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THE EFFECTS OF AGE ON STROOP INTERFERENCE IN CLINICAL VS. HEALTHY GROUPS OF CHILDREN

The Stroop task is widely used to assess attentional dysfunction due to a frontal or fronto-parietal deficit and is also thought to be related to the maturation of the prefrontal cortex. The study aimed to prove the diagnostic usefulness of the Polish Names and Colors Interference Test (TINiK) in a clinical setting and to investigate the pattern of performance on four TINiK subtasks according to the type of brain damage (focal or diffuse) and age of the patients. A total of 107 subjects (62 female, 45 male) aged 11-18 were divided into two groups: children aged 10;4-14;6 and adolescents aged 14;7-17;10 within each diagnostic category: healthy (H – 35), heterogeneous focal brain damage (BD – 36) and cardiac arrhythmia (CA – 36). The number of correct responses in the 60s time limit was collected for each TINiK task. The H group significantly outperformed both clinical groups. The H and CA groups show improvement of performance systematically with age on all TINiK subtasks although at a different level. The BD group displayed merely non-significant developmental improvement especially among the adolescent group. A discriminant analysis using the four basic TINiK scores was able to significantly differentiate the BD from the H group (83.1%) and the BD from the CA group (74.6%), but less well the CA from the H group (63.9%). TINiK has acquired preliminary neuropsychological validation in Polish children. Developmental improvement in interference control may be hampered by various neuropathological mechanisms which are yet to be identified.

Key words: child, development of cognitive control, Stroop interference, age effect, children with brain damage, children with cardiac arrhythmia

Introduction

There has been much debate in recent years about the ways in which executive control should be measured and how it grows and declines across the lifespan (Anderson et al., 2008). The Stroop interference task (Stroop, 1935) is a well-established executive function measure of accepted utility in neuropsychological assessment

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of children and adults. Children's performance on the Stroop task improves with age until approximately 17-19 years (e.g. Comalli et al., 1962; Okuniewska, 2001).

The functional data from a neurodevelopmental fMRI study with Stroop task (Adleman et al., 2002) revealed that prefrontal activation increases parallel to this behavioral development of better interference control. Schroeter et al. (2004) were the first to provide evidence for ongoing correspondence between developmental changes in Stroop-processing brain networks and increased ability to control the Stroop interference. The specific networks mediating Stroop performance cover a range of brain areas and their connections, each of them can have different developmental trajectories. Recent developmental functional imaging findings enable us to point to the period of adolescence as the critical phase for cognitive control maturation. Rubia et al. (2006) suggest a progressive maturation of task-specific brain networks mediating cognitive control functions especially in the period of transition from childhood to adulthood, in the age range of approximately 11-19.

In this study we were interested in finding out if the development of cognitive control can be differently disturbed through the focal and diffuse nature of brain lesions in children and adolescents with focal brain damage and with cardiac arrhythmia.

At the more operational level, we wanted to compare the Stroop task performance of focal brain damaged and tachycardic children and adolescents with that of typically developing children of matched age and find out which type of pathology produces more vulnerability to cognitive interference.

The aim of the study was threefold:

- to examine if there are differences in Stroop performance between clinical (cardiac arrhythmia, focal brain damage) and control (healthy) groups of children and adolescents
- to explore the diagnostic validity of the Polish experimental version of the Stroop test
- to compare the interference control level reached in the younger and older developmental and diagnostic subgroups.

Method

Participants

One hundred and seven children aged between 11 and 18 years took part in the study. The age and gender distribution is shown in Table 1. The analysis of gender effects (using ANOVA in equinumerous groups and the Mann-Whitney U test in groups markedly differing in numerical strength) showed no significant differences. These results concur with the findings of our previous studies on Stroop interference effects (Okuniewska, 2001; Okuniewska, 2007; Okuniewska, 2009).

