Title: Verbal fluency in children with ADHD: strategy using and temporal properties

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Running head: **Verbal fluency strategies in children with ADHD**

Abstract

Verbal fluency tasks are commonly used in cognitive and developmental neuropsychology in assessing executive functions, language skills as well as divergent thinking. 22 typically developing children and 22 children with ADHD between the ages of 8 and12 years were examined using verbal fluency tasks, prepotent response inhibition and working memory tests. The clinical group showed impaired inhibitory and spatial working memory processes. We used different qualitative analyses of verbal fluency tasks to explore the lexical and executive strategies (word clustering and switching), and the temporal properties of the responses. Children with ADHD had a leeway in applying relevant lexical or executive strategies related to difficulties in strategy using. The reduced efficiency of children with ADHD in semantic fluency task is based on suboptimal shifting between word clusters, and related to the lack of ability of producing new clusters of items. The group difference appeared at the level of accessing and/or activating common words; however the executive process of searching the lexicon extensively is intact.

Keywords: ADHD; executive functions; verbal fluency

Introduction

Attention Deficit/Hyperactivity Disorder (ADHD) is the most common psychiatric disorder affecting approximately 5% of children in the population (Ramtekkar, Reiersen, Todorov, & Todd, 2010; Scahill et al., 1997). According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR; American Psychiatric Association, 2000), the symptoms – inattentive behavior, hyperactivity, and impulsivity – should be present for at least six months, and must be observed in at least two different settings such as home and school.

Executive functions in ADHD

The large heterogeneity that can be observed in ADHD should be based on multifactor etiology, but the core neuropsychological evidences are related to executive functions (EF, see Sjöwall, Roth, Lindqvist, & Thorell, 2012; Willcutt et al., 2010; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). However, no consensual definition of these top-down processes has been delineated (Castellanos, Sonuga-Barke, Milham, & Tannock, 2006). The first theoretically designed explanation of the atypical executive achievement in ADHD was Barkley's (1997) model of inhibition dysfunction that secondarily disrupts other EF components. Inhibitory control deficits are very often reported in ADHD (e.g. Castellanos, et al., 2006; de Jong et al., 2009; Willcutt, et al., 2005), however the atypical EF is not sufficient to explain all the cognitive characteristics in ADHD (Baron, 2007; Sjöwall, et al., 2012). Executive functions have at least three components (inhibition, shifting, and updating; see Miyake et al., 2000; Wu et al., 2011), but on higher levels, other components are also known to exist, such as planning, self regulation, monitoring, and strategy using (Zelazo & Müller, 2002). The inference to be drawn from meta-analyses is that the executive profiles of ADHD have a large heterogeneity (Sergeant, Geurts, & Oosterlaan, 2002; Willcutt, et al., 2005). These divergent results cannot be explained only by difference between tests or procedures applied, or the nature of executive functions, which means that EF components are unique and diverse at the same time (Miyake, et al., 2000). One of the most frequently used tests to measure inhibition in ADHD is the Stroop task (Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005; Willcutt, et al., 2005). Despite that the sensitivity of the measurement for the prepotent response inhibition impairment in ADHD is debated, the variants of the Stroop are the most known EF task in neuropsychological practice (Lansbergen, Kenemans, & van Engeland, 2007; van Mourik, Oosterlaan, & Sergeant, 2005). Several studies suggest the dysfunction of working memory (WM), however this cognitive symptom is not specific to ADHD, and can be observed in many of other developmental psychiatric syndromes such as autism spectrum disorder, conduct disorder, oppositional defiant disorder, etc. (Arnsten & Rubia, 2012; Martinussen & Tannock, 2006). Children with ADHD, even without comorbid learning disorders have impairments in visual-spatial storage and in verbal and visual-spatial central executive processes; however the verbal maintenance seems to be intact (de Jong, et al., 2009; Martinussen & Tannock, 2006).

Measuring executive functions with verbal fluency tasks

Verbal fluency tasks have been commonly used in neuropsychological assessment to detect executive dysfunctions and lexical access (Matute, Rosselli, Ardila, & Morales, 2004; Sergeant, et al., 2002; Tucha et al., 2005). Solving these tasks requires control of organized search, generation of items within a specific category (semantic or phonemic), and respect to the time limit (which is usually sixty seconds) to produce a self-generated strategy for finding the relevant items, or at least inhibit the irrelevant ones (Matute, et al., 2004). Verbal fluency tasks are widely used to assess divergent thinking as well (Eslinger & Grattan, 1993; Matute, et al., 2004).Within this function the different forms of fluency measurements are related to spontaneous flexibility, where the production of a diversity of elements is needed (Eslinger & Grattan, 1993). Classical scoring of the verbal fluency tasks records the number of correctly generated words and the number of errors which informs us about divergent thinking and executive or language dysfunctions (Lezak, 1995). Most of the studies report phonemic fluency differences in ADHD (Grodzinsky & Diamond, 1992; Loge, Staton, & Beatty, 1990; Sergeant, et al., 2002), but opposite results can be found as well (Fischer, Barkley, Edelbrock, & Smallish, 1990; McGee, Williams, Moffitt, & Anderson, 1989; Reader, Harris, Schuerholz, & Denckla, 1994; Tucha, et al., 2005), where differences were found solely in semantic fluency. These previous findings usually do not explain the reason behind differences of verbal fluency achievement, but it is supposed that phonemic fluency depends on EF more than semantic fluency.

