J Neural Transm (2008) 115: 235–239
DOI 10.1007/s00702-007-0817-2
Printed in The Netherlands

Journal of Neural Transmission

Color perception deficits in co-existing attention-deficit/hyperactivity disorder and chronic tic disorders

V. Roessner[1], T. Banaschewski[2], A. Fillmer-Otte[1], A. Becker[1], B. Albrecht[1], H. Uebel[1], J. Sergeant[3], R. Tannock[4], A. Rothenberger[1]

[1] Department of Child and Adolescent Psychiatry, University of Goettingen, Goettingen, Germany
[2] Department of Child and Adolescent Psychiatry and Psychotherapy, Central Institute of Mental Health, Mannheim, Germany
[3] Department of Clinical Neuropsychology, Faculteit der Psychologie, Vrije Universitat, Amsterdam, The Netherlands
[4] The Hospital for Sick Children, Toronto, Canada

Received 31 July 2007; Accepted 22 August 2007; Published online 27 September 2007

Summary. Preliminary findings suggest that color perception, particularly of blue-yellow stimuli, is impaired in attention-deficit/hyperactivity disorder (ADHD) as well as in chronic tic disorders (CTD). However, these findings have been not replicated and it is unclear what these deficits mean for the comorbidity of ADHD + CTD.

Four groups (ADHD, CTD, ADHD + CTD, controls) of children with similar age, IQ and gender distribution were investigated with the Farnsworth-Munsell 100 Hue Test (FMT) and the Stroop-Color-Word Task using a factorial design. Color perception deficits, as indexed by the FMT, were found for both main factors (ADHD and CTD), but there were no interaction effects. A preponderance of deficits on the blue-yellow compared to the red-green axis was detected for ADHD. In the Stroop task only the 'pure' ADHD group showed impairments in interference control and other parameters of Stroop performance. No significant correlations between any FMT parameter and color naming in the Stroop task were found. Basic color perception deficits in both ADHD and CTD could be found. Beyond that, it could be shown that these deficits are additive in the case of comorbidity (ADHD + CTD). Performance deficits on the Stroop task were present only in the 'pure' ADHD group. Hence, the latter may be compensated in the comorbid group by good prefrontal capabilities of CTD. The influence of color perception deficits on Stroop task performance might be negligible.

Keywords: Color vision; dopamine; prefrontal; neuropsychology

Correspondence: Veit Roessner, Department of Child and Adolescent Psychiatry, University of Goettingen, von-Siebold-Strasse 5, 37075 Goettingen, Germany
e-mail: vroessn@gwdg.de
Tobias Banaschewski, Department of Child and Adolescent Psychiatry, Central Institute of Mental Health, P.O. Box 12 21 20, 68072 Mannheim, Germany
e-mail: tobias.banaschewski@zi-mannheim.de

Introduction

It has been shown in two non-replicated studies only that color perception, particularly on the blue-yellow axis (BY), may be impaired in attention-deficit/hyperactivity disorder (ADHD) (Banaschewski et al. 2006) as well as chronic tic disorders (CTD) (Melun et al. 2001). This deficit has been linked to deviations in the dopaminergic system assumed to underly both disorders (Tannock et al. 2006). Although impairment of color perception with higher vulnerability of the BY axis has also been found in other dopaminergic disorders (e.g., Parkinsonism; Sartucci and Porciatti 2006) and states (cocaine withrawal; Desai et al. 1997), its fundamental mechanisms remain unclear (Tannock et al. 2006). Whereas in CTD hyperdopaminergic neurotransmitter functioning is believed to play a central role in its pathophysiology (Minzer et al. 2004; Yoon et al. 2007), in ADHD most authors favor a hypodopaminergic model (Sadile and Viggiano 2005). In view of the association between color vision deficits and dopaminergic deviances underlying both disorders, color vision deficits, particularly on the BY axis, in the comorbid condition, ADHD + CTD, are of special interest. Based on existing studies of neurophysiological (Moll et al. 2001; Kirov et al. 2007a, b) and neuropsychological (Roessner et al. 2007a) parameters in ADHD + CTD, impairments in the comorbid condition appear to be additive. Therefore we extended our previous study on color perception in ADHD (Banaschewski et al.

