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Interference Effect and Reading Skills in Children with Attention Disorders[1]

Aim of this study was to examine the performance on Polish experimental version of classical Stroop test in 36 ADHD-C children in comparison with 35 healthy children matched for age and IQ WISC-R. It was hypothesized that children with ADHD will exhibit diminished ability to control interference and will make more errors than their healthy counterparts. In contradictory with expectations, there was showed little if any evidence for specific deficit in interference control in this ADHD sample. A remarkable finding of this study was to demonstrate the developmental differences in reading skills in age range 8-11 years between typically developing children and ADHD group which displays a virtually no progress in reading automaticity and color naming speed over the period.

Key words: *interference control, Stroop test, ADHD-C, school children, reading*

Introduction

According to Colin MacLeod, "…we can think of attention as the 'front end' of cognition, the first step in the selection of the dimension(s) to which we will devote our processing" (MacLeod & McDonald, 2000, p. 390). Attention plays a critical role in information processing. As many authors agree attention does not refer to a single process, but to an attentional networks system which involves different mechanisms subserved by separate brain areas (Posner & Petersen, 1990; Posner, 1994; Berger et al., 2007). An adequate attentional functioning is required for an optimal development of complex cognitive abilities in children and plays a key role in children's educational progress, correct school behavior and social relationship. Reading is one of the complex cognitive skills which demands conscious learning by instruction and automating. The reading process relies on the accurate integration of attentional, visual, orthographic, phonological and semantic information. The present study address an interaction among the efficiency of executive control and reading skills from the clinical and developmental psychology perspective.

Disturbances of attention are common in the pediatric population. One of the most common developmental disorders of childhood which affects approximately every twentieth of school age children, is the attention deficit hyperactivity disorder (ADHD) (Dąbkowski, 2007; Pocklington and Maybery, 2006). For almost 20 years, ADHD has been characterized by behavioral symptoms of inattention, hyperactivity and impulsivity. The tripartite syndrome must be more pronounced than expected for the child's developmental level (significant impairment), must be present before age 7 (early onset) and must be chronic (not due to transient events), and pervasive in at least two settings (e.g. at school and at home) (DSM-IV-TR, APA, 2000). There is the consistent finding across studies that children with ADHD do not have generalized cognitive impairment, but that they do manifest specific deficits (Swanson et al., 1998) related to overlapping neuropsychological domains of executive functions, working memory, attention and inhibition (Seargent et al., 2003).

The most influential theoretical model of ADHD (Barkley, 1997) incorporates the deficits in inhibitory

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control, including poor interference control, as one of the core symptoms of defective executive functioning in these children. Different neuropsychological tests assess distinct but often overlapping components of executive functioning with lower or greater consensus and low to modest discriminant validity in the diagnosis of ADHD (Pineda et al., 2007). The Stroop Color-Word Task (Stroop, 1935; see McLeod, 1991 for review) is a widely used neuropsychological method for measure of interference control in studies with ADHD groups of both clinical and research interest (van Mourik et al., 2005; Sayal et al., 2006; Kiliç et al., 2007; Lansbergen, et al., 2007; Albrecht et al., 2008). Barkley (1997) found that out of 10 studies, 9 suggested that individuals with ADHD were impaired on the Stroop test. Some authors recommend it as the standard part of a test battery in clinical settings (Doyle et al., 2000; Golden & Golden, 2002) because of its robust empirical diagnostic criteria. It is also to stress that the observation of child's behavioral and emotional changes during the attentionally demanding Stroop test is of known clinical diagnostic value itself (e.g., fidgeting or extraneous body movement, out-of-seat, off-task, spontaneous verbalizations). The Stroop task is also unique in the sense of its potential to confront processes that are voluntary and intentional (executive control) with processes that many believe are involuntary and automatic (word reading, naming). The Stroop task use conflict interference situation, participants are presented with stimuli having two dimensions, and are required under time pressure to attend to one dimension whilst ignoring the concurring other. The Stroop test appears in this context to be primarily a measure of interference control which protects any delay in response from competing responses. The classic Stroop test (Stroop, 1935) produces a clear response conflict: the participant must suppress an automatic, overlearned, prepotent response (e.g., reading the word "*red*") in favor of a less automatic response (e.g., naming the color of the printed word, where the ink's color and the word's semantic content conflict, such as in the word "*red*" printed in green ink). A majority of studies have found children with ADHD impaired on this test, they exhibit pronounced increases in latency on the critical incongruent interference condition relative to control children (Gorenstein et al., 1989; Barkley et al., 1992; Barkley & Grodzinsky, 1994; Grodzinsky & Barkley, 1999; Houghton et al., 1999; Homack & Riccio, 2004; Pocklington & Maybery, 2006; van Mourik et.al., 2008). Homack and Riccio (2004) analysed outcomes of 33 published studies on Stroop performance in children and adolescents with ADHD and found poorer scores than controls children across all three subtests of the typical Stroop task. Another meta-analysis mentioned was conducted on 17 independent studies and has yielded the findings lending support to the previous notion of poor performance of the ADHD children on all three dependent variables measured in the Stroop task (word reading, color naming and interference color-word naming) with the effect sizes larger and more homogeneous for the first two parts of the test than for the interference score (van Mourik et al., 2005).

