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**Distinct Patterns of Executive Dysregulation Distinguish Children
with Tourette Syndrome from Children with ADHD or Autism
Spectrum Disorders**

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Abstract (203 words)

Everyday executive regulation was investigated in children with Tourette Syndrome (TS) compared with children with Inattentive or Combined subtypes of Attention-Deficit/Hyperactivity Disorder (ADHD-I, ADHD-C), children with Autistic Spectrum Disorders (ASD) and Typically Developing Children (TDC). **Method:** Nineteen children with TS, 33 with ADHD-C, 43 with ADHD-I, 34 with ASD, and 50 TDC participated (8-17 yrs.). Parents completed the Behavior Rating Inventory of Executive Function (BRIEF). **Results:** Children with either TS, ADHD-C, ADHD-I or ASD had significantly greater executive function problems on all BRIEF scales compared with TDC. Children with TS or ADHD-C were higher than those with ADHD-I or ASD on the Inhibit scale, and children with ASD were higher than those with ADHD-I or ADHD-C on the Shift scale. Scale configurations dissociated TS from ASD on the Emotional Control (EC) and Shift scales, TS from ADHD-C on the EC and Inhibit scales, and TS from ADHD-I on the EC and Plan/Organize scales. **Conclusion:** Paired BRIEF scales successfully dissociated executive function problems in children with TS from other common neurodevelopmental disorders. Identifying a distinguishing pattern of executive dysregulation for children with TS using a rating scale and strategic scale classifications represents a promising tool for the clinician treating this group of children.

Keywords: Tourette syndrome, ADHD, Autistic Spectrum Disorders, Executive function, EF behaviors.

Introduction

Tourette Syndrome (TS) is a neurodevelopmental disorder characterised by motor and phonic tics persisting for a minimum of one year (Plessen, 2013). Whereas the diagnostic criteria are restricted to the presence of chronic tics, executive dysregulation affecting attentional, behavioral and emotional control is associated with the disorder and often represents the most debilitating aspect of the condition (Carter et al., 2000; Singer, 2005). As many as 70% of patients with TS in clinical settings report experiencing emotional control problems (Budman, Rockmore, Stokes, & Sossin, 2003), and these problems tend to increase during childhood for children with TS (Hoekstra, Lundervold, Lie, Gillberg, & Plessen, 2013). Problems regulating emotions present more frequently in children than in adults, are more problematic for children than for adults and are common reasons for psychiatric referral in children with TS (Budman, Bruun, Park, Lesser, & Olson, 2000).

There is general agreement that adaptive control of behavior depends on intact executive function (EF) (Jurado & Rosselli, 2007), which refers to the top-down, mental processes involved in monitoring, regulating and mediating thoughts, emotions and behavior (Diamond, 2013; Zelazo & Cunningham, 2007). Impaired EF is, however, not only a characteristic feature of TS but it is also associated with a wide range of neurodevelopmental disorders including Attention-Deficit/Hyperactivity Disorder (ADHD) and Autistic Spectrum Disorders (ASD) (Happé, Booth, Charlton, & Hughes, 2006; Hill, 2004a, 2004b; Mahone, Koth, Cutting, Singer, & Denckla, 2001; Wåhlstedt, Thorell, & Bohlin, 2008). Emerging evidence indicates a pathogenic association and a phenomenological overlap among these three childhood-onset disorders (Clarke, Lee, & Eapen, 2012; Freeman & Tourette Syndrome International Database, 2007; Roessner, Becker, Banaschewski, Freeman, & Rothenberger, 2007). Despite indications of an overlap of symptoms, however, few studies have compared everyday executive dysregulation in children with TS to children with other common

neurodevelopmental disorders. Obtaining a more distinct characterization of EF problems in children with TS might improve treatment prospects for this disorder.

Self-regulatory abilities needed for adaptive functioning in everyday situations are commonly measured using rating scales, such as the Behavior Rating Inventory of Executive Function (BRIEF). The BRIEF assesses children's behavior in natural settings and provides a measure of fundamental emotional, behavioral and cognitive regulatory processes (Gerard A Gioia, 2000). The rating scale is completed by a parent or teacher and provides eight non-overlapping scales reflecting commonly agreed upon domains of EF behaviors: Inhibit, Shift, Emotional Control, Working Memory, Initiate, Plan/Organize, Organization of Materials, and Monitor, which are combined to form three broad classifications of executive functioning— Behavioral Regulation, Metacognition, and the Global Executive Composite (GEC).

Research applying the BRIEF indicates that, relative to TDC, the rating scale is sensitive in detecting behavior difficulties in children with TS (Mahone et al., 2002), ADHD (McCandless & O'Laughlin, 2007; Toplak, Bucciarelli, Jain, & Tannock, 2008), and ASD (Gilotty, Kenworthy, Sirian, Black, & Wagner, 2002; L. E. Kenworthy et al., 2005).

In a study comparing EF behavior in children with TS with and without comorbid ADHD to children with ADHD on the BRIEF, the children with only TS were rated as less impaired than the children with ADHD or with TS+ADHD on scales measuring behavioral inhibition and working memory and on the Metacognition Index, Behavioral Regulation Index and Global Executive Composite (Mahone et al., 2002). The subtypes ADHD-I and ADHD-C are by many considered distinct disorders (Milich, Balentine, & Lynam, 2001), and several studies administering the BRIEF in children with ADHD have discriminated between ADHD-C and ADHD-I. In a study by Gioia and colleagues, the Inhibit subscale was useful in distinguishing the more severe inhibitory impairment characteristic of children with ADHD-C from less severe impairment in children with ADHD-I (G. A. Gioia, Isquith, Guy, &

Kenworthy, 2000). In a separate study, the results on the Behavior Regulation Index indicated more severe behavior regulation problems in children with ADHD-C compared to children with ADHD-I (McCandless & O'Laughlin, 2007). To our knowledge, no studies have compared children with TS to these two subgroups of ADHD on a rating scale assessing everyday EF behavior.