2006) by two groups (ADHD + CTD, CTD) and used a 2 (ADHD, not ADHD) × 2 (CTD, not CTD) factorial design to clarify which factor (ADHD versus CTD) influences color vision parameters especially in the case of ADHD + CTD.

Methods

Sample

A total of 69 children aged 8.0–12.6 years participated in the study, which was approved by the local medical ethics committee. All parents and children provided informed consent. Within this sample, 55 children were recruited from the department of Child and Adolescent Psychiatry of the University of Goettingen: 14 met ICD-10 diagnostic criteria for ADHD, 22 met criteria for CTD, 19 for ADHD + CTD. The remaining 14 children, who constituted the control group, were recruited from local primary schools.

All patients were diagnosed according to ICD-10 criteria based on information ascertained from clinical interview with the parents, teacher reports, behavior rating scales, and medical reports. Rating scales included the parent-rated child behavior checklist (CBCL) (Achenbach et al. (2007, accepted)), the Strengths and Difficulties Questionnaire (SDQ; (Rothenberger and Woerner 2004), the Yale Tourette Syndrome Symptom List (Cohen et al. 1985), the Tourette Syndrome Severity Scale (Shapiro et al. 1988) and a German version of the ADHD symptom list (FBB-HKS; (Bruehl et al. 2000). Those children using methylphenidate were free of medication for at least 48 h before being tested while D2-blockers (CTD-only: $n = 2$; ADHD + CTD: $n = 7$), serotonin reuptake inhibitors ($n = 1$) and atomoxetine ($n = 3$) were continued.

Age-matched normal children, serving as control subjects, were included only if they had never met a psychiatic diagnosis except a diagnosis of dyslexia ($n = 2$). Additionally, the T-scores of the control children on the attention problems scale of the CBCL were required to be below 55. T-scores on the CBCL scales Delinquent and Aggressive Behavior were required to be below 60.

All children underwent standardized IQ testing, as well as testing of spelling abilities and word fluency (LPS; Horn 1983). The groups were matched for age (ANOVA: $F(3,65) = 0.2$, ns), gender ($\chi^2_{(3)} = 0.58$, ns) and IQ (ANOVA: $F(3,65) = 2.1$, ns). Moreover, the groups did not differ in their spelling abilities ($F(3,65) = 0.8$, ns) or word fluency ($F(3,65) = 0.8$, ns). Three children in the ADHD group, none in the CTD group, two in the ADHD + CTD group, and two in the control group met diagnostic criteria for dyslexia. Also, all children had normal or corrected to normal vision and were free of ophthalmologic disorders or congenital color blindness and had a full-scale IQ above 85.

Measures

Color discrimination ability was investigated binocularly using the Farnsworth-Munsell 100 Hue Test (FMT) (Farnsworth 1943), which is a widely used clinical instrument for measuring chromatic discrimination (Kinnear and Sahraie 2002). It consists of four trays containing a total of 85 removable color reference caps (incremental hue variation) spanning the visible spectrum. Color vision abnormalities and aptitude were determined by the ability of the child to place the color caps in order of hue. Error scores are measures of accuracy in arranging the caps so as to form a gradual transition in chroma between two anchor caps reflecting the number of misplacements. Blue-yellow (BY) and red-green (RG) partial error scores and the total error score were computed. At last the difference between the BY error score and the RG error score was computed. All testing was performed under standard light conditions in the same room and at the same place. The illuminance was maintained at 325 lux, measured with a LT Lutron LX-101 Lux-meter.

Further, we used the German version (Farb-Wort-Interferenztest) of the Stroop-Color-Word Task (Baeumler 1985) in order to correlate probable basic color perception deficits with performance in a practical neuropsychological task with single color stimuli. In the first condition, the speed of reading color words (red, green, yellow and blue) is measured (Stroop-Word). In the second condition, the participant has to name the colors of four bars that are printed in these colors (Stroop-Color). In the third condition, the participant is required to name the colors of color-words that are printed in incongruous colors (Stroop-Color/Word). Naming time and errors were recorded for each subtest separately.