Healthy children were recruited from primary and secondary schools. Patients were recruited from neurosurgery and cardiological clinics at the second author's

Table 1. Demographic data

	Focal Brain Damage (BD)		Cardiac Arrhythmia (CA)		Healthy (H)	
	Younger 10;4-14;6	Older 14;7-17;10	Younger 10;4-14;6	Older 14;7-17;10	Younger 10;4-14;6	Older 14;7-17;10
N =107	36		36		35	
	19	17	18	18	17	18
Age (Mean)	13;2	16;4	13;3	16;10	12;8	16;9
Male (N=45)	14	10	8	7	5	1
Female (N=62)	5	7	10	11	12	17

place of employment. Examination took place individually in a quiet room at school or at the hospital (clinical groups). All the subjects were mainstream school students and proficient readers in the intellectual norm according to the parents' interview. Children having other diseases potentially affecting cognitive development were not included in the study.

Focal brain damaged group (BD)

Heterogeneous focal brain lesions based on MRI results. The lesion etiology was diverse (e.g. tumor, cavernoma, cortical dysplasia, cystic lesion, brain injury). The side of lesions and frontal involvement (61.1% overall) is presented in Table 2. All patients except those with lesions connected with brain injury were examined before neurosurgery.

Cardiac arrhythmia group (CA)

Children with paroxysmal tachycardia: either atrioventricular nodal reentry tachycardia (AVNRT – 19 pts) or atrioventricular reentry tachycardia (AVRT – 17 pts) characterized by a high heart rate (even 250-300 beats/minute) and associated with transient brain anoxia and serious stress. All patients were scheduled for radiofrequency ablation and examined before treatment.

Table 2. Side of lesions and frontal lesion subgroups

Side of lesions	N (%)	Frontal lesions	N (%)
left focal lesions	14 (38.9%)	left frontal lesions	3 (8.3%)
right focal lesions	8 (22.2%)	right frontal lesions	7 (19.4%)
bilateral focal lesions	14 (38.9%)	bilateral frontal lesions	12 (33.3%)

Procedure

The Names and Colors Interference Test (TINiK, Test Interferencji Nazw i Kolorów), a Polish experimental version of the Stroop test (Okuniewska, 2009), was used for testing.

Four A4 experimental cards preceded by training trials were presented by a trained psychologist to children in four conditions in succession:

- reading – reading color names, words printed in black,
- color naming – naming the color of bars,
- interference naming – naming the color of ink, words printed in incongruent colors,
- switching – alternate interference naming and reading.

The number of correct responses in the 60s time limit was collected for each task. Participants were requested to work down the columns one item at a time and speak aloud the name or the color of the word as quickly and as accurately as possible.

Results

The two-way ANOVA (diagnosis x age, 3x2) showed significant differences between the three diagnostic groups in all TINiK tasks:

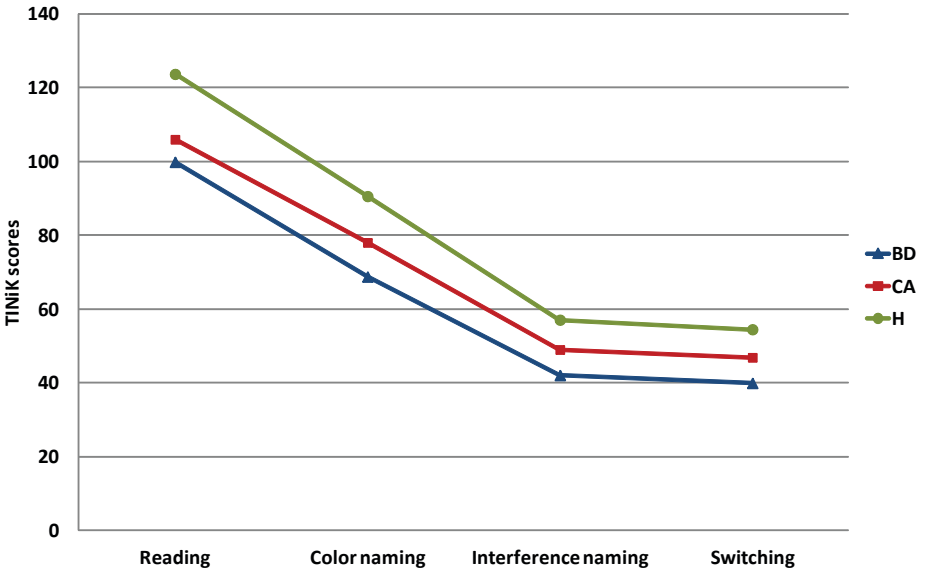
- Reading: $F(2,104) = 16.974$, $p < 0.001$, $\eta^2 = 0.252$;
- Color naming: $F(2,104) = 22.714$, $p < 0.001$, $\eta^2 = 0.310$;
- Interference naming: $F(2,104) = 20.361$, $p < 0.001$, $\eta^2 = 0.287$;
- Switching: $F(2,104) = 15.429$, $p < 0.001$, $\eta^2 = 0.234$.