Only one study concerning ADHD focused on the strategic scoring opportunities in verbal fluency tasks (Tucha, et al., 2005), nonetheless the classical (quantitative) analysis shows, as it is, a part of the real achievement. If the fluency scoring protocol measures the number and types of clusters, i.e., a group of similar words, and the switching between those in the oral performance, then it could result in more sensitive indices of language and executive computation (Tucha, et al., 2005). This different approach of verbal fluency focuses on the better specified individual cognitive profiles due to including additional tasks relying on separate skills of strategy using. The qualitative scoring system (adapted to Hungarian language by Mészáros, Kónya, & Kas, (in press) highlights the self-generated strategy-use, which consists of two procedures: clustering and switching. The effectiveness of these processes determines the number of responses in verbal fluency tasks, and could also shed light on the structure of the mental lexicon (e.g. Tucha, et al., 2005). Clustering means recalling two or more related words (Troyer, Moscovitch, & Winocur, 1997). Phonemic clusters are defined as successively generated words beginning with the same phoneme (e.g., *f*alcon, *fl*y, *fl*ea), or with the same first two phonemes in phonemic fluency tasks (e.g., *si*lk, *si*ck, *si*mple), words that are homonyms (e.g., form, farm), rhymes (e.g., beagle, eagle) as well as assonances, and words with the same letters at the first and last position. Semantic clusters are defined as successively generated words belonging to the same subcategory and with explicitly related content (e.g., tiger, lion, cat, panther). Phonemic clusters are generated predominantly during phonemic fluency task; meanwhile semantic clusters are generated mainly during semantic fluency tasks (i.e., task-consistent clusters), but task-discrepant clusters occur, as well. Switching means the transition from one cluster to a neighboring (or overlapping) cluster and/or the transition between independent words. Troyer et al. (1997) indicates that the switching procedure is underpinned by strategic search and mental set shifting, which are subcomponents of the EF. It is important to differentiate switches between clusters from switches between independent items (words). Switching might denote the deficit of clustering, especially when it takes place between two independent words (Abwender, Swan, Bowerman, & Connolly, 2001). “Cluster Switching” (e.g., owl, falcon / giraffe, elephant) and ”Sharp Switching” (switches between non-related words, e.g., antelope / mouse / seal or father/ form/ feast) are assigned in phonemic and in semantic fluency tasks, respectively.

Qualitative analysis of verbal fluency tasks was effective in predicting Alzheimer’s Disease (AD) onset (Raoux et al., 2008). Less switching occurred in the future AD subjects than in the elderly controls during five years before dementia incidence. In various psychiatric populations, like patients with depression, Huntington Disease, Parkinson’s Disease, HIV-associated dementia, deficits in fluency have been related to a reduced number of switches (Fossati, Bastard Guillaume, Ergis, & Allilaire, 2003; Raoux, et al., 2008). Impaired shifting abilities could explain the decline in semantic fluency performance occurring in EF related syndromes (Raoux, et al., 2008). Analysis of switching and clustering showed fewer switches and smaller word clusters on phonemic and verbal fluency tasks in adult ADHD (Tucha, et al., 2005). However qualitative analysis of verbal fluency is often neglected in fluency studies with childhood disorders (Hurks et al., 2010).

Another rarely noted form of analysis of verbal fluency achievement is temporal segmentation. The self-directed timing of the responses can inform about strategic skills. Merely one previous study found that children with ADHD produced fewer words in verbal fluency, but only in the first fifteen seconds (Hurks et al., 2004). According to the lexical organization model, two stores are activated differently in fluency tasks: a long-term store (“topicon”) that contains common words which are easy to access, and a more extensive lexicon that is needed to search after the former is exhausted (Hurks, et al., 2010). The achievement in the first quarter minute of the fluency measurement is related to the automatically activated production from the topicon, while later word generation is based on effortful control. The authors suggest (Hurks, et al., 2004) that children with ADHD may have a developmental delay in automatic processing of abstract verbal information.

To the best of our knowledge, there is only one study with adult patients in the ADHD literature applying qualitative scoring in verbal fluency tasks (Tucha, et al., 2005), and to date we have not had results on children with ADHD. In the current study we examined strategic thinking used by children with ADHD in verbal fluency tasks. We expected that the clinical group would have executive impairments in regard to inhibition, and verbal and spatial working memory. We hypothesized that children with ADHD would have less extensive strategy-using (clustering and switching) than the typically developing group which would appear in the level of access to the topicon.