Statistical analysis

The groups were compared for differences in color perception ability as indicated by the FMT and Stroop task performance using analyses of variance (ANOVA) with ADHD (yes/no) and CTD (yes/no) as factors. In case of significant interaction effects, separate univariate ANOVAs followed by Sidak-adjusted comparisons of estimated marginal means were conducted. To compare deficits in color perception in more detail, i.e. differences between the BY and RG axis, the confidence intervals have been calculated at $\alpha = 5\%$ and indicate significant differences between both axes if they do not include zero.

Furthermore, correlations between the FMT parameters and the Stroop parameter color naming were computed for each group to test effects of the respective color perception performance on color naming as measured by the Stroop task. Homogeneity of correlations across groups were tested using the method described by Rosenthal (1991). In case of homogeneity of correlations, correlations for the total sample were computed. All analyses were performed using SPSS 14.0.

Results

On the FMT analyses of errors on the BY (partial error score BY) and RG (partial error score RG) axis as well as their combination (total mean error score) revealed main effects of CTD as well as ADHD but no interaction effect (see Table 1). For the color difference score a trend for a main effect ADHD was found; however according to our hypothesis one-tailed post-hoc testing of means showed significant higher difference scores in children with ADHD (alone and in combination with CTD) than in children not suffering from ADHD (controls and CTD). The confidence intervals indicated that only for the factor ADHD (CI: 7.0–21.7, $d = 0.68$) there were stronger deficits on the BY than on the RG axis.

In the German version of the Stroop test (Baeumler 1985) for all parameters (word reading, color naming, color/word naming, interference score) there were at least trends towards interaction effects. Therefore separate univariate ANOVAs (all $F(3,65) > 3.2$, $p < 0.03$) followed by post-hoc tests (Sidak adjusted) had been performed indicating a general impairment of the 'pure' ADHD group, whereas there were no differences on any Stroop variable between the other three groups (CTD, ADHD + CTD, controls).

Table 1. *2 × 2 ANOVA for the factors ADHD and CTD and descriptive measures*

	Controls ($n = 14$)		ADHD ($n = 14$)		CTD ($n = 22$)		ADHD + CTD ($n = 19$)		ANOVA $F(1,65)$ (partial η^2)					
	M	SD	M	SD	M	SD	M	SD	ADHD		CTD		ADHD × CTD	
Full-scale IQ	112.4	(13.7)	104.6	(7.2)	105.7	(11.9)	103.3	(9.2)	3.7^{+}	(0.05)	2.2	(0.03)	1.0	(0.02)
Age (years)	10.7	(0.8)	10.4	(0.9)	10.6	(1.4)	10.7	(1.3)	0.1	(0.00)	<0.1	(0.00)	0.6	(0.01)
Spelling abilities (T-score)	50.3	(12.7)	45.4	(8.4)	48.0	(7.7)	46.7	(7.8)	1.9	(0.03)	<0.1	(0.00)	0.6	(0.01)
Word fluency ($n/3$*min)	25.8	(7.5)	26.7	(11.6)	22.4	(5.6)	24.5	(9.7)	0.5	(0.01)	1.8	(0.03)	0.1	(0.01)
Child behavior checklist (CBCL)														
Attention problems	51.6	(3.1)	65.1	(8.7)	57.0	(8.0)	67.1	(9.3)	37.4^{***}	(0.37)	3.5^{+}	(0.05)	0.8	(0.01)
Delinquent behavior	53.0	(4.6)	63.7	(9.3)	52.4	(4.9)	59.3	(7.6)	28.4^{***}	(0.31)	2.3	(0.03)	1.3	(0.02)
Aggressive behavior	50.5	(1.6)	68.5	(16.9)	52.5	(4.9)	63.4	(10.0)	37.2^{***}	(0.37)	0.4	(0.01)	2.2	(0.03)
Farnsworth-munsell 100 hue														
Total mean error score	52.4	(29.2)	89.6	(31.5)	101.6	(37.3)	154.5	(52.5)	21.3^{***}	(0.25)	34.1^{***}	(0.34)	0.6	(0.01)
Partial error score blue–yellow	27.1	(18.1)	51.4	(21.2)	55.2	(24.7)	85.0	(29.8)	20.2^{***}	(0.24)	26.3^{***}	(0.29)	0.2	(0.01)
Partial error score red–green	25.2	(12.2)	38.2	(14.2)	46.4	(20.1)	69.5	(27.5)	13.2^{**}	(0.17)	27.7^{***}	(0.30)	1.1	(0.02)
Color difference score	1.9	(10.3)	13.2	(17.6)	8.9	(25.3)	15.4	(23.1)	3.0^{+}	(0.05)	0.8	(0.01)	0.2	(0.01)
Stroop														
Word (sec/72 items)	43.9	(10.2)	56.9	(26.5)	41.4	(9.5)	41.6	(9.6)	3.3^{+}	(0.05)	6.1^{*}	(0.09)	3.2^{+}	(0.05)
Color (sec/72 items)	65.9	(13.0)	83.6	(28.0)	65.9	(12.2)	67.3	(19.9)	4.4^{*}	(0.06)	3.2	(0.05)	3.2^{+}	(0.05)
Color/word (sec/72 items)	121.5	(33.9)	177.5	(53.4)	125.5	(30.9)	129.7	(35.3)	10.3^{**}	(0.14)	5.5^{*}	(0.08)	7.7^{**}	(0.11)
Interference[a]	55.6	(24.5)	93.9	(47.6)	59.6	(20.8)	62.4	(25.1)	7.9^{**}	(0.11)	3.5^{+}	(0.05)	5.9^{*}	(0.08)

