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Verbal fluency over time as a measure of automatic and controlled processing in children with ADHD

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Abstract

The performance of ADHD children on semantic category fluency (SCF) versus initial letter fluency (ILF) tasks was examined. For each participant, word production was recorded for each 15-s time slice on each task. Performance on both fluency tasks was compared to test the hypothesis that children with ADHD are characterized by a performance deficit on the ILF task because performance on this task is less automated than performance on the SCF. Children classified with ADHD ($N = 20$) were compared to children with other psychopathology ($N = 118$) and healthy controls ($N = 130$). Results indicated that the groups could not be differentiated by the total number of words produced in 60 s in either fluency task. As hypothesized, a significant interaction of group by productivity over time by type of fluency task was found: ADHD children had more problems finding words in the first 15 s of the IFL than did children in the other two groups, and as compared with their performance on the SCF. Results were taken to indicate that children with ADHD symptoms show a delay in the development of automating skills for processing abstract verbal information.

Keywords: ADHD; Automatic-controlled processing; Verbal fluency; Children

1. Introduction

Impulsive behavior, inattention, and overactivity in young children can be a risk factor for abnormal psychological development later (Sagvolden & Sergeant, 1998; Taylor, Chadwick, Heptinstall, & Danckaerts, 1996; Weiss & Trokenberg Hechtman, 1993). If these behaviors cause significant impairments in social or academic functioning and are inconsistent with the developmental level of the child, they may be indicative of the clinical diagnosis 'Attention-Deficit/Hyperactivity Disorder' (ADHD; American Psychiatric Association, 1994), a syndrome that affects approximately 1–5% of children (Barkley, 1998). Kroes et al. (2001) have estimated the prevalence of ADHD within a population of Dutch school-aged children at 3.8%.

Over the years, several causes of ADHD have been proposed. For instance, neurological evidence is pointing towards an involvement of the frontal-striatal circuits in ADHD (Barkley, 1998; Oades, 1998; Sagvolden & Sergeant, 1998). Furthermore, from a neuropsychological perspective, ADHD is associated with deficits in well-defined cognitive domains, including sustained attention and executive functioning (Barkley, 1998; Pennington & Ozonoff, 1996). According to Lezak (1995), the term 'executive functioning' encompasses those capacities that enable a person to engage successfully in independent, purposive, self-serving behavior. Examples

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of executive functioning are non-verbal working memory, internalization of speech, self-monitoring, and self-regulation (Barkley, 1998; Perugini, Harvey, Lovejoy, Sandstrom, & Webb, 2000). Another cognitive function highly correlated with executive functioning and attention capacity, which is often used to evaluate cognitive functioning in ADHD, both clinically and experimentally, is the fluency of speech (Barkley, 1998; Monsch et al., 1994; Rosser & Hodges, 1994). This function is usually defined as the number of words produced, usually within a restricted category and over a limited period of time (usually 60 s) (Lezak, 1995). Two major categories of verbal fluency tasks can be distinguished, namely (A) *semantic category fluency* (SCF; that is, recitation of examples of a given category) and (B) *initial letter fluency* (ILF; that is, generating words beginning with a given initial letter).

Earlier studies of ADHD and verbal fluency provided inconclusive results. A number of studies found significant differences between children with ADHD and controls on either the SCF or the ILF, in that children with ADHD performed significantly worse (Grodzinsky & Barkley, 1999; Grodzinsky & Diamond, 1992; Klorman et al., 1999; Koziol & Stout, 1992; Loge, Station, & Beatty, 1990; Pineda, Ardila, & Rosselli, 1999; Schuerholz, Singer, & Denckla, 1998). In contrast, also a large number of studies found no differences between these groups (Barkley, Grodzinsky, & DuPaul, 1992; Fischer, Barkley, Edelbrock, & Smallish, 1990; Grodzinsky & Diamond, 1992; Kusche, Cook, & Greenberg, 1993; Loge et al., 1990; Pineda et al., 1999; Reader, Harris, Schuerholz, & Denckla, 1994; Weyandt & Willis, 1994), with the observation that the ILF tended to discriminate somewhat better between ADHD and controls than the SCF (Sergeant, Geurts, & Oosterlaan, 2002). However, these studies included only the total number of words produced over a set period of 60–90 s as the main outcome variable, whereas recent experiments have shown that, in healthy adults, the pattern of word production over time is relevant (Troyer, 2000). For example, experiments have shown in healthy adults and children that the effectiveness of word production changes from approximately the first 15–20 s to the last 40–45 s of a 1-min task. In the first period, a ready pool of frequently used words appears to be available and is automatically activated for production. As time passes, the pool becomes exhausted and the search for new words becomes both more effortful and less productive (Crowe, 1998; Hurks et al., in press). By measuring performance over time, the fluency task can be used to measure the effectiveness of both automatic and controlled processing, in which automatic processing is believed to be generally fast and relatively unconscious and controlled processing slow, effortful, and attention-demanding (Fodor, 1983; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977).