However, as the ADHD is polytypic syndrome (e.g., hyperactive/impulsive type or combined type) with multiple biological bases (e.g., dopamine transfer deficit or norepinephrine deficit theory) and the Stroop tasks used differ markedly in forms (e.g., card or computerized) and number of procedural (e.g., item studies or time-for-each-card studies, appropriate neutral condition) and methodological variables involved (e.g., moderator variables, methods of quantifying Stroop interference), the results of many research are difficult to compare or often inconclusive.

Some authors conclude that Stroop results obtained so far do not provide strong evidence for a core deficits in interference control in ADHD (Frazier et al., 2004; Lansbergen et al., 2007; van Mourik et al., 2008). It has been more recently reported that neuropsychological deficits associated with ADHD can be exacerbated by some moderating factors: deficient error awareness (O'Connell et al., 2009); rapid naming deficiencies; poor blue-yellow colour discrimination (Banaschewski et al., 2006); high rate of co-morbidity with learning disabilities, especially with reading disorders (25% - 40% , cf. van Mourik, 2005) and with other psychiatric disorders.

Thus, findings mentioned above suggest that there are multiply sources of heterogeneous effect sizes on the interference score in ADHD. The question remains if a deficit in interference control is specific to ADHD and if the Stroop paradigm might be sensitive enough to indicate other important cognitive difficulties in this group of children.

On account of the existent inconsistency in the literature the central goal of the current study is to find out if there is a specific profile of Stroop test performance in ADHD children without obvious reading disorders compared to healthy children. There are grounds for supposing that other indirect measures of interference control in Stroop task should be also analyzed instead of the interference effect alone, and then the particular pattern of results could be established. The second goal would be to further examine the influence of the main moderating variables: intelligence and reading skills on the Stroop effect among the ADHD group. Specifically, it was hypothesized that children with ADHD will exhibit diminished ability to control interference and will make more errors. The third aim of the study is to examine the role of neurodevelopmental changes in children's ability to manage the Stroop demands during the age period tested. The hypothesis of a different rate at which ADHD and control children make cognitive progress in the Stroop subtasks would be tested.

Method

Participants

A total of 71 school-age children in the age range of 8 to 11 years participated in the study, 25 females and 46 males. The precise number of participants in each experimental and control subgroups presents the Table 1, as also the means and SDs for age and IQs.

The children were recruited from public schools in the metropolitan Warsaw area on the basis of informed consent from child and parent. They were self-selected by responding to a written request distributed by a teacher to every child in class. Questionnaires and interviews were provided by school psychologist with the parents and teachers of children to determine developmental, medical and learning history. The teachers in our sample had previous experience and training in recognition possible symptoms of ADHD in the school settings.

An experimental group of children were recruited in the same way except for the older subgroup which has been mostly diagnosed at a community mental health center as having ADHD combined type, but no psychiatric disorders and no learning disabilities. All children had normal intelligence, reading achievement and oral-language processing, were native speakers of Polish and were all right-handed.