M Mean, *SD* standard deviation. Effects are from 2 × 2 ANOVA with ADHD and CTD as factors. The effect sizes presented in Table 1 are the partial eta squared produced by the ANOVA. Cohen (1977) provides the following guidelines for interpreting the partial eta squared (η^2) value: 0.01–0.059 = small effect size; 0.06–0.139 = medium effect size; >0.14 = large effect size.

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$; $^{+}p < 0.1$.

[a]The interference score was computed as follows: (Color/Word)–(Color).

Correlations between all FMT variables under investigation and color naming were homogenous across groups (all $\chi^2_{(3)} < 3.1$, $p > 0.25$), but were not significant, not even for the total sample (total error score: $r = 0.10$, $p = 0.44$; BY error score: $r = 0.12$, $p = 0.36$; RG error score: $r = 0.06$, $p = 0.62$; color difference score: $r = 0.09$, $p = 0.44$).

Discussion

On a color perception test (FMT), children of all patient groups (CTD, ADHD and ADHD + CTD) made more errors than their typically developing peers. This is in line with previous findings of impaired color perception in ADHD (Banaschewski et al. 2006) and CTD (Melun et al. 2001) as well as in other disorders with altered dopaminergic mechanisms (Desai et al. 1997; Muller et al. 1999; Shuwairi et al. 2002). The significance of both main effects (CTD, ADHD) in the absence of an interaction effect on any FMT parameter is congruent with an additive model in the comorbid group (ADHD + CTD). This is in line with other results compatible with an additive model of ADHD + CTD e.g., on psychopathology (Roessner et al. 2007b), neuropsychology (Roessner et al. 2007a), sleep (Kirov et al. 2007a, b) and motor inhibition (Moll et al. 2001). Furthermore, our findings support previous reports of a preponderance of color perception deficits on the BY compared to the RG axis in ADHD (Birch 1997; Banaschewski et al. 2006). Although the same has been reported for CTD (Melun et al. 2001) our results did not support differences in color perception deficits between the BY and the RG axis in CTD. This might be attributable to uncontrolled comorbid ADHD symptoms in Melun et al.'s (2001) study and in part to differences between our and Melun et al.'s study in gender ratio (Tannock et al. 2006) and in age groups included since the age dependent changes of the yellowing of the aging crystalline lens as well as the dopaminergic metabolism are positively correlated with BY deficits (Weale 1991; Geller and Hudnell 1997).