Method

Participants

22 children with ADHD (19 boys and 3 girls) between ages of 8 and 12 years, from a local child psychiatry hospital were recruited to participate in the current study. Only those children who had been diagnosed with ADHD by a team (a licensed clinical psychologist and a board-certified child psychiatrist) at the hospital according to the DSM-IV-TR criterions (American Psychiatric Association, 2000) were included in the study. The children with ADHD were in the age range of 100 to 152 months (M = 129.18 months, SD = 14.17 months); those strongly manifesting co-morbid disorders (autism spectrum disorder, learning disorder, obsessive-compulsive disorder, specific language impairment, or major depression) were not included in the present study. Comorbid diagnosis included conduct disorder (one case) and Tourette syndrome (two cases). In addition, three children with ADHD were excluded on the basis of low verbal IQ to avoid language constraints in the verbal fluency task; their scores were lower than 5.5 standard points (1.5 SD below mean) on the WISC-IV Vocabulary or Similarities subtests (see also section *2.3 Materials*). The IQ scores of the clinical group in the four subtests were: Vocabulary (M = 10.3, SD = 2.64), Similarities (M = 10.05, SD = 2.56), Digit Span (M = 9, SD = 1.56), and Block Design (M = 9.65, SD = 2.28). Five children with ADHD were excluded by reason of not finishing the neuropsychological assessments. The participants neither had a history of visual impairment, nor neurological and psychiatric disease. According to the policy of the hospital, ADHD subtypes were not identified with regard to their high instability (Valo & Tannock, 2010)[1]. Additionally, a dimensional approach which argues against subtyping was described by Lahey & Willcutt (2010).

The typically developing (TD) children were recruited from several primary schools in Hungary. 22 children (19 boys and 3 girls from the 2nd to the 6th grades) were chosen from a larger pool to match the ADHD group on two characteristics: gender and age – considering the same school grade and a maximum difference of six months in age. The TD children were in the age range of 97 to 150 months (M = 128.68 months, SD = 14.43 months); 36.4% of them was in the third and 22.7% was in the fourth school grade (the same ratio as in the clinical group).

Procedure

Four tasks were administered to investigate working memory and inhibition in one or two sessions (see below) in 13 schools located in the capital and in the countryside as a part of a more comprehensive screening project (Kóbor, Takács, Urbán, & Csépe, 2012). Individual testing of the TD group took place in a quiet room at the schools during school hours, while children with ADHD were examined at the hospital. Children with ADHD had another session for the four WISC-IV subtests. One session was between 30 to 60 minutes. Children with ADHD discontinued medication for 24 hours prior to test administration. Parents completed the Hungarian version of the Strengths and Difficulties Questionnaire (SDQ, Goodman, 1997; Kóbor, Takács, & Urbán, in press), to confirm the presence/absence and the severity of symptoms in day-to-day life.

The study was approved by the local research ethics committee for education and psychology of our university. The schools were informed about the aim of the research in writing and in person as well. Test administration was held under the informed consent of one of the children's parents, and the children gave an oral agreement before beginning the measurement procedure. Participants were allowed to have short breaks between each task if they felt like doing so.

The different tasks were administrated by using a latin square counterbalancing method. As such, the order of tasks was: Syllable Span, Stroop Test, Corsi Blocks and Verbal Fluency. The computerized tasks were written in Presentation 14.4 software, except the Verbal Fluency which was administered manually.

Materials

NEPSY-I Verbal Fluency

We used the Verbal Fluency from the NEPSY-I (Neuropsychological Assessment of Children) neuropsychological test battery (Korkman, Kirk, & Kemp, 1998). In this task participants are given 60 seconds to produce as many different words as possible. In the first and second subtasks, semantic fluency is measured, and the child is asked to recite animals, and then food and drink items. In the third and fourth subtasks, phonemic fluency is measured, and the child has to generate words beginning with phoneme “Sz” (in English version that is S) and F. The simplest scores derived from this task are the total number of correct items (repetitions and items out of category are not allowed) produced in every 15 seconds, but in the analyses we also used more precise quantitative and qualitative indicators; the scoring system of which is described below (see section *Strategy-based coding and scoring system of verbal fluency tasks*).

Stroop Test

A computerized version of the Golden Stroop test (Golden, 1978) was administered for measuring prepotent response inhibition. The outcome variable used in the analyses is the difference score of average reaction times (measured in “color-word” and “color” conditions) as an indicator of interference (see Lansbergen, et al., 2007).

The 3DM

Standardized tests were administered for measuring working memory. Two subtests, the Corsi Blocks and the Syllable Span were used from the comprehensive 3DM-H (Dyslexia Differential Diagnosis Maastricht – Hungarian Version; Blomert & Vaessen, 2009), an originally Dutch computerized test battery for the assessment of developmental dyslexia, which was adapted to Hungarian by Dénes Tóth and Valéria Csépe.

