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Brain State Regulation and RAN/RAS Performance in Primary School Children

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Abstract. The topic of this paper is an analysis of the influence of brain state regulation (specifically, the functions of the first energetic unit of the brain, according to Luria) on performing a RAN / RAS technique. Three groups of primary school children participated in the study: children with good brain state regulation (*n* = 101) and children with poor brain state regulation, who were divided in two groups: those with slow processing speed and rapid fatigue (*n* = 29) and those with hyperactivity and impulsivity (*n* = 20). Each child passed a full Lurian neuropsychological battery of tests for children between the ages of 5 and 9 years old (Akhutina et al., 2013), followed by the RAN / RAS technique. The present study revealed a complex and varied picture of the combined influence of brain state regulation and executive functions on performing the RAN / RAS technique in children with poor brain state regulation. More clearly, the results showed that weakness of the first brain unit influences children with slow cognitive tempo: data were obtained about the impact of slowness on the execution time of the first "Objects" subtest and RAS subtests. Children with hyperactivity showed large fluctuations of success and execution time with the subtest. According to the literature, that is typical of children with ADHD who have severe symptoms of hyperactivity-impulsivity and executive function weakness.

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Introduction

The Rapid Automatized Naming and Rapid Alternating Stimulus (RAN/RAS) technique is successfully used by many psychologists to predict the risk of dyslexia, because it has a clear linguistic component and requires visual-verbal connections (Dencla & Rudel, 1976). Meanwhile, recent research has shown slow naming speed to be an effective indicator of vulnerability to neurocognitive problems in learning and information processing in general; that is, naming speed is sensitive to various learning disabilities (LD), not only to reading disabilities (Waber, Wolff, Forbes & Weiler, 2000; Waber, 2011). There are two propositions explaining this effect. Slow naming speed may be caused by a deficit of executive functions (Denckla & Cutting, 1999) or by problems with automatization; in other words, there is a problem transitioning from an energy-consuming controlled task to less energy-intensive automatic actions (Waber, 2011). The second proposition related to sufficiency of energy resources is in line with the concept of brain state regulation as a function of the first (energetic) unit of the brain (Luria, 1973). According to Alexander Luria's seminal conceptualization of functional organization of the brain, there are three principal functional units in the brain. The *first unit* includes the brain stem and primitive cortex. This unit provides an optimal level of activation of other brain structures through a double reciprocal relationship with the cortex, influencing its tone and experiencing its regulatory influence itself. The *second unit* occupies the posterior regions of the cortex; its function is reception, analysis and the storage of information. The *third unit* includes the frontal lobes. This unit is involved in the programming, regulating and verification of human actions (executive functions). The concerted participation of all three units is necessary for any mental activity (Luria, 1970 and 1973).

The role of deficits in brain state regulation in the mechanism of ADHD and learning disabilities is increasingly discussed in the literature (Sergeant, 2005; Van der Meere, 2005; Sonuga-Barke, Wiersema, van der Meere, & Roeyers, 2010), and it has been shown that there are two variants of poor activation control: hyperactivity-impulsivity and slowness-fatigue (Agris, Akhutina, & Korneev, 2014; Akhutina, Korneev, Matveeva, & Agris, 2015). The first variant is close to the combined type of ADHD, and the second variant is close to ADD without hyperactivity or the syndrome of sluggish cognitive tempo (Brown, 2005; Sergeant, 2005; van der Meere, 2005; Nigg, 2005; McBurnet, Pfiffner, & Frick, 2001; Becker & Langberg, 2014; Barkley, 2014). However, the role of weak energetic functions in poor RAN/RAS performance has not been discussed in the literature. The aim of our study is to show that poor brain state regulation can influence RAN/RAS performance, and to analyze the differentiated influence of the variants of the first brain unit weakness on performing the RAN/RAS technique.

Method

Participants

Ninety-nine primary school children from Moscow schools participated in the study. Fifty-six children were examined twice while studying in the first and second grades. Twenty-five children were only examined in first grade and eighteen were examined only in second grade.

Procedure

Each participant passed a full Lurian neuropsychological battery of tests for children aged between 5 and 9 years old (Akhutina et al., 2013) and was examined using the RAN/RAS technique. The full RAN/RAS technique consists of six subtests, each presented on a separate sheet. Each subtest has five different stimuli of randomly alternated objects, for a total of 50 stimuli per sheet (see Fig. 1). The RAN stimuli include objects, colors; digits; letters; the RAS stimuli include alternating letters and digits; and alternating letters, digits and colors. Before each subtest, the child performed training tasks by naming five elements of a series (shown randomly). Once the examiner was confident in the child's correct naming, he asked the child to name all of the stimuli one by one as quickly as possible and without errors. The time of execution and number of mistakes are registered.