Both automatic and controlled information processing have been investigated in studies on the cognitive performance of children with ADHD, but results are inconsistent. Several authors have shown that children with ADHD perform less well than controls in situations demanding automatic and/or more controlled processing strategies (Ackerman, Anhalt, Holcomb, & Dykman, 1986; Borcherding et al., 1988; Hazell et al., 1999), whereas other authors have not (Van der Meere & Sergeant, 1988). Comparison of children with ADHD and controls on both types of fluency, evaluated by their performance over time, may help clarify these conflicting results. Given the deficits in executive functioning in ADHD, we hypothesize that children with ADHD perform significantly worse on both types of information processing (automatic vs. controlled) than do healthy control subjects.

In the present study, we evaluated verbal information processing in ADHD, using an extensive, two-fold controlled design. Children with ADHD were compared to healthy children and to a group of children with at least one DSM-based disorder other than ADHD. The second control group was included in view of recent evidence that children with ADHD are at risk of developing other psychiatric disorders and learning disabilities (Barkley, 1998). Thus, we also compared the ADHD group with psychiatric controls, to determine the specificity of possible ADHD-related findings. Finally, because the behavioral expression of ADHD changes over time, and at least some symptoms are present before age 7 years (American Psychiatric Association, 1994), and because the period between the ages 5 and 7 years is believed to be critical for later cognitive (and more specifically language) development (Bernstein, 1989; Riva, Nichelli, & Devoti, 2000), language development may be influenced most by the early expression of ADHD (Levy, Hay, McLaughlin, Wood, & Waldman, 1996). For this reason, we decided to relate child psychiatric data gathered when the child was approximately 6–7 years to later cognitive functioning at an age when the child had been to school for 2–3 years.

In sum, we investigated the performance of children with ADHD in a controlled design on two types of the fluency task and as a function of time.

2. Methods

2.1. Subjects and procedure

The present study is based on data collected within a research program entitled 'Study of Attention Disorders Maastricht (SAM)' and is embedded in an extensive, longitudinal design. The SAM study consists of three separate phases (for an extensive description of the study see Kalff et al., 2001; Kroes et al., 2001).

Stage 1 (months 1–9): selection of subjects. During this phase, all caregivers of children frequenting the second grade of normal kindergarten were asked to give permission for participation in the SAM study ($n = \pm 2300$). In the Netherlands, the second grade precedes the first class of elementary school in which children learn to read and write. Response rate was 57.5% ($n = 1317$). The children were examined as part of the routine health examination carried out by the school doctors. By law, these physicians are allowed to use medical information anonymously for epidemiological purposes. In this way, it was possible to compare two random samples of 200 non-responders with 200 responders with regard to child characteristics (sex, age), family variables (parental occupation, nationality, and family structure), and environmental variables (living area), collected from the medical status of the Youth Health Care. This comparison was necessary because of the relative large percentage of non-responders; however, no significant differences between the groups were found (for a full description, see Kroes et al., 2001). Next, based on the Dutch version of the Child Behavior Checklist (CBCL; Achenbach & Edelbrock, 1983; Verhulst, Koot, & Van der Ende, 1996), three groups were selected from the responders group for the second stage. Group E (externalizing group; $n = 173$, that is, approximately 7.5% of the total sample) consisted of children who scored high either on the CBCL externalizing broad-bent scale (>90th percentile) or on the CBCL Attention problems subscale (>95th percentile). According to Chen, Faraone, Biederman, and Tsuang (1994), this selected group contains children with a putative risk for the development of ADHD. Next, group I (internalizing group; $n = 59$, that is, approximately 2.6% of the total sample) contained children scoring within a clinical range on the CBCL Internalizing scale (>90th percentile), but did not fulfill the criteria for group E membership. Finally, a matched control group ($n = 220$, that is, approximately 9.6% of the total sample) was formed consisting of children with low CBCL total problem scores (<90th percentile) and who were matched to groups E and I in terms of age (±2 months), sex and school (urban vs. rural).