ASD is a term encompassing children with High Functioning Autism (HFA), Asperger's Syndrome (AS), or Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS). Evidence for executive dysfunction in ASD is high and is associated with the social and cognitive difficulties observed in these children (Hughes, Russell, & Robbins, 1994; Ozonoff, 1997; Pennington & Ozonoff, 1996). A study comparing children with ASD to children with ADHD-C and ADHD-I on the BRIEF reported more severe behavior regulation difficulties for the ASD group compared to both ADHD subgroups (Semrud-Clikeman, Walkowiak, Wilkinson, & Christopher, 2010). Another study reported the ASD group to be distinguishable by more severe impairment in cognitive flexibility as measured on the BRIEF Shift scale, whereas the ADHD-C group was unique in the frequency and severity of inhibitory deficits (Gerard A Gioia, Isquith, Kenworthy, & Barton, 2002). An extensive review concludes that the severity and pattern of EF deficits are distinct for ASD and ADHD, with larger effect sizes being associated with impaired cognitive flexibility in ASD than for any other executive dysfunction measured in ADHD or TS (L. Kenworthy, Yerys, Anthony, & Wallace, 2008; Pennington & Ozonoff, 1996).

In sum, the existing literature suggests that there are different executive function related behavior characteristics associated with common neurodevelopmental disorders including TS, ADHD-C, ADHD-I, and ASD. Despite examples of individual scales in the BRIEF identifying behavior characteristics associated with some disorders, the general picture is that individual subscales and indexes alone cannot be used to differentiate between

diagnoses (Gerard A Gioia et al., 2002). In most rating scales, measuring an overarching psychological construct thought to be composed of distinguishable sub-processes will be sensitive to the general effect of severity. The severity dimension, which is the rationale for computing sum scores for cognitive constructs, provides good power to differentiate between clinical subjects and TDC. Yet analyzing the severity of disturbances is seldom sufficient to discriminate between clinical groups. For this we need qualitative analyses of profiles.

Children with TS, ASD, ADHD-I or ADHD-C, for example, may be expected to be rated as having more difficulties regulation emotions than their typically developing peers. However, whereas parents of children with TS report emotional control difficulties to be the most problematic behavioral symptom (Budman et al., 2003; Dooley, Brna, & Gordon, 1999), research has not identified such difficulties to be the most problematic behavioral deficit in children with ASD, ADHD-I, or ADHD-C. Nevertheless, subjects with ASD, ADHD-I or ADHD-C score higher than TDC on the Emotional Control (EC) subscale on the BRIEF (Gilotty et al., 2002; McCandless & O'Laughlin, 2007). A high score on the EC subscale, however, may merely reflect the level of severity of EF disturbance, as will be the case when other subscales are also scored high, or even higher than the subjects' EC score. Level of severity may differ both within and between clinical groups. By contrasting the EC scale score with another strategic scale score, however, we can control for the severity effect. For example, subjects with ASD are considered to be characterized by cognitive inflexibility (Corbett, Constantine, Hendren, Roche, & Ozonoff, 2009), whereas subjects with TS are expected to exhibit a relatively smaller impairment in this domain. A plausible hypothesis would then be that while both groups can have somewhat elevated ratings on many BRIEF scales, a relatively higher EC score in the context of a relatively lower Shift score would be more typical of children with TS in comparison with subjects with ASD, and vice versa. By applying this strategic analysis approach, two scales based on highly characteristic behavior

patterns associated with the conditions are chosen rather than looking for an overall pattern among all eight BRIEF subscales.

Similarly, evidence from factor and cluster analytic studies in children with ADHD suggests that ADHD-C is more characterized by a lack of inhibitory control whereas ADHD-I is more characterized by sluggish, disorganized behavior (Diamond, 2005; Milich et al., 2001). Symptoms of disinhibition and disorganization in children with TS are most often associated with a comorbid ADHD diagnosis. Thus, we might expect that a high EC score in the context of a relatively lower Inhibit score would characterize children with TS compared to a low EC score but high Inhibit score in children with ADHD-C. Similarly, a high EC score in the context of a lower Plan/Organize score would characterize TS, compared to a low EC score but high Plan/Organize score in children diagnosed with ADHD-I. The current practice of interpreting BRIEF results already makes use of this strategic qualitative process approach, e.g. high Working Memory impairment and less severe impairment in Inhibition is an indication of ADHD-I rather than ADHD-C (G. Gioia & Isquith, 2001). Accordingly, when trying to differentiate between the two ADHD subtype diagnoses, two scales may be considered strategic, while the other six scales may be less uniquely relevant.