The post hoc comparisons (Bonferroni test) revealed significant differences between all diagnostic groups except for the Reading task between the BD and CA groups ($p = 0.462$). The interaction effects of diagnosis and age are not statistically significant. The H group significantly outperformed both clinical groups on all four TINiK tasks (Figure 1). The lack of any significant difference in Reading between the BD and CA groups can be interpreted as confirmation of their assumed relatively balanced intelligence level and psychomotor rate.

Table 3. The mean and SD scores in TINiK tasks

TINiK tasks	BD (N = 36)		CA (N = 36)		H (N = 35)	
	Mean	SD	Mean	SD	Mean	SD
Reading	99.86	22.83	106	15.05	123.71	15.78
Color naming	68.78	14.59	78.06	14.61	90.60	13.68
Interference	42.08	8.96	49.03	10.90	57.11	11.46
Switching	39.94	12.20	46.92	11.57	54.51	10.45

Figure 1. Mean TINiK scores in diagnostic groups



TINiK: Diagnostic validity – preliminary findings

A discriminant analysis using the four basic TINiK scales was able to significantly differentiate the BD group from the H group (83.1%) and the CA group from the H group (74.6%). The results were poorer for differentiating the BD from the CA group (63.9%).

Stroop performance during healthy and disturbed development

Participants were further divided into age subgroups, according to current knowledge of critical periods of brain development and cognitive control improvement. The age range for the younger groups: 10;4-14;6 and for the older groups: 14;7-17;10 (see Table 4).

The H and CA groups show improvement in performance systematically with increasing age on all TINiK subtasks although at a significantly different level. The CA group shows a consistently lower level of skills under examination than the H group. This could be considered the influence of situational factors (hospitalization) alone. However, this factor should not have the same impact on the test performance of younger and older participants.

The BD group reveals merely non-significant developmental improvement in adolescence as regards simple verbal skills (reading, color naming) as well as more complex executive skills (interference naming, switching). The frontal lesion site did not contribute significantly to the outcomes of the BD group in this sample.

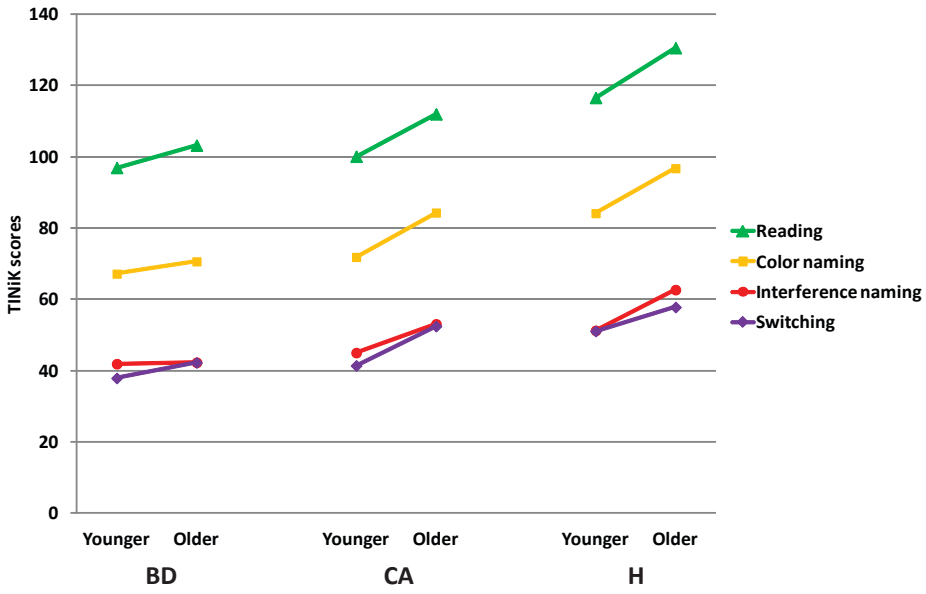
Table 4. Mean scores and differences between age subgroups in TINiK tasks

