SUSTAINED ATTENTION AND IMPULSIVITY IN TOURETTE SYNDROME: RELATIONSHIP TO ATTENTION DEFICIT HYPERACTIVITY DISORDER AND OBSESSIVE-COMPULSIVE BEHAVIOUR

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ABSTRACT

The purpose of this study was to determine whether children with Tourette Syndrome (TS) have impairments in sustained attention and impulsivity that are not accounted for by comorbid Attention Deficit Hyperactivity Disorder (ADHD). A secondary goal was to determine whether poor performance on a continuous performance task (CPT) was related to the severity of obsessive-compulsive behaviour (OCB) and tic severity. 58 children were compared on the CPT: 17 children with TS (TS-Only group), 9 children with TS and ADHD (TS-ADHD group), 16 children with ADHD (ADHD group), and 17 controls. Contrary to recent findings, only the TS-ADHD group made more errors of omission (misses) on the CPT than controls. However, although the difference between TS-Only children and controls was not statistically significant, 35% of TS-Only children had scores which fell below 2 standard deviations from the control mean in terms of sustained attention. Compared to controls, neither TS-ADHD children nor TS-Only children showed impulsivity as measured by errors of commission (false alarms), although a subgroup of TS-ADHD children had clinically significant impulsivity problems. Severity of OCB was related to errors of commission independently of ADHD and TS ratings. The results of this study suggest that only a subgroup of TS children have measurable deficits in sustained attention and that impulse-control problems in TS children may also be related to comorbid OCB. The TS-specificity of attention problems given the base rate of attention problems in clinical samples in general and the role of tic location as a confound in 1) the measurement of attention in TS and 2) the diagnosis of ADHD in TS are also discussed.

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INTRODUCTION

MEASURING ATTENTIONAL PROCESSES

Attention is a broadly defined psychological construct which subsumes several different, presumably dissociable, processes. Attention research has traditionally been hampered by disparate and conflicting approaches to methodology, theoretical modelling, and conceptual approaches. Apart from early writings by Luria (1973) and others, attempts at synthesizing research findings into a coherent, unified theory of attention have therefore met with limited success (Sohlberg & Mateer, 1989). Cohen (1993) has commented on the difficulties inherent in attention research and proposed a comprehensive model of attention which attempts to integrate findings from cognitive, psychophysiological, and neuropsychological studies. He proposes that attention depends on four functionally distinct neurobehavioral dimensions: sensory selection (i.e., filtering, focusing, and automatic shifting), attention control (i.e., intention, initiation, and inhibition, as mediated by premotor and prefrontal systems), attentional capacity (i.e., attentional resources, arousal and effort), and sustained attention. Sustained attention reflects the efficacy of the other factors over time.

Sohlberg and Mateer (1989) provide a synthesis of attentional theories which follows similar lines of reasoning. They defined selective or focused attention as the ability to withstand distraction and inhibit responding in order to respond to specific stimuli in the environment. They also noted the importance of the attentional control or executive system in regulating attention. The attentional control or executive functioning mechanisms refer to planning ability, the ability to shift attention and behavior in response to the environment, and self-control (Lezak, 1983). Disorders of attention control would thus lead to cognitive "rigidity" (i.e., the inability to shift attention) and disinhibition (i.e. the inability to prevent the shifting of attention, presumably manifest in high levels of distractibility and impulsivity). Like Cohen (1993), Sohlberg and Mateer (1989)

noted that sustained attention refers to two dimensions of focused attention: the duration of attentional ability and the consistency of performance over time.

Other theories of attention have provided subtypes of attentional mechanisms. Mirsky (1989) factor-analyzed measures of attention and postulated four functional subgroups of attention processes measured by conventional neuropsychological tests. These were encoding, sustaining, focusing/manipulating, and shifting.

DESCRIPTION OF TOURETTE SYNDROME

In 1885, the French neurologist Gilles de la Tourette was the first to document an as yet unrecognized syndrome consisting of involuntary motor tics accompanied by vocalizations (for an English translation of de la Tourette's 1885 paper, see Goetz & Klawans, 1982). Today, the validity of Tourette's syndrome (TS) as a clinical entity is well established, and its diagnostic criteria follow the profile recorded by de la Tourette. As noted in DSM-III-R (Diagnostic and Statistical Manual of Mental Disorders, Third Edition, Revised, American Psychiatric Association, 1987), a tic is an "involuntary, sudden, rapid, recurrent, nonrhythmic, stereotyped motor movement or vocalization" (p. 78). In TS, the anatomical location, severity, frequency and complexity of tics change over time. The disorder typically follows a fluctuating, lifelong course punctuated by periods of quiescence followed by tic exacerbation. Tics must be present for at least one year, with more recent diagnostic criteria requiring tic-free periods of less than three months (DSM-IV, 1994). Onset is typically at age 7 (Shapiro & Shapiro, 1982; Caine, McBride, Chiverton, Bamford, Rediess & Shiaio, 1988), with most persons experiencing a decrease of symptoms with increasing age. In addition, males afflicted with TS outnumber females three to one, as is the case with several other developmental disorders with early childhood onset such as Attention-deficit Hyperactivity Disorder (ADHD; see Appendix 2 for diagnostic criteria), autism and conduct disorder (Rutter & Garmezy, 1983). For DSM-III-R diagnostic criteria for TS, see Appendix 1.

COMORBIDITY IN TS

ADHD, attention problems, impulsivity, and hyperactivity co-occur with TS in 50 to 90% of children comprising clinical samples (Comings & Comings, 1988; Sverd, Curley, Jandorf & Volkersz, 1988). In contrast, non-clinical, community-based TS samples yield estimates of ADHD comorbidity of less than 30% (Caine, McBride, Chiverton, Rothman, Young, Katz, Shaywitz, & Bennett, 1988), an estimate that is still substantially higher than the population prevalence of ADHD, which averages 5 to 6 percent of children in the general population (Barkley, 1990). Reports that increasing tic severity is associated with increased severity of ADHD lend credence to the theory that the two disorders may somehow share a common neural substrate (Comings & Comings, 1988). However, the high comorbidity rate in clinical samples cannot be attributed to known inheritance models (Pauls, Hurst, Kruger, Leckman, Kidd, & Cohen, 1986), suggesting that factors other than genetics contribute to comorbidity rates.

Obsessive-compulsive disorder (OCD) is a condition characterised by recurrent, intrusive, disturbing thoughts and/or stereotyped, repetitive actions that are compulsively executed (Goodman, McDougle, Price, Riddle, Pauls, & Leckman, 1990). From 30 to 90% of clinically referred children with TS have comorbid OCD (Jagger, Prussoff, Cohen, Kidd, Carboni, & John, 1982; Montgomery, Clayton, & Friedhoff, 1982; Pauls, Towbin, Leckman, Zahner & Cohen, 1986). In contrast to the comorbidity rates in TS, the population prevalence of OCD in children is less than one percent (Flament, Whitaker, & Rapoport, 1988). The age of onset of OCD is, on average, at age 10 (Swedo & Rapoport, 1989). The onset of OCD symptoms usually predate psychiatric diagnosis by approximately 2 years (Allsopp & Verduyn, 1990; Last & Strauss, 1989), likely because of the covert, internalized nature of some OCBs (obsessive-compulsive behaviours) and because OCBs lie along a developmental continuum with normal childhood behaviours concerning superstition, order, and rituals. In cases where OCD is complicated by TS,

OCD diagnosis may not occur until 7 to 10 years after onset of OCD symptoms (Toro, Cervera, Osejo, & Salamero, 1992), likely because of the behavioral similarity of complex tics and compulsive rituals.

As many as 57% of clinically referred children with OCD have a lifetime history of tics (Swedo, Rettew, Gershon, & Rapoport, 1992). The prevalence of tics in OCD has also been estimated at 20% (Swedo, Rapoport, Leonard, Lenane, & Cheslow, 1989). As is the case with TS-ADHD comorbidity, high prevalence rates of tics in OCD and of obsessions and compulsions in TS suggest that TS and OCD share a common etiology or pathological process, or more simply, are "alternate expressions of the same disorder" (p.28, Rapoport, Leonard, Swedo, & Lenane, 1993). Genetic studies lend added support to the latter theory (Leckman & Chittenden, 1990; Pauls, Towbin, Leckman, Zahner, & Cohen, 1986).

BRAIN MECHANISMS AND TS

It has been said that the pathogenesis of TS "remains nearly as obscure as when the illness was first described more than a century ago" (p. 213, Stoetter, Braun, Randolph, Gernert, Carson, Herscovitch, & Chase, 1992). Although researchers are a long way from identifying causal agents, significant strides have been made in terms of identifying brain systems which may be involved in the disorder's phenomenology. As with other disorders of unknown etiology, however, researchers are forced to rely on indirect sources of causality such as imaging studies, pharmacological treatment, and existing data on similar disorders whose etiology is better understood.

The initiation, execution and inhibition of movement is controlled by three major brain regions: the cerebral cortex, the cerebellum, and the basal ganglia. Disorders of the basal ganglia are associated with difficulties initiating, sustaining and stopping movement, as well as disorders of muscle tone and involuntary movement (Gilman & Newman, 1992). The basal ganglia are also involved in more cognitively related processes, possibly due to its intimate

connections with the frontal lobes and the limbic system, the latter of which is involved in the regulation of emotion, motivation and learning (Carlson, 1991). More importantly, the limbic system is thought to contribute to the production of a goal-oriented behaviour, emotional output, and the suppression or inhibition of unwanted and inappropriate responses (Modell, Mountz, Curtis, & Greden, 1989).

The basal ganglia are comprised of three interconnected structures: the caudate nucleus, the putamen and the globus pallidus; together, the first two structures are also identified as the striatum (Gilman & Newman, 1992). PET studies suggest striatal and frontal lobe involvement in TS (Chase, Geoffrey, Gillespie, & Burrows, 1986), likely in the form of dopamine-mediated circuits between the striatum, thalamus and cortex (Leckman, Pauls, Peterson, Riddle, Anderson, & Cohen, 1992). Hypoactivity of these areas has also been found to correlate with tic severity (Chase et al., 1986). Overall, results from PET and stereotaxic lesioning studies point to the basal ganglia as probable pathogenic loci (Leckman, Knorr, Rassmusson, & Cohen, 1991). The role of the basal ganglia in the pathogenesis of other movement disorders such as Parkinson's disease and Huntington's chorea also lends indirect support to the theory that basal ganglia involvement is involved in TS (Steingard & Dillon-Stout, 1992).

Dopamine agonists such as stimulants (most commonly methylphenidate) are a routine part of pharmacotherapy for ADHD. Increases in abnormal movements, such as buccal-lingual tics and other stereotypic movements, as well as increased perseverative and compulsive behaviours have been reported in ADHD children undergoing drug treatment with stimulants (Frye & Arnold, 1981; Koizumi, 1985). According to one study, (Borcherding, Keysor, Rapoport, Elia & Amass, 1990), as many as 79% of ADHD children experienced either tic-like movements or obsessive-compulsive symptoms such as cleaning and checking behaviours, as well as perseverative, detail-oriented behaviours. Though tic-like behaviours and compulsive behaviours did not usually occur concurrently, the study also suggests a link between motor tics, obsessive-

compulsive behaviours and overactivity of dopaminergic processes. The literature on animal studies as reviewed by Goodman et al. (1990) supports the same conclusion. Overactivity of dopamine receptors in the limbic system has been posited as a probable etiology of TS, based on the success of dopamine antagonists such as Haloperidol in reducing tic severity (Singer, Trifiletti, & Gammon, 1988). The fact that the basal ganglia is a dopamine-rich structure adds further lines of evidence to its role in TS. In addition, in approximately 25 to 50 percent of persons with TS who initiate pharmacotherapy involving dopamine agonists (such as methylphenidate), tics increase in severity (Golden, 1988). Dopamine-related dysfunction thus appears plausible in the syndrome's etiology, although tic exacerbation with dopamine agonists is not typical of all persons with TS, since reports of decreases in tic frequency have also been documented (Sverd, Gadow, & Paolicelli, 1989), and small sample sizes preclude clear generalisation of results to the general TS population (Cohen & Leckman, 1988). Of course, a unitary view of dopaminergic imbalance as solely responsible for TS would also be a simplistic interpretation of the mechanisms involved, given the intimate interdependence of dopamine and other neurotransmitters such as serotonin, norepinephrine and others (Leckman, Riddle & Cohen, 1988).

BRAIN MECHANISMS AND OCD

In the case of OCD, imaging studies, most notably those involving PET, implicate the caudate nucleus (Baxter, 1990), as well as the orbital and the prefrontal gyri of the frontal lobe (Swedo, Shapiro, Grady, et al., 1989; for a review of other studies, see Baxter, 1992). The presence of obsessions and compulsions in other diseases of the basal ganglia such as post-encephalitic Parkinsonism (von Economo, as cited in Wise & Rapoport, 1989) and Sydenham's chorea (Swedo, Rapoport & Cheslow, 1989) also lend support to the theory of basal ganglia involvement in OCD. Modell et al. (1989), based on this and other evidence, have proposed that OCD results from deregulation of

reciprocal feedback loops connecting the orbital region of the frontal lobe to the striatum.

Serotonin is thought to play a major role in producing OCD symptoms, based on the success of serotonin antagonists such as clomipramine (Anafranil) and fluoxetine (Prozac) in treatment protocols (King, Riddle, & Goodman, 1992). Again, since the basal ganglia are also one of the most serotonin-rich areas of the cortex (Wise & Rapoport, 1989), these results are consistent with the view of OCD and TS as arising out of deregulation of serotonin and dopamine systems originating in these structures. Goodman et al. (1990) postulate that TS-OCD results from an imbalance in both serotonin and dopamine systems.

Leckman et al. (1992) have hypothesized that TS represents a failure of inhibition of specific circuit loops that connect the cortex, striatum, and thalamus and which receive afferents from the primary motor and premotor cortex in the frontal lobe. They hypothesized that disinhibition of circuits would be associated with tics, while obsessions would result from disinhibition of limbic and prefrontal circuits. Consistent with this view is Bornstein's (1991) interpretation of tics and compulsions as manifestations of perseverative tendencies arising out of frontal deregulation.