The aim of the current study is to identify EF behavior characteristics in children with TS that may distinguish them from typically developing children and from children with ADHD-C, ADHD-I, or ASD. Two primary hypotheses were explored. First, a review of the EF literature indicates that children with TS may exhibit deficits in EF behavior regardless of the co-occurrence of comorbidities. In terms of the severity of EF disturbances, we expect parents of children with TS to report more severe problems on all scales and general indices of EF behavior compared to the TDC group. We also predict that neither overall severity nor severity of impairment on individual scales will be sufficient to discriminate between the clinical groups. Second, we expect that applying strategic qualitative profile analyses may

differentiate the TS subjects from the children with ASD, ADHD-C or ADHD-I, who are also characterized by clinically impaired EF behavior. We predict that a scale configuration consisting of the subscales EC and Shift will differentiate between TS and ASD, the EC and Inhibit subscales will differentiate the TS from the ADHD-C and, the EC and Plan/Organize will discriminate between the TS and the ADHD-I groups. A more accurate characterization of problem behaviors associated with TS beyond tics should improve treatment outcome and differential diagnostics for children with TS.

Method

Participants

The sample consisted of 179 children between 8 and 17 years (19 with TS, 33 with ADHD-C, 43 with ADHD-I, 34 with ASD and 50 TDC). All clinical participants were first-time referrals to the Child and Adolescent Mental Health Centres in Innlandet Hospital Trust (IHT) in Norway. The TDC were recruited from local schools and received a small gift for participating. The participants in the groups did not differ significantly in age, educational level or ethnic background. They did differ with respect to distribution of gender, mother's education level, estimated IQ based on results from the Wechsler Abbreviated Scale of Intelligence (WASI) and symptoms of inattention and hyperactivity/impulsivity.

Demographic and clinical characteristics are presented in Table 1. Four of the participants were receiving medication for behavior problems at the time of assessment (two children with TS: low dose of Quetiapine and Aripiprazole, respectively; two children with ADHD: low dose of Risperidone and Quetiapine, respectively). None of the other participants were on medication during the six months prior to testing, nor upon testing, as most of the participants were first-time referrals to child health services. Six of the children with TS (32%) had co-occurring ADHD (three with ADHD-I and three with ADHD-C), which is a common rate for

this population (Robertson, Eapen, & Cavanna, 2009). (More details about the TS group are available in (Hovik, Plessen, Skogli, Andersen, & Øie, 2013), the ADHD group in (Skogli, Teicher, Andersen, Hovik, & Øie, 2013), and the ASD group in (Andersen, Hovik, Skogli, Egeland, & Oie, 2013).

INSERT TABLE 1 ABOUT HERE

Ethics statement

Parents and children (12 years and older) signed consent forms before participating in the study. The study was approved in advance by the Regional Committee for Medical Research Ethics in Eastern Norway (REK-Øst), and by the Privacy protection ombudsman for research at Innlandet Hospital Trust. The study was conducted in accordance with the Helsinki Declaration of the World Medical Assembly.

Procedures

Diagnostic assessments were based on interviews of participants and parents separately using the Schedule for Affective Disorders and Schizophrenia for School Age Children/Present and Lifetime version – 2009 (K-SADS-PL) (Kaufman et al., 1997). Exclusion criteria were premature birth (< 36 weeks), neurological disorder, estimated full scale IQ < 70, or previous stimulant treatment. The interviewers were experienced psychologists and educational therapists. The results from the K-SADS-PL interviews and supporting information were reviewed independently by the supervising senior clinician who is a specialized psychologist in neurodevelopmental disorders (M.Ø.). Disagreements were discussed in meetings with all the clinicians present to arrive at a 'best estimate' DSM-IV

consensus diagnosis (Gargaro, Rinehart, Bradshaw, Tonge, & Sheppard, 2011). The diagnostic evaluations were supplemented with information provided in self-report forms completed by the parent or parents: the Yale Global Tic Severity Scale (YGTSS) (Leckman et al., 1989), the ADHD Rating Scale-IV (DuPaul, Power, Anastopoulos, & Reid, 1998), the Autism Spectrum Screening Questionnaire (ASSQ) (Ehlers, Gillberg, & Wing, 1999), and Child Behavior Checklist (CBCL) (Achenbach & Rescorla, 2001). Normative data from the ASSQ (Ehlers et al., 1999), the ADHD Rating Scale IV manual (DuPaul et al., 1998), and T-scores above 65 on the syndrome and DSM-oriented scales in CBCL (Achenbach & Rescorla, 2001) were applied to assess clinical significance. Information from teachers about the child's school functioning (academic, social and emotional competencies) is mandatory on referral to IHT and was available to the clinicians. If both parents could not report on K-SADS-PL and rating scales together, information from mothers was used. When information on the K-SADS-PL was not consistent with rating scales, information from K-SADS-PL was emphasised in the assessment. All diagnoses had to fulfil DSM-IV criteria (Association & DSM-IV., 1994). TDC were also screened in interviews (child and parent separately) for any psychiatric condition fulfilling DSM-IV criteria, as well as head injuries involving loss of consciousness or known dyslexia.

Participants were part of a larger research project investigating cognitive, emotional and behavioral development in children and adolescents with neuropsychiatric disorders. The data for the current study were collected for the children with TS, ADHD-C, ADHD-I, ASD and TDC as part of a standard clinical neuropsychological evaluation.