Stage 2 (*months 15–25*): caregivers of 403 children of the originally selected group agreed to a semi-structured, psychiatric interview, using the Amsterdam Diagnostic Interview for Children and Adolescents (ADIKA). This instrument assesses the presence of several DSM classifications for childhood psychopathology, including ADHD, using a systematic, horizontal approach. Based on these ADIKA results, three independent groups were formed: (a) children, who met during phase 2 all DSM-IV criteria for ADHD (*ADHD group*), (b) children, who met in stage 2 the DSM-criteria for psychopathology (other than ADHD; *psychiatric control group*), and (c) controls (*normal controls*). Children with both ADHD and any other psychopathology were submitted to group a.

Furthermore, *in stage 3* (*months 39–49*), all selected children were again asked to participate in the SAM study. In total, 284 of the 403 children for whom we had ADIKA results in phase 2 agreed to participate in the follow-up (70.5%). Because of the relative large dropout of participants in stage 3, responders and non-responders of stage 3 were tested for group differences in terms of sex, parental occupation, and ADIKA results (stage 2). Cramér's V testing revealed no significant differences between responders and non-responders on these variables (sex: value = .002, $p = .965$; parental occupation: value = .083, $p = .258$; ADIKA results: value = .109, $p = .091$). Next, all children were tested neuropsychologically by means of an extensive test protocol including assessment tools such as the Verbal Fluency Test, Vocabulary scores, and the Dutch Klepel Reading Test, which is a test for reading nonwords. A neuropsychologist or one of three well-trained assistants administered the test battery. Testing took place in a room at the child's school. The examiner was blind to group membership of the children.

Next, of the 284 cases included, fifteen children had to be excluded, because of: (a) known use of Methylphenidate or Pipamperon (ADHD group $n = 5$; psychiatric control group $n = 4$; and control group $n = 2$) or (b) missing data in relation to LOA-codes ($n = 4$) or Klepel reading scores ($n = 1$). After this deletion of cases, data from 268 children were still available for the analyses: 20 children in the ADHD group, 118 children in the psychiatric control group, and 130 normal controls. Variables influential on research outcome were summed in Table 1, including age (as measured at *stage 3*), sex, the level of occupational achievement of the caregiver (LOA), and an estimate of verbal abilities and reading skills.

Additionally, in Table 2, the distribution of psychopathology other than ADHD was provided for each group (ADHD, psychiatric controls, and normal controls). No children were excluded from the ADHD-group and the psychiatric control group because of the (co-) occurrence of specified psychopathology.

2.2. Measurements

The Amsterdam Diagnostic Interview for Children and Adolescents (ADIKA; Kortenbout van der Sluijs, Levita, Manen, & Defares (1997): this is the Dutch translation of the Diagnostic Interview for Children and Adolescent (DICA; Ezpeleta et al., 1997; Granero Pérez, Ezpeleta Ascaso, Doménech Massons, & De la Osa Chaparro, 1998; Kortenbout van der Sluijs et al., 1997). The ADIKA is a semi-structured psychiatric interview that yields scores for several child psychiatric syndromes according to DSM-III-R guidelines and was adapted by

Table 1
Group characteristics and diagnostic data of the sample ($n = 268$)

	ADHD ($n = 20$)		Psychiatric ($n = 118$)		Controls ($n = 130$)		Contrasts
Sex (boys:girls):	14:6		71:47		65:65		n.s.
	Mean	*SD*	Mean	*SD*	Mean	*SD*	
Age	9.2	0.3	9.2	0.4	9.1	0.4	n.s.
Vocabulary-score:	9.0	2.6	8.9	2.5	8.8	2.9	n.s.
Klepel-score:	8.8	3.6	10.7	2.9	10.7	2.6	$p = .019$
LOA-score:	3.0	1.7	3.7	2.0	4.5	1.9	$p < .001$

Associations between ordinal and/or interval variables (group membership vs. age, Block design scores, and LOA) were calculated by use of ANOVA. In contrast, χ^2-tests were used to measure the associations between nominal (sex) and ordinal variables (groups).