BRAIN MECHANISMS AND ADHD

Behavioral markers of ADHD in children, particularly impulsivity and disinhibition, are frequently likened to the behaviour of adults with frontal lesions (Barkley, 1991). Reduced attentional control from damage to frontal structures leads to failures to inhibit responses to irrelevant stimuli or to resist from impulsive behaviour. In addition, hyperactivity can also result from frontal damage, primarily because of reduced executive control of response inhibition mechanisms (Cohen, 1993). For example, patients with frontal lobe lesions described by Luria and Homskaya (1970) showed high levels of distractibility manifested by a continual redirection of attention to irrelevant, extraneous information. The core problem in ADHD has thus been conceptualised as a

dysfunction of frontal systems which mediate attention and impulsivity. A few studies have provided evidence of frontal pathology in some samples of ADHD children and adolescents. Frontal and striatal hypofusion as measured by PET scan has been reported with a small sample of children with other neurological problems (Lou, Henriksen, & Bruhn, 1984; Lou, Henriksen, Bruhn, Borner, & Nielsen, 1989). One study using MRI also found similar results (Hynd, Semrud-Clikeman, Lorys, Novey, & Eliopulos, 1990). Overall, however, neuroanatomical evidence for frontal pathology in ADHD has remained scant despite behavioral parallels between ADHD children and some frontal lobe patients.

NEUROPSYCHOLOGICAL PROFILE OF CHILDREN WITH TS

Studies on the specific neuropsychological and cognitive profile of children with TS are numerous. However, few studies to date have screened children with co-existing disorders such as ADHD. Given the high incidence of ADHD in clinically-referred TS samples in general, it is reasonable to assume that some of the deficits reported in the past in children with TS may have been the result of co-occurring ADHD. The high rate of OCD in TS, which by itself may be associated with circumscribed cognitive difficulties, may also be a confound. Likely for this reason, attempts to determine TS-specific deficits in children using neuropsychological tests have met with mixed success.

A consistent finding across studies is lowered performance on a subtest of the WISC-R (Wechsler Intelligence Scale for Children, Revised; Wechsler, 1974), the Digit Symbol subtest, which measures aspects of focused attention, short-term memory, processing speed, and graphomotor speed. Fine motor and graphomotor problems in children with TS have also been identified by some researchers (Harcherik, Carboni, Shaywitz, Shaywitz, & Cohen, 1982). Though the IQ of children with TS falls within the normal range (Incagnoli & Kane, 1981), one set of investigators found that when ADHD comorbidity was assessed in children with TS, the TS children with ADHD had lower Iqs than those with TS only (Dykens, Riddle, Leckman, Hardin, Schwartz, & Cohen, 1990).

An ongoing study (Denckla, Harris, Aylward, Singer, Reiss, Reader, Bryan, & Chase, 1991) has recently compared executive functioning of children with TS and a co-occurring ADHD diagnosis (TS-ADHD) and normal children, using both cognitive tests and neuro-imaging. Preliminary results with a small sample (N = 8) suggested that 5 children with TS-ADHD had impaired performance on tests of organization, attention and inhibition. On average, children with the two conditions had larger ventricles, larger caudates, and a smaller globus pallidus than control children as measured by MRI. Despite the small sample size and resulting restriction on generalisation the TS population at large, this study presents the possibility that cognitive deficits in some children with TS-ADHD may be related to structural anomalies. However, whether these anomalies are specific to TS, to ADHD, or to a subgroup of children affected by both disorders remains to be elucidated.

A recent study has examined the difference in neuropsychological functioning, and more specifically, the difference in attentional abilities, between children with TS and those with TS-ADHD (Yeates & Bornstein, 1994), based on the premise that earlier reports of neuropsychological deficits in children with TS were the result of other comorbid disorders. After statistically controlling for obsessive-compulsive symptoms and tic-severity, the researchers concluded that children with TS-ADHD had deficits in encoding (as measured by the Digit Span subtest of the WISC-R), focusing/executing (as measured by the Trail Making Test of the Halstead-Reitan Battery; HRB, Reitan & Wolfson, 1985), and sustaining attention (as measured by the Speech Sounds Perception Test of the HRB). Other tests thought to measure encoding (Arithmetic), focusing/executing (WISC-R Digit Symbol), shifting (Wisconsin Card Sorting Test; Heaton, 1981), and sustaining attention (Seashore Rhythm Test of the HRB) were not significantly different between groups. The researchers note, however, that the criterion validity of the Speech Sounds Perception Test as a measure of sustained attention has not been fully established. In addition, the test battery lacked a well validated measure of sustained attention.

Another approach to clarifying the relationship between TS and ADHD has been to measure tic severity and the probability of comorbid ADHD. Thus, some studies have reported a higher rate of ADHD in children most severely affected by TS (Comings & Comings, 1987b). However, this approach has had limited impact, since other studies report independence between tic severity and ADHD diagnosis (Randolph, Hyde, Gold, Goldberg, & Weinberger, 1993). The presence of "mental tics" (Matthews, 1988, p. 411), which consist of "sudden, intrusive thoughts that cannot be ignored or suppressed" has also been advanced as a possible mechanism underlying distractibility and inattention in TS.

NEUROPSYCHOLOGY OF OCB

Swedo and Rapoport (1989) reported that compulsions such as those requiring counting or repetitions of numbers are likely to significantly interfere with school functioning. Keller (1989) proposed that OCD was likely to interfere with test performance and mental efficiency, presumably because of the amount of cognitive energy taken up by obsessions and spent on attempting to resist compulsions. Attention problems could thus be one manifestation of OCD. Denckla (1989) has proposed that OCD results from involvement of brain areas such as frontal and basal ganglia systems associated with "attentiveness, reflectivity and self-control" (p. 111). Her conclusions are based in part on the number of children with OCD who had attention deficit disorder in early childhood. In one of the only studies addressing the question of attention in OCD, Cox, Fedio, and Rapoport (1989) concluded that OCD children did not have measurable concentration problems based on their normal performance on a test battery which included measures such as list-learning and reaction time paradigms. However, the fact that the researchers did not have direct measures of attention limits the validity of their conclusions. In other studies, impaired performance on Digit Symbol and Digit Span, tests of focused attention and encoding, have been reported with adults (for a review, see

Flament & Rapoport, 1984). Poor planning and strategy use on the Rey-Osterrieth Complex Figure Test and weak performance on the Wisconsin Card Sorting Test, measures of executive functioning, have also been reported in children with OCD (Flament & Rapoport, 1984).

Keller (1989) found a subgroup of children with marked impulsivity, as suggested by both high ratings on a behavioral rating scale and by extreme impulsivity during testing of the WISC-R. Anecdotal comments from the children suggest that impulsivity was used as a way to "break through" their rumination, perfectionism and stereotypies. Indirect support for OCD-related problems in the inhibition of impulsivity comes from Huntington's chorea, another disorder of the basal ganglia where impulsivity is a common clinical feature (Kaufman, 1985).

NEUROPSYCHOLOGICAL PROFILE OF CHILDREN WITH ADHD

There is no pathognomonic sign which signals the presence of ADHD in a child, nor does diagnosis rely on a specific set of test results. Instead, the DSM-III-R relies on the presence of certain behaviours, which, by themselves, are not indicative of pathology and are found to some extent, in all children. These criteria include excessive impulsivity, overactivity, and distractibility (Appendix 2).

Although the behaviour of children with ADHD has been likened to that of patients with frontal lobe lesions, neuropsychological studies of children with ADHD have not reliability found poor performance on tests purported to measure frontal lobe processes such as executive functioning and mental flexibility (for a review, see Barkley, 1990; 1991). One exception is the Continuous Performance Task (CPT), a computerized task in which the child attends to rapidly presented stimuli (typically letters or numbers) over time, with the goal of responding to targets and refraining from responding to non-targets. In this paradigm, impulsivity is operationalized as the false alarm rate (e.g., the number of commission errors or responses to non-targets) and the hit rate (e.g.,

and errors of omission or missed targets) is believed to measure sustained attention.

Children with ADHD typically respond more impulsively on the CPT than control children (Barkley, 1991). Results regarding inattention are less clear, with some studies finding that ADHD children perform more poorly than controls and other clinical groups (such as children with conduct disorder) in terms of both impulsivity and inattention on the CPT (Klee & Garfinkel, 1983) and others finding differences only in terms of impulsivity. In a review of existing studies, Barkley (1991) has cautioned the use of omission errors as cognitive markers of ADHD, and concluded that impulsivity as measured by commission errors may be a more reliable marker of ADHD. In sum, based on these findings, the primary dysfunction in ADHD (or at least, the dysfunction most reliably measured by conventional psychological tests) can thus be conceptualised as behavioral dyscontrol such as impulsivity and disinhibition. Less reliable markers are attention deficits on the CPT.

THE CPT IN TS RESEARCH

One study has posited that disorders of attention may be a "cardinal feature" of persons with TS, based on the number of omission errors (targets missed) on a CPT (p. 728, Randolph, Hyde, Gold, Goldberg, & Weinberger, 1993). Identical twins with TS were administered the vigilance task, with co-twins with the severest TS missing the most targets. The number of omission errors was unrelated to ADHD diagnosis, and all subjects made more errors than controls, regardless of tic severity. This study suggests that children with TS may have deficits of sustained attention which cannot be explained by a co-occurring ADHD condition. Recent studies which found increased inattention errors on the CPT in comparison to controls support this assertion (Stokes, Bowden, Camfield, Backman, & Dooley, 1991; Gladstone, Carter, Schultz, Riddle, Scahill, & Pauls, 1993). Both these studies also found that TS children made more impulsivity errors on the CPT. However, neither study controlled for

the presence of comorbid ADHD in their TS groups.

SIGNAL DETECTION THEORY AND ADHD

Signal detection theory (SDT) provides a more fine-tuned analysis of sustained attention and impulsivity than more traditional measures of omission and commission errors on vigilance paradigms such as the CPT (Corkum & Siegel, 1993). Specifically, SDT allows the measurement of both the subject's ability to detect targets and the subject's degree of laxitude or caution (i.e. the subject's "guessing strategy") in reporting whether a stimulus is a target or a non-target. Nichols (1972) has highlighted the usefulness of SDT measures in investigating information processing efficiency in different pathological conditions and in determining the predisposition of persons with various psychological problems towards one type of response over another. In clinical groups such as ADHD, where peripheral problems in perception are not involved, poor performance on SDT measures are posited to arise from problems in higher-level cognitive systems such as attention or inhibitory control. Three main measures are used in SDT research on ADHD and other childhood disorders such as learning disabilities. Sensitivity is conceptualized as a measure of attention, and response criterion and response bias, as measures of impulsivity (Corkum & Siegel, 1993).

In signal detection theory, vigilance is defined as the ability to identify targets during the specified task. Sensitivity (discrimination capacity, or d') provides a measure of the discriminability of signals from noise. The subject's ability to discriminate signals from noise varies with the subject's sensitivity to the signal (Hannay, 1986). Sensitivity can be defined as "a measure of the basic competence of the subject at a task, with contamination from the guessing strategy removed" (Graves & Jones, 1992, p. 493). SDT measures require assumptions of normality and equal variance for the response distribution. In clinical studies where these assumptions are not always met, routine use of nonparametric measures is recommended (Hannay, 1986).

In ambiguous situations in vigilance paradigms (e.g. when the subject is unsure whether a given stimulus was a target or a non-target), the subject adopts a decision threshold at a particular sensory level. Any stimuli perceived as being above this threshold or "response criterion" (C) is thus deemed to be a target; stimuli perceived as being below the criterion are deemed to be noise (O'Dougherty, Nuechterlein, & Drew, 1984). In other words, the response criterion reflects the amount of "evidence" a subject needs before making a decision to respond that a given stimulus is a target. The lower the criterion, for example, the greater the likelihood that non-targets will be identified as targets by the subject. A child with low response criterion adopts a very liberal strategy in which all ambiguous stimuli are responded to as if they were targets (O'Dougherty et al., 1984). This child would consequently have a high false alarm rate. The extreme case of this "risky" response strategy is illustrated by a hypothetical case in which the child presses the button continuously throughout the CPT task (Sostek, Buchsbaum, & Rapoport, 1980). In contrast, a high response criterion can be conceptualized as an extremely conservative approach in which no ambiguous targets are deemed by the subject to be targets. This type of strategy would be evidenced by an extremely cautious subject whose response profile would consist of few false alarms but a number of missed targets, the "cost" of a very conservative approach. Unlike traditional parametric response criterion measures, there is as yet no nonparametric index of response criterion which is independent of sensitivity (Hannay, 1986). Use of the false alarm rate may thus provide an alternate measure of response criterion (Richardson, 1972) which is independent of sensitivity.

Response bias also reflects the subject's tendency to respond in a particular direction, under the assumption that not all responses are equally likely for a given subject independent of his or her sensitivity to the targets (Swanson, 1981). Response bias is the ratio of two probabilities (i.e. a calculation of the "odds" of responding in a particular manner; Nichols, 1972), based on the subject's response criterion. The ratio is 1) the probability that the

subject responded that the stimuli was a target, to 2) the probability that s/he responded that it was a non-target. Bias is also itself used as a measure of response criterion (Hannay, 1986). Response bias (*B*) can be defined as "a measure of the guessing (response) strategy, with the effect of basic competence at the task removed" (Graves & Jones, 1992, p. 493). Unlike the response criterion, however, response bias is dependent upon sensitivity, and in some cases, may be difficult to interpret on its own without careful consideration of other SDT measures. Caution is thus recommended in interpreting group differences (Hannay, 1986). Davies and Parasuraman (1982) suggest calculating both C and *B* to offset the reliability problems of some bias measures.

Sostek et al. (1980) found that hyperactive children had lower sensitivity than controls, and that stimulants increased sensitivity. O'Dougherty et al. (1984) found similar deficits in hyperactive children in addition to a lower response bias in comparison to controls. Nuechterlein (1983) found that hyperactives had an atypically liberal response criterion in identifying ambiguous stimuli as targets but did not have differences in sensitivity in comparison to controls. O'Dougherty et al. (1984) posited that differences in age and group selection may have accounted for these discrepant results since age changes in sensitivity have been documented. This point has also been made by Corkum and Seigel (1993) with regards to sustained attention as measured by hit rate on the CPT. Seidel (1989) found differences between controls and ADHD children on sensitivity but not bias. He noted that hit rate and false alarms identified clinical subjects as well or better than the signal detection measures. One reason for the lack of agreement concerning SDT analyses of ADHD may be the variety of parametric, nonparametric, and bias measures used across studies. However, Corkum and Siegel (1993) have reported that overall, low sensitivity is a more reliable finding than low response bias in SDT research with ADHD children.