3DM-H Syllable Span

In this non-word working memory task, children are asked to repeat a sequence of nonsense syllables presented via headphones. 13 experimental trials of two- to six-syllable length were presented without feedback. The outcome variable used in the analyses was an adjusted form of correct answers, which takes into account the properly recalled items and the proper sequences separately as well as simultaneously; if an item is in a correct absolute position, the algorithm gives extra points for it, but all of the correct answers, either by recall or sequence were reckoned with.

3DM-H Corsi Blocks

In this task three to nine blocks flashes on the screen following a series of fixed sequences, and the children have to reproduce the sequences. The outcome variable used in the analyses was an adjusted form of correct answers; the algorithm was the same as described above in relation to the Syllable Span task: each correctly recalled item yields a point, but a correct answer in a correct position within the string yields an extra one.

WISC-IV

Four subtests of the Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV, Nagyné Réz, Lányiné Engelmayer, Kuncz, Mészáros, & Mlinkó, 2008; Wechsler, 2003) were admitted only with the ADHD group. We did not measure IQ performance in the TD group by reason of the Hungarian school system which is fundamentally not inclusive for children with atypical intelligence. The subtests used were the Vocabulary, Similarities, Digit Span and

Block Design according to the international protocol of the NeuroDys project (Landerl et al., in press).

Strategy-based coding and scoring system of verbal fluency tasks

The scoring system used in the current study was adapted to Hungarian by Andrea Mészáros, Anikó Kónya and Bence Kas (in press). In the Verbal Fluency task several quantitative indicators were calculated providing a more reliable account on the characteristics of the Hungarian language and grammar (viz., Hungarian is an agglutinative language). The quantitative indicators are the number of correct responses, number of errors (or rule violations, e.g., nonsense words, words from another category, etc.), number of repetitions (e.g., *bread*, tea, apple, *bread*), or perseverations (e.g., tea, *apple, apple,* cheese).
The qualitative indicators used in our study were the number of semantic and phonemic clusters, the size of the clusters (number of words belonging to the cluster minus one as the clusters start with the their second element according to Troyer's (1997) system), and the mean cluster size (size of the clusters divided by the number of clusters) assigned per phonemic and semantic subtasks. In the analyses only the task-consistent clusters were applied, and independent words are not considered as clusters.

Results

Before performing any statistical analyses all the assumptions relevant to the actual test were checked.[2] Using the first tasks as levels of a factor, several One-Way between-subjects ANOVAs were performed on the main outcome variables of tasks (adjusted correct answers of the Syllable Span, difference score of the Stroop Test, adjusted correct answers of the Corsi Blocks and correct items in the Verbal Fluency), however there was no significant effect of task order in any of the analyses, thus the obtained differences in results are not due to the task administration (e.g., the effect of fatigue).

Basic group comparisons

Considering matching appropriateness, TD group and children with ADHD did not differ in mean age ($t(42) = -.12$, $p = .908$) and in gender distribution (equal ratio of boys and girls in both groups); mean difference in age between genders was not significant in regards to the Welch's modified t-test ($t(11.95) = .66$, $p = .524$). Basic differences between groups in the main outcome variables and their descriptive statistics can be found in Table 1. Children with ADHD had higher scores on the SDQ Hyperactivity/inattention scale ($t(32) = -7.9$, $p < .001$) and on the Total difficulties score ($t(32) = -8.01$, $p < .001$).

To account for multiple testing, we used the Bonferroni correction and considered significant only those indices for which $p < 0.05/16 = 0.003$. Nevertheless, the high effect sizes obtained for significant results indicate that the observed differences are valid (see Table 1).

Table 1 Mean scores and standard deviations for the main neuropsychological measures and the SDQ.

Measures	TD (*n* = 22)		ADHD (*n* = 22)			
	M	*SD*	*M*	*SD*	*t*-value	Cohen's *d*
Age in months	128.68	14.43	129.18	14.17	n.s.	-
SDQ Hyperactivity/inattention	2.87	1.88	7.84	1.77	-7.9	-2.79
SDQ Total difficulties	6.4	4.39	21.47	6.14	-8.02	-2.84
Correct responses in phonemic fluency	17.82	8.61	13.86	6.61	n.s.	-
Correct responses in semantic fluency	35.18	10.13	24.59	8.42	3.77*	1.14
Correct responses in Verbal Fluency	53.00	17.32	38.45	12.81	3.17*	.96
Difference score for Stroop RT[a]	653.71	376.12	1240.57	640.91	-3.68*	-1.12
Syllable Span[b]	39.21	9.10	32.89	10.61	n.s.	.64
Corsi Blocks[c]	49.9	16.03	25.50	20.96	4.21*	1.30
Cluster Switching (semantic)	6.23	3.39	2.91	2.20	3.85*	1.16
Cluster Switching (phonemic)[e]	1.00	8.00	1.00	7.00	n.s.	-
Sharp Switching (semantic)	10.05	3.99	10.09	4.94	n.s.	-
Sharp Switching (phonemic)	11.73	5.15	10.45	5.43	n.s.	-
Sum of Errors (Verbal Fluency)[d]	-	-	-	-	n.s.	.44
Sum of Repetitions (Verbal Fluency)[e]	.50	2.00	1.00	4.00	n.s.	- .37
Sum of Perseveration (Verbal Fluency)[d]	-	-	-	-	n.s.	-