Table 2
Distribution of psychopathology, other than ADHD, found in the three groups (ADHD, psychiatric controls, and normal controls)

Type of comorbidity (number of cases)	ADHD	Psychiatric	Controls
No psychopathology	—	—	130
No psychopathology other than ADHD	1	—	—
Anxiety disorders	2	42	—
Mood disorders	—	5	—
Mood disorders and anxiety disorders	1	7	—
Conduct disorders	4	17	—
Conduct disorders and anxiety disorders	3	12	—
Conduct disorders, mood disorders, and anxiety disorders	—	1	—
Conduct disorders, mood disorders, and anxiety disorders	4	3	—
Disorders of elimination	2	19	—
Disorders of elimination and anxiety disorders	—	3	—
Disorders of elimination and mood disorders	—	2	—
Disorders of elimination, mood disorders, and anxiety disorders	—	1	—
Disorders of elimination and conduct disorders	1	5	—
Disorders of elimination, conduct disorders, and anxiety disorders	1	—	—
Disorders of elimination, conduct disorders, and mood disorders	—	1	—
Disorders of elimination, conduct disorders, mood disorders, and anxiety disorders	1	—	—
Number of cases	20	118	130

using the criteria of DSM-IV for diagnosing ADHD (American Psychiatric Association, 1987; American Psychiatric Association, 1994). In line with these criteria, children were classified as ADHD if they showed a persistent pattern of inattention and/or hyperactivity–impulsivity that was more frequent and severe than that typically observed in individuals of comparable development (American Psychiatric Association, 1994). Children were included in the 'psychiatric control group' if they fulfilled the criteria for at least one child psychiatric syndrome (with the exception of ADHD).[1] Although the Dutch version of the DICA-III-R interview has not been separately validated, DICA and DICA-III-R have been demonstrated to have high test–retest reliability and moderate correlations with clinician based diagnoses (Ezpeleta et al., 1997; Welner, Reich, Herjanic, Jung, & Amado, 1987).

Verbal fluency test (Korkman, Kirk, & Kemp, 1998): this test is a subtest of the NEPSY-battery and is believed to be a measure of retrieval from semantic memory. It includes two independent types of verbal fluency, namely, semantic category fluency (SCF) and initial letter fluency (ILF). SCF involves recitation of examples of a given category, whereas ILF involves the generation of words beginning with a given initial letter. The verbal fluency test consisted of: (A) two trials of a SCF type task (e.g., to name as: (1) many animals and (2) things you can eat or drink) and (B) two trials of an ILF type task (e.g., including the letters 'M' and 'S' [subtasks 3 and 4]). According to the Van Loon list presenting imageability ratings of Dutch words (Van Loon, 1985), words that begin with the letters M or S are common in the Dutch language (respectively 4.3 and 11.7% of the Dutch words begin with these letters). Consistent with standard instructions, participants were

[1] Such as mood disorders (e.g., major depression, dysthemia, and bipolar syndrome), anxiety disorders (e.g., separation anxiety, phobia, overanxious disorder, and avoidant disorder), conduct disorders (e.g., oppositional disorder), disorders of elimination (e.g., functional encopresis and functional enuresis), obsessive compulsive disorder, post traumatic stress disorder, and pervasive developmental disorders.

asked each time to generate over 60 s as many words as possible of the above-mentioned categories, excluding the names of humans and cities. For each subtask, total number of correct responses, incorrect responses (e.g., words not beginning with the appropriate letter or not an exemplar of the category), and perservations (e.g., repetitions of correct words, morphological variants [for instance when a child says car and cars]) were recorded over (A) 1–15 s, (B) 16–30 s, (C) 31–45 s, and (D) 46–60 s. To reduce error variances, data were averaged over the time samples A, B, C, and D for each type of fluency.