Measure of EF behavior

One or both parents of each child completed the parent version of the BRIEF (G. A. Gioia et al., 2000), the most widely used rating scale of executive functions across the life span. The

BRIEF for children and adolescents aged 5-18 years includes 86-item parent and teacher forms that allows professionals to assess everyday behavior in the home and school environments (G. A. Gioia et al., 2000). The rating instrument is composed of eight clinical scales, two broad indices and one overall score. The Behavior Regulation Index (BRI) consists of the clinical scales Inhibit, Shift, and Emotional Control, and the Metacognition Index (MCI) consists of the clinical scales Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor scales. An overall measure of behavior problems is given in the Global Executive Composite (GEC). The current study used the Norwegian version of the parent-rating form, which has shown high internal consistency (Chronbach's $\alpha = .76-.92$) (Fallmyr & Egeland, 2011) and similar levels to that reported for the English version (.80-.98) (Gerard A Gioia, 2000). Evidence of construct validity for the instrument has been demonstrated by convergent and discriminant analyses with several established behavior and attention rating scales (G. A. Gioia et al., 2000). The results from a Norwegian study using the BRIEF to rate adults indicated that healthy Norwegian controls score significantly lower than healthy American controls (Løvstad et al., 2012). Results reported in a study in the Netherlands involving a similar age group as in the current study suggest that the American norms for TDC are higher than for European TDC (Huizinga & Smidts, 2010). Accordingly, the clinical range in the current study is based on the mean value for the Norwegian TDC in the study, and we have applied the same criteria for clinical cut-off rates as in the original manual (G. A. Gioia et al., 2000). Higher T-scores on the BRIEF indicate a higher degree of impairment.

Scale classifications

Based on the earlier mentioned research on behavior characteristics of the clinical groups, pairs of clinical subscales were strategically selected to investigate their ability to differentiate

between TS and other clinical groups. In the analyses comparing the TS and ADHD-C group, the EC and Inhibit subscales were used. For the TS and ADHD-I group comparison, the Emotional Control and Plan/Organize subscales were applied. In the TS and ASD comparison, the Emotional Control and Shift subscales were analyzed. Table 2 provides an overview of the percentage of children in each clinical category scoring in the clinical range on the specific subscales.

INSERT TABLE 2 ABOUT HERE

Data Analyses

Data analyses were conducted using the statistical package IBM SPSS Statistics for Windows, version 18.0 (SPSS, Inc., Chicago, IL). Demographic characteristics were investigated using the Chi-square test for independence (nominal variables) and analysis of variance (ANOVA) (continuous variables) followed up by post-hoc tests for group comparisons when appropriate. Ratings on the individual subscales and indices on the BRIEF data were analyzed with ANOVAs and post-hoc analyses with a Bonferroni correction for multiple comparisons. Repeated measures ANOVAs were conducted on each pair of scales to compare the parent ratings of the children with TS with each of the other clinical groups. For the evidence-based assessment analyses of the scale pairs, a categorical variable was derived for each pair by subtracting the score on the paired scale from the EC scale, i.e. Shift scale minus EC scale. A positive number was labelled “1” indicating a higher level of EC compared to the paired scale, and a negative number was labelled “2” indicating the opposite. A Chi-square test for independence was then conducted for each pair to examine rates of classification into diagnostic groups.

Results

Overall, ANOVAs with post-hoc comparisons (Bonferroni) revealed that parent ratings on the BRIEF were consistently significantly higher on all clinical scales and indexes for each of the clinical groups compared with the TDC. This finding suggests a greater level of global EF impairment in children with clinical diagnoses. (See Table 3 for overview). In the ANOVAs examining individual scales, the TS/ADHD-C groups were rated as significantly more impaired than the ADHD-I/ASD groups on the Inhibit scale, and the ASD group was rated as significantly more impaired than the ADHD-I/ADHD-C groups on the Shift scale.

EF ratings for the TS children without a co-occurring ADHD condition were compared with those for the TDC in ANOVAs with post-hoc comparisons (Bonferroni) in order to see whether it was the co-occurring ADHD that was responsible for the higher impairment ratings. The same higher pattern of EF dysfunction was found for the TS children without comorbid ADHD compared to the TDC with the exception of the Organization of Materials scale for which there was no longer a difference between groups. In these follow-up analyses, the TS-only group also showed significantly lower impairment compared to the ADHD-C group on the Plan/Organize and Organization of Materials subscales and the MCI index, whereas the TS-only group was rated lower on the Plan/Organize subscale than was the ADHD-I group.

INSERT TABLE 3 ABOUT HERE

The TS group was compared in Repeated Measures ANOVAs with each of the other clinical groups on pairs of scales selected based on the a priori hypotheses. For the first comparison of scale pairs, the TS and ASD groups were compared on the Emotional Control and Shift scales. A mixed between-within subjects analysis revealed a significant interaction between

ratings on the two scales and group, Wilks Lambda = .84, $F(1, 50) = 9.5$, $p < .01$, partial eta squared = .16, with no significant main effects. Figure 2 shows the interaction, with the TS group rated as substantially higher on the EC scale than the Shift scale and the ASD group showing the reverse pattern. The mixed between-within subjects analysis comparing the EC and Inhibit scale ratings for children with TS and those with ADHD-C again revealed a significant interaction between the two scales and group, Wilks Lambda = .92, $F(1, 49) = 4.4$, $p < .05$, partial eta squared = .08, and no main effects. The TS group was rated as having greater problems with emotion regulation while the ADHD-C group was rated as having greater problems with inhibitory control. For the final comparison, the mixed model analysis revealed a significant interaction between the TS and ADHD-I groups and ratings on the EC and Plan/Organize, Wilks Lambda = .83, $F(1, 59) = 12.5$, $p < .01$, partial eta squared .18, with no main effects. Children with TS were rated as having greater difficulties on the EC scale than on the Plan/Organize scale while children with ADHD-I showed the opposite pattern. IQ and gender did not explain significant variance when entered as covariates in the above analyses. The analyses were repeated after removing the six children in the TS group who were also diagnosed with comorbid ADHD. In each instance, this resulted in a stronger interaction effect. Figure 2 presents a visual depiction of the strategic pair comparisons with the TS only children (i.e. excluding the children with comorbid TS and ADHD or ASD).