There was no difference between children with ADHD and typically developing controls in the phonemic fluency subtasks of Verbal Fluency. However, the semantic subtasks could clearly differentiate (having a very large effect size) between ADHD group and controls with poorer performance for the ADHD group. The same result was obtained in Verbal fluency total score. The clinical group showed fewer cluster switching in the semantic subtasks than the TD group, but not in the phonemic fluency. We did not find a between-group difference in the number of errors, repetitions, and perseverations. Children with ADHD showed strong deficit in the spatial WM task (Corsi Blocks) compared to controls. The group difference in Syllable Span did not reach significance. Evidence of deficit in prepotent response inhibition in ADHD can be recognized in the present study. In the outcome variable of the Stroop Test there was significant difference between groups with large effect size.

Temporal features of Verbal Fluency task

As the first step of examining strategic thinking in the Verbal Fluency test, group differences between temporal units (15-second-long temporal quarters) were analyzed.

A three-way (2*4*2) mixed ANOVA was performed with the clinical status (TD vs. ADHD) as a between-subjects factor, the 15-second-long temporal quarters (with 4 levels) and subtask type (phonemic vs. semantic) as within-subjects factors. The assumption of sphericity was not violated in this analysis, neither were other assumptions (see Footnote 1). This was also true for the further tests in the rest of the paper. In the post hoc tests and in the follow-up analyses of significant interactions, Bonferroni correction was used to control the overall α not to be higher than .05 (for further ANOVAs as well). Concerning results, main effect of group, $F(1, 42) = 10.03$, $p < .01$, $\eta^2 = .19$, main effect of subtask type, $F(1, 42) = 147.03$, $p < .001$, $\eta^2 = .78$, and main effect of temporal quarters, $F(3, 126) = 86.97$, $p < .001$, $\eta^2 = .67$ were all significant. All two-way interactions were significant, namely group * subtask type interaction, $F(1, 42) = 8.21$; $p < .01$, $\eta^2 = .16$, group * temporal quarters, $F(3, 126) = 9.06$; $p < .001$; $\eta^2 = .18$, and subtask type * temporal quarters, $F(3, 126) = 14.52$, $p < .001$, $\eta^2 = .26$. Three-way interaction between group, subtask type, and temporal quarters was not significant, $F(3, 126) = 1.62$, $p = .19$. According to the main effects, we could conclude that the whole sample generated most of the correct responses during the first 15 seconds. Post hoc tests revealed that the main effect of temporal quarters was due to significant differences between the first quarter (0-15 seconds) and all the further time windows ($p < .001$, respectively), and the second quarter (15-30 seconds) and all the others ($p < .001$, respectively). The third (30-45 seconds) and fourth (45-60 seconds) quarters were not different from one another; the number of generated words was similar in the second half of Verbal Fluency task. As we will see later on, semantic subtasks were easier for the whole sample, M(semantic) = 7.47, $SD = 2.66$ vs. M(phonemic) = 3.96, $SD = 1.96$, and children with ADHD generated less items than their typically developing counterparts, M(TD) = 6.63, $SD = 2.17$ vs. M(ADHD) = 4.81, $SD = 1.6$. Concerning other results, the most important and relevant outcome of the present study is the significant group * temporal quarters interaction (see Figure 1). Follow-up analyses showed that this effect was caused by a “lag” describing the performance of children with ADHD. They generated less words in the first quarter (0-15 seconds), $t(42) = 4.36$, $p < .001$; M(TD) = 10.52, $SD = 3.1$; M(ADHD) = 6.75, $SD = 2.62$, but later performance of the two groups declined gradually in a similar manner (mean differences were not significant). To explore the causes underpinning this time-locked deviation, strategic-based patterns of performance were analyzed hereafter.

