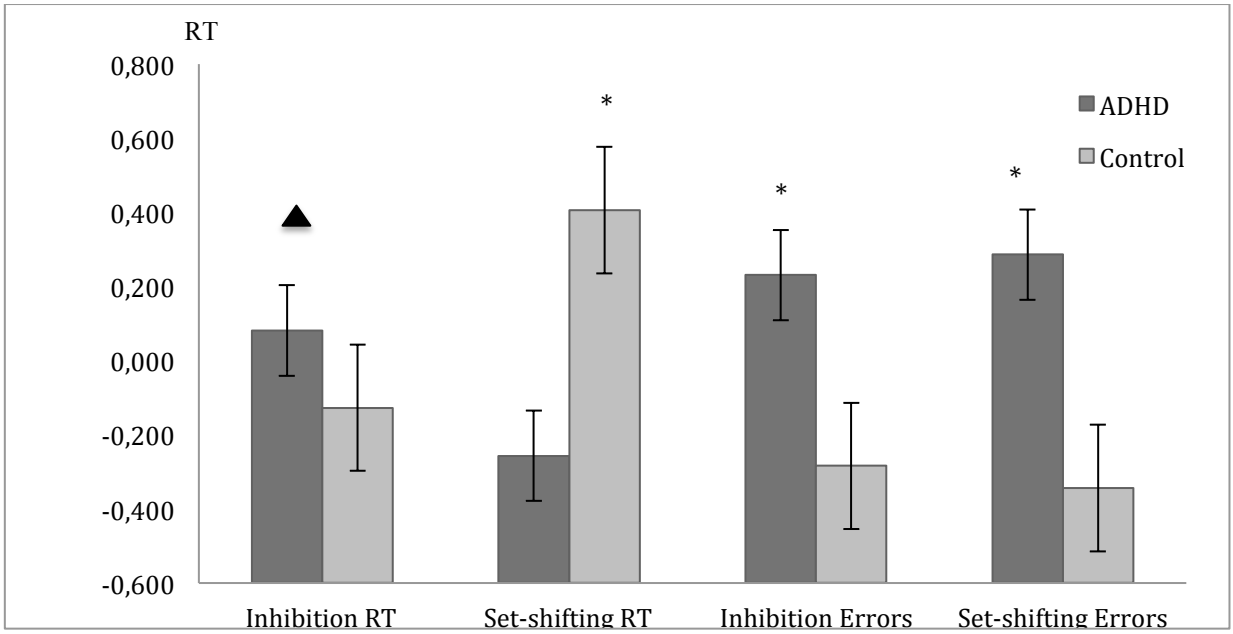

Figure 1. *The estimated marginal means from the between-group analyses of interaction effects and of main effect of ADHD.* *p<.05, ▲ = covariated with trait anxiety.

Appendix A

Guidelines for publishing, Journal of attention disorders

Journal of Attention Disorders (*JAD*) focuses on basic and applied science concerning attention and related functions in children, adolescents, and adults. *JAD* publishes articles including, but not limited to, diagnosis, comorbidity, neuropsychological functioning, psychopharmacology, and psychosocial issues. The journal welcomes manuscripts addressing timely, notable topics in practice, policy, and theory, as well as review articles, commentaries, in-depth analyses, empirical research articles, and case presentations or program evaluations that illustrate theoretical issues or new phenomena.

Submission

Style for all submissions must follow that of the *Publication Manual of the American Psychological Association* (6th ed.). Submission to the journal implies that the manuscript has not been published elsewhere and is not in consideration by any other journal. Submission to the Applied Research section should be no more than 30 double-spaced pages, including an abstract of 150 words or less using a sectional guideline (Objective, Method, Results, and Conclusion), a brief biographical statement for each contributing author, endnotes, references, tables, and figures, all on separate pages. Author names and affiliations should appear on a separate cover page and the manuscript should be formatted for anonymous review.

Journal of Attention Disorders only accepts submissions electronically. Electronic submissions should be sent to http://mc.manuscriptcentral.com/jad. Submissions must be in Microsoft Word. Please ensure that tables are editable files in Word or Excel, not images. Artwork should have a resolution of 300 dpi or higher. Images are best submitted separately from the text document. Please do not embed images into your file, as embedding raster

image files (photographs) in Word or similar programs automatically reduces the resolution below what is needed for quality print publication.

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Biographical statement

Linn Løkeland Krebs (b.1988) is a psychology student at the University of Bergen, graduating in January 2014. Her research interests are children and adults with ADHD.

Ingrid Arnestad (b.1988) is a psychology student at The University of Bergen, graduating January 2014. Her interests in research are ADHD and emotional problems in children.