The control children had no history of medical, behavioral or attentional problems. The entire sample had never been exposed to psychotropic medications before the tests. ADHD children were not taking any medication for a chronic condition on a daily basis for the last 3 months prior to the study.

ANOVA showed no significant effects of gender on TINiK tasks performance: Reading – $F(1,69) = 1.65$, $p = 0.203$; Color naming – $F(1,69) = 2.29$, $p = 0.134$; Interference naming – $F(1,69) = 0.36$, $p = 0.551$.

Procedure, Task and Measures

Each participant was tested individually in a quiet room in school on two – three occasions by a trained school psychologist.

All children underwent standardized IQ testing with a Polish version of WISC-R (Matczak, Piotrowska, Ciarkowska, 1997) and had full-scale IQ above 85. Younger groups of children (age range 8-9;6) did not differ in regard of IQs. The older group (age range 9;7-11) significantly differs on IQs, as expected for this clinical sample .

Polish experimental version of Stroop test for children (TINiK – Test Interferencji Nazw i Kolorów, *The Names and Colors Interference Test*, Okuniewska, 2001) was used at the second session. It is a classical procedure using cards with item-matrices.

Before the main TINiK testing each child was presented with 12 item not timed samples to determine ability to discriminate and correctly name the colors as well as to understand the instructions and practice the reading, naming and interference task.

There are three subtasks of the TINiK which will undergo further analyses (the results of the fourth TINiK switching task, will be not refer to in this issue). In the first condition (Reading) the number of correct read color names (czerwony, niebieski, brązowy, zielony; eng.: *red, blue, brown, green*) written in black ink was measured during the 60 seconds interval. In the second condition, the participants named the colors of bars that are printed in that four colors (Color naming). In the third condition, the child is required to name the colors of color-words that are printed in incongruent colors (Interference naming). The whole false word expression was counted as an error and the number of self-corrections was also calculated.

The number of words correct read (or colors correct named on next cards) in a 60 sec. limit is used as the sub-

Table 1. Demographic data

		Experimental group		Control group	
		Younger (8;0-9;6)	Older (9;7- 11;0)	Younger (8;0-9;6)	Older (9;7-11;0)
N = 71, N (Exp.) = 36, N (Con.) = 35		21	15	20	15
Age	Mean	8;11	10;0	9;0	9;10
Gender	Male (N=46)	17	11	10	8
	Female (N=25)	4	4	10	7
II Full Scale WISC-R	Mean	111.48	103.13*	119.87	112.65*
	SD	11.62	17.36	9.43	9.16
II Verbal Scale WISC-R	Mean	109.48	100.33*	111.45	116.60*
	SD	12.73	16.92	12.31	11.04
II Performance Scale WISC-R	Mean	111.38	105.33*	116.90	116.60*
	SD	11.40	16.62	9.05	9.39

* $p < 0.01$

Table 2. Differences between experimental and control groups on the TINiK tasks

	N	Mean	SD	N	Mean	SD	F	p
	Younger Experimental			Younger Control				
Reading	21	68.48	16.77	20	82.25	12.77	8.689	<0.005
Color naming	21	46.57	5.96	20	63.20	8.75	50.993	<0.0001
Interference naming	21	24.29	7.74	20	33.10	7.62	13.483	<0.001
	Older Experimental			Older Control				
Reading	15	71.18	18.97	15	95.53	12.27	16.276	<0.0001
Color naming	15	52.47	12.26	15	71.93	8.02	26.468	<0.0001
Interference naming	15	26.87	8.30	15	42.07	9.31	22.290	<0.0001
	Experimental			Control				
Reading	36	69.86	17.53	35	87.86	14.01	22.749	<0.0001
Color naming	36	49.03	9.44	35	66.94	9.41	64.103	<0.0001
Interference naming	36	25.36	7.97	35	36.94	9.40	31.429	<0.0001

task score. The higher raw score the better is the performance. The Interference effect was calculated by subtracting the Interference naming score from the Color naming score, the last treated as a baseline, neutral condition. The lower Interference effect shows better performance (resistance to interference).