SUMMARY AND GOALS OF THE PRESENT STUDY

CPT HYPOTHESES

Because a large number of clinically-referred children with TS also have comorbid ADHD and/or OCD, it has traditionally been difficult to ascertain whether deficits in attention and impulsivity, when found in TS children, are the result of TS-related, ADHD-related, or OCD-related dysfunction. Previous research suggests that children with TS may have difficulty sustaining attention while children with ADHD may have difficulty inhibiting impulsive responding on the CPT according to traditional CPT measures, in addition to probable sustained attention problems according to SDT research. Sustained attention can be operationalized as hit rate and sensitivity, while impulsivity can be defined as false alarm rate (i.e., responses to non-targets, also used as a measure of response criterion in SDT research) and response bias on the CPT.

On the basis of these assumptions, TS-related dysfunction in the ability to sustain attention would cause children with TS (regardless of comorbid ADHD) to miss more targets and have a lower sensitivity than control children. However, TS children without ADHD (TS-Only) and TS children with comorbid ADHD (TS-ADHD) would differ on false alarms and response bias, variables that have been thought to reflect ADHD-related dysfunction in regulating impulsivity. As noted above, two studies of children with TS found increases in false alarms in comparison to controls. However, comorbid ADHD had not been controlled for in either study. If impulsivity as measured by the CPT really is a correlate of ADHD and not TS, TS-Only children should not differ from control children in number of false alarms.

One study to date (Keller, 1989) has reported problems with impulsivity in children with OCD. Other research findings on the presence of attention deficits in OCD remain equivocal. However, persistent obsessions and

preoccupations with rituals could conceivably cause distraction and interfere with the ability to sustain attention. However, this latter "reduced allocation" model remains speculative.

OTHER MEASURES OF ATTENTION

A related goal was the exploratory analysis of other measures of attention. Specifically, these were relevant subtests of the WISC-III used in previous research with TS children with and without ADHD (Yeates & Bornstein, 1994) and specified in Mirsky's (1989) attention model. Of note, an a priori decision was made not to match groups on FSIQ since the IQ itself is a composite of measures that were of interest to the study as dependent variables. These were: the Digit Symbol subtest, a measure of focused attention (Barkley, 1991; Yeates & Bornstein, 1994), and Digit Span and Arithmetic, measures of encoding/manipulating (Barkley, 1990). Unlike the visually-presented CPT, these subtests also measure aspects of auditory attention. The Mazes subtest, an executing or attentional control task, measures planning and ability to follow a visual pattern. Poor performance on this task can be related to impulsivity (Sattler, 1992). Symbol Search is a modified cancellation task which requires speed, accuracy, and processing speed. Cohen (1993) has noted that cancellation tasks measure aspects of sustained attention. However, because Symbol Search subtest is only two minutes long, it may be better described as a focused attention task, as have done Sohlberg & Mateer (1989) for cancellation tasks in general.

MEASURES OF OCB

A related goal was to investigate the relationship of a revised measure of OCB, the Leyton Obsessional Inventory, Parent Version (Janzen, Sherman, & Joschko, 1994), a parent-rated version of the original Leyton scales originally designed as a self-report measure of OCB in adolescents (Leyton Obsessional Inventory—Child Version; Berg, Whitaker, Davies, Flament & Rapoport, 1988),

with measures of impulsivity and attention on the CPT (for details regarding internal consistency, factor structure, questionnaire items, and modified administration of the LOI-PV, see Appendix 3).

SUMMARY OF ASSUMPTIONS:

1. Low sensitivity and missed targets on a CPT are measures of inattention.

2. A high false alarm rate on a CPT reflects impulsivity and behavioral disinhibition, as does a low response criterion and response bias.

3. Children with TS miss more targets on a CPT than controls, independent of concurrent ADHD diagnosis (Randolph et al., 1993).

4. Children with ADHD make more false alarms (Barkley, 1991) and have reduced sensitivity to targets (Corkum & Siegel, 1993) in comparison to control children on a CPT.

5. OCB is related to difficulty inhibiting impulsive responding (Keller, 1989).

PREDICTIONS/HYPOTHESES:

1. TS-Only and TS-ADHD children have lower sensitivity and miss more targets than controls on a CPT because of TS-related dysfunction in attention.

2. TS-ADHD and ADHD children make more false alarms and have a lower response criterion and response bias on a CPT than controls and children with TS-Only because of ADHD-related dysfunction in regulating impulsivity.

3. Increased severity of OCB is related to difficulty inhibiting impulsive responding.

METHOD

PARTICIPANTS

Participants were 59 children (11 girls and 48 boys) between the ages of 7 and 15 from Victoria, Nanaimo, Vancouver, and surrounding areas in British Columbia, Canada.

1) TS-ADHD and TS-Only Groups

Inclusion criteria for children with Tourette syndrome were diagnosis by a pediatric neurologist, paediatrician or child psychiatrist, IQ above 80, and absence of any other known neurological or other condition which could affect performance on cognitive tests.

Children with TS were recruited from three sources: the Vancouver Island Tourette Syndrome Association, the Jack Ledger Child and Adolescent Psychiatric Unit Tourette Syndrome Clinic at the Queen Alexandra Centre for Children's Health in Victoria, and from the caseload of a child psychiatrist affiliated with B.C.'s Children's Hospital in Vancouver.

Of 26 TS children thus recruited, one child with TS was excluded from the analyses after testing with the WISC-III (Wechsler Intelligence Scale for Children, Third Edition; Wechsler 1991) because his measured full-scale IQ was below 80.

Eight children had a comorbid ADHD diagnosis a) noted in a psychiatric report, b) diagnosed by their referring psychiatrist, c) noted in a neuropsychological report, or d) diagnosed by their referring neuropsychologist. These children comprised the TS-ADHD group. The remaining 17 children formed the TS-Only group.

Five of the TS children were taking medications for reduction of tic severity or of obsessive-compulsive symptoms at the time of testing. In the TS-ADHD group, 3 children were taking medication: one child was taking Haloperidol, a dopamine antagonist, another child was taking clonidine, an adrenergic agonist, and one child was taking thioridazine, a drug which blocks the release of acetylcholine (Bassuk, Schoonover, & Gelenberg, 1983). In the TS-Only group, one child was taking Haloperidol and the other imipramine, a tricyclic antidepressant that is a serotonin antagonist (Shatzberg & Cole, 1986). Two children in the TS-ADHD group who were habitually taking Ritalin were not medicated at the time of the testing.

None of the children were diagnosed with OCD. However, 9 of the 25 TS children recruited above (36%) were thought to display varying degrees of obsessive-compulsive behaviours (OCB), as judged by their referring psychiatrist or pediatric neurologist.

Prior to entering the study, 15 of the 25 children with TS had 1) undergone psychological testing with a clinical psychologist or school psychologist and/or 2) seen a psychologist, psychiatrist or other mental health professional for treatment of school and/or behavioral problems. Another eight children had been referred to the study by their psychiatrist. Information on prior referral history was unavailable for two children who had been contacted through the Tourette Syndrome Association.

2) ADHD Group

Children with a diagnosis of ADHD were identified 1) at random from consecutive files of children referred for neuropsychological assessment at the Queen Alexandra Centre for Children's Health, and 2) from files specifically selected by two neuropsychologists from their caseloads at the aforementioned facility. A total of 16 children who had no known history of tics, TS, or obsessive-compulsive behaviour, as well as IQ above 80 were identified (WISC-R or WISC-III). Children with history of thought disorder, severe emotional

stressors, or other neurologic condition (such as a movement disorder) were excluded. Children who were taking medication (e.g., methylphenidate, other stimulant, or other psychoactive medication) at the time of testing were also excluded.

3) Control Group

The control group consisted of 18 children without history of neurological disease, remedial education classes, grade failure, or clinical referral, recruited through Victoria area schools. These children had been contacted by letter for a prior normative study on the CPT but had not yet participated.

One control child was excluded from the analyses because high levels of restlessness and inattention were noted during the testing session. The Conners Parent Rating Scale (CPRS-48) Hyperactivity Index for this child was also above 1.5 standard deviations from the normative mean (Goyette & Ulrich, 1978).

Table 1 displays group means for age, full scale IQ (FSIQ), and socioeconomic status (SES) for the four groups.

TABLE 1: Means, Standard Deviations across groups for Age, Full-Scale IQ (FSIQ), and Socioeconomic Status (SES)

		CONTROLS N = 17	TS-ONLY N = 17	TS-ADHD N = 8	ADHD N = 16
AGE	Mean	10.78	10.70	10.97	9.71
	SD	(1.37)	(2.36)	(3.03)	(2.12)
FSIQ *	Mean	114.53	106.59	102.13	107.63
	SD	(7.75)	(17.54)	(5.72)	(13.18)
SES	Mean	58.94	48.87	48.79	43.16
	SD	(14.40)	(19.92)	(16.24)	(12.12)

* The ADHD children's FSIQ was measured with either of two versions of the same test (the WISC-R or the WISC-III); the group mean in the table is a group average which treats the two versions as equivalent. The actual means are as follows: WISC-R FSIQ for 12 children was 110.67 (SD = 12.84) and WISC-III FSIQ for 4 children was 98.5 (SD = 10.76).

PROCEDURE

Children with TS and control children were tested either at the University of Victoria Psychology Clinic, the Sunny Hill Hospital for Children in Vancouver, or at a registered psychologist's office in Nanaimo, B.C. Children with ADHD had been tested at the Queen Alexandra Centre for Children's Health in Victoria, B.C.

TEST BATTERY

The test battery consisted a CPT, the Seidel Continuous Attention Test

(SCAT; Seidel, 1988), and the WISC-III. The Yale Global Tic Severity Scale (YGTSS; Leckman, Riddle, et al., 1989), a semi-structured interview for tic severity was also completed with parents and children. For tic severity subscale scores, see Appendix 4.

The parent also completed the 48-item Parent Conners Rating Scale (CPRS-48, Conners, 1991), which has traditionally been used to differentiate children with ADHD from other clinical groups and from normal children. Items describing problem behaviours on the CPRS-48 are scored on a four-point scale from 0 ("not at all") to 3 ("very much"). Higher ratings therefore reflect higher behavioral abnormality as compared to the normative group. Five factor scores (Conduct Problem, Learning Problem, Psychosomatic, Impulsive-Hyperactive and Anxiety) and a Hyperactivity Index are computed and then converted to age-scaled z-scores using the norms reported by Goyette, Conners, and Ulrich (1978). For actual subscale means, see Appendix 6.

While their children were being tested, parents completed a child history form used at the University of Victoria Psychology Clinic which provided information on prenatal and early childhood events and allowed the calculation of the parents' socioeconomic status, as measured by the Blishen scales (Blishen, Carroll, & Moore, 1981). For illustration purposes, a listing of representative occupations is provided in Appendix 5.

Parents also completed the ADHD Rating Scale (DuPaul, 1991), the Social Skills Rating Scale (Gresham & Elliott, 1990) and the Home Situations Questionnaire (HSQ; Barkley 1991) for use in future studies. An experimental self-report measure of OCB based on the Leyton scales (LOI-CVR) was also administered. This measure was not used in the analyses because of poor agreement with OCB as determined by the child's psychiatrist, and because the reading level required was too high for most of the children (Laura Janzen, personal communication).

Prior to participating, both parents and children completed consent forms (Appendix 7). Each parent was sent a two-page summary report of their child's

performance on the test battery.

In summary, the test battery consisted of:

1) SCAT
2) WISC-III
3) LOI-PV
4) CPRS-48
5) YGTSS
6) ADHD Rating Scale
7) HSQ
8) SSRS
9) LOI-CVR
10) Child History Questionnaire

DEPENDENT VARIABLES

CPT PARADIGM

The SCAT is a revised and locally normed version of the CPT. It consists of two fifteen minute tasks. In the first task, letters are presented one by one on an Apple II-c microcomputer in random sequence at a rate of 1.5 seconds and for duration of 0.2 seconds. 600 letters are presented, of which 90 (15%) are letter "X" targets. The child must press the space bar when an "X" is presented, as rapidly as possible. In the second condition, the child responds only if the "X" has been immediately preceded by an "A", and must inhibit responding to the A itself, to letters following the A that are not X, and to X's not preceded by A's. This "A then X" condition was used in the analyses because the presence of the anticipatory "A", which signals that the target is forthcoming, better allows for measuring impulsivity; the research base for this task is also more extensive, especially in terms of its use with ADHD children.

The SCAT records misses (number of targets not responded to) and false alarms (number of responses made to non-targets).

SIGNAL DETECTION MEASURES

Nonparametric measures of sensitivity and response bias were calculated according to Grier (1971). Response criterion was defined as the false alarm rate as recommended by Richardson (1972). Since the maximum number of false alarms possible was constant for every subject (600 trials - 90 targets, or 510 possible false alarm trials), the false alarm rate in this case was simply the number of false alarms divided by the constant 510. Thus, because the two measures were essentially interchangeable in assessing for group differences, number of false alarms was used as a measure of response criterion because it was more easily interpretable than the false alarm rate. See Appendix 8 for SDT formulae.

OBSERVATIONS OF TICS

Very early in the study, upon noting the frequency of blinking and other eye movement tics reported by the participants or their parents, and observing frequent eye tics in children during the CPT administration, the author began recording the type of tics observed during the administration of the CPT. Because assumptions regarding the role of inattention as contributing to poor CPT performance are only valid in the absence of motor problems, these tic observations were later used to clarify whether poor performance on the CPT was related to eye tics, a type of tic phenomena which may have interfered with the visual demands of the task.