During the assessment and traditional analysis of performance tests, behavior patterns reflecting brain state regulation levels were recorded. Behavioral symptoms included slow tempo, fatigue, hyperactivity, impulsivity and perseverative behavior (see details in Akhutina et al., 2015). Factor analysis of the five listed measures allowed us to extract two factors explaining 78% of the variance.

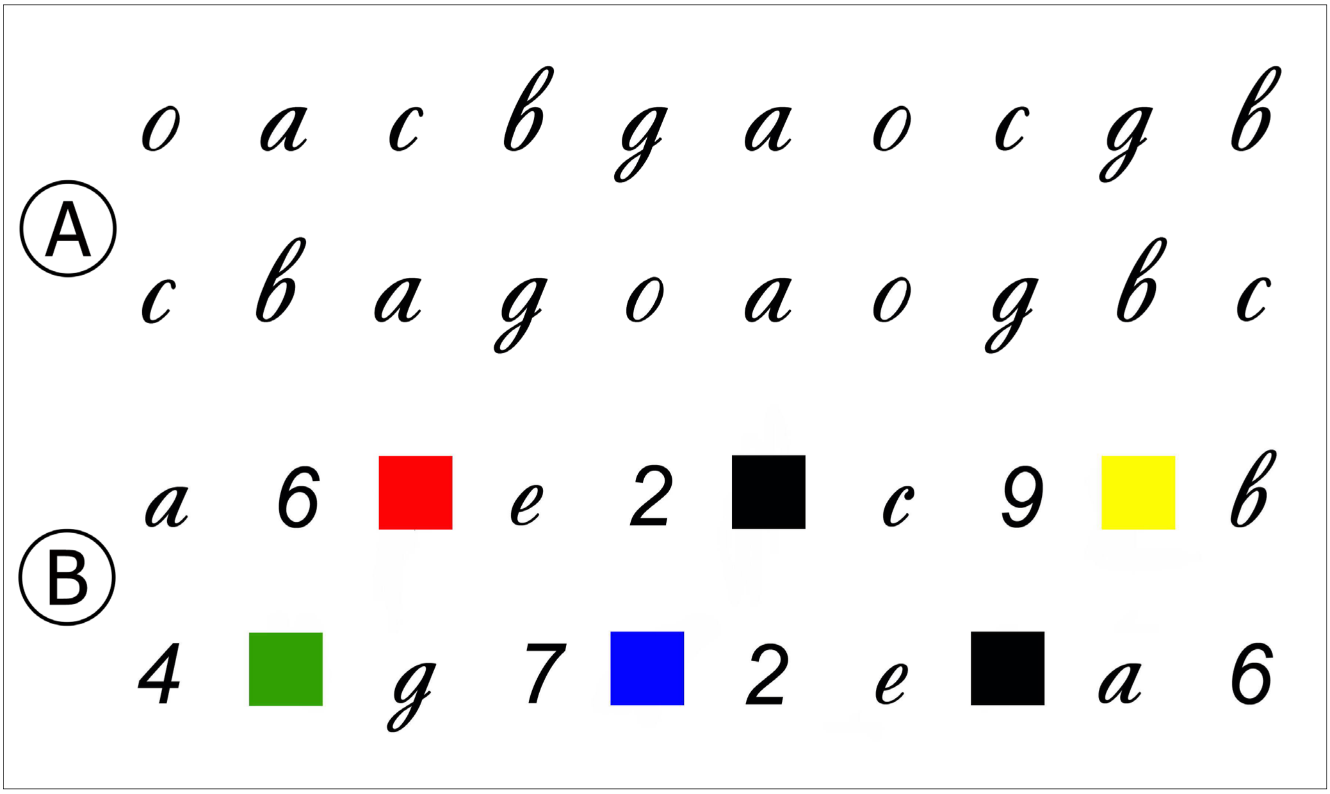

Figure 1. Sample stimuli from a Rapid Automatized Naming (RAN) subtest with Cyrillic letters (A) and Rapid Alternating Stimulus (RAS) subtest with alternating letters, digits and colors (B).