	N	Mean	SD	N	Mean	SD	F	p
	Age range 10;4-14;6			Age range 14;7-17;10				
				BD				
Reading	19	96.89	22.07	17	103.18	23.88	0.673	0.418
Color naming	19	67.16	13.79	17	70.59	15.65	0.489	0.489
Interference naming	19	41.89	7.67	17	42.29	10.45	0.017	0.896
Switching	19	37.89	12.86	17	42.24	11.36	1.140	0.293
				CA				
Reading	18	100.06	15.51	18	111.94	12.27	**6.504**	**0.015**
Color naming	18	71.83	10.28	18	84.28	15.87	**7.797**	**0.009**
Interference naming	18	45.00	6.53	18	53.06	12.96	**5.551**	**0.024**
Switching	18	41.39	7.15	18	52.44	12.65	**10.428**	**0.003**
				H				
Reading	17	116.53	18.20	18	130.50	9.24	**8.337**	**0.007**
Color naming	17	84.12	14.22	18	96.72	10.12	**9.213**	**0.005**
Interference	17	51.24	9.28	18	62.67	10.69	**11.352**	**0.002**
Switching	17	51.06	9.73	18	57.78	10.31	3.923	0.056

The children with cardiac arrhythmia performed significantly worse than their healthy counterparts on all TINiK tasks. Another study has shown that children and adolescents with paroxysmal AVNRT and AVRT are at risk of developing significant deficits in memory functioning (Maryniak et al., 2009). The present work reveals that executive functions could be affected too. The mechanisms that lead to cognitive deficits in this group of children remain unknown. Various coexisting factors may influence cognitive functioning in children and adolescents with cardiac arrhythmia: recurrent transient brain anoxia, incoherence stimulus appearing during paroxysmal tachycardia attacks, stress. More studies are needed to assign their cognitive developmental pattern.

TINiK has acquired preliminary neuropsychological validation in a clinical setting. Healthy adolescents showed evident progressive age-related changes in simple reading and naming tasks and in more complex executive tasks (interference control and switching). In contrast, focal brain damaged adolescents did not show expected progress within this critical period.

Figure 2. Group comparisons of age impact on TINiK performance



Conclusions

The overall performance pattern (Figure 2) confirms the claim that attentional functions and cognitive control as measured by TINiK develop throughout adolescence concurrently with anatomical brain maturational changes. TINiK has acquired preliminary neuropsychological validation in a clinical setting. The results suggest that focal brain damage disturbs the developmental course of structural/functional relations in a more salient way than diffuse changes caused by paroxysmal tachycardia. Developmental improvement in interference control may be hampered by various neuropathological and environmental mechanisms which are yet to be identified.

Limitation of the study

A high performance level in cognitive control tasks relies especially on the functioning of frontoparietal networks, so efforts should be made in future to recruit a more homogenous BD group. Age at insult and age of onset of paroxysmal tachycardia attacks was not analyzed here but both could modify our findings by creating new diagnostic groups. This is the goal of the next investigation to find out if the aforementioned variables impact Stroop interference task results.

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