Vocabulary test: this subtest of the Wechsler Intelligence Scales for Children—Dutch Version (WISC—Dutch Version by De Bruyn et al., 1986) was used to provide an estimate of general ability (Lezak, 1995). The examiner asked the child to explain the meaning of certain words. The complexity of words increased with each item. Range of standard scores is 1–19 (mean score = 10, $SD = 3$). Reliability and validity are believed to be average to good (De Bruyn et al., 1986).

Klepel reading test (Van den Bos, Lutje Spelberg, Scheepstra, & De Vries, 1994): this test provides a standardized measure of non-word decoding. For 2 min, the child had to read as many words as possible from a list of non-words. With each item the complexity of words increased. Standard scores range from 1 to 19 (mean score = 10, $SD = 3$). This task was included as a covariate because of the assumed relation between the development of the ability to organize and retrieve words phonemically and reading skills (Riva et al., 2000).

Level Occupational Achievement of the caregiver (LOA): this variable was based on the full description of the parental occupation and was originally scored on a 7-point-scale, ranging from unskilled to scientific skilled labor (Directoraat-Generaal voor de Arbeidsvoorziening, 1989). Housewives and househusbands were coded as a separate category. When the LOA differed between mother and father, the highest score was chosen. Finally, if data was missing for one caregiver, the score available was chosen for the analyses.

3. Results

3.1. Word production over time and type of fluency

Group performance on the fluency task, in terms of word production over time for both SCF and ILF, was analyzed in a 2×4 (Type of fluency task × Time interval) General Linear Model (GLM) repeated measures design. The grouping variable consisted of three independent categories, namely: (1) children with ADHD, (2) psychiatric controls, and (3) normal controls. The child's sex, Klepel reading scores, vocabulary scores, and the LOA of the caregiver were included as covariates for they accounted for at least some variance in the verbal fluency scores. Preliminary experiments showed that the age of the child did not correlate with test performance over all groups, and thus age was not included as a covariate in the analyses. Corrections were made for unequal sample sizes within a non-experimental research design. The critical value for rejecting the null hypotheses was chosen at $p < .05$.

Significant main effects were found for type of fluency task (Type: $F(1, 261) = 1138.80$, $p < .001$; partial eta squared = .814), word production as a function of time (Time: $F(3, 259) = 982.67$, $p < .001$; partial eta squared = .919), and the interaction between these factors (Type × Time: $F(3, 259) = 159.20$, $p < .001$; partial eta squared = .648). Overall, children produced significantly more words in the SCF (unadjusted for covariates: $\text{mean}_{\text{SCF}} = 14.4$ [$SD = 3.6$]) than on the ILF ($\text{mean}_{\text{ILF}} = 7.1$ [$SD = 2.8$]). Secondly, word productivity decreased significantly with each succeeding quartile of 60 s, averaged over types of fluency (unadjusted for covariates: $\text{mean}_{1\text{–}15\,\text{s}} = 4.6$ [$SD = 1.0$]; $\text{mean}_{16\text{–}30\,\text{s}} = 2.6$ [0.9]; $\text{mean}_{31\text{–}45\,\text{s}} = 1.9$ [0.8]; $\text{mean}_{46\text{–}60\,\text{s}} = 1.6$ [0.8]). Thirdly, the significant interaction of Type by Time indicated that the decrease in word production was not parallel in the SCF and ILF, although in both tests the number of words produced decreased with time. Fourthly, with regard to the covariates, significant interactions were found for Sex by Type of test ($F(1, 261) = 4.23$, $p = .041$; partial eta squared = .016), Sex by Time samples ($F(3, 259) = 2.65$, $p = .049$; partial eta squared = .030), and Klepel reading test scores by Time samples ($F(3, 259) = 4.38$, $p = .005$; partial eta squared = .048). In addition, significant between-subjects effects were found for LOA ($F(1, 261) = 25.43$, $p < .001$; partial eta squared = .089), Klepel reading scores ($F(1, 261) = 22.35$, $p < .001$; partial eta squared = .079), and Vocabulary scores ($F(1, 261) = 13.12$, $p < .001$; partial eta squared = .048).