INSERT FIGURE 2 ABOUT HERE

The Chi-square test for independence (with Yates Continuity Correction) indicated a significant association between all three pair classifications. The TS children with comorbid ADHD-I, ADHD-C or ASD were excluded in the analyses in order to avoid the possible confounding effect of co-occurring disorders on the results. A significant association was

found between diagnosis and high/low on the EC and Shift scale for the TS only and ASD children $\chi^2 (1, n = 44) = 7.8, p < .01, \phi = .48$. Of the children with TS, 70% had a higher score on the EC scale compared to the Shift scale, and of the children with ASD 83% had a higher score on the Shift scale compared to the EC scale. Significant associations were also revealed between diagnosis and high/low on the EC and Inhibit scales for the TS only and ADHD-C children $\chi^2 (1, n = 43) = 4.3, p < .05, \phi = -.37$, and diagnosis and high/low on the EC and Plan/Organize scales for the TS only and ADHD-I children $\chi^2 (1, n = 53) = 4.4, p < .05, \phi = -.34$. Among the children with ADHD-C, 73 % had a higher score on the Inhibit scale compared to the score on the EC scale, and 70% of the children with TS only had a higher score on the EC scale compared to the Inhibit scale. On the scale classification comparing EC to Plan/Organize scales, 63% the children with ADHD-I had a higher score on the Plan/Organize scales compared to the score on the EC, whereas 80% of the TS only children had a higher score on the EC scale compared to the score on the Plan/Organize scale.

Discussion

Confirming our first hypothesis, the TS group was rated as more impaired on all BRIEF scales compared to the TDC. With the exception of the Organization of Materials scale, this finding was sustained after excluding the TS children with co-occurring ADHD from the analyses. Children with TS were rated as having clinically significant EF difficulties in the everyday environment regardless of whether or not they were also diagnosed with comorbid ADHD. This finding contrasts with an earlier study that found that children with TS without ADHD were rated more similarly to TDC on measures of executive dysfunction on the BRIEF (Mahone et al., 2002). A number of differences in the TS participants between the two studies may explain the contrasting findings. First, the participants in the current study were

first-time referrals for TS, whereas the children with TS in the study by Mahone et al. (2002) were already diagnosed patients in treatment. Being in treatment may have reduced the level of symptom reporting in the earlier study, while the need for treatment by the specialist health services at the time of testing in the present study may have resulted in a tendency for parents to report higher levels of symptoms. Second, the mean age in the current study is somewhat older (almost 12 years) than in the Mahone study (10 years). Developmental factors involved in the executive regulation processes might play a role in the reporting of behavioral difficulties. Regardless, our findings of no difference between the children with TS without comorbid ADHD and the TDC on the Organization of Materials subscale emphasizes the need to discriminate between TS with and without comorbid ADHD in future studies examining difficulties in EF behaviors.

In the overall comparison between clinical groups, the ratings on individual scales showed the TS and ADHD-C groups to be more impaired than the ADHD-I and ASD groups on the Inhibit scale, and the ASD group to be more impaired on the Shift scale compared to the ADHD-I and ADHD-C groups. The global analysis did not discriminate between the clinical categories. The general picture is that children in the clinical groups were rated by their parents as exhibiting higher levels of EF problems in a range of everyday situations compared to TDC. These findings provide evidence supporting the idea that there is considerable overlap of EF behavioral problems in children with neurodevelopmental disorders.

In our second hypothesis, we predicted that strategic pairs of subscales could discriminate between TS and other diagnostic categories. The first scale comparison tested whether the EC and Shift scales could differentiate between children with TS and children with ASD. Whereas behavioral rigidity and cognitive inflexibility across functional domains characterizes ASD and distinguishes this group from children with TS (Geurts, Corbett, &

Solomon, 2009; Ozonoff, Strayer, McMahon, & Filloux, 1994), differences in emotional control between the two groups is less clear. A study comparing children with ASD with typically developing children found the former to have elevated scores on all Behavioral Regulation scales on the BRIEF, with the strongest effect size for the Shift scale (Semrud-Clikeman et al., 2010). The analyses in our study confirmed the prediction that the groups of children with TS and ASD would have dissociable ratings when comparing the groups on the EC and Shift subscales, with the TS group rated relatively higher on the EC subscale and the ASD lower, and the opposite pattern for ratings on the Shift subscale.

In the Mahone et al. (2002) study comparing TS with ADHD groups on the BRIEF, the authors recommended distinguishing between the main subtypes of ADHD (e.g. combined and inattentive subtypes) in future studies using the BRIEF. The common tendency to group children with the subtypes ADHD-C and ADHD-I together when examining executive difficulties risks ignoring the unique underlying profile of difficulties associated with children with ADHD-C compared to children with ADHD-I (Diamond, 2005; Milich et al., 2001). Separate analyses were therefore conducted for the two ADHD subgroups.