Results

An analysis of variance was performed on the data to detect any difference in TINiK performance between the experimental ADHD group and control group. The mean raw scores, SDs and differences are presented in Table 2. According to our first hypothesis the ADHD group showed poorer performance than the control group on the Reading, Color naming and Interference naming conditions. The younger control group outperformed the younger ADHD group on all TINiK tasks. Similar differences were obtained between the older control group and the older ADHD group.

Figure 1. presents level of performance obtained by experimental and control group of participants on the three TINiK tasks. The ascending lines allow tracking the improving rate of performance in both regards of comparison: between Exp. and Contr. groups and between age groups. It is worth noting that younger control group outperforms the older experimental group on all tasks.

This stage of analysis arises a further question about the nature of global diminished performance by ADHD children. The poorer interference naming score in this group could be taken as a confirmation of inhibition control hypothesis. We will prove it twofold: through the errors and interference effect analysis.

The inattentiveness and impulsivity attributing to ADHD behavior should have produced a numerous mistakes and omission errors. However, the analysis of errors and self-corrections showed no significant differences. The ADHD group did not differ from the controls on the error scores. The mean percentages of errors were very small in all groups of participants (in reading and color naming – smaller than 0.6%, in interference naming – smaller than 4%): in the younger ADHD group – 0.08%, 0.43%, and 3.53%, in the older ADHD group – 0.06%, 0.44%, and 1.39%, in the younger control group – 0.21%, 0.58%, and 1.38%, and in the older control group – 0.11%, 0.44%, and 1.17%, for reading, color naming, and interference naming conditions, respectively. It seems as the TINiK performance course in ADHD groups was rather slower and careful than impulsive and full of errors. If so, then the inhibition hypothesis earn no support from the error analysis.

Secondly, we want to know what is the pure Interference effect for both groups. We assumed poorer interference control in the clinical group on the grounds of referred

Figure 1. The mean scores in TINiK tasks

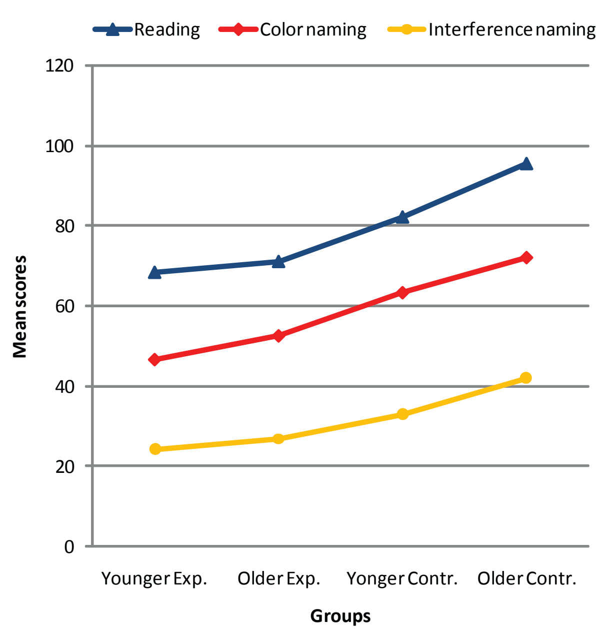


Table 3. Means interference effect in children's groups

Groups	N	Mean	SD	F	p
Younger Experimental	21	22.29	6.732	**11.853**	**0.001**
Younger Control	20	30.10	7.786		
Older Experimental	15	25.60	11.255	1.390	0.248
Older Control	15	29.87	8.348		
Experimental	36	23.67	8.906	**10.016**	**0.002**
Control	35	30.00	7.911		

literature and reduced scores on Interference naming. The assumption was not confirmed in our sample. The ADHD groups showed less interference than healthy groups after scores for the Color naming (the purported naming speed measure) are controlled.