In the Stroop task possibly depending on color perception ability (Tannock et al. 2006) the results of the factorial design were not compatible with an additive model. The

group comparisons for all Stroop task parameters under investigation revealed that only the 'pure' ADHD group was impaired. These results from unmedicated children add evidence to the ongoing controversial discussion about deficits on the different Stroop parameters in ADHD (Sergeant et al. 2002; Lawrence et al. 2004; Boonstra et al. 2005; van Mourik et al. 2005; Lansbergen et al. 2007). Probably too many confounding factors are involved in the very complex Stroop task that a clear disorder-specific picture cannot be detected, or perhaps expected. In terms of CTD, our findings are in line with the general consensus that patients with CTD and even ADHD + CTD did not differ in all Stroop parameters under investigation from controls (Channon et al. 1992; Brand et al. 2002; Channon et al. 2003; Lavoie et al. 2007; Marsh et al. 2007; Roessner et al. 2007a). The good Stroop task performance of the ADHD + CTD group might be attributable to enhanced prefrontal capabilities in CTD (Rothenberger 1990; Serrien et al. 2005; Plessen et al. 2007) compensating the prefrontal deficits usually related to ADHD symptoms (Pliszka et al. 2000; Albrecht et al. 2005).

The correlations between the FMT and the Stroop task did not support the notion that color perception deficits measured by the FMT may have a negative influence on Stroop performance. This is in line with the findings of Banaschewksi et al. (2006) and mitigates the argument of others that color perception may have a substantial influence on Stroop performance (Laeng et al. 2005; Tannock et al. 2006).

However, several limitations of the present findings must be considered. First, the inclusion of clinically referred children with CTD and/or ADHD limits the generalizability of our findings to epidemiological samples. Second, continuation of antipsychotics in some children during testing might have confounded the results, although e.g., for both tiparide (Rothenberger and Eggers 1982; Eggers et al. 1988) and risperidone (Allain et al. 2003) there is no evidence of influencing cognitive performance in short-term low-dose medication in healthy volunteers or children with tic disorders. Third, the use of a single clinical measure of color perception (FMT), requiring substantial capacities in sustained attention, should be seen with caution in testing children with ADHD free of stimulant medication. Hence, future studies should include an additional measure of color perception as well as both the color perception independent counting stroop task (Flowers et al. 1979; Albrecht et al. accepted) and the Stroop color word interference task (Stroop 1935) to further clarify color vision deficits in ADHD and CTD on neuropsychological task performance.

References

Achenbach T, Becker A, Döpfner M, Heiervang E, Roessner V, Steinhausen H-C, Rothenberger A (2007) Multicultural assessment of child and adolescent psychopathology with the ASEBA and SDQ instruments: research findings, applications, and future directions. J Child Psychol Psychiatry (accepted)

Albrecht B, Banaschewski T, Brandeis D, Heinrich H, Rothenberger A (2005) Response inhibition deficits in externalizing child psychiatric disorders: an ERP-study with the stop-task. Behav Brain Funct 1: 22

Albrecht B, Uebel H, Tannock R, Sergeant JA, Rothenberger A, Banaschewski T (2007). Interference control in ADHD: differential Stroop effects for colour-naming and counting. J Neural Transm, DOI: 10.1007/s00702-007-0818-1

Allain H, Tessier C, Bentue-Ferrer D, Tarral A, Le Breton S, Gandon M, Bouhours P (2003) Effects of risperidone on psychometric and cognitive functions in healthy elderly volunteers. Psychopharmacology (Berl) 165(4): 419–429

Baeumler G (1985) Farbe-Wort-Interferenz-Test (FWIT). Hogrefe, Goettingen

Banaschewski T, Ruppert S, Tannock R, Albrecht B, Becker A, Uebel H, Sergeant JA, Rothenberger A (2006) Colour perception in ADHD. J Child Psychol Psychiatry 47(6): 568–572

Birch J (1997) Clinical use of the American Optical Company (Hardy, Rand and Rittler) pseudoisochromatic plates for red-green colour deficiency. Ophthalmic Physiol Opt 17(3): 248–254

Boonstra AM, Oosterlaan J, Sergeant JA, Buitelaar JK (2005) Executive functioning in adult ADHD: a meta-analytic review. Psychol Med 35(8): 1097–1108