The second scale classification tested whether the Emotional Control and Inhibit scales could discriminate between the TS and ADHD-C groups. Both TS and ADHD-C are disorders characterized by excess motor activity (Leckman, 2002), but with widely varying criteria for diagnosis depending on whether the symptoms involve tics or restlessness. Both disorders are presumed to be symptomatic of anomalous basal ganglia-thalamo-cortical loops involving regions of the prefrontal cortex thought to mediate executive functioning (Denckla & Reiss, 1997). Children with TS-only are thought to have a different social-emotional profile than those with TS+ADHD (Carter et al., 2000), however, and thus the emotional salience of behaviors in the TS and ADHD-C group may be somewhat different. Emotional outbursts are reported to be particularly common in clinically referred children with TS (Budman et al.,

2000), and are not necessarily related to symptoms of hyperactivity (Singer & Rosenberg, 1989). Yet some studies report aggressive behavior (e.g. swearing, throwing, punching) in children with TS to be associated with the co-occurrence of ADHD (Stephens & Sandor, 1999). In our analyses, the EC and Inhibit subscales dissociated between children with TS and children with ADHD-C, with the former exhibiting more problems regulating emotions and the latter group exhibiting relatively more difficulties inhibiting impulsive behaviors. These findings remained after controlling for both IQ and gender.

The third comparison tested the ability of the Emotional Control and Plan/Organize scales to discriminate between children with TS and children with ADHD-I. A previous study comparing children with ADHD-I and ADHD-C on the BRIEF concluded that metacognitive difficulties better characterize children with ADHD-I, whereas behavior regulation difficulties better characterized children with ADHD-C (Gerard A Gioia et al., 2002). Although Working Memory is a metacognitive process considered to be a core deficit in children with ADHD-I (Diamond, 2005), it is a common impairment in children with neurodevelopmental disorders as well (Alloway & Gathercole, 2006). It may therefore be well-suited for differentiating ADHD-I from normal performance, but not for differentiating ADHD-I from other neurodevelopmental disorders. The metacognitive subscale Plan/Organize was chosen for this scale classification to contrast the often disorganized behavior associated with ADHD-I with the relatively better metacognitive skills associated with TS (Mahone et al., 2002). In our analyses, a dissociation on the EC and Plan/Organize scales distinguished children with TS from children with ADHD-I. Children with TS were more elevated on the EC scale while children with ADHD-I were more elevated on the Plan/Organize scale. These findings also held after controlling for IQ and gender.

Accurate identification of EF deficits is relevant not only for diagnosis but, perhaps more so, for prognosis because children with differing EF profiles will likely respond

differently to interventions (Semrud-Clikeman et al., 2010). Important differences in outcome from treatment, for example, were shown for children with ADHD-C and ADHD-I subtypes who underwent the same general treatment for ADHD (Pfiffner et al., 2007), suggesting the need for accurate identification of behavior profiles even in quite similar psychopathologies. This study indicates that about three out of four children with TS have more problems controlling their emotions than with inhibition, mental flexibility, and planning/organizing abilities, whereas only about one in four children with ASD or ADHD-C have more problems controlling their emotions than with mental flexibility and inhibition, respectively. A failure to detect emotional dysregulation could represent a failure to address a potentially serious source of distress for children with TS and their families in their everyday lives. Some argue that a focus on specific executive function difficulties rather than on diagnosis would provide a better basis for clinical treatment in any event (Pelham, 2001). Undoubtedly, obtaining a more accurate and detailed characterization of the executive difficulties of a child referred for treatment for his or her challenges in daily life will provide a better basis on which to design a tailored treatment program aimed at alleviating such difficulties. A better characterization of executive function difficulties associated with neurodevelopmental disorders examined in the current study may provide a better understanding of the similarities and differences in behavioral impairment in these childhood-onset disorders and thereby improve treatment prospects in general as well.

This study had several strengths and weaknesses. Although the group of children with TS is rather small, a strength is that the group was recruited from a clinical population with a representative rate of comorbid conditions (Robertson et al., 2009). The division into ADHD-C and ADHD-I subgroups is another strength (Mahone et al., 2002), as is the absence of medication use in all but two of the children with TS. The uneven gender distribution in the group with TS compared with the group with ADHD is a limitation, though the distribution is

no different than that commonly reported in epidemiological studies of children with TS (Freeman et al., 2000; Robertson et al., 2009), and did not influence the results noticeably. The approach of using strategic scale classifications to differentiate clinical groups represents a promising first step for the more discriminate use of rating scales in differentiating executive function difficulties.

Conclusion

The present study indicates that parents of children with TS who were referred for treatment reported significant difficulties with executive functions in the everyday environment compared with TDC irrespective of co-occurring conditions. While there was considerable overlap in reported executive function problems in children with TS, ADHD-C, ADHD-I and ASD, comparison of ratings on select scales helped distinguish between children with TS and children with ADHD-C, ADHD-I or ASD. This suggests that children with a range of common developmental disorders show executive function difficulties in general, but that there may be more specific characteristics in everyday executive function for select groups. Specifically, children with TS showed greater problems with emotion regulation than any other group, children with ASD showed greater problems with cognitive and behavioral flexibility than other groups, children with ADHD-C showed greatest difficulties with inhibitory control, and those with ADHD-I showed greater difficulties with planning and organizing than other clinical groups. Identifying the specific deficit in executive function for individual children may guide treatment toward more targeted interventions versus a global omnibus executive function rating or intervention.

Declaration of conflicting interests

The co-authors Gerard A. Gioia and Peter K. Isquith maintain financial interest in the BRIEF as developers of the instrument. The first author and other co-authors declare no conflict of interest with respect to authorship or publication of this article.

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TABLES

Table 1: Demographic characteristics: means and standard deviations for the five groups.