Fifth, using Pillai's trace criterion, the factor 'group' (ADHD, psychiatric controls, and controls) did not differ in the total number of words produced over 60 s, irrespective of the test used (Group × Type: $F(2, 261) = 2.27$, $p = .106$; partial eta squared = .017). Furthermore, no interaction was found between group membership and number of words produced in different time intervals (Group × Time: $F(6, 520) = 1.81$, $p = .094$; partial eta squared = .021). In contrast, there was an interaction of Group by Time by Type of test ($F(6, 520) = 2.09$, $p = .052$; partial eta squared = .024). This finding indicated that performance of groups was not linear across different time intervals and types of fluency.

Additional GLM multivariate testing revealed only a significant interaction between groups and performance (words produced) as a function of time on the ILF task (ILF: Group × Time $F(6, 520) = 3.53$, $p = .002$; partial eta squared = .039). This interaction could primarily be

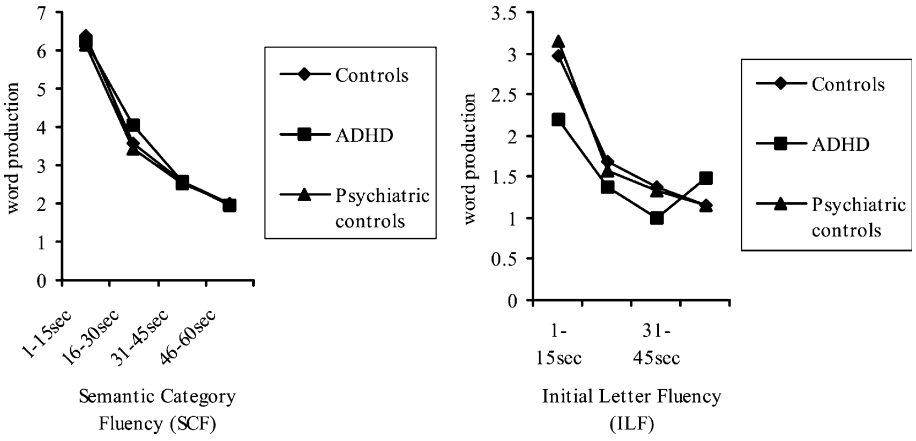

Fig. 1. Productivity-scores over different time samples, groups, and type fluency tests (semantic vs. initial letter fluency). *Note*. Evaluated at covariates appeared in the model: LOA, Klepel, Vocabulary test, and sex.

explained by the large group differences in test performance over the first 15 s of the ILF. Children diagnosed with ADHD in phase 2 produced significantly fewer words during the first 15 s of the ILF than did children in the control groups ($F(2,261) = 5.62$, $p = .004$, partial eta squared = .041; after Bonferoni correction, A vs. C: $p = .022$; A vs. B: $p = .003$; B vs. C: $p = .805$). Over the succeeding time intervals, all groups performed at a comparable level (16–30 s: $F(2,261) = 1.03$, $p = .357$, partial eta squared = .008; 31–45 s: $F(2,261) = 1.77$, $p = .172$, partial eta squared = .013; 46–60 s: $F(2,261) = 1.43$, $p = .241$, partial eta squared = .011). Fig. 1 presents group performance for each type of fluency (ILF and SCF). For all analyses, Levene's Test of Equality of Error Variances was not significant.

To examine additionally whether these last-mentioned results are primarily attributable to concurrent phonological impairments, the relation between fluency, Klepel reading test scores, and group membership (ADHD, psychiatric controls, and healthy controls) was further examined. For this purpose, zero-order correlations between the variables were calculated. It was found that the correlations between the variable 'group' and the dependent variables (type of fluency × time sample) *before* correcting for Klepel scores were highly comparable with the correlations the variable 'group' and the dependent variables (type of fluency × time sample) *after* correction for Klepel scores. Based on these findings, it can be assumed that the results found in this study can not be solely described to phonological or reading impairments.

3.2. Error analyses

Errors were coded as one of five types: (1) intrusions (i.e., noncategorical or non-initial letter errors, and names of people or cities), (2) perseverations, (3) non-words, (4) miscues (i.e., words starting with a non-initial letter that is phonologically comparable to the initial-letter or words containing the initial letter but not starting with it). Error scores for each individual were transformed to display a bimodal distribution (i.e., individuals either made errors of a certain type or they did not). For each type of errors, the raw data for errors were collapsed over all the time intervals and across the same type of fluency. The data within each of these error conditions were compared for group performance by use of the Pearson χ^2 test. When there were less than five cases in a cell, the Fisher's Exact Test was chosen. Again, the grouping variable consisted of three independent categories, namely: (1) children with ADHD, (2) psychiatric controls, and (3) normal controls.