Brand N, Geenen R, Oudenhoven M, Lindenborn B, van der Ree A, Cohen-Kettenis P, Buitelaar JK (2002) Brief report: cognitive functioning in children with Tourette' syndrome with and without comorbid ADHD. J Pediatr Psychol 27(2): 203–208

Bruehl B, Doepfner M, Lehmkuhl G (2000) Der Fremdbeurteilungsbogen für hyperkinetische Störungen (FBB-HKS). Prävalenz hyperkinetischer Störungen im Elternurteil und psychometrische Kriterien. Kindheit und Entwicklung 9: 116–126

Channon S, Flynn D, Robertson MM (1992) Attentional deficits in Gilles de la Tourette syndrome. Neuropsychiatry, Neuropsychol Behav Neurol 5: 170–177

Channon S, Pratt P, Robertson MM (2003) Executive function, memory, and learning in Tourette's syndrome. Neuropsychology 17(2): 247–254

Cohen DJ, Leckman JF, Shaywitz BA (1985) The Tourette Syndrome and other tics. In: Shaffer D (ed) The clinical guide to child psychiatry. The Free Press, Lonon

Desai P, Roy M, Roy A, Brown S, Smelson D (1997) Impaired color vision in cocaine-withdrawn patients. Arch Gen Psychiatry 54(8): 696–699

Eggers C, Rothenberger A, Berghaus U (1988) Clinical and neurobiological findings in children suffering from tic disease following treatment with tiapride. Eur Arch Psychiatry Neurol Sci 237(4): 223–229

Farnsworth D (1943) The Farnsworth Munsell 100-Hue dichotomous tests for colour vision. J Optical Soc Am 33: 568–576

Flowers JH, Warner JL, Polansky ML (1979) Response and encoding factors in ignoring irrelevant information. Memory Cognit 7: 86–94

Geller AM, Hudnell HK (1997) Critical issues in the use and analysis of the lanthony desaturate color vision test. Neurotoxicol Teratol 19(6): 455–465

Kinnear PR, Sahraie A (2002) New Farnsworth-Munsell 100 hue test norms of normal observers for each year of age 5–22 and for age decades 30–70. Br J Ophthalmol 86(12): 1408–1411

Kirov R, Banaschewski T, Uebel H, Kinkelbur J, Rothenberger A (2007a) REM-sleep alterations in children with co-existence of tic disorders

and attention-deficit/hyperactivity disorder: impact of hypermotor symptoms. Eur Child Adolesc Psychiatry 16 Supp I: I/45–I/50

Kirov R, Kinkelbur J, Banaschewski T, Rothenberger A (2007b) Sleep patterns in children with attention-deficit/hyperactivity disorder, tic disorder, and comorbidity. J Child Psychol Psychiatry 48(6): 561–570

Laeng B, Lag T, Brennen T (2005) Reduced Stroop interference for opponent colors maybe due to input factors: evidence from individual differences and a neural network simulation. J Exp Psychol Hum Percept Perform 31(3): 438–452

Lansbergen MM, Kenemans JL, van Engeland H (2007) Stroop interference and attention-deficit/hyperactivity disorder: a review and meta-analysis. Neuropsychology 21(2): 251–262

Lavoie ME, Thibault G, Stip E, O'Connor KP (2007) Memory and executive functions in adults with Gilles de la Tourette syndrome and chronic tic disorder. Cognit Neuropsychiatry 12(2): 165–181

Lawrence V, Houghton S, Douglas G, Durkin K, Whiting K, Tannock R (2004) Executive function and ADHD: a comparison of children' performance during neuropsychological testing and real-world activities. J Atten Disord 7(3): 137–149

Marsh R, Zhu H, Wang Z, Skudlarski P, Peterson BS (2007) A developmental fMRI study of self-regulatory control in Tourette' syndrome. Am J Psychiatry 164(6): 955–966

Melun JP, Morin LM, Muise JG, DesRosiers M (2001) Color vision deficiencies in Gilles de la Tourette syndrome. J Neurol Sci 186(1–2): 107–110

Minzer K, Lee O, Hong JJ, Singer HS (2004) Increased prefrontal D2 protein in Tourette syndrome: a postmortem analysis of frontal cortex and striatum. J Neurol Sci 219(1–2): 55–61