Table 1. Results of neuropsychological assessment of the first and third unit functions

Group	Index of hyperactivity average (std. dev.)		Index of slow tempo average (std. dev.)		Programming and control index average (std. dev.)		Serial organization index average (std. dev.)	
	1 grade	2 grade	1 grade	2 grade	1 grade	2 grade	1 grade	2 grade
N	−0.62 (0.88)	−0.57 (0.94)	−1.05 (1.70)	−1.16 (1.63)	−1.12 (2.96)	−1.03 (2.88)	−0.34 (2.39)	−0.39 (2.43)
H	3.35 (1.05)	3.57 (1.22)	0.03 (1.70)	0.44 (1.94)	3.95 (5.40)	3.38 (5.46)	1.42 (3.22)	1.14 (3.62)
S	0.01 (1.67)	0.14 (1.64)	3.84 (1.03)	3.87 (1.06)	1.80 (3.52)	1.72 (3.64)	0.32 (3.80)	0.49 (3.88)

Table 2. Execution time (in seconds) and number of mistakes in three groups of children

Subtest	Group	Execution time average (std. dev.)		Number of mistakes average (std. dev.)	
		1 grade	2 grade	1 grade	2 grade
Objects	N	52.7 (7.4)	47.5 (8.2)	2.9 (1.7)	2.5 (1.6)
	H	57.4 (10.4)	51.1 (14.8)	3.9 (2.4)	2.6 (1.3)
	S	59.7 (11.8)	55.2 (8.2)	3.6 (3.9)	3.5 (3.8)
Colors	N	52.0 (10.3)	45.9 (10.4)	2.4 (1.7)	2.8 (2.1)
	H	61.6 (21.9)	48.7 (11.0)	2.8 (1.6)	2.4 (1.8)
	S	55.8 (15.5)	51.9 (13.2)	2.1 (1.5)	2.3 (1.6)
Digits	N	35.1 (8.3)	28.6 (6.4)	1.4 (1.4)	1.1 (0.9)
	H	36.2 (8.7)	28.4 (9.9)	1.3 (1.0)	1.5 (1.1)
	S	34.7 (7.3)	27.9 (6.2)	0.8 (1.0)	1.2 (1.7)
Letters	N	32.4 (9.6)	26.7 (5.0)	2.4 (3.3)	2.0 (1.9)
	H	33.5 (7.5)	27.0 (4.9)	2.9 (4.0)	3.0 (2.0)
	S	32.3 (6.3)	30.3 (6.5)	1.5 (1.4)	2.3 (2.3)
Letters and digits	N	41.0 (11.8)	31.4 (6.6)	2.9 (2.4)	2.5 (2.0)
	H	42.0 (10.9)	27.1 (4.5)	2.7 (1.5)	1.8 (1.0)
	S	38.9 (7.5)	34.0 (3.3)	2.2 (2.2)	2.2 (1.6)
Letters, digits and colors	N	44.5 (12.8)	34.6 (6.7)	3.0 (2.3)	2.5 (2.2)
	H	49.8 (15.9)	31.3 (5.1)	4.2 (3.2)	2.1 (1.5)
	S	44.3 (8.9)	35.7 (5.0)	2.8 (2.6)	2.5 (2.1)

The higher the index, the worse the state of higher mental functions.

The first factor has high factor loadings on slowness, fatigue and perseveration, while the second factor has high loadings on hyperactivity and impulsivity. Based on the results, we calculated two indices: (1) index of slow tempo, which includes parameters of slowness, fatigue and perseveration, and (2) index of hyperactivity, which includes parameters of hyperactivity and impulsivity. On the basis of these indices we identified three groups of children: (a) Group N included children with good regulation of activation, and neither index exceeded the sample average by more than 0.5 of the standard deviation; (b) Group H children showed severe symptoms of hyperactivity; (c) Group S children had slow cognitive tempo. In both the H and S groups, indexes of hyperactivity or slow tempo exceeded the average in the whole sample by more than 0.5 of the standard deviation and were higher than the other index. Group N included 49 children in first grade (mean age 7.8±0.41 y.o.) and 52 children in second grade (8.8±0.4 y.o.); Group H included 12 first graders (7.4±0.43) and 8 second graders (8.9±0.4); Group S included 15 first graders (7.7±0.27) and 14 second graders (8.7±0.35).

The results of the neuropsychological assessment also allowed us to evaluate the third brain unit state: programming and control index (executive function index) and serial organization index.

Results

The results of the neuropsychological assessment showed that the first and second grades' H and S groups were similar in severity of the first unit symptoms. Executive function was worst in the H group, while the S group was between the H and N groups. The same hierarchy of severity was found in serial organization functions in the three groups, but the symptoms of weakness of serial organization functions were not very severe (see Table 1).

The results of RAN / RAS tests are presented in Table 2.