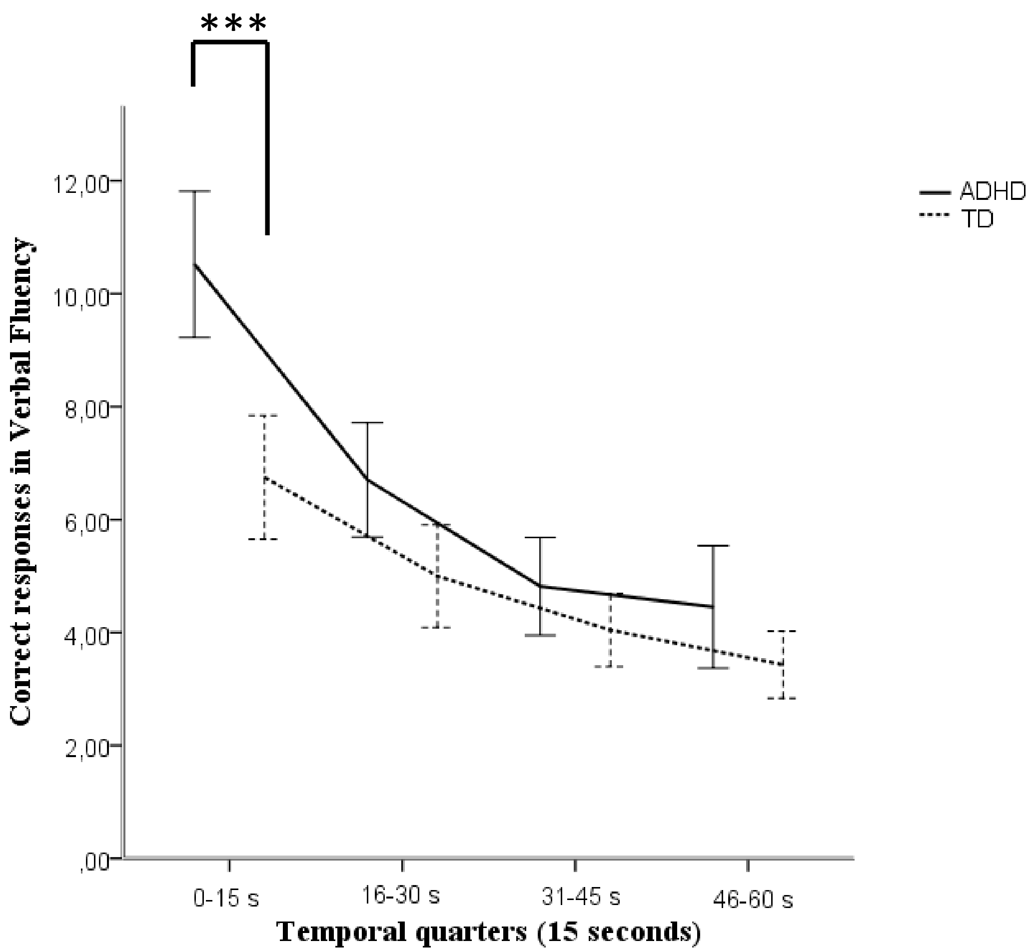

Figure 1 Mean performance on the Verbal Fluency test in four temporal quarters split by group.

Note. ***: $p < 0.01$. Error bars show 95% CI for mean. ADHD: Attention Deficit/Hyperactivity Disorder. TD: typically developing.

Strategic-based differences

Two two-way (2*2) mixed ANOVAs were conducted with clinical status (TD vs. ADHD) as a between-subjects factor and cluster type (phonemic vs. semantic) as a within-subjects factor. First, *phonemic* and *semantic mean cluster sizes* were used as dependent variables. Main effect of group was not significant ($F(1, 42) = .01$; $p = .928$), neither was group * cluster type interaction, $F(1, 42) = .03$, $p = .871$, but main effect of cluster type was found to be significant, $F(1, 42) = 16.85$; $p < .001$, $\eta^2 = .29$, indicating better performance (i.e., larger clusters in average) in the semantic subtasks for the whole sample once again, *M*(semantic) = 2.08, *SD* = 0.51 vs. *M*(phonemic) = 1.43, *SD* = 0.88, irrespective of clinical status.

In the next step *number of phonemic clusters* and the *number of semantic clusters* were used as dependent variables. All possible effects were significant: main effect of group, $F(1, 42) = 8.45$, $p < .01$, $\eta^2 = .17$, main effect of cluster type, $F(1, 42) = 159.41$, $p < .001$, $\eta^2 = .79$, but group * cluster type interaction, $F(1,42) = 14.09$, $p < .001$, $\eta^2 = .25$, overwrote these main effects. These results indicate that children generated greater number of clusters in semantic subtasks than in phonemic subtasks, *M*(semantic) = 8.59, *SD* = 3.58 vs. *M*(phonemic) = 2.71, *SD* = 1.81, and strategy-use is more available for the typically developing group than for children with ADHD, irrespective of subtask type, *M*(TD) = 6.55, *SD* = 2.36 vs. *M*(ADHD) = 4.75, *SD* = 1.69. Considering the significant interaction and the results above on mean cluster sizes, it could be noted that for children with ADHD generating semantic clusters is easier than generating phonemic ones, which is also true for controls, but this strategic surplus is significantly different between the two groups. Follow-up analysis (see Figure 2) indicated that the control group produced more semantic clusters, $t(42) = 3.75$, $p < .001$, than children with ADHD, *M*(TD) = 10.36, *SD* = 3.33 vs. *M*(ADHD) = 6.82, *SD* = 2.92, and this was not true for phonemic ones: *M*(TD) = 2.72.36, *SD* = 2 vs. *M*(ADHD) = 2.68, *SD* = 1.64. Children generated more semantic than phonemic clusters in the TD, $t(21) = 12.62$, $p < .001$, and in the ADHD group, as well, $t(21) = 5.83$, $p < .001$.