RESULTS

1. STATISTICAL CONSIDERATIONS AND ALPHA LEVELS

The analyzes were conducted using the SYSTAT version 5.01 statistical package (Wilkinson, 1990). To control for experiment-wise error, an alpha level of .05 was adopted for predicted comparisons. Bonferroni-corrected alpha levels were adopted for unpredicted comparisons. However, comparisons with alpha levels of .05 which did not reach statistical significance under Bonferroni adjustment were nonetheless reported for exploratory purposes, with the assumption that any interpretations derived from these comparisons lead to increased probability of committing Type I errors. Correlational effect size was determined using Cohen's (1988) criteria for behavioral science research, where correlations of .50, .30, and less than .30 are considered large, medium and small correlations, respectively.

2. GROUP MEANS AND CORRELATIONS FOR SUMMARY DATA AND DEPENDENT VARIABLES

Group differences in age, FSIQ, and SES rating were not significant, as determined by one-way ANOVAs and Tukey's honestly significant difference (HSD) test. For means, see the section describing subject selection and sample characteristics. Table 2 displays group means for SDT measures of sensitivity (SENS), Misses, False Alarms (FA), as well as for the LOI-PV scale of OCB severity and the CPRS-48 Hyperactivity Index (HYP). Table 3 displays the correlation matrix.

TABLE 2: Means, Standard Deviations across groups for Sensitivity (SENS), Response Bias (BIAS), Misses, False Alarms (FA), LOI-PV, and CPRS-48 Hyperactivity Index (HYP)

		CONTROLS N = 17	TS-Only N = 17	TS-ADHD N = 8	ADHD N = 16
SENS	Mean	0.993	0.972	0.952	0.921
	SD	.008	0.027	0.034	0.053
	z score		-2.62	-5.13	-9.00
MISSES	Mean	2.18	8.65	15.25	22.31
	SD	(2.40)	(8.56)	(11.46)	(17.46)
	z score		2.70	5.45	8.39
FA	Mean	2.06	5.41	7.75	21.75
	SD	(3.38)	(7.71)	(6.92)	(14.27)
	z score		0.99	1.68	5.83
BIAS	Mean	.670	.729	.680	.583
	SD	(.260)	(.240)	(.316)	(.205)
	z score		0.23	0.04	-0.34
LOI-PV	Mean	4.41	14.39	14.83	N/A
	SD	(3.94)	(14.79)	(13.85)	
	z score		2.53	2.64	
HYP	z score	- 0.72	1.39	2.53	2.63
	SD	(0.70)	(1.55)	(0.89)	(1.50)

N.B. Z scores were derived from control group data; LOI-PV data were not available for the ADHD group; z scores from the CPRS-48 are derived from norms provided by Goyette & Ulrich, as cited in Conners, 1990.

TABLE 3: Intercorrelations Between Measures for All Groups (N = 58)

	SENS	FA	BIAS	MISSES	LOI-PV
FA	-.54 [1]				
BIAS	-.10	-.49 [1]			
MISSES	-.98 [1]	.38 [1]	.22		
LOI-PV *	-.37 [2]	.46 [1]	-.05	.31 [3]	
HYP	-.39 [1]	.48 [1]	-.05	.34 [1]	.48 [1]

N.B. data on the LOI-PV was not available for the ADHD children

[1] $p < .01$, two-tailed

[2] $p = .03$, two-tailed

[3] $p = .05$, two-tailed

3. AGE EFFECTS

Pearson product-moment correlations for age, SES, FSIQ and CPT measures are presented in Appendix 9. In previous studies, CPT performance has been found to correlate with age of children (Corkum & Siegel, 1993). As expected, similar patterns were also observed in the current study for sensitivity and number of misses. In contrast, number of false alarms and bias were not correlated with age.

In most cases, whenever age is not of interest as a predictor variable, the confound of age with CPT performance is easily dealt with by using age-normed scores. However, CPT age-normed scores were not available for all the age ranges used in the current study. Age effects were thus controlled

statistically. Specifically, effects of age were partialed out of sensitivity and number of missed targets. The residuals, representing the variance in sensitivity and missed targets not accounted for by age, were then used in all further analyses. Further references to sensitivity and misses within the context of statistical analyses therefore refer to the above defined age-adjusted scores.

4. TS, ADHD, AND SUSTAINED ATTENTION (AS MEASURED BY SENSITIVITY AND NUMBER OF MISSED TARGETS)

1) SENSITIVITY

To differentiate the effects of TS and ADHD on sensitivity, a 2 x 2 (TS/Non-TS x ADHD/Non-ADHD) factorial analysis of variance was performed. The interaction effect of TS and ADHD diagnoses was significant [$F(1, 54) = 5.56$, $p = .02$]. The main effects of ADHD [$F(1, 54) = 22.23$, $p < .0001$] was also significant. The main effect of TS diagnosis was not significant.

Actual probability levels for pre-planned pairwise comparisons using the Tukey honestly significant difference (HSD) test of pairwise means are presented in Table 4. Both ADHD and TS-ADHD children had lower sensitivity than the control children. No differences between control children and those with TS-Only were found, or between children with TS-Only and those with TS-ADHD.

TABLE 4: Probability Levels for Pre-Planned Pairwise Comparisons using the Tukey HSD Test for Sensitivity

	TS-ONLY	TS-ADHD	ADHD
CONTROLS	.32	.03 *	.0001 *
TS-ONLY		.43	.002 *
TS-ADHD			.37

* indicates significant differences

2) NUMBER OF MISSED TARGETS

To differentiate the effects of TS and ADHD on hit rate, a 2 x 2 (TS/Non-TS x ADHD/Non-ADHD) factorial analysis of variance was run with CPT misses as dependent variable. The interaction effect of TS and ADHD diagnoses approached significance [$F(1, 54) = 3.65$, $p = .08$] and the main effect of TS diagnosis was not significant. The main effects of ADHD [$F(1, 54) = 17.64$, $p < .0001$] was significant.

Probability levels for pre-planned pairwise comparisons using the Tukey honestly significant difference (HSD) test of pairwise means are presented in Table 5. Using an alpha level of .05, both the TS-ADHD and the ADHD group missed significantly more targets than the control children. No differences between control children and those with TS-Only were found, or between children with TS-Only and those with TS-ADHD. However, an examination of means (Table 2) reveals that the performance of TS-Only children fell between that of controls and TS-ADHD children, with TS-Only children making approximately three times more misses than controls. Overall, these results were similar to those obtained for number of misses.

TABLE 5: Probability Levels for Pre-Planned Pairwise Comparisons using the Tukey HSD Test for Missed Targets

	TS-ONLY	TS-ADHD	ADHD
CONTROLS	.33	.03 *	.0001 *
TS-ONLY		.42	.02 *
TS-ADHD			.78

* indicates significant differences

5. *TS, ADHD AND IMPULSIVITY (AS MEASURED BY FALSE ALARMS AND BIAS)*

1) FALSE ALARMS

To differentiate the effects of TS and ADHD on response criterion (number of false alarms), a 2 x 2 (TS/Non-TS x ADHD/Non-ADHD) factorial analysis of variance was performed with CPT false alarms as dependent variable. The predicted main effect of ADHD diagnosis was found to be significant [$F(1, 54) = 18.99$, $p < .0001$]. The TS diagnosis main effect was also significant [$F(1, 54) = 4.44$, $p = .04$], as was the interaction of TS and ADHD [$F(1, 54) = 11.79$, $p = .001$].

Probability levels for pre-planned pairwise comparisons using the Tukey honestly significant difference (HSD) test of pairwise means are presented in Table 6. Using an alpha level of .05, only the ADHD group had measurable impulsivity problems compared to the other groups. Notably, the TS-ADHD group did not differ from the TS-Only group in number of false alarms. In addition, despite their common ADHD diagnosis which should have translated in increased false alarms, the TS-ADHD group made fewer false alarms than "pure" ADHD children.

TABLE 6: Probability Levels for Pre-Planned Pairwise Comparisons using the Tukey HSD Test for False Alarms

	TS-ONLY	TS-ADHD	ADHD
CONTROLS	.71	.47	.0001 *
TS-ONLY		.93	.0001 *
TS-ADHD			.005 *

* indicates significant differences

2) RESPONSE BIAS

To differentiate the effects of TS and ADHD on response bias, a 2 x 2 (TS/Non-TS x ADHD/Non-ADHD) factorial analysis of variance was performed with CPT false alarms as dependent variable. None the main or interaction effects were significant or approached significance.

6. EXPLORATORY ANALYSES OF OTHER MEASURES OF ATTENTION AND IMPULSIVITY

To differentiate the effects of TS and ADHD on other measures of attention and impulsivity, 2 x 2 (TS/Non-TS by ADHD/Non-ADHD) factorial analyses of variance were run with Digit Symbol, Symbol Search, Digit Span, Arithmetic, and Mazes as dependent variables. None of the main or interaction effects were significant even before Bonferroni adjustment of p values. Table 7 presents group means and standard deviations. Means for other WISC-III subtests are presented in Appendix 10.

TABLE 7 Group Means for Other Measures of Attention and Impulsivity

		CONTROLS	TS-Only	TS-ADHD	ADHD
Digit Symbol	Mean	11.00	9.77 (3.85)	6.75	9.23
	SD	(2.96)		(3.88)	(4.01)
	N	17	17	8	14
SYMBOL SEARCH	Mean	11.94	11.31	9.63	10.00
	SD	(3.36)	(4.13)	(4.03)	(4.55)
	N	16	16	8	4
DIGIT SPAN	Mean	10.75	11.07	10.13	8.57
	SD	3.11	(4.85)	(3.31)	(2.59)
	N	16	15	8	14
ARITHMETIC	Mean	12.47	11.29	9.63	9.00
	SD	2.40	(4.34)	(2.63)	(2.22)
	N	17	17	8	14
MAZES	Mean	9.58	10.79	9.14	11.00
	SD	(4.46)	(4.19)	(2.67)	(3.72)
	N	12	14	7	13

N.B. Means for the ADHD group are composites of WISC-III and WISC-R scales scores, and therefore should be regarded as estimates only; N varies with each group because some children were not administered all the supplementary subtests of the WISC-III and WISC-R (i.e. Symbol Search, Mazes, and Digit Span)

7. RATINGS OF TS, ADHD, OCB, AND CPT PERFORMANCE

The next goal was to determine how well severity of TS, ADHD and OCD predicted performance on the CPT. An initial step was to examine the correlation matrix of variables of interest. The ADHD children were excluded from the analyses because YGTSS and OCB ratings were not available for them. Six children with TS were also excluded because of missing LOI-PV data. Correlations between the CPT and tic ratings (YGTSS), ratings of ADHD (Hyperactivity Index of the CPRS-48), and ratings of obsessive-compulsive symptoms (LOI-PV) are presented in Table 8. All three rating scales were moderately correlated with sensitivity, misses, and false alarms (response criterion), but not with response bias. Response bias was therefore not included in the regression analyses.

Given the similar magnitude of correlations between the rating scales and three of the CPT variables, a second step was to perform standard multiple regressions using the OCB, ADHD and TS ratings to predict sensitivity, misses, and false alarms. Table 9 displays the results of the regression analyses.

TABLE 8 *Intercorrelations Between CPT Measures and Ratings of TS (YGTSS), ADHD (Hyperactivity Index of the CPRS-48), and OCB (LOI-PV) for Control and TS Children (N = 36) using age-adjusted scores*

	SENS	*MISSES*	*FA*	*BIAS*	*YGTSS*	*HYP*
MISSES	*-.99*[1]					
FA	*-.70*[1]	*.59*[1]				
BIAS	*-.17*	*.25*				
YGTSS	*-.44*[2]	*.43*[2]	*.35*[3]	*.04*		
HYP	*-.43*[2]	*.44*[2]	*.28*	*.07*	*.76*[1]	
LOI-PV	*-.45*[2]	*.42*[2]	*.47*[2]	*.05*	*.52*[1]	*.48*[2]

[1] *p < .001, two-tailed*

[2] *p < .01, two-tailed*

[3] *p < .05, two-tailed*

A) SENSITIVITY

When YGTSS, HYP and LOI-PV were regressed simultaneously on sensitivity, the model was significant (R^2 = .28, p = .01). However, none of the variables contributed uniquely to predicting sensitivity.

B) MISSES

When YGTSS, HYP and LOI-PV were regressed simultaneously on number of missed targets, the model was also significant (R^2 = .27, p = .02). As with sensitivity, none of the variables contributed uniquely to the prediction of

number of misses.

C) FALSE ALARMS

When YGTSS, HYP and LOI-PV were regressed simultaneously on false alarms, the model accounted for a significant amount of the variance (R2 = .23, p = .04). Evaluation of the semi-partial correlations showed that only the LOI-PV contributed uniquely to the prediction of impulsivity (sr = .37). Thus, when TS and ADHD were controlled for, OCB contributed significantly to predicting impulsivity.

TABLE 9 *Summary of Regression Analyses for Variables Predicting CPT Variables (N = 36)*

	B	SE B	BETA	T	p	sr
SENS						
HYP	-.002	.004	-.14	.28	.63	-.07
YGTSS	< -.001	< .001	-.21	.26	.48	-.11
LOI-PV	< -.001	< .001	-.27	.73	.13	-.23
MISSES						
HYP	.91	1.37	.19	.29	.51	.10
YGTSS	.08	.13	.19	.26	.51	.10
LOI-PV	.17	.13	.23	.73	.21	.19
FA						
HYP	-.16	1.03	-.05	.28	.87	-.02
YGTSS	.04	.10	.14	.26	.66	.07
LOI-PV	.22	.10	.42	.73	.03	.37

N.B. Regression terms are as follows: regression coefficients (B), standardized regression coefficients (SE B), Beta weights (BETA), tolerance values (T), p values (p), and the semipartial correlations (sr)

8. *CLINICALLY SIGNIFICANT DIFFERENCES*

Because group means can obscure individual results and may not be directly relevant and interpretable in terms of clinically significant impairments in performance, a difference of 2 or more standard deviations below the control group mean was used as criterion for detecting children with impaired performance on the CPT. Z scores from the control mean for the TS-Only, TS-ADHD, and ADHD children as a group are presented in Table 2.

A) SENSITIVITY AND MISSES

Using this criterion, 6 of 17 children in the TS-Only group (35%), 6 of 8 children in the TS-ADHD group (75%), and all children in the ADHD group had impairments in sensitivity in comparison to the control mean. Results for misses were identical for the TS-Only and Control groups. Fifteen (94%) of the ADHD children had scores which were below 2 standard deviations from the control group mean.