A repeated measures ANOVA was performed with within-group factor SUBTEST and between-group factor GROUP. A significant effect of factor SUBTEST was found on the **time parameter** in first grade children ($F(5, 330) = 109.3$, $p < .001$, $\eta^2 = .623$). This implies that changes in execution time from subtest to subtest were significant. The longest execution times were required for the first two subtests, “Objects” and “Colors”, followed by the subtests “Letters, digits and colors” and “Letters and digits”, and the shortest times of execution were observed in subtests “Digits” and “Letters”. The influence of interaction GROUP × SUBTEST was significant, but small ($F(10, 330) = 2.1$, $p = .021$, $\eta^2 = .061$. The differences between the groups in the different subtests varied: they were minimal in the subtests “Digits”, “Letters” and “Letters and digits”; in the first two subtests “Objects” and “Colors”, the two groups with the first brain unit weakness were slower, and in the last subtest “Letters, digits and colors” the H group was slow. In second graders, the factor SUBTEST ($F(5, 310) = 149.0$, $p < .001$, $\eta^2 = .706$) significantly affected the time of execution. The longest times of execution were found in the first two subtests, “Objects” and “Colors”, with the minimum time of execution observed in subtests “Digits” and “Letters”. Slightly more time was required for naming in subtests “Letters and digits” and “Letters, digits and colors”. Also, the influence of interaction GROUP × SUBTEST was significant ($F(10, 310) = 2.8$, $p = .002$, $\eta^2 = .083$). The differences between groups changed from subtest to subtest: they were minimal in subtests “Digits” and “Letters and digits”. In the first two subtests both groups with weak first unit function were slower, while in the last two subtests children with low tempo were slower, but children with hyperactivity were faster. Post hoc analysis showed significant differences in time between groups N and S in subtest “Objects” in first ($p = .035$) and second ($p = .022$) grades. Groups S and H significantly differed only in second grade in the subtest “Digits and letters” ($p = .047$).

In the first grade, the influence of factor SUBTEST on the **number of mistakes** was significant ($F(5, 330) = 9.8$, $p < .001$, $\eta^2 = .129$), so the number of mistakes changed from subtest to subtest. The maximum number of mistakes was observed in the first subtest “Objects” and in the last subtest “Letters, digits and colors”. The lowest number of mistakes was observed in the third subtest,“Digits”. In second grade children, the influence of factor SUBTEST was also significant ($F(5, 310) = 4.3$, $p = .001$, $\eta^2 = .064$): the lowest number of mistakes was observed in the third subtest “Digits”, and in other subtests the average number of mistake was similar. The factor GROUP and the interaction between GROUP and SUBTEST factors were not significant, indicating that children from different groups made similar numbers of mistakes.

Analysis of **correlations** showed the presence of significant correlations between the time of execution and neuropsychological indices of the first and third brain units. In the first grade, the following significant correlations were observed: between time of execution and index of slow tempo in the subtest “Objects” ($r = .361$, $p = .008$, hereinafter Bonferroni correction for multiple correlation was used); between time of execution and programming and control index in subtests “Objects” ($r = .319$, $p = .028$), “Letters and digits” ($r = .290$, $p = .064$), “Letters, digits and colors” ($r = .268$, $p = .068$); between time of execution and serial organization index in subtests “Digits” ($r = .331$, $p = .024$), “Letters, digits and colors” ($r = .323$, $p = .028$). In the second grade, there was a significant correlation between time of execution and index of slow tempo in the subtest “Objects” ($r = .382$, $p = .008$). In the first grade, there was also a significant correlation between number of mistakes in the subtest “Letter and Digits” and Programming and control index ($r = .424$, $p < .001$) and index of serial organization of movement ($r = .305$, $p = .044$).

Discussion

The present study revealed a complex picture of the combined influence of the first brain unit state and executive functions state (including programming and control functions and serial organization functions) on performance of the RAN/RAS technique. It is noteworthy that this effect was different in various subtests. The influence of the SUBTEST and GROUP factor interaction in the first and especially in the second grade is associated with a decrease of **execution speed** in children with a deficit in first brain unit function in the first two and last two (most difficult) subtests. Specifically, the differences manifested between S and N group children in the first subtest. Since the order of subtest presentation was constant, it is impossible to separate the influence of the first sequence number and content of the subtest. Because this subtest is the first in the RAN/RAS technique, the problem of initiating task was most acute here. On the other hand, naming in the subtest “Objects” required inhibition of more words-competitors, similar in sound and meaning, than in subtests with different content, so probably it demands more energy resources. In general, it can be noted that the speed of test execution is associated with the severity of slow cognitive tempo and fatigue rather than with hyperactivity and impulsivity. In the **number of mistakes** made, the three groups with different activation component states appeared indistinguishable. This, in our opinion, may be due either to the relatively small sample or to a large spread of errors. Characteristically, the high standard deviation of the error rate is typical for the group S in the first subtest in both grades (it differs from the group N at the level of $p < .05$ for the Levene test).