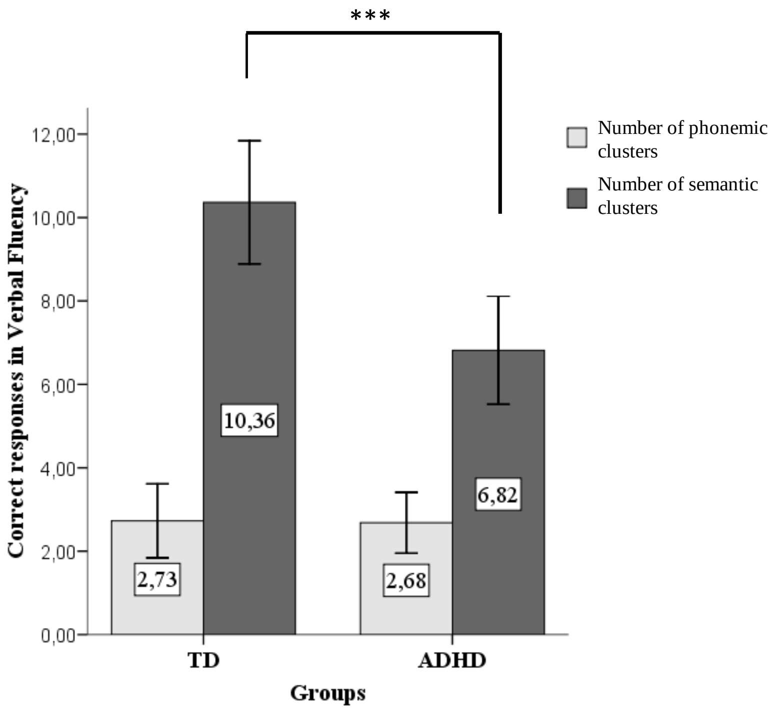

Figure 2 Mean number of the generated phonemic and semantic clusters in the two groups. *Note.* ***: $p < 0.01$. Error bars show 95% CI for mean. ADHD: Attention Deficit/Hyperactivity Disorder. TD: typically developing.

Discussion

As the results indicate, the clinical group differs from the TD group on the measurements of executive functions: prepotent response inhibition in the Stroop task and word generating in the semantic fluency. In line with previous studies, children with ADHD showed strong deficit in the spatial WM task (Corsi Blocks) compared to controls (de Jong, et al., 2009; Martinussen & Tannock, 2006). The obtained results in verbal fluency are in line with some previous studies (Fischer, et al., 1990; McGee, et al., 1989; Reader, et al., 1994; Tucha, et al., 2005). In our approach we argue that the reduced efficiency of children with ADHD in semantic fluency task is based on suboptimal shifting strategy between clusters, and lack of ability of producing word clusters. This disadvantage can be localized in time to the first fifteen seconds. This result is similar to that of previous findings (Hurks, et al., 2004). According to the lexical organization model, the group difference that appeared in the level of topicon indicates that children with ADHD have an impairment in accessing and/or activating common words, however the executive process of searching the lexicon extensively is intact (Hurks, et al., 2010). In line with previous findings (de Jong, et al., 2009; Sjöwall, et al., 2012), the clinical group differs in various executive functions measures (inhibition and working memory), however spontaneous flexibility seems to be intact in ADHD (Eslinger & Grattan, 1993).

Clustering is related to temporal lobe functioning. It is specifically impaired among patients with temporal lobectomy for intractable epilepsy; however it is unaffected by focal frontal lesions. In contrast, switching is related to frontal functioning, as indicated by impaired performance among patients with left dorsolateral and superior frontal lobe lesions, and it is decreased in situations where divided attention is required (Troyer, 2000; Troyer, Moscovitch, & Winocur, 1997). Comparative functional magnetic resonance imaging studies proved that inferior prefrontal underactivation in executive tasks is specific to ADHD (Arnsten & Rubia, 2012). Based on longitudinal results, impairment in other regions, including temporal lobe, could be due to a delayed cortical maturation (Shaw et al., 2007). Language development may be influenced most by the early expression of impulsive and inattentive symptoms (Hurks et al., 2004). Impairments in automatized strategy using and lexical access could be an important manifestation of delayed cognitive development in ADHD.Language dysfunctions are not core deficits in ADHD (Engelhardt, Ferreira, & Nigg, 2011; Willcutt, et al., 2005), however one third of the symptoms in the hyperactive-impulsive domain are specific to language using (i.e., talking excessively, blurting out answers before questions are completed, and interrupting or intruding on conversation). In simple language tasks like lexical decision paradigm or rapid naming, children with ADHD show lower achievement than typically developing children; though their scores are still higher than that of children with reading disorder (de Jong, et al., 2009; van de Voorde, 2009). Barkley (1997) suggests the role of internalized language on behavioral control, which is associated with disinhibition. ADHD children often have difficulties with waiting for turns in conversations and with the maintenance of the topic. Their narrative speech is also characterized by disorganization and poor cohesion. Nonspecific language impairments in children with ADHD be indicated by delayed onset of words, poor performance on standardized tests with complex verbal requirements, and pragmatic problems in conversations (Engelhardt, et al., 2011). It seems that regulation mechanisms also work on a lower level in executive and motor response control or even in language use (Engelhardt, Ferreira, & Nigg, 2009). Grammatical encoding (converting conceptual elements of the message into units of the mental lexicon) is a computation partly related to executive functions in the sense that words are activated in a certain order and used in fluent speech (Engelhardt, et al., 2009). According to our results the main difference between children with ADHD and TD group was found in the difficulties of strategy using, showing that children with ADHD had a leeway in applying relevant lexical or executive strategies.