On the ILF, a trend was found for children with ADHD to make more errors of the miscues-type compared to the control children ($\chi^2 = 4.84$, $p = .089$; Table 3). No group differences were found in terms of intrusions ($\chi^2 = 3.11$, $p = .191$), perseverations ($\chi^2 = 0.20$, $p = .914$), and non-words ($\chi^2 = 0.27$, $p = .913$). On the SCF, however, children with ADHD tended to make more intrusions compared to the controls (intrusions: $\chi^2 = 5.63$, $p = .043$; perseverations: $\chi^2 = 0.06$, $p = .968$; non-words: $\chi^2 = 2.26$, $p = .317$). Caution is necessary when interpreting these last results, because of the overall low number of errors.

4. Discussion

In a clinical setting, verbal fluency tests are used to evaluate the cognitive performance of children with ADHD. Successful performance on these tasks relies strongly on attention capacity and executive functioning (Monsch et al., 1994; Rosser & Hodges, 1994), which are aspects of cognition frequently mentioned in relation to ADHD (Barkley, 1998). Unfortunately, evidence is still inconclusive with regard to the influence of ADHD on the performance on the verbal fluency tasks (e.g., Felton, Wood, Brown, Campbell, & Harter, 1987; Loge

Table 3
Error analyses

Type of error	SCF						ILF					
	ADHD		Psychiatric		Controls		ADHD		Psychiatric		Controls	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Intrusions												
0 intrusion	18	90	116	98	129	99	18	90	108	92	125	96
1 intrusion	2	10	2	2	1	1	2	10	10	8	5	4
Perseverations												
0 perseveration	14	70	85	72	92	71	16	80	97	82	105	81
1 perseveration	6	30	33	28	38	29	4	20	21	18	25	19
Non-words												
0 non-word	20	100	117	99	125	96	18	90	103	87	116	89
1 non-word	0	0	1	1	5	4	2	10	15	13	14	11
Miscues												
0 miscue	20	100	118	100	130	100	12	60	96	81	104	80
1 miscue	0	0	0	0	0	0	8	40	22	19	26	20

et al., 1990). Many studies used the total number of correct words generated over a set period of 60–90 s as the main outcome variable, whereas, in theory, the pattern of word production over time may provide additional information about the cognitive processes underlying fluency performance (Troyer, 2000).

In our study, the number of correct words produced on both types of verbal fluency (semantic category fluency [SCF] and initial letter fluency [ILF]) decreased significantly with time (defined in quartiles of 15 s) in all groups of children. This is consistent with findings from previous studies of healthy adult participants (Crowe, 1998; Monsch et al., 1994; Rosser & Hodges, 1994). This decrease can be explained in terms of the model of lexical organization (Crowe, 1996; Smith & Claxton, 1972), which states that there are two types of stores, namely: (1) a long-term store ('topicon') which is readily accessible and contains common words, and (2) a more extensive lexicon which is searched after the 'topicon' is exhausted. It can thus be hypothesized that, during the first time period (1–15 s) of either type of fluency task, a ready pool of frequently used words is available and automatically activated for production. As time passes the pool becomes exhausted and production becomes both more effortful and less productive (Crowe, 1998). Therefore to examine the link between test performance and ADHD, it may be relevant to include variables, such as automatic and controlled processes, as a function of time in addition to the overall performance on a fluency task.

In this context, children with ADHD, psychiatric controls and controls were found in the study presented in this article to produce over 60 s a similar total number of words on both verbal fluency tasks. Thus, the normal way of scoring performance on the verbal fluency task could not discriminate between ADHD children on the one hand and psychiatric and healthy controls on the other. In contrast, there was a significant interaction of groups by word production over time and as a function of type of fluency, after correction for sex, LOA, vocabulary, and reading skills. Analyses indicated that children classified as having ADHD earlier in life performed significantly less well than their controls (psychiatric or healthy) over the first 15 s of a complex, ILF task. In contrast, no significant interaction was found between groups, word production, and time samples on the SCF task.