B) FALSE ALARMS AND BIAS

When a clinically significant deviation of 2 standard deviations from the group mean was taken into account in assessing impulsivity problems in the TS children defined by false alarms, only 2 children from the TS-Only group (12%) had false alarm scores which were within the impaired range. One third of children (33%) from the TS-ADHD group had false alarm scores which were 2 standard deviations or more below the control mean. In contrast, 10 (63%) of the ADHD children had similar problems. Only one child with TS-ADHD (6%) had a bias score which fell two or more standard deviations below the control group mean. Two control children (12%) and one child with TS-Only (6%) also had similar scores. None of the ADHD children had scores which were in this range.

C) OTHER ATTENTION TESTS

In the case of the Digit Symbol subtest, the number of children with scores below 2 standard deviations were as follows: 1 child in the TS-Only group (6%), 3 children in the TS-ADHD group (38%), and 2 children in the ADHD group (14%). On the remaining WISC-III attention/impulsivity tests (i.e., Digit Span, Symbol Search, Mazes, Arithmetic), few if any children across groups were identified as having impaired performance. At most, one child per group was identified as having clinically significant performance impairments for each of the tests.

9. TIC SEVERITY

The overall mean difference between TS-Only and TS-ADHD groups on global tic severity was 4.11, a nonsignificant difference as determined by T-test. Means for subscore scales of the YGTSS are presented in Appendix 4.

10. TIC LOCATION AND CPT PERFORMANCE

It was thought that eye movement tics could possibly contribute to poor performance on the CPT by interfering with the visual demands of the CPT. This hypothesis was tested in two ways: by 1) relating CPT performance to the presence of habitual eye movement tics as reported in the YGTSS, 2) relating CPT performance to examiner observations during CPT administration (since the YGTSS only measures habitual tics which may or may not have occurred during the administration of the CPT), and 3) determining the prevalence of examiner-observed eye tics in children with clinically significant impairments in performance on the CPT.

Table 10 presents the percentage of children in each group with tics in particular body locations as reported on the YGTSS. Overall, the presence of eye movement tics as determined by the YGTSS was not correlated with CPT

measures (all correlations were between -.06 and .05, $p > .05$, 2-tailed).

According to examiner observations during the CPT administration, CPT variables were clearly not related to presence of eye tics. As with the YGTSS ratings, correlations were negligible. Specifically, the magnitude of correlations ranged from -.07 to .07 ($p > .05$, 2-tailed).

According to examiner observations, only 2 of the 11 children (one in the TS-Only group and one in the TS-ADHD group) with clinically significant problems in sustaining attention had eye blinking or eye movement tics during CPT administration.

Overall, these results suggest that eye movement tics were not related to CPT performance.

11. TIC LOCATION AND ADHD

Table 10 shows the percentage of children with tics in particular locations across groups, taken from the YGTSS tic checklist. The most striking difference between TS children with and without ADHD concerned the presence of whole body tics, with a substantially larger proportion of TS-ADHD children having tics that involved the whole body. Whole body tics were defined as tics involving movement of the entire body, such as hopping, jumping, standing and kicking, etc., as well as bouts of tics involving simultaneous arm, torso, and leg movements. To a lesser degree, TS-ADHD children were more likely to have tics of the legs and arms, in comparison to the TS-Only children, and TS-Only children were more likely to have eye and shoulder movements.

TABLE 10: Percentage of TS-Only and TS-ADHD Children with Tics in Particular Locations

LOCATION OF TIC	TS-Only	TS-ADHD	DIFF
Eye (blinking, eye movements)	13 (76%)	5 (56%)	20%
Head (facial, mouth and head tics)	15 (88%)	7 (88%)	0%
Shoulder (movements and shrugs)	10 (59%)	3 (38%)	21%
Arm (finger, hand and arm tics, including copropraxia)	6 (35%)	4 (50%)	15%
Leg (toe, foot and leg tics)	7 (41%)	5 (63%)	22%
Body (whole body tics, such as hopping, jumping, paroxysms involving simultaneous arm, torso and leg movements)	3 (18%)	6 (75%)	57%
Phonic (vocal tics including palilalia, coprolalia and echolalia)	15 (88%)	7 (88%)	0%
Touching Tics (compulsions/tics of touching self, others, or objects)	8 (47%)	4 (50%)	3%
Compulsions (compulsions involving symmetry, cleanliness, etc.)	4 (24%)	2 (25%)	1%

N.B. Percentage indicated in parentheses; DIFF = difference between TS-Only and TS-ADHD children, in percentage

DISCUSSION

This study was aimed at determining whether children with TS have impairments in sustained attention and impulsivity, in comparison to control children, that are not accounted for by comorbid ADHD. Based on previous research, the following predictions were made: 1) children with TS would have deficits in sustained attention but not impulsivity in comparison to control children; 2) children with TS-ADHD would have similar impairments in impulsivity and sustained attention as children with ADHD; and 3) impulsivity would be related to OCB. The findings are discussed according to these hypotheses as well as in light of the possible confound of tic location in the diagnosis of ADHD in TS, and the effect of sensory modality in the use of the CPT. Implications of the study for future research and for clinical diagnosis and intervention are also incorporated.

ATTENTION IN THE TS-ONLY GROUP

As a group, TS-Only children did not have statistically significant impairments in sustained attention compared to controls. These results do not support the assertion that sustained attention problems are a "cardinal feature" of children with TS, as had posited previous researchers (Randolph et al., 1993). Notably however, despite the fact that none of the TS-Only children had a comorbid diagnosis of ADHD, one third of the group had clinically significant attention problems defined as sensitivity or misses falling two or more standard deviations below the control group mean. Two hypotheses may account for this finding.

First, the results suggest that there may exist a subgroup of TS children with attention problems. One possibility is that a third factor such as a common etiology causes TS and attention problems within this subgroup, but that the two phenomena occur independently in other children (Pennington, Groisser, & Welsh, 1993). Frontal-striatal dysfunction contributing to both inattention and

TS is one such hypothetical etiology. However, it is also possible that this subgroup simply reflects the base rate of attention problems in children referred to clinical settings. In other words, if the results of this study are reliable in reflecting expected base rates and not TS-specific problems in sustaining attention, in any given group of clinically referred children, approximately one third would perform poorly on the CPT regardless of diagnosis. Attention problems are known to be a correlate of several etiologically distinct disorders seen in clinical settings, such as learning disabilities, schizophrenia, anxiety disorders, conduct disorders, and autism (Quay, 1986). Although children with psychosis were excluded from the study, it is possible that some of the children in the sample had features of other childhood disorders that are also associated with attention problems. These children with attention problems would thus be characterised by a higher rate of other co-occurring conditions.

Second, although attention problem base rate data were not available, most children seen in clinical settings are referred following school problems. Because attention is essential to adequate school functioning, children with TS who have attention problems may be more frequently referred than TS children without attention difficulties, thus skewing clinical samples towards a higher prevalence of TS children with attention problems than would be expected in the general population. Thus, determining the syndrome-specificity of associated features such as attention problems requires a priori knowledge of the base rate of these problems in the clinical population under examination, possibly by comparing to other clinical groups, as well as an investigation of the prevalence of attention problems in children with TS in the general population who have not been clinically referred.

Given the resulting generalization problems associated with the use of clinical samples, the results would tend to support the theory that attention problems are <u>not</u> an associated feature of children with TS, since the majority of TS children without ADHD did <u>not</u> have measurable deficits in the ability to sustain attention, despite prior clinical referral histories which suggest either 1) a

higher rate of other comorbid clinical diagnoses affecting attentional processes or 2) a higher rate of attention problems due to possible referral biases favouring children with school difficulties.

It is possible, of course, that the TS children were referred because they had TS, not because they had other problems such as attention difficulties. However, it is well known that clinical samples of persons with a specific disorder are not representative of persons in the general population with the same disorder. For example, persons in clinical samples typically present with a more severe form of the disorder and with a higher rate of comorbid conditions (Fallon & Schwab-Stone, 1992) than those who have never been referred. Given the rate of prior clinical referral of the children in this study, it is safe to assume that the children clearly represent a "clinical" sample, as are most children in TS research. Again, the self-selection inherent in clinical samples limits the generalization of the findings to other clinical samples only and tells us little about the phenomenology of the disorder in the general population. For example, if these results are replicated, clinicians should be aware that one of every three children with TS who is referred to a clinical setting for assessment or treatment is likely to present with severe attention problems which potentially affect their daily functioning. However, a teacher who has a child with TS in his class cannot assume that the child has a higher likelihood of having attention problems than any other of his pupils. Further research on the prevalence of attention problems in 1) clinical groups in general, and 2) TS children in the general population should shed light on these questions.

IMPULSIVITY IN TS

Two findings concerning impulsivity and ADHD diagnosis require explanation: 1) the performance differences between TS-ADHD and ADHD children on the CPT, and 2) the difference in tic location between TS-ADHD and TS-Only children. Specifically, despite being diagnosed with ADHD (which

is associated with impulsivity problems in existing research), children with TS-ADHD did not have statistically significant impulsivity problems in comparison to controls or TS-Only children on the CPT. More importantly, despite their common ADHD diagnosis which should have translated into similar response inhibition problems, TS-ADHD children were less impulsive than ADHD children as measured by number of false alarms. Only one third of TS-ADHD children had clinically significant impulsivity problems in comparison to two thirds of the ADHD children as determined by false alarms. In addition, children with TS-ADHD had a much higher rate of whole body tics than TS children not diagnosed with ADHD.

One preliminary explanation for the findings are that the cognitive correlates of ADHD differ in TS-ADHD and in pure ADHD. Thus, deficits in the regulation of impulsivity on the CPT which are a common and reliable finding in "pure" ADHD (Barkley, 1990) would not occur in the majority of children who are diagnosed as having TS-ADHD because of some TS-specific expression of ADHD, dictated by TS-specific neural mechanisms. However, a simpler explanation is that the behavioral similarity between whole body tics and overactivity/restlessness lead to mislabelling of some complex tics as manifestations of ADHD in children with TS. That the TS-ADHD and ADHD group differed on the CPT is consistent with this hypothesis, as is the fact that the TS-ADHD children had a much higher rate of whole body tics than the TS-Only children.

It is important to note that the majority of TS-ADHD children had clinically significant problems in sustaining attention, even if their impulsivity problems were not comparable to those of the ADHDs. Putting these facts together suggests that it is possible that TS children who present with both attention problems as well as whole-body tics are indistinguishable, behaviorally, from children with ADHD. Thus, for some children, TS would appear to produce only the behavioral symptoms of ADHD, not the full ADHD syndrome. This type of phenomenon is termed the phenocopy hypothesis, as described by Pennington

et al. (1993) with regards to reading disability comorbidity in ADHD. In cases where the comorbid group is similar behaviorally but not cognitively to the "pure" group, it is assumed that a common brain dysfunction for the two disorders cannot be supported.

There is an interesting and somewhat paradoxical implication that stems from these findings. If tic phenomenology confounded the diagnosis of ADHD in TS, then the TS-ADHD group may have in fact been comprised of a number of children without ADHD. In other words, the group would have consisted of a number of "TS-Only" children mislabelled as TS-ADHD. Given the high rate of attention problems in the TS-ADHD group (75%), most of these speculative "TS-Only" children probably had severe attention problems. Therefore, the rate of attention problems in TS-Only may be much higher than 35%, as was previously determined, and may far exceed the base rate of attention problems in clinical groups. In summary, the question of attention problems in TS may be more complex than was previously thought, given the possible confound of tic phenomenology in ADHD diagnosis. Regardless of the rate of attention problems, this confound does help explain the high rates of TS-ADHD comorbidity which were previously unexplained by genetic analyses (Pauls et al., 1986) and not fully accounted for by sampling biases inherent in clinical studies (Fallon & Schwab-Stone, 1992).

Whether differences in CPT performance would emerge between TS and ADHD children if one used the revised diagnostic criteria from the DSM-IV, which divides ADHD into subgroups with and without hyperactivity, is perhaps a relevant question. In the past, children with attention problems only may have been less likely to be diagnosed with ADHD using DSM-III-R criteria because only approximately five items in the list of criteria were arguably related to attention problems (see items 3, 6, 7, 12, and 13 in Appendix 2) and eight out of fourteen possible criteria were required for diagnosis. With the newer DSM-IV system, it is possible to be diagnosed with Attention Deficit/Hyperactivity Disorder (AD/HD) based on either primarily inattentive features (using these five

items in addition to others) or on the presence of hyperactivity-impulsivity only. Of course, since the diagnosis of AD/HD can be maintained only if the symptoms "are not better accounted for by another mental disorder" (DSM-IV, p. 85), we are back to having to determine whether attention problems are a feature of TS before we can diagnose AD/HD in TS children. Determining the prevalence and features of children with AD/HD in children with TS in future research according to DSM-IV criteria is a first step, as is ensuring that tics and hyperactive-impulsive behaviour are clearly differentiated in studies of TS children.

A more pragmatic hypothesis which can also partly explain the results is that contact with a psychiatrist for treatment of TS resulted in a higher identification rate of mild ADHD in TS. The fact that ADHD and TS-ADHD children had similar CPRS-48 Hyperactivity Index ratings suggests otherwise, however, unless another factor such as confusion between certain tics and hyperactivity contributed to inflating the Hyperactivity Index and "masked" mild ADHD in the TS-ADHD group.

As noted above, it is clear from the findings from this study that the TS-ADHD and the ADHD group differed cognitively on the CPT in terms of impulsivity. Insofar as the CPT reflected brain functioning (and not interference from tics, for example), it follows that the two groups also differed in terms of the brain systems involved in the genesis of their neuropsychological difficulties, and presumably, treatments of these two conditions would also differ. For example, treatments that focus exclusively on increasing behavioral self-control such as reinforcing non-impulsive behaviours may be more appropriate for ADHD children, and treatments aimed at decreasing attentional lapses by making stimuli more relevant or salient may be more appropriate for TS-ADHD children. More importantly, differentiating hyperactivity from tic phenomena may be useful in pharmacotherapy, since different approaches are used in the pharmacological treatment of ADHD (i.e., dopamine agonists) and TS (i.e., dopamine antagonists). It is important to ensure that ADHD-like behaviours are

not actually tic phenomena, particularly since dopamine agonists have been found to exacerbate tic symptoms in some children (Barkley, 1991).