Moll GH, Heinrich H, Trott GE, Wirth S, Bock N, Rothenberger A (2001) Children with comorbid attention-deficit-hyperactivity disorder and tic disorder: evidence for additive inhibitory deficits within the motor system. Ann Neurol 49(3): 393–396

Muller T, Kuhn W, Buttner T, Przuntek H (1999) Colour vision abnormalities and movement time in Parkinson' disease. Eur J Neurol 6(6): 711–715

Plessen KJM, Royal JM, Peterson BS (2007) Neuroimaging of tic disorders with co-existing attention-deficit/hyperactivity disorder. Eur Child Adolesc Psychiatry 16 Suppl I: I/60–I/70

Pliszka SR, Liotti M, Woldorff MG (2000) Inhibitory control in children with attention-deficit/hyperactivity disorder: event-related potentials identify the processing component and timing of an impaired right-frontal response-inhibition mechanism. Biol Psychiatry 48(3): 238–246

Roessner V, Becker A, Banaschewski T, Rothenberger A (2007a) Executive functions in children with chronic tic disorders with/without ADHD – new insights. Eur Child Adolesc Psychiatry 16 Suppl 1: 36–44

Roessner V, Becker A, Banaschewski T, Rothenberger A (2007b) Psychopathological profile in children with chronic tic disorder and co-existing ADHD: additive dffects. J Abnorm Child Psychol 35(1): 79–85

Rosenthal R (1991) Meta-analysis: a review. Psychosom Med 53(3): 247–271

Rothenberger A (1990) The role of frontal lobes in child psychiatric disorders. In: Rothenberger A (ed) Brain and behavior in child psychiatry. Springer, Berlin Heidelberg New York Tokyo, pp 34–58

Rothenberger A, Eggers C (1982) The influence of tiapride on the ERPs of children with multiple tics. Event-related potentials in children: basic concepts and clinical applications, Elsevier, Amsterdam 6: 423–428

Rothenberger A, Woerner W (2004) Strengths and Difficulties Questionnaire (SDQ) – evaluations and applications. Eur Child Adolesc Psychiatry 13 Suppl 2: II1–II2

Sadile AG, Viggiano D (2005) Is the hypodopaminergic hypothesis plausible as neural bases of ADHD? Behav Brain Sci 28(3): 440–441

Sartucci F, Porciatti V (2006) Visual-evoked potentials to onset of chromatic red-green and blue-yellow gratings in Parkinson' disease never treated with L-dopa. J Clin Neurophysiol 23(5): 431–435

Sergeant JA, Geurts H, Oosterlaan J (2002) How specific is a deficit of executive functioning for attention-deficit/hyperactivity disorder? Behav Brain Res 130(1–2): 3–28

Serrien DJ, Orth M, Evans AH, Lees AJ, Brown P (2005) Motor inhibition in patients with Gilles de la Tourette syndrome: functional activation patterns as revealed by EEG coherence. Brain 128(Pt 1): 116–125

Shapiro AK, Shapiro ES, Young JG, Feinberg TE (1988) Gilles de la Tourette syndrome. Raven Press, New York

Shuwairi SM, Cronin-Golomb A, McCarley RW, O'Donnell BF (2002) Color discrimination in schizophrenia. Schizophr Res 55(1–2): 197–204

Stroop JR (1935) Studies of interference in serial verbal reactions. J Exp Psychol 28: 643–662

Tannock R, Banaschewski T, Gold D (2006) Color naming deficits and attention-deficit/hyperactivity disorder: a retinal dopaminergic hypothesis. Behav Brain Funct 2: 4

van Mourik R, Oosterlaan J, Sergeant JA (2005) The Stroop revisited: a meta-analysis of interference control in AD/HD. J Child Psychol Psychiatry 46(2): 150–165

Weale RA (1991) Effects of senescence. In: Kulikowski JJ, Walsh V, Murray IJ (eds) Limits of vision, vol. 5, pp 277–285. CRC Press, Boca Raton, FL

Yoon DY, Gause CD, Leckman JF, Singer HS (2007) Frontal dopaminergic abnormality in Tourette syndrome: a postmortem analysis. J Neurol Sci 255(1–2): 50–56