Variable	TS	ADHD-C	ADHD-I	ASD	TDC	Group comparison		Post-hoc ^{e)}
	(n=19)	(n=33)	(n=43)	(n=34)	(n=50)	<i>F/Chi-square</i>	<i>p</i>	
Age in years (SD)	11.8 (2.2)	11.6 (2.1)	11.6 (1.9)	11.9 (2.3)	11.6 (2.0)	0.1	ns	
Gender (male/female)	16/3	20/13	20/23	28/6	32/18	14.9	<i>p</i> < .01	
Mother's education (yrs)	12.2 (2.4)	12.6 (2.3)	13.1 (1.9)	13.0 (2.6)	14.6 (2.4)	6.0	<i>P</i> < .01	All clinical groups<TDC
Full Scale IQ (WASI) ^{a)}	101.9 (15.2)	96.8 (13.8)	94.2 (15.2)	98.2 (18.6)	103.8 (12.9)	2.7	<i>p</i> < .05	ADHD-I < TDC
Inattention ^{b)}	13.7 (8.9)	16.6 (5.8)	14.8 (5.2)	12.5 (5.7)	1.6 (1.9)	54.9	<i>p</i> < .01	TDC<All clinical groups
Hyperactivity/ Impulsivity ^{c)}	11.9 (6.7)	13.6 (5.6)	6.7 (5.2)	7.8 (6.3)	0.9 (1.3)	37.5	<i>p</i> < .01	TDC<ADHD-I&ASD< TS&ADHD-C
CBCL – Total Problems ^{d)}	65.0 (8.8)	62.9 (8.0)	60.3 (8.1)	64.1 (9.6)	37.9 (8.7)	74.5	<i>p</i> < .01	All clinical groups<TDC

^{a)} Wechsler Abbreviated Scale of Intelligence (WASI), ^{b)} ADHD rating scale IV. ^{c)} ADHD rating scale-IV. ^{d)} Child Behavior Checklist (CBCL). ^{e)} Fishers LSD.

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Table 2: Percentage of children in the various groups rated in the clinical range* on each subscale.

<u>BRIEF Scales</u>	TS	ADHD-C	ADHD-I	ASD	TDC
	(n=19)	(n=33)	(n=43)	(n=34)	(n=50)
Inhibit	78%	88%	65%	79%	10%
Shift	78%	67%	67%	91%	8%
Emotional Control	94%	79%	84%	85%	8%
Initiate	67%	76%	77%	77%	10%
Working Memory	78%	94%	98%	85%	12%
Plan/Organize	78%	94%	95%	85%	10%
Organization of Materials	50%	73%	51%	47%	6%
Monitor	83%	94%	88%	94%	8%
<u>BRIEF Indexes</u>					
Behavior Regulation Index ^{a)}	83%	88%	84%	91%	10%
Metacognition Index ^{b)}	89%	94%	95%	94%	10%
Global Executive Composite ^{c)}	89%	97%	95%	94%	10%

*Clinical range is defined as a score higher than 1.5 SD above the mean value for the TDC.

^{a)} Inhibit, Shift, & Emotional Control. ^{b)} Initiate, Working Memory, Plan/Organize, Organization of Materials, & Monitor. ^{c)} All eight clinical scales.

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Table 3: Results on BRIEF scales and indexes: means, standard deviations and ANOVAs with post-hoc group comparisons (Bonferroni).

Variable	TS	ADHD-	ADHD-	ASD	TDC	Group comparison		Eta ²	Post-hoc*
	(n=19)	C	I	(n=34)	(n=50)	F	P		
Inhibit	65 (14.3)	67 (14.9)	55 (11.8)	59 (15.1)	42 (3.4)	F(4,173) = 25.8	<.001	.37	TDC<ADHD-I&ASD<TS&ADHD-C
Shift	62 (15.2)	59 (13.9)	55 (10.5)	68 (14.0)	41 (4.9)	F(4,173) = 32.6	<.001	.43	TDC<ADHD-I&ADHD-C<ASD TDC<TS
Emotional Control	65 (12.8)	61 (15.7)	59 (12.7)	61 (13.3)	41 (4.3)	F(4,173) = 26.6	<.001	.38	TDC<All clinical groups
Initiate	60 (12.1)	61 (11.6)	59 (11.7)	59 (11.0)	41 (6.7)	F(4,173) = 30.8	<.001	.42	TDC< All clinical groups
Working Memory	65 (15.8)	70 (11.3)	69 (8.6)	65 (12.3)	42 (4.6)	F(4,173) = 61.3	<.001	.59	TDC< All clinical groups
Plan/Organize	59 (14.2)	66 (10.0)	65 (9.5)	62 (11.4)	41 (4.9)	F(4,173) = 50.6	<.001	.54	TDC< All clinical groups
Org. of Materials	52 (13.0)	59 (10.2)	55 (11.4)	54 (11.8)	42 (7.6)	F(4,173) = 17.6	<.001	.29	TDC< All clinical groups
Monitor	61 (13.2)	65 (11.7)	59 (11.6)	63 (12.7)	39 (5.6)	F(2,134) = 43.8	<.001	.50	TDC< All clinical groups
Behavior Regulation Index ^{a)}	66 (14.2)	64 (15.6)	57 (10.8)	64 (13.2)	40 (4.0)	F(4,172) = 36.0	<.001	.46	TDC< All clinical groups
Meta-cognition Index ^{b)}	61 (14.3)	68 (12.2)	64 (9.6)	62 (10.8)	40 (5.2)	F(4,173) = 56.8	<.001	.57	TDC< All clinical groups
Global Executive Composite	64 (14.2)	68 (13.5)	62 (10.2)	64 (11.6)	39 (4.9)	F(4,173) = 54.2	<.001	.56	TDC< All clinical groups

c)

* $p < .05$ with Bonferroni correction for multiple comparisons. ^{a)} Inhibit, Shift, & Emotional Control. ^{b)} Initiate, Working Memory, Plan/Organize, Organization of Materials, & Monitor. ^{c)} All eight clinical scales.