An interesting finding was the difference between the measures of response criterion and response bias. Although these two measures are thought to measure the same construct, the response criterion analyses using false alarms were consistent with previous research in suggesting that ADHD children employ an extremely lax, impulsive response strategy in vigilance paradigms. The non-significant group differences for response bias, particularly between controls and ADHD children, suggest that bias was likely not a reliable measure. Nichols (1972) notes that even nonparametric bias measures can be problematic, particularly for extreme responders. Davies and Parasuraman (1982) also discuss limitations of existing bias measures.

OCB AND IMPULSIVITY

An interesting finding was the relationship between impulsivity on the CPT as determined by false alarms, and ratings of OCB, ADHD, and TS. While all three variables were moderately correlated with CPT impulsivity, the OCB ratings emerged as a unique predictor of false alarms which could not be attributed to either ADHD or TS severity.

Of course, the results regarding severity of OCB and CPT measures are preliminary since the LOI-PV has yet to undergo reliability studies and validity studies with TS children with full blown obsessive-compulsive disorder (OCD). Moreover, comparison with children with "pure" OCB (or OCD) would have helped clarify whether the results are specific to children with TS, or whether they are characteristic of all children with high rates of OCB. There is some evidence that the OCB behaviour of children with TS differs from that of children with OCD. For example, the compulsive behaviour of TS children may consist of more touching rituals whereas that of OCD children, of more washing rituals (Swedo & Rapoport, 1989). Other researchers have also noted differences in the nature of obsessions in OCD children with and without TS

(George, Trimble, Ring, Sallee, & Robertson, 1993). However, the results of the present study are consistent with the conceptualisation of OCB as an inability to inhibit persistent thoughts and resist from performing unintended actions, phenomena which are possibly attributable to attention control problems arising out of frontal-striatal dysfunction.

OTHER FACETS OF ATTENTION

No group differences in other measures of attention from the WISC-III were detected. These results suggest that when attention problems occur in TS, they may be restricted to sustained attention and not include problems with focused attention and encoding/manipulating. More importantly, given the lack of significant differences across groups and the few clinically significant problems identified in the ADHD group using these measures, these results underline the fact that the WISC-III has limited usefulness as a screening measure for ADHD.

CONFOUNDS IN THE USE OF THE CPT

There was no evidence that presence of eye movement tics interfered with CPT performance. However, a more sensitive measure than examiner observation and YGTSS may have found otherwise. One possibility, for example, is videotaping tics or measuring more precise electrophysiological indices of muscle movement during the CPT administration, since not all tics may be easily visible by an observer. In addition, it is possible that other types of tics not measured in this study, such as head movements or hand movement tics, may have affected CPT performance. These are possibilities for future research.

The inclusion of an auditory sustained attention/attentional control task in the test battery would also have allowed testing of the modality-specificity of sustained attention problems in those children with clinically significant difficulties. There are, at present, no theories positing a modality-specific

attention impairment in TS. However, although attention has traditionally been thought of as a supramodal process dependant on higher-order systems which act upon information incoming from the sensory modalities (Neisser, 1976; Posner, Snyder, & Davidson, 1980), it appears that a certain amount of attentional processing does occur at lower levels of the attentional system. Although these mechanisms are poorly understood, attentional processing occurs in secondary and tertiary cortical areas specific to each sensory modality (Cohen, 1993). Some theories of attention such as that of Heilman, Watson and Valenstein (1985) have posited that attention impairments can occur as a result of damage to the sensory component of attentional processes. As a result, it is possible to envision the existence of modality-specific attentional deficits, as suggested by Mesulam's model of attention (1981). Of course, even studies positing a modality-specific component to attention agree that higher-order, supramodal processing is a central component of attentional functioning. The relative contribution of the "central", higher-order systems, versus sensory, "peripheral" systems, however, in paradigms attempting to measure attention deficits is not known. Future studies incorporating paradigms which measure attentional processes in different modalities may be useful in answering these questions.

SUMMARY AND CONCLUSIONS

The results of this study imply that the measurement of attention problems in children with TS is clearly more complex than previous research would suggest. Tic phenomenology and the use of clinically-referred children were likely important confounds. The need for clearer differentiation between complex tics and hyperactive behaviour, and inclusion of community-based samples of children with TS in research was highlighted in furthering understanding of TS in children. The results suggested several avenues for future research, such as the use of DSM-IV criteria, more precise tic measurement and modality-specific measurements of attention processes, as

well as extension of the findings to children with OCB without TS. Comprehensive investigations of these and related research questions will help clarify whether the assumptions derived from this study, perhaps in conjunction with other factors yet to be determined, contribute substantially to further delineating the phenomenology of TS in children.

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APPENDIX 1: DIAGNOSTIC CRITERIA FOR TOURETTE SYNDROME

A. Both multiple motor and one or more vocal tics have been present at some time during the illness, although not necessarily concurrently.

B. The tics occur many times a day (usually in bouts), nearly every day or intermittently throughout a period of more than one year.

C. The anatomic location, number, frequency, complexity, and severity of the tics change over time.

D. Onset before age 21.

E. Occurrence not exclusively during Psychoactive Substance Intoxication or known central nervous system disease, such as Huntington's chorea and postviral encephalitis

From:

American Psychiatric Association, (1987). Diagnostic and Statistical Manual of Mental Disorders (3rd Ed., Revised) (p. 80). Washington, DC: Author.

APPENDIX 2: DIAGNOSTIC CRITERIA FOR ATTENTION-DEFICIT HYPERACTIVITY DISORDER

Note: Consider a criterion met only if the behaviour is considerably more frequent than that of most people of the same mental age.

A. A disturbance of at least six months during which at least eight of the following are present:

(1) often fidgets with hands or feet or squirms in seat (in adolescents, may be limited to subjective feelings of restlessness)
(2) has difficulty remaining seated when required to do so
(3) is easily distracted by extraneous stimuli
(4) has difficulty awaiting turn in games or group situations
(5) often blurts out answers to questions before they have been completed
(6) has difficulty following through instructions from others (not due to oppositional behavior or failure of comprehension), e.g., fails to finish chores
(7) has difficulty sustaining attention in tasks or play activities
(8) often shifts from one uncompleted activity to another
(9) has difficulty playing quietly
(10) often talks excessively
(11) often interrupts or intrudes on others, e.g., butts into other children's games
(12) often does not seem to listen to what is being said to him or her
(13) often loses things necessary for tasks or activities at school or at home (e.g., toys, pencils, books, assignments)
(14) often engages in physically dangerous activities without

considering possible consequences (not for the purpose of thrill-seeking), e.g., runs into street without looking

Note: the above items are listed in descending order of discriminating power based on data from a national field trial of the DSM-III-R criteria for Disruptive Behavior Disorders.

B. Onset before the age of seven.

C. Does not meet the criteria for Pervasive Developmental Disorder.

Criteria for Severity of Attention-deficit Hyperactivity Disorder:

Mild: Few, if any, symptoms in excess of those required to make the diagnosis and only minimal or no impairment in school and social functioning.

Moderate: Symptoms or functional impairment intermediate between "mild" and "severe"

Severe: Many symptoms in excess of those required to make the diagnosis and significant impairment in functioning at home and school and with peers.

From:

American Psychiatric Association, (1987). Diagnostic and Statistical Manual of Mental Disorders (3rd Ed., Revised) (p. 80). Washington, DC: Author.

APPENDIX 3: OVERVIEW OF THE LEYTON OBSESSIONAL INVENTORY–PARENT VERSION

AGES: age 7 to 15

DESCRIPTION:

A revised version of the Leyton Obsessional Inventory–Child Version originally derived by Berg, Whitaker, Davies, Flament & Rapoport (1988), was adapted for parent use by removing the "I" at the beginning of the item and presenting pronouns in the third person. The original content of the 20 items and summary scores were preserved, with an additional experimental response category of "Don't Know" added to determine, in future studies, the types of behaviours that are not known to parents, given the internalized nature of some obsessive-compulsive behaviours. These were also coded "0" in the analyses. "Yes" responses were coded 1 and "No" as 0. The degree of interference experienced by the child according to the parent was coded along a Likert-type scale, as in the original survey form.

Instructions are printed at the top of the form and are fairly self-explanatory. The examiner was encouraged to read the instructions aloud and remind the parent to think about his/her child's current behaviour, not worst or past behaviours.

Two scores are derived from the LOI-PV: the Interference score (which provides an index of the amount of impairment in daily life caused by the OCB, as defined by amount of time spent doing the OCB and degree to which it interferes with doing other tasks), and the Situations score (number of types of OCBs performed by the child). The Interference score was used for the analyses since previous research had determined its reliability and construct validity with children. The Situations score does not provide an index of the frequency of the symptom, a measure which is more useful in understanding the degree to which the child's behaviours approach the clinical range, since

"OCB-type" behaviours occur along a continuum, from behaviours performed by almost all children (e.g., considering 22 as a favourite number, having to check homework, etc.) to severe obsessive-compulsive actions (e.g., having to check homework 22 times).

PARTICIPANTS:

Participants were 16 control children, 13 TS children without OCB (as determined by their psychiatrist or neurologist), and 7 children with known OCBs determined in the same manner (TS-OCB group). All of these subjects were children described above whose parent had completed the LOI-PV. An additional 5 TS children never seen by a psychiatrist or neurologist were also included in the TS group without known OCBs.

ANALYSIS:

TABLE 11: LOI-PV Interference scores for controls, TS children, and TS children with OCB (TS-OCB); N = 42

	CONTROLS	TS	TS-OCB
LOI-PV	4.12 (3.88) (N = 16)	11.17 (8.42) (N = 18)	21.86 (19.17) (N = 7)

The LOI-PV demonstrated high internal reliability (Chronbach's alpha of .94). Using Cohen's (1988) criteria for correlational effect size, the LOI-PV was moderately correlated with presence of OCB as determined by psychiatrist ($r = .47$, $p = .002$). A higher correlation was not expected, given the YES/NO nature

of the psychiatric opinion which was not based on severity of symptoms. Moreover, TS complicates the diagnosis of OCD because of behavioral similarity between complex tics and obsessive-compulsive phenomena. OCD may be diagnosed in TS years after the onset of symptoms—by some reports as much as 7 to 10 years post-onset (Toro et al., 1992). Thus, a substantial portion of the TS group may have included cases of "undetected" OCB and have included children whose symptoms have not yet reached clinical severity. For these reasons, psychiatric diagnosis was likely to underestimate the presence of OCB when it occurred in the sample. In theory, undiagnosed OCB children would nonetheless obtain high ratings on the LOI-PV, given previous research with other versions of this instrument. Despite the similar clinical manifestation of complex tics and of compulsive behaviours complicating the detection of significant group differences on the LOI between TS children with and without OCB, TS-OCB children had higher LOI-PV scores than TS children without psychiatrically-determined presence of OCB (Table 11). These findings give preliminary support to the LOI-PV's validity in determining severity of OCB symptoms.

A factor analysis replicated previous research with the child-rated version of the scale in finding a conceptually valid four-factor solution. Factors were extracted from LOI-PV Interference Scores by means of a principal components analysis with Varimax rotation. A four-factor solution was specified a priori in order to allow comparison to previous research with the LOI-CV. Bartlett's test of sphericity indicated the suitability of the data for factor analysis. The rotated factor matrix was converged in 12 iterations. Together, the factors accounted for 69% of the variance. One large factor accounting for 40% of the variance was extracted (Eigenvalue = 7.94), along with three lesser factors accounting for 12% (Eigen. = 2.47), 9.5% (Eigen. = 1.89) and 7.4% (Eigen. = 1.48) of the variance, respectively. A cutoff of .60 for factor loadings was used to determine item association to specific factors. The first factor consisted of number-related behaviours (e.g., counting, repetition). The three lesser factors consisted of

contamination-related behaviours (e.g., washing, dirt preoccupation), order-related behaviours (e.g., neatness, arranging objects a certain way), and obsessional guilt (e.g., bad conscience, uncertainty), respectively. These factors fit with the conceptual understanding of OCD as a disorder which is associated with counting-, cleaning-, order- and guilt-related behaviours. The LOI-PV is unique in its easy administration and abbreviated length, and the results thus provide further encouragement for continuing psychometric refinement and validation of this parent measure of obsessive-compulsive behaviour.

APPENDIX 4: SELECTED EXAMPLES FROM THE BLISHEN SCALES

Occupation	SES Index
Government Administrators	66.84
Economists	69.18
Physicians	101.32
Lawyers	75.60
Geologists	71.01
Psychologists	62.26
University Teachers	75.87
Elementary Teachers	63.64
Registered Nurses	55.26
Secretaries	41.82
General Office Clerks	37.93
Real Estate Sales	49.99
Security Guards	31.95
Janitors	26.36
Bakers	30.55
Sawmill Sawyers	33.71
Welders	41.42
Shoemakers	25.37
Construction Electricians	47.94
Carpenters	34.86
Bus Drivers	34.93
Parcel Carriers	21.86

(From Blishen, Carroll, & Moore, 1981, pp. 474-483)

APPENDIX 5: YALE GLOBAL TIC SEVERITY SCALE SCORES

TABLE 12: Tic Severity Scores for TS Subjects

	TS-ONLY N = 17	TS-ADHD N = 8
YGTSS	34.47 (15.5)	30.38 (13.62)
Num. Motor	2.35 (1.06)	2.5 (1.20)
Num. Phonic	1.53 (0.94)	1.5 (0.93)
Freq. Motor	3.82 (1.67)	3.13 (1.64)
Freq. Phonic	3.12 (1.76)	2.25 (1.39)
Complexity Motor	1.59 (1.42)	2.13 (1.25)
Complexity Phonic	1.18 (1.33)	1.25 (1.49)
Intensity Motor	2.29 (1.16)	2.5 (1.20)
Intensity Phonic	1.82 (1.07)	1.75 (1.28)
Impairment	13.53 (7.86)	10 (7.56)

N.B. Standard deviations are in parentheses; Control children were also administered the scale and all scores were 0.