Correlation analysis showed that on the timing performance of subtest “Objects” also influenced programming and control functions state, it is clearly revealed at the first-graders. In general, the state of executive functioning was more affected in first graders, and it was more evident in the performance on RAS-subtests: there were correlations between these indices and the number of mistakes. Several researchers have commented about the influence of executive functions on performing the RAN/RAS technique (Kail & Hall,1994; Denckla & Cutting, 1999; Stringer, Toplak, & Stanovich, 2004), and our data support this view. The different impact of the first brain unit weakness on various subtests, distinguished also depending on the variant of this weakness, requires further experimental study with large samples to confirm (or reject) the hypothesis about RAN/RAS performance depending on the state of regulation of activation. Our results partially support this hypothesis: we obtained data on the effect of slow cognitive tempo on execution times of the first and most difficult subtests. Similar data were obtained by us on the other techniques aimed at assessing the first brain unit state (Akhutina et al., 2015).

As for the impact of hyperactivity, groups H in the first and especially the second grade were very small (12 and 8 people). They showed large fluctuations of success and execution times in the subtests. In the first grade, they were slower than the other groups of children in five of the six subtests; in the second grade, they were the fastest in the RAS-subtests and subtest "Numbers", and the second-fastest in the other subtests. Additionally, H group children in the first grade made more mistakes than the other children in four subtests, but in the second grade they made more errors in only two subtests. In particular (and against expectations), they made few mistakes in the RAS-subtests. According to the literature, these variations of tempo and success in test performance are typical of children with ADHD who display severe symptoms of hyperactivity-impulsivity and executive function weakness. In the opinion of Sonuga-Barke, the deficit in executive functioning in ADHD is context-sensitive and dynamic, and its manifestations largely depend on motivation (Sonuga-Barke et al., 2010). At the same time Sonuga-Barke and a number of other authors have expressed the opinion that variability in test performance by these children is related to brain state regulation deficits (Sergeant, 2005; van der Meere, 2005; Sonuga-Barke et al., 2010), a suggestion which was also confirmed in our study (Agris, Akhutina, & Korneev, 2014; Akhutina et al., 2015).

Conclusion

The present study revealed a complex and varied picture of the combined influence of the first brain unit state and executive functions state on RAN/RAS technique performance. More clearly, it showed that first brain unit weakness influences children with slow cognitive tempo: we obtained data about the impact of slowness in execution times of the first and most difficult subtests. Children with hyperactivity showed large fluctuations in success and execution times of the subtests; according to the literature, that is typical of children with ADHD who have severe symptoms of hyperactivity-impulsivity and weak executive functions. Research on the influence of first brain unit weakness on RAN/RAS technique performance will continue.

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Регуляция активации мозга и выполнение методики RAN / RAS младшими школьниками

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Аннотация. В работе анализируется взаимосвязь состояния функций регуляции активации мозга (функций I — энергетического — блока мозга, по А.Р. Лурия) и показателей выполнения методики RAN / RAS (*Rapid Automatized Naming and Rapid Alternating Stimulus Tests*). В исследовании участвовали три группы испытуемых: дети с хорошей регуляцией активации (n = 101) и две группы детей с плохой регуляцией активации: дети с замедленным когнитивным темпом и быстрой утомляемостью (n = 29) и дети с гиперактивностью — импульсивностью (n = 20). Все дети прошли полное нейропсихологическое исследование по батарее тестов А.Р. Лурия, адаптированной для детей 5–9 лет (Ахутина и др., 2013), и выполнили тесты на быстрое автоматическое называние слов из одной категории (RAN) и называние слов из двух или трех категорий (RAS). Проведенное исследование обнаружило сложную и пеструю картину связей выполнения методики RAN / RAS с состоянием функций энергетического блока и управляющих функций. Более отчетливо влияние слабости I блока мозга проявилось у детей с медленным когнитивным темпом: получены данные о влиянии замедленности на время выполнения первого субтеста «Объекты» и RAS-субтестов. Дети с гиперактивностью обнаружили большие колебания успешности и времени выполнения проб, что, по данным литературы, характерно для детей с СДВГ с выраженными проявлениями гиперактивности-импульсивности и слабости управляющих функций.

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