Parent ratings of executive dysregulation

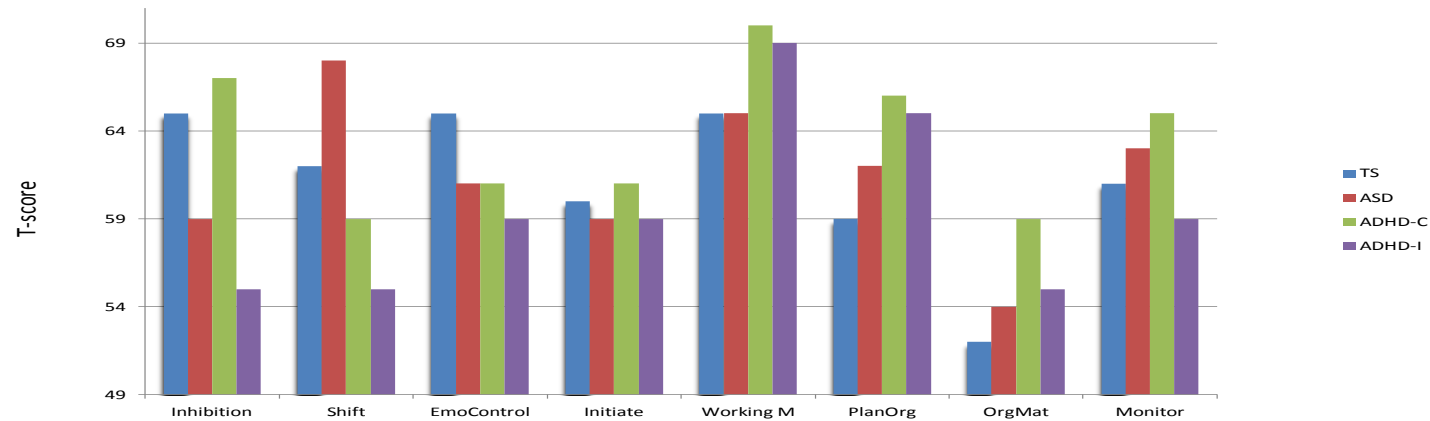


Figure 1. Ratings of executive dysregulation in clinical range per diagnostic category, i.e. baseline at 1.5 SD above mean value of typically developing children in Norway. Each 5 T-score increment indicates a 1 SD increase in rating. A higher rating indicates a more serious behavior regulation problem.

Dissociating TS from ADHD-C, ADHD-I and ASD

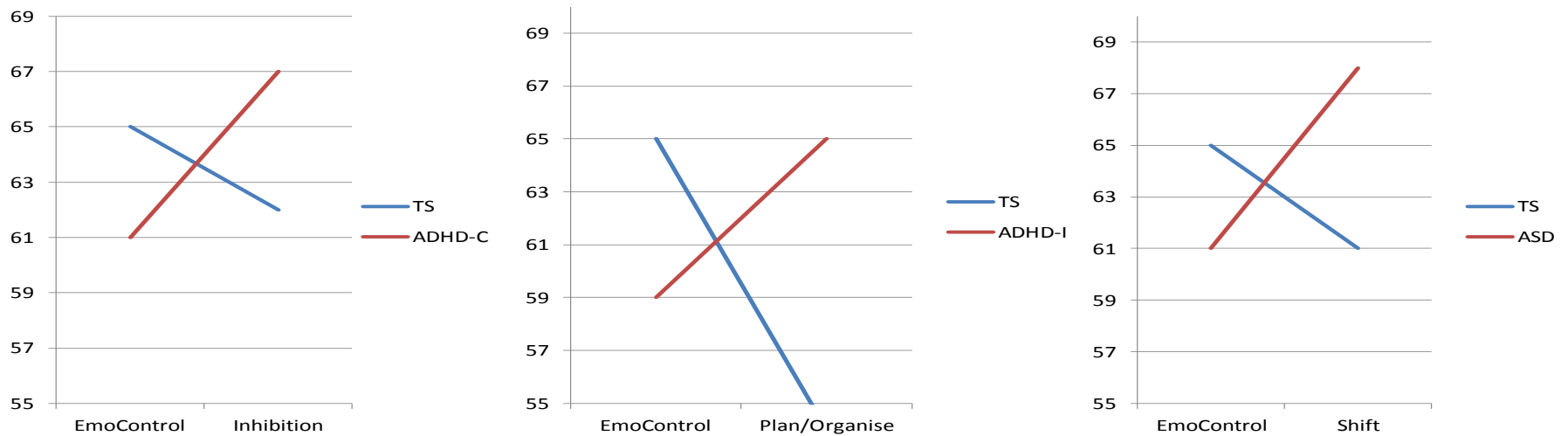


Figure 2. Comparing EF behavior on strategic scale classifications for Tourette Syndrome (TS) compared to ADHD-Combined (ADHD-C), ADHD-Inattentive (ADHD-I) and Autistic Spectrum Disorder (ASD), respectively.

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