APPENDIX 6: CPRS-48 RATINGS

TABLE 13 Group Means for CPRS-48 Ratings

		CONTROLS N = 17	TS-Only N = 17	TS-ADHD N = 8	ADHD N = 16
CONDUCT PROBLEM	Mean	-0.32	0.83	0.91	2.05
	SD	(0.96)	(1.59)	(0.86)	(1.66)
LEARNING PROBLEM	Mean	-0.22	1.30	3.19	3.12
	SD	(0.89)	(1.66)	(1.10)	(1.55)
PSYCHO-SOMATIC	Mean	-0.22	1.26	0.94	1.39
	SD	(0.55)	(1.88)	(1.20)	(1.64)
INATTENTION-HYPERACTIVITY	Mean	-0.67	1.30	1.73	-1.86
	SD	(0.66)	(1.67)	(0.87)	(1.18)
ANXIETY	Mean	0.12	1.54	0.71	1.40
	SD	(0.83)	(1.39)	(1.07)	(1.45)
HYPER. INDEX	Mean	-0.72	1.39	2.53	2.63
	SD	(0.70)	(1.55)	(0.89)	(1.50)

N.B. Standard deviations are in parentheses

APPENDIX 7

INFORMED CONSENT - PARENT VERSION

I understand that my child will participate in a study on Tourette's syndrome. Participation in this study will involve my child being asked to

1) answer some questions or perform some activities involving general knowledge, memory, eye-hand coordination, and reasoning abilities
2) complete an attention task that is somewhat similar to a computer game

I also understand that I will be asked to fill out some questionnaires on my child's behaviour and personality.

I understand that all information collected in this research will be kept strictly confidential, and that the identity of participating children will not be revealed at any time.

I understand that my child's results will not be discussed with my child's teacher(s) or any other persons unless I specifically request such a disclosure.

I understand that my child is free to withdraw from this study at any time (even after the testing has begun) and that this will in no way affect my child's school program.

I understand that there is virtually no risk or discomfort involved in this testing (i.e., no more than normally associated with academic testing)

I have read and understood the above information.

Name of Child:_____ Grade:_____
Date of Birth:_____

Name of Parent:_____ Home Phone:_____
Signature:_____ Work Phone: _____
Date:_____

If you would like to receive a summary of the final results of this project, please provide your mailing address below:

_____
_____
_____
_____
_____

INFORMED CONSENT - CHILD/ADOLESCENT VERSION

I understand that I will participate in a research study on Tourette's syndrome. Participation in this study will mean that I will be asked to

1) answer some questions or perform some activities involving general knowledge, memory, eye-hand coordination, and reasoning abilities
2) complete an attention task that is somewhat similar to a computer game

I also understand that my parent will be asked to fill out some questionnaires on my behaviour and personality.

I understand that all information collected in this research will be kept strictly confidential, and that my identity and the identity of all participants will not be revealed at any time.

I understand that my results will not be discussed with my teacher(s) or any other persons unless I or my parents specifically request it.

I understand that I am free to withdraw from this study at any time (even after the testing has begun) and that this will in no way affect my school program or any services provided by the Arbutus Society for Children.

I understand that there is no risk or discomfort involved in this testing (that is, no more than normally associated with academic testing).

I have read and understood the above information.

Name:_____
Grade:_____
Date of Birth: _____

If you would like to receive a summary of the final results of this project, please provide your mailing address below:

_____
_____
_____
_____
_____

APPENDIX 8: SIGNAL DETECTION THEORY MEASURES

SENSITIVITY (range 0 to 1):

SENS = .5 + [(y-x) * (1+y-x)] / [4y(1-x)]

RESPONSE BIAS (range -1 to 1)

B = [y(1-y)-x(1-x)] / [y(1-y)+x(1-x)]

when

y = proportion of targets to which subject responds (hits / possible hits)

x = proportion of nontargets to which subjects responds (false alarms / possible false alarms)

if y=1, y was estimated at 2 to the (-1/t) power **

if x=0, x was estimated at 1-[2 to the (-1/t)] power **

RESPONSE CRITERION

C = false alarm rate (false alarms / possible false alarms) ***

* Grier (1971)

** Davies & Parasuraman (1982)

*** Richardson (1972)

APPENDIX 9: INTERCORRELATIONS OF AGE, SES, FSIQ AND CPT VARIABLES

TABLE 14: Intercorrelations of Age, SES, FSIQ, and CPT

	SENS	FA	BIAS	MISSES	AGE	SES
FA	-.54 [1]					
BIAS	-.10	-.49 [1]				
MISSES	-.98 [1]	.38 [2]	.22			
AGE	.30 [3]	-.03	-.13	-.33 [2]		
SES	-.20	-.25	.20	-.18	-.19	
FSIQ	.16	-.001	-.22	-.19	-.24	.32 [3]

N.B. Means for the ADHD group are composites of WISC-III and WISC-R scales scores, and therefore should be regarded as estimates only

[1] $p < .0001$, two-tailed

[2] $p < .01$, two-tailed

[3] $p < .05$, two-tailed

APPENDIX 10: GROUP MEANS FOR OTHER WISC-III SUBTESTS

TABLE 15 Group means for other WISC-III subtests

		CONTROL N = 17	TS-Only N = 17	TS-ADHD N = 8	ADHD N = 16
INFORMATION	Mean	11.71	11.71	10.63	10.57
	SD	(2.31)	(2.31)	(2.88)	(3.59)
VOCABULARY	Mean	12.59	11.65	10.75	12.14
	SD	(2.21)	(3.04)	(1.48)	(2.83)
COMPREHENSION	Mean	12.63	10.94	12.00	11.21
	SD	(3.88)	(3.31)	(2.07)	(3.38)
SIMILARITIES	Mean	12.47	10.88	10.63	13.00
	SD	(1.94)	(2.74)	(1.92)	(2.83)
PICTURE	Mean	11.71	10.65	11.00	11.29
COMPLETION	SD	(2.73)	(2.85)	(1.69)	(2.59)
PICTURE	Mean	11.29	9.82	10.13	10.71
ARRANGEMENT	SD	(3.10)	(4.29)	(1.69)	(2.37)
BLOCK DESIGN	Mean	13.41	11.06	10.63	10.57
	SD	(3.02)	(4.21)	(1.51)	(2.21)
OBJECT	Mean	11.00	11.44	11.13	11.43
ASSEMBLY	SD	2.29	3.31	(2.69)	(2.62)

N.B. Means for the ADHD group are composites of WISC-III and WISC-R scales scores, and should be regarded as estimates only

APPENDIX 11: VARIABLE LIST AND RAW DATA

SUBJECT INFORMATION AND DEMOGRAPHICS

ID	subject identification number
GROUP	control (-1), TS-Only (0), TS-ADHD (1), ADHD (2)
SEX	girls (2), boys (1)
SES	socioeconomic status
MEDS	medication status at time of testing (yes = 1, no = 0)
TSMAIN	diagnosis of TS
ADHDMAIN	diagnosis of ADHD

WISC-III

FSIQ	Full-Scale IQ
VIQ	Verbal IQ
PIQ	Performance IQ
PC	Picture Completion
INF	Information
COD	Coding
SIM	Similarities
PA	Picture Arrangement
ARITH	Arithmetic
BLOCK	Block Design
VOC	Vocabulary
OA	Object Assembly
COMP	Comprehension
SYMBOL	Symbol Search
DIGIT	Digit Span
MAZES	Mazes

TIC SEVERITY AND LOCATION

YNMOT	number of motor tics
YNPHON	number of vocal tics
YFMOT	frequency of motor tics
YFPHON	frequency of vocal tics
YIM	intensity of motor tics
YIP	intensity of vocal tics
YCMOT	complexity of motor tics
YCPHON	complexity of vocal tics
YINTERM	interference from motor tics
YINTERP	interference from vocal tics

YIMPAIR	impairment from tics
YGLOBAL	Yale Global Tic Severity Total Score
YEYE	presence of eye movement tics as determined from the YGTSS
OBSEYE	presence of eye movement tics observed during CPT

CPRS-48 FACTOR SCALES

CP	Conduct Problem
LP	Learning Problem
PSOM	Psychosomatic
IH	Impulsive-Hyperactive
ANX	Anxiety
HYP	Hyperactivity Index

CPT VARIABLES

AXRT	CPT reaction time
AXFA	CPT false alarms
AXVAR	CPT variability
AXMISSES	CPT misses
SENS	CPT sensitivity
X	X to calculate SDT measures
Y	Y to calculate SDT measures
BIAS	response bias

PARENT LEYTON SCORES

MINT	LOI-PV interference score
MSITU	LOI-PV number of situations

ID	GROUP	AGE	SEX	SES	FSIQ	VIQ	PIQ	PC
33	-1	12.50	1.00	42.30	118	121	112	14
12	-1	11.17	2.00	50.07	109	114	102	14
60	-1	10.50	1.00	65.63	124	111	135	14
32	-1	12.33	2.00	60.73	113	118	106	14
55	-1	10.50	1.00	56.83	124	126	117	13
56	-1	11.17	1.00	69.18	128	127	125	14
34	-1	14.08	1.00	49.99	101	102	99	10
22	-1	11.75	1.00	63.64	114	111	107	7
13	-1	9.75	2.00	62.36	119	111	125	12
52	-1	8.83	1.00	62.87	109	111	106	9
59	-1	9.83	2.00	65.36	113	106	119	11
8	-1	9.75	1.00	48.83	121	131	104	9
53	-1	10.92	1.00	57.19	110	105	115	16
6	-1	10.75	1.00	60.73	109	112	104	8
5	-1	11.17	1.00	52.09	112	108	113	14
57	-1	9.33	1.00	32.84	101	108	94	8
58	-1	9.00	1.00	101.32	122	126	113	12
31	0	9.25	1.00	54.05	112	102	121	13
16	0	11.42	1.00	48.14	94	98	91	10
15	0	7.08	1.00	63.64	119	98	129	9
9	0	15.50	1.00	60.65	99	100	98	8
2	0	10.92	1.00	40.28	100	106	94	10
25	0	12.50	1.00	63.64	120	119	116	16
35	0	9.92	1.00	24.11	84	87	83	10
38	0	10.25	1.00	101.32	124	139	103	11
37	0	8.25	1.00	44.56	111	110	111	12
24	0	7.50	2.00	60.73	141	125	151	16
30	0	10.08	1.00	68.12	114	121	106	10
4	0	12.17	2.00	57.04	84	92	78	8
18	0	7.58	1.00	26.36	106	106	106	13
19	0	13.25	1.00	48.24	93	98	89	8
27	0	10.50	1.00	31.95	84	89	82	6
36	0	12.00	1.00	24.11	135	112	127	13
17	0	13.75	1.00	30.93	92	94	91	8
26	1	13.92	1.00	44.32	94	89	102	13
23	1	7.50	1.00	63.64	99	113	83	8
11	1	13.50	1.00	40.28	103	113	91	10
1	1	9.92	1.00	41.69	112	102	121	13
28	1	9.92	1.00	40.79	101	105	98	12
29	1	7.58	1.00	59.44	104	105	103	10
7	1	15.67	1.00	24.59	107	112	102	11
10	1	9.75	2.00	75.60	97	97	99	11
63	2	8.58	1.00	55.26	96	112	81	9
49	2	9.83	2.00	65.63	106	103	109	15
46	2	11.67	2.00		102			
67	2	12.67	2.00	33.71	96	94	99	11
62	2	10.08	1.00	50.18	100	114	84	10
65	2	12.17	1.00		86	82	93	7
51	2	6.17	1.00	46.00	126	120	128	15
45	2	13.92	1.00	34.15	126	120	128	15

44	2	10.08	1.00		111	107	114	11
43	2	9.00	1.00		118	120	102	10
48	2	8.17	1.00		127			
41	2	8.25	2.00		115	117	109	14
50	2	10.92	1.00	34.93	111	107	114	11
64	2	8.42	1.00	40.28	85	77	98	9
66	2	7.17	1.00	28.31	112	113	110	12
47	2	8.25	1.00		105	112	98	9

INF	COD	SIM	PA	ARITH	BLOCK	VOC	OA	COMP
12	9	15	13	12	12	15	11	13
13	13	12	5	7	11	14	8	16
14	13	9	14	10	19	10	16	16
11	14	13	9	14	9	11	8	16
11	9	14	17	16	12	15	12	16
17	13	12	14	15	18	14	9	15
9	8	13	10	12	11	9	10	9
12	10	9	15	16	13	14	10	8
8	15	13	11	13	14	10	16	15
12	7	13	15	11	12	13	11	10
8	15	14	12	9	14	10	12	14
11	11	15	8	14	15	17	10	
14	7	13	9	12	18	12	11	3
11	9	14	12	13	14	13	10	9
10	15	11	9	13	9	11	13	12
12	7	9	9	11	11	12	10	13
14	12	13	10	14	16	14	10	17
9	11	12	18	9	12	11	12	11
8	7	12	8	6	9	11	9	11
9	12	15	12	8	19	9	19	7
10	9	10	8	12	11	9	12	9
11	7	13	15	9	5	13	8	9
11	7	12	11	19	17	12	11	12
6	5	8	3	7	9	8	10	9
17	16	13	10	19	8	16	7	18
11	9	9	11	11	13	11	13	16
15	18	12	18	17	19	16	18	11
13	13	12	7	12	13	16	11	14
10	4	7	5	7	7	10	8	9
12	12	10	7	9	10	12	12	11
9	6	10	7	10	9	9	11	10
8	11	6	7	8	7	7		11
15	7	16	13	18	13	17	13	14
11	12	8	7	11	7	11	9	4
7	6	9	10	7	11	9	11	8
14	4	13	10	10	9	12	6	12
11	2	13	9	13	11	11	11	13
7	13	10	12	11	13	10	15	14
10	4	12	10	5	9	13	13	14
14	12	9	9	9	11	9	10	13
13	6	11	12	12	12	12	10	12
9	7	8	9	10	9	10	13	10
9	7	13	8	9	5	14	7	15
11	7	13	11	6	14	13	10	10
5	11	10	9	10	9	8	9	12
14	3	13	8	7	9	13	8	15
7	6	7	6	8	11	7	14	5
16	15	15	14	10	11	15	14	11
16	15	15	14	10	11	15	14	11

