

EXECUTIVE DYSFUNCTIONS IN CHILDREN WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER

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One hundred and twenty-four male children ranging in age from seven to 12 years-old were selected. The sample was divided into two groups: (1) sixty-two with attention deficit hyperactivity disorder (ADHD) children; and (2) sixty-two normal matched controls (N-ADHD). Three tests were individually administered: (1) Wisconsin Card Sorting Test (WCST); (2) Verbal fluency and semantics (animals and fruits); and, (3) Picture Arrangement subtest of the WISC-R. For all the test scores, statistically significant differences were found between both ADHD and N-ADHD groups. Two separate factor analyses were performed, using the normal and ADHD groups. Four factors were found for the N-ADHD group, which accounted for 85.7% of the variance. The factor structure presented some similarities in both groups: Factor 2, 3 and 4 in the control group corresponded to factors 1, 2 and 3 in the ADHD group. Nonetheless, in the ADHD group Factor 1 (Abstraction and Flexibility Factor) was absent. Results are interpreted as supporting the hypothesis of executive dysfunction in children with ADHD.

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FRONTAL LOBES AND EXECUTIVE FUNCTION

The name executive function have been proposed to refer to the multi-operational system mediated by prefrontal areas of the brain and their

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reciprocal cortical and subcortical connecting pathways (Stuss and Benson, 1986). This term includes self-regulation, control of cognition (metacognition), temporal organization of behavior, monitoring of behavior, selective inhibition of responses to immediate stimuli, planning behavior, and control of attention (Readers, Harris, Shuelholz and Denckla, 1994; Stuss and Benson, 1986; Weyandt and Willis, 1994).

The frontal lobe represents a complex neurological system (Hécaen, 1964; Luria, 1966; Welsh and Pennington, 1988). Within the frontal lobe, the prefrontal cortex is believed to integrate intentional behavior that requires a planned and coordinated sequence of actions (Fuster, 1989; Ingvar, 1985; Luria 1966, 1969, 1973; Norman and Shallice, 1985; Stuss and Benson, 1984). The complexity of the frontal lobes is evident in the interconnections of the prefrontal cortex with the limbic (motivational) and reticular activating (arousal) systems, the posterior associative cortex, and the motor regions within frontal lobes themselves (Barbas and Mesulam, 1981; Johnson, Rosvold and Mishkin, 1968; Porrino and Goldman-Rakic, 1982; Reep, 1984; Welsh and Pennington, 1988). This interconnection, especially the dorsomedial thalamic nucleus projections, defines the fundamental aspects of the isocortical organization of the prefrontal cortex (Reep, 1984). In humans, the prefrontal cortex reaches about one third of the total cortex (Fuster, 1981).

The prefrontal cortex is believed to be responsible for three categories of neuropsychological functioning: Executive, regulatory, and social (Dennis, 1991). It implies the ability to maintain set in problem solving and in carrying out a strategic and sequential plan. The prefrontal cortex also assumes the ability to make controlled mental representations of a task, to plan and self-monitor performances, to follow social rules, and to use environmental cues (Luria, 1966; Passler, Isaac and Hynd, 1985; Stuss, 1992).

Frontal lesions impair anticipation, planning, goal establishment, set maintenance, self-monitoring, and cognitive flexibility. These patients present preservation, disinhibition, and an inability to use environmental cues to guide behavior (Benson and Stuss, 1982; Passler *et al.*, 1985; Petrides and Milner, 1982; Robinson, Heaton, Lehman and Stilson, 1980; Stuss and Benson, 1983, 1984; Welsh and Pennington, 1988). Frontal lobes lesions are also associated with what Lhermitte (1986) described as "utilization behavior" – "environmental dependency syndrome".

Prefrontal cortex also participate in the organization of language and verbally controlled behavior. Several authors have proposed that an alternation of the internal scheme of verbal expression may exist in frontal

damaged patients, (e.g., Luria, 1966; Jouandet and Gazzaniga, 1979). Defects in narrative and spontaneous language are often observed; and impairments in the ability to generate creative and active verbal programs are reported in patients with prefrontal lobe pathology (Ardila, 1984; Derouesne, 1979; Luria, 1969, 1973; Novoa and Ardila, 1987; Ramier and Hecaen, 1970).

NEURODEVELOPMENT OF FRONTAL LOBES

The development of frontal lobe function continues at least through age 12 and possibly through the age of 16 (Chelune and Baer, 1986; Chelune, Ferguson, Koon and Dickey, 1986; Levin *et al.*, 1991; Obrzut and Hynd, 1986; Passler *et al.*, 1985; Welsh, Pennington and Groisser, 1991). Passler *et al.* (1985) state that the greatest period of development of frontal lobe function in children is from six to eight years-old. By age 10, the ability to inhibit attention to irrelevant stimuli and control preservative responses is fairly developed. Mastery of this ability is observed around the age of 12.

A delay in frontal lobe maturation, normally extending from around six years up to about 10 to 12 years (Benson, 1991; Passler *et al.*, 1985; Willis and Widerstrom, 1986) has been proposed to explain the low performance in executive function tests in younger children. It is recognized that the prefrontal areas are among the last areas of the brain to myelinate and that, further, there is a considerable chronologic variation (Mattes, 1980). Characteristically, males myelinate later than females. Variations in the age at which myelin formation begins, the rate at which it is accomplished, and the age at which sufficient myelin is available to allow prefrontal control functions suggest that delayed myelination could explain, at least partially, Attention-deficit Hyperactivity Disorder (ADHD) symptomatology (Benson, 1991). ADHD has been defined as a disorder characterized by developmentally inappropriate degrees of inattention, impulsiveness, and hyperactivity, even though people with this disorder generally display some disturbance in each of these areas, but to a varying degree (American Psychiatric Association, 1994).

Passler *et al.* (1985) and Stuss (1992) have proposed what may be considered as "cognitive guidance" changes with age, and that the operations sustaining executive functions also change in the same manner. Younger children may use some more basic devices to operate their cognitive tasks. Older children may be using some "higher operative devices" which would implicate more stable categorical organization. These

different cognitive strategies are likely to be affected in a different way for children with ADHD.

There appears to be a differential timing in development of specific functions organized according to a hierarchical order. At an inferior