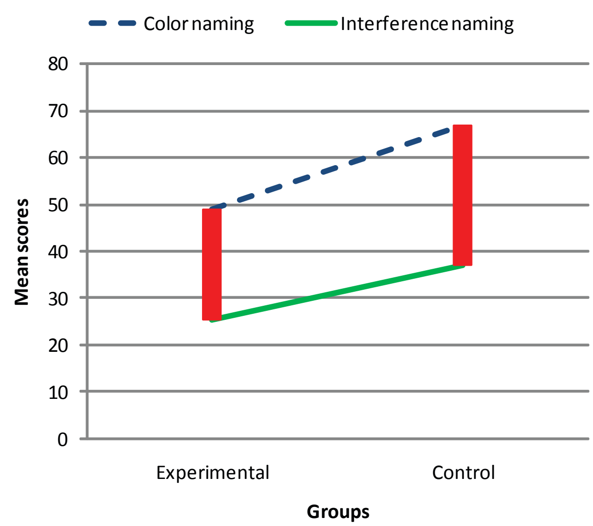
The comparison of interference effect calculated as a difference between color naming score and interference naming score revealed the significantly smaller effect size in the ADHD group than in the control group (totally). Interference effect was significantly smaller in the younger experimental group than in the younger control group. However, there was no significant differences between older (experimental and control) groups (see Table 3). Figure 2 visualizes (the red bars) the relationship between the test scores taken into account and the interference effect size.

It is difficult to resist the conclusion of little evidence to support the notion of a deficit in interference control in children with ADHD in our sample.

A specific profile of TINiK test performance in ADHD children from our sample could be reconstructed as follow: the raw scores of Reading and Interference naming are lower about 1 SD and the Color naming scores – about 2 SD than analogical scores of the control group matched for age. Surprisingly, children with ADHD in our sample showed less pure interference effect than their healthy counterparts, at about 1 SD.

To explain this paradoxical finding the two variables potentially influencing the interference effect: reading skills and intelligence level need to be examine in more detailed fashion. For this reason the participants with ADHD (Experimental group) were divided into two roughly equal subgroups: those who obtained subtask results (Reading) lower than the median value ("slow readers", <72) and those with results higher than median ("fast readers", >72).

Figure 2. Mean TINiK scores and interference effect in Experimental and Control groups



The experimental group was also divided into two further subgroups on the basis of selected WISC-R scores. At first, the correlations between mean TINiK scores and two WISC-R factors of presumed relevance (Freedom from Distractibility Factor and Perceptual Organization Factor) were carried out. A significant correlation was merely revealed with Freedom from Distractibility Factor: Reading ($r = 0.55$, $p < 0.001$), Color naming ($r = 0.60$, $p < 0.001$), and Interference naming ($r = 0.49$, $p < 0.001$). Various studies indicate that the ability to concentrate and ignore irrelevant information is a general problem in ADHD (van Mourik et al., 2008). Thus, the mean score of Freedom from Distractibility Factor (FDF) was used for dividing the experimental group into two roughly equal subgroups: children with lower and higher scores on Freedom from Distractibility Factor ("higher FDF", >29 and "lower FDF", <29).

To examine whether FDF and reading skills were influencing the Interference effect together the mean of Interference naming scores in subgroups arranged as mentioned above, were compared using the two-way ANOVA. The main effect of FDF level did not reach statistical significance and did not interact with reading skills while the "slow readers" appeared significantly slower in Interference naming task than "fast readers" (see Table 4).

Table 4. Influence of FDF (WISC-R) and reading skills on interference naming

		Mean	SD	F	p	η2
Reading skills	Slow readers	24.31	2.38	**5.414**	**0.026**	**0.14**
	Fast readers	32.08	2.34			
WISC-R FDF	Higher FDF	27.38	2.38	0.238	0.629	0.01
	Lower FDF	29.01	2.34			
Reading skills * Intelligence				0.614	0.439	0.02

Table 5. Differences between age groups on TINiK scores

	N	Mean	SD	N	Mean	SD	F	p
	Younger Experimental			Older Experimental				
Reading	21	68.48	16.771	15	71.18	18.971	0.308	0.582
Color naming	21	46.57	5.963	15	52.47	12.264	3.670	0.064
Interference naming	21	24.29	7.740	15	26.87	8.297	0.917	0.345
	Younger Control			Older Control				
Reading	20	82.25	12.769	15	95.53	12.269	**9.302**	**<0.005**
Color naming	20	63.20	8.752	15	71.93	8.022	**9.156**	**<0.005**
Interference naming	20	33.10	7.622	15	42.07	9.308	**9.816**	**<0.005**

It could be reasonable argued that ADHD children in our sample did not differ from controls in Interference naming task because of their inability of concentrate and suppress distractors (as measured by WISC-R FDF) but rather as a result of lower reading skills.