9	13	14	10	9	11	12	15	12
15	3	13	13	12	14	15	12	12
12	11	15	12	14	10	10	10	13
9	13	14	10	9	11	12	15	12
6	7	8	12	6	10	8	11	3
9	11	15	11	9	12	15	11	13
10	8	17	12	7	10	13	10	13

SYMBOL	DIGIT	MAZES	YNMOT	YNPHON	YFMOT	YFP	YIM	YIP
12	11	8	0	0	0	0	0	0
12	11	6	0	0	0	0	0	0
17	13		0	0	0	0	0	0
13	9		0	0	0	0	0	0
15	8	15	0	0	0	0	0	0
14	11	14	0	0	0	0	0	0
8	9	11	0	0	0	0	0	0
10	10	8	0	0	0	0	0	0
18	10	10	0	0	0	0	0	0
			0	0	0	0	0	0
14	12	7	0	0	0	0	0	0
8	19	19	0	0	0	0	0	0
12	13	4	0	0	0	0	0	0
5	13	8	0	0	0	0	0	0
10	6	5	0	0	0	0	0	0
11	6		0	0	0	0	0	0
12	11		0	0	0	0	0	0
11	6	9	3	3	5	4	4	2
9	7	5	3	2	5	3	3	3
13	13	13	0	0	0	0	0	0
6	9	8	4	2	5	4	3	2
9	14	11	3	2	4	2	2	2
18	12	16	2	2	4	3	3	2
5	4		3	1	4	4	4	2
16	18	13	2	0	2	0	2	0
9	10	16	3	2	5	4	2	3
17	9	16	0	1	0	5	0	2
17	15	16	2	1	5	4	2	2
6	14	5	3	1	4	2	3	2
12	9	7	3	2	5	5	3	4
11		9	3	2	5	5	2	2
			2	2	4	5	1	1
13	15		2	3	5	3	3	2
9	11	7	2	0	3	0	2	0
5	14		2	2	2	3	2	2
10	11	12	4	2	3	3	3	2
8	5	9	3	2	5	3	3	2
11	13	12	0	0	0	0	0	0
3	13	7	2	2	3	3	2	2
14	9	8	3	0	4	0	3	0
12	10	11	3	2	5	3	3	2
14	6	5	3	2	3	3	4	4
	10	6						
	8	13						
16	4	10						
6	6	12						
7	10	4						
	10	14						
	10	14						

	10	9
	13	
	11	12
	10	9
	5	16
11	7	8
	6	16

YCMOT	YCPHON	YINTERM	YINTERP	YIMPAIRY	GLOBAL	CP	LP	PSOM
0	0	0	0	0	0	0.00	-0.30	-0.50
0	0	0	0	0	0	-0.80	0.80	-0.60
0	0	0	0	0	0	-1.40	-1.20	-0.70
0	0	0	0	0	0	0.30	-0.40	1.00
0	0	0	0	0	0	-0.90	-0.30	-0.70
0	0	0	0	0	0	0.90	-0.70	0.30
0	0	0	0	0	0	-0.90	-1.20	0.10
0	0	0	0	0	0	-1.10	0.20	0.30
0	0	0	0	0	0	0.30	-0.50	-0.60
0	0	0	0	0	0	-0.90	-0.90	-0.60
0	0	0	0	0	0	-0.80	-1.10	-0.60
0	0	0	0	0	0	-1.10	-0.70	-0.70
0	0	0	0	0	0	1.60	1.70	0.30
0	0	0	0	0	0	-1.10	0.20	-0.70
0	0	0	0	0	0	-0.10	-0.70	0.30
0	0	0	0	0	0	1.60	1.70	0.30
0	0	0	0	0	0	-1.10	-0.30	-0.70
1	4	3	4	30	63	4.90	4.10	3.20
3	0	4	1	20	47	2.60	3.10	4.90
0	0	0	0	0	0	-1.20	-1.40	-0.60
4	2	2	2	10	40	0.60	0.20	0.50
2	2	2	2	10	33	0.90	2.10	-0.70
3	0	1	1	10	31	-0.30	0.20	-0.50
3	0	5	2	30	58	-0.70	0.70	-0.70
0	0	0	0	10	18	-1.40	-1.20	-0.70
2	3	2	3	10	39	-0.60	3.00	1.60
0	0	0	1	10	19	-0.10	-0.50	0.20
1	1	2	2	10	32	1.90	2.60	2.20
0	0	1	1	10	27	0.00	-0.40	0.10
3	3	1	1	10	40	1.60	1.40	4.90
0	2	1	1	10	33	1.20	2.80	2.30
2	2	1	1	20	42	1.60	0.70	1.20
3	1	2	2	20	46	2.20	1.90	2.90
0	0	1	0	10	18	0.90	2.80	0.60
2	2	1	3	20	41	1.90	4.10	0.60
1	0	1	1	10	30	0.60	1.90	2.70
3	0	2	2	0	25	0.90	3.70	-0.50
0	0	0	0	0	0	0.60	2.10	-0.70
2	2	2	2	10	32	-0.40	3.60	1.20
2	0	2	0	20	34	1.60	1.90	1.60
3	2	3	2	10	38	0.10	3.40	0.50
4	4	3	3	10	43	2.00	4.80	2.10
						2.54	2.19	2.36
						0.63	4.14	0.29
						3.10	3.50	-0.80
						-0.40	0.70	0.30
						4.13	4.13	3.78
						4.06	4.13	3.78

3.22	4.54	2.20
2.89	2.14	2.20
1.22	4.74	-0.70
3.22	4.54	2.20
-0.30	0.20	1.60
0.31	2.46	-0.57

IH	ANX	HYP	AXFA	AXRT	AXVAR	AXMISS	YEYE	TSMAIN
-1.50	0.70	-0.70	0	549.34	103.37	2		1
-0.10	-0.40	-0.40	0	498.53	111.90	0		1
-1.50	-0.90	-1.50	0	481.36	69.11	0		1
-0.90	2.30	-0.90	0	433.49	97.78	0		1
-1.10	0.70	-0.80	0	525.64	92.35	3		1
-1.10	0.70	-0.60	0	564.26	77.44	0		1
-1.10	0.70	-1.40	0	505.17	79.77	1		1
-0.30	-0.40	-0.40	5	542.77	197.50	0		1
-0.50	-0.40	-0.90	1	505.29	124.81	0		1
-1.10	0.50	-1.10	0	587.85	129.15	3		1
-0.90	-0.40	-1.50	2	562.26	154.77	4		1
-0.70	0.20	-1.00	2	471.20	95.56	1		1
0.10	0.20	0.50	1	591.38	116.61	4		1
0.10	-0.90	-0.80	1	539.88	187.60	6		1
-0.70	-0.90	-1.00	5	438.15	154.26	1		1
1.00	0.70	1.30	13	450.02	196.73	8		1
-1.10	-0.40	-1.00	5	435.54	101.62	4		1
3.50	2.30	4.60	6	457.98	135.10	6	1	2
2.60	3.40	3.30	8	492.53	175.90	5	1	2
-1.50	0.00	-1.50	5	562.20	224.23	22	0	2
1.60	1.60	0.70	32	420.99	420.99	22	1	2
3.10	3.40	2.10	2	466.12	88.96	6	1	2
3.60	-0.60	1.50	2	513.06	130.31	4	0	2
-0.30	-0.10	-0.30	8	699.87	137.52	5	1	2
-0.30	2.80	-0.80	0	628.53	93.67	0	1	2
-0.30	1.90	0.70	0	658.71	215.38	27	1	2
2.60	0.70	0.90	11	715.10	203.43	18	0	2
-0.70	3.90	1.40	1	555.16	133.50	2	1	2
-0.90	0.90	0.00	0	539.09	128.60	1	1	2
3.00	1.40	2.60	8	666.01	220.31	11	1	2
1.30	2.40	3.10	2	431.40	110.81	12	1	2
1.80	1.20	1.70	0	503.77	140.07	2	1	2
1.70	1.60	2.00	6	369.84	109.52	1	1	2
1.30	-0.60	1.70	1	511.74	118.56	3	1	2
-0.10	1.60	1.70	5	507.28	166.33	3	1	2
2.20	2.40	2.20	2	677.48	165.91	29	1	2
2.20	-0.10	3.50	2	673.27	208.77	8	1	2
1.00	0.20	1.50	5	459.43	148.50	1	0	2
2.60	0.70	2.80	13	680.58	330.75	24	1	2
1.80	1.40	2.20	12	656.77	283.29	30	0	2
2.10	-1.00	2.20	21	411.73	131.29	10	1	2
2.00	0.50	4.10	2	610.11	182.20	17	0	2
2.22	1.67	2.26	22	493.74	174.71	15		1
1.19	0.90		36	790.21	349.09	29		1
1.61		4.05	7	515.12		49		1
1.00	0.40	3.00	11	593.44	214.81	12		1
1.40	-0.40	1.00	11	496.24	165.93	11		1
			53	461.18	153.69	17		1
3.03	2.92		33	469.93	173.12	21		1
3.03	2.92	4.15	33	469.93	173.12	21		1

3.47	3.37	5.31	23	606.87	225.23	11	1
2.63	1.24	3.03	24	457.12	194.54	12	1
1.78		2.63	34	527.43		13	1
0.09	-0.10	1.74	4	632.28	278.82	14	1
3.47	3.37		23	606.87	225.23	11	1
-0.30	-0.50	0.20	2	764.71	243.93	62	1
			27	752.26	304.03	55	1
1.36	0.96	1.54	5	423.79	94.64	4	1

ADHDMAIN	MINT	MSITU	MEDS	OBSEYE	SENS	Y	X	BIAS
1	6	4			0.994	0.978	0.001	0.883
1	1	1			0.999	0.999	0.001	0.698
1	1	1			0.999	0.999	0.001	0.698
1	11	11			0.999	0.999	0.001	0.698
1	6	3			0.991	0.967	0.001	0.919
1	2	2			0.999	0.999	0.001	0.698
1	2	2			0.997	0.989	0.001	0.780
1	1	1			0.997	0.999	0.010	0.121
1	0	0			0.999	0.999	0.002	0.591
1	2	2			0.991	0.967	0.001	0.919
1	4	2			0.988	0.956	0.004	0.832
1	9	5			0.996	0.989	0.004	0.475
1	10	4			0.988	0.956	0.002	0.912
1	1	1			0.983	0.933	0.002	0.939
1	12	6			0.995	0.989	0.010	0.062
1	5	3			0.970	0.911	0.025	0.531
1	2	2			0.986	0.956	0.010	0.628
1	22	8	1	1	0.980	0.933	0.012	0.685
1	50	16	0	0	0.982	0.944	0.016	0.545
1	1	1	0	0	0.935	0.756	0.010	0.900
1	39	13	0	0	0.914	0.756	0.063	0.517
1			0		0.982	0.933	0.004	0.882
1	2	1	0	0	0.988	0.956	0.004	0.832
1			0	0	0.982	0.944	0.016	0.545
1	11	7	0	0	0.999	0.999	0.001	0.698
1	12	6	0	1	0.925	0.700	0.001	0.987
1	7	3	0	0	0.942	0.800	0.022	0.767
1	6	5	0	1	0.994	0.978	0.002	0.835
1	9	6	1	1	0.997	0.989	0.001	0.780
1			0	0	0.964	0.878	0.016	0.748
1	2	1	0	1	0.965	0.867	0.004	0.935
1	17	7	0	0	0.994	0.978	0.001	0.883
1	9	3	0	1	0.994	0.989	0.012	-0.028
1			0	0	0.991	0.967	0.002	0.885
2	0	0	1	0	0.989	0.967	0.010	0.537
2	28	11	0	0	0.918	0.678	0.004	0.965
2	31	14	1	1	0.977	0.911	0.004	0.908
2			0	0	0.995	0.989	0.010	0.062
2	7	3	0	1	0.923	0.733	0.025	0.775
2	22	7	0	0	0.906	0.667	0.024	0.813
2			1	1	0.959	0.889	0.041	0.429
2	1	1	0	0	0.951	0.811	0.004	0.950
2					0.944	0.833	0.043	0.542
2					0.887	0.678	0.071	0.538
2					0.854	0.456	0.014	0.896
2					0.960	0.867	0.022	0.691
2					0.963	0.878	0.022	0.671
2					0.915	0.811	0.104	0.244
2					0.917	0.767	0.065	0.494
2					0.917	0.767	0.065	0.494

2	0.955	0.878	0.045	0.427
2	0.951	0.867	0.047	0.441
2	0.942	0.856	0.067	0.330
2	0.958	0.844	0.008	0.888
2	0.955	0.878	0.045	0.427
2	0.824	0.311	0.004	0.964
2	0.805	0.389	0.053	0.652
2	0.986	0.956	0.010	0.628

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Publications

Sherman, E.S., Strauss, E., Spellacy, F., & Hunter, M. (in press). Construct validity of WAIS-R factor scores: Neuropsychological test correlates in adults referred for evaluation of possible head injury. Psychological Assessment.

Douglas, V.I., Barr, R.G., Desilets, J.A., & Sherman, E.S. (in press). Do high doses of stimulants impair flexible thinking in Attention deficit hyperactivity disorder? Journal of the American Academy of Child and Adolescent Psychiatry.

Presentations

Sherman, E.S., Janzen, L., & Joschko, M. (1994). Sustained attention and impulsivity in Tourette syndrome: Relationship to attention deficit hyperactivity disorder and obsessive-compulsive behaviour. Paper presented at the Twenty-Second Meeting of the International Neuropsychological Society, Seattle, WA.

Sherman, E.S., Strauss, E., & Spellacy, F. (1994). Neuropschological Test Correlates of WAIS-R Factor Scores. Poster presented at the Twenty-Second Meeting of the International Neuropsychological Society, Seattle, WA.

Honours and Awards

Queen's Fellowship for Speaking French (1985-1986)
The Robert and Douglas Vickery Graduate Award (1994)

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Title of Thesis: SUSTAINED ATTENTION AND IMPULSIVITY IN TOURETTE SYNDROME: RELATIONSHIP TO ATTENTION DEFICIT HYPERACTIVITY DISORDER AND OBSESSIVE-COMPULSIVE BEHAVIOUR

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