Several explanations can be proposed based on these findings. For one, children who show behavior related to ADHD at age 7 years (that is, at a phase during which brain maturation occurs) may show a delay in performance on tests measuring recently acquired automatic processes at age 9, when compared with control children and children with one or more psychiatric problems other than ADHD. The idea of impaired automation of skills in ADHD is supported by research of Dykman et al. (in Ackerman et al., 1986). Moreover, the disturbed pattern in performance over time seemed specific for ADHD: children classified as having ADHD performed significantly less well on the initial letter fluency than children assigned to the psychiatric or the healthy control groups.

Also, when comparing an initial letter to semantic fluency tasks the difference may not only be in how much effort the task 'requires' but also in how 'difficult' the task is. Priming studies suggest that language is represented semantically (Collins & Loftus, 1975; Jescheniak & Levelt, 1994; Mercer, 1976), so when asked to generate words according to a category, this matches with the way in which language is stored. An initial letter fluency task is different in that language is not 'organized' alphabetically, thus this type of task is

relatively novel to most participants and likely requires more executive function than does a semantic fluency task. For deficits in executive functioning are often mentioned in relation to ADHD, this may well add to the explanation of the finding that children suffering from ADHD perform less well than controls on the initial letter fluency tests and no differences were found between groups on the semantic category fluency test.

Additionally, these results emphasize the importance of 'testing the limits' when clinically assessing a child with ADHD characteristics. From the present results, it can be concluded that children classified as having ADHD are able to achieve on a similar level of performance as controls, if they are given sufficient time to do a task. Thus, the total time on task is relevant, in a way that children with ADHD seem to need extra time to 'start the engine.' However, because of relative small samples and effect sizes additional research is needed to test the above-mentioned assumptions.

Finally, while studying the errors made by the subjects, a trend was found for children with ADHD to make more errors of the miscues-type (i.e., words starting with a non-initial letter that is phonologically comparable to the initial-letter or words containing the initial letter but not starting with it) on the ILF than the controls. These results may indicate that ADHD children use search strategies (i.e., the child may either use the sound of the letter to retrieve other words or use its visual image) inefficiently. Using only the sound of the letter to retrieve words beginning with for instance the letter 's' may give rise to miscues such as words starting with 'z' or 'c' or words containing but not starting with an 's.' More research in this area is still needed to study the primary approach used by the ADHD group as opposed to the other groups.

The present study includes some limitations. For instance, the DSM classifications were measured solely on basis of the outcome of a semi-structured interview with the caregivers of the child. Cross-informant reports, like Teacher Reports, were not included here. Therefore, it is possible that the number of children with externalizing behavior was overestimated. However, Barkley (1998) reported evidence of a 90% overlap between parent reports and teacher reports. An additional limitation is that the exclusion and drop out of children in the analyses (37% of the selected sample) could limit the generalizability of the results to the population.

Also, no measurement of broader based language abilities was included in the test protocol (e.g., standard test of semantic abilities and of general word retrieval abilities under a non-speeded condition): a limitation that is of concern given the known impairments in verbal fluency associated with specific language impairments.

Lastly, the study used only a 2-year follow-up. McKay, Halperin, Schwartz, & Sharma (1994) reported that response organization was pivotal to output processing, and noted that the development of response organization largely accounted for the improvement in information processing efficiency between 7 and 9 years of age. Cross-sectional studies indicate that word fluency improves with increasing age to at least 13 years, with written word fluency increasing up to 18 years (Levin, Song, Ewing-Cobbs, Chapman, & Mendelsohn, 2001). Furthermore, significant deviations were found between the test performance of healthy children aged 9 and adults (Hurks et al, in press). Over 60 s, healthy children produced more correct responses on the SCF task than on the ILF task, while with adults this relation was inverted. Over 60 s, adults appeared to be more successful in producing words in the ILF task (Butters, Granholm, Salmon, Grant, & Wolfe, 1987). Therefore, at the moment of neuropsychological testing (age 9), the cognitive development of the children in this study may have passed or was about to pass an important milestone in terms of controlled processing. From this perspective, these children should be tested again when they are older to see whether there are differences in, for example, automatic and effortful processing.

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