Traditionally the outcome variable of the verbal fluency task is the total number of correct words generated in 60 seconds. This scoring method does not provide insight to the diversity of cognitive processes underlying the performance, such as inhibition or shifting, various strategies, and lexical access (Hurks, 2012). The demonstrated qualitative scoring technique could lead us to objective evidence of ADHD through a neuropsychological assessment which is not biased by expectations and beliefs of respondents.

The usefulness of the qualitative fluency scores in assessment and diagnosis was demonstrated with sample patient profiles of adults (Troyer, 2000). As ours is an experimental study, we cannot give clear instructions how to evaluate the given results in case of children with ADHD in the clinical practice. Further clinical research with specific focus on individual profiles and the procedure of assessment is needed.

Additionally, our results shed light on the importance of timing in neuropsychological testing. As it was suggested before, children with ADHD could perform on a similar level of typically developing counterparts, if they have enough time for solving the verbal fluency task (Hurks, et al., 2004). It should be noted that children with ADHD need more time to access their mental lexicon.

In a recent study (Hurks, 2012), children from grade 3 to 6, were explicitly trained to use clustering strategies in a 6-7 minutes practice session. The fluency instruction was effective in enhancing children’s task performance in grade 6. Children from the oldest group generated more words over the last 45 seconds of the task, and per cluster, as well. Cluster size was increased in younger children; however, following the strategy resulted in lower number of total words. Knowledge on strategy using as an important aspect of executive functions, thinking, and problem solving should be encompassed in general education and curriculum (Hurks, 2012). Teaching the strategies should include teacher modeling, rapid feedbacks, extensive practice, and examples of knowledge generalization. In higher grades, explicit instruction could lead to better performance. For further direction, researching the effectiveness of this training in ADHD could be fruitful.

In our study IQ was used to exclude children with ADHD who had very low verbal skills, but it was not assessed in the typically developing group, consequently the children cannot be matched on intelligence level. However, IQ is similar to EF in many ways, thus this matching aspect could lead on artificial results (van de Voorde, 2009). It is important to explore neuropsychological differences that are independent of overall cognitive functioning, nonetheless lower IQ appears to be an inherent characteristic of ADHD (de Jong, et al., 2009;

Frazier, Youngstrom, Glutting, & Watkins, 2007). As another limitation, we would note that the wide age range could affect some of the obtained effects, because performance on the administered EF tasks develops by age. We would admit that sample size was relatively small; however the obtained large effect sizes indicate robust effects.

In conclusion, children with ADHD showed impairments in prepotent response inhibition, spatial WM, and semantic fluency. According to the combined analysis of clustering and switching, and temporal processes, reduced fluency in ADHD was based on suboptimal strategy using, and on lower level of access the topicon. This study proposes that in clinical diagnostics the complex, language-based neuropsychological tasks are important to detect cognitive atypicalities beyond the executive disfunctions in ADHD.

Footnotes

1: However this protocol is extensively used in Hungary, as a research information we should note that all of our participants met the criteria of ADHD-C in regard to their symptoms.

2: Checking the measurement level of the dependent variables and testing if they are normally distributed within groups; testing the homogeneity of variances in the two groups (and the sphericity of dependent variables with more than two levels); testing if the observed covariance matrices of the dependent variables are equal across groups, etc.

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Figure legends

Figure 1 Mean performance on the Verbal Fluency test in four temporal quarters split by group.

Note. ***: p < 0.01. Error bars show 95% CI for mean. ADHD: Attention Deficit/Hyperactivity Disorder. TD: typically developing.

Figure 2 Mean number of the generated phonemic and semantic clusters in the two groups.

Note. ***: p < 0.01. Error bars show 95% CI for mean. ADHD: Attention Deficit/Hyperactivity Disorder. TD: typically developing.