Finally, the third hypothesis of a different maturational rate at which ADHD and control children make cognitive progress in interference control as measured by TINiK was tested using the one-way ANOVA. There was found no significant difference between mean scores of both younger and older ADHD groups on three TINiK measures, the noticed improvement with age did not revealed significance. Conversely, the control age groups differed significantly (see Table 5) on all TINiK tasks. The obvious improvement on reading skills in healthy children is not replicated in the ADHD groups.

Summary and Discussion

The ADHD is recently desribed as a developmental pathology in self-regulation abilities (Berger et al., 2007). This view stress the importance of mature executive attention and language acquisition for the gradual development of self-regulation in children. The amount of famous Stroop Interference has been widely taken as an index of efficiency of cognitive control mechanisms in ADHD. Aim of this study was to examine Stroop test performance in ADHD children in two relative narrow age brackets to make apparent the course of developmental changes in abilities of reading, color naming and interference control in comparison with analogous skills in healthy children. The past literature suggested rather ambiguously the slowness of the reading speed, difficulties in rapid color naming and weakness in interference control in this clinical sample. The ADHD group in study presented here showed poorer performance than the control group on measures of word reading, color naming and interference naming but did not differ from the control group on error number and paradoxically did obtain lower Interference effect (see Table 6).

This profile in regard to relative stronger reduced color naming scores seems to confirm the specific color perception problems in ADHD described recently in literature (cf. Albrecht et al., 2008; Banaschewski et al. 2006).

In contradictory with expectations, there was showed little if any evidence for specific deficit in interference control in ADHD - this finding replicates the growing body of disagreement with previous overgeneralization (Frazier et al.,2004; Homack and Riccio, 2004; van Mourik, 2009). Moreover, the research which explore in more detail the cognitive disorders inherent to the ADHD showed, for instance, that on the computerized Counting-Stroop test the interference score was not higher in ADHD than in healthy children (Albrecht et.al, 2008).

On the basis of this and other evidence from an Auditory Stroop-task, these authors propose a differential attentional pattern rather than an single core deficit for these children (van Mourik et al., 2009).

A more remarkable finding of this study was that we managed to demonstrate the developmental differences in reading skills in age range 8-11 years between typically developing children and ADHD. The virtually lack of progress in word reading (black ink) in ADHD children during such a long period needs to be clarified. This finding, if replicated, would earn more attention in future investigations. It would be of interest to prove if a general slowing

Table 6. Research studies in which the similar findings are reported

Results in interference naming task	Interference effect size	Research studies
Control group > ADHD group	Control group < ADHD group	Scheres et al., 2004; Reeve & Schandler, 2001; Seidman et al., 2001
Control group > ADHD group	Control group = ADHD group	Willcutt et al., 2005; Golden & Golden, 2002; Nigg et al., 2002; Rucklidge & Tannock, 2002

hypothesis provide a more fruitful explanation of ADHD reading speed and interference naming than that provided by the deficit in inhibition hypothesis (Okuniewska, 2001).

Some limitations should be also noted. First, we need to stress that the children with ADHD-C in our sample had all relative high IQs and presented no evident comorbid reading or psychiatric disorders what is not typical within the ADHD spectrum. Second, although combined parent and teacher information reflects the optimal sources of diagnostic data obtained in usual clinical practice, it seems be desirable to confirm the diagnosis according to DSM-IV criteria by a multidisciplinary team consisting of a child psychiatrist, a child neurologist, and a child psychologist. It was not the case in our younger experimental group recognized as children with probable ADHD by educated teachers basing on both the severity of symptoms and the impact of these problems on the class and home. Establishing the diagnosis of ADHD requires parents consulting the specialist services. The next limitations is that rejecting the theory of core deficit on interference control does not exclude the possibility that ADHD may consist of a different distribution of attentional resources and that children with ADHD demonstrate deficits on interference task under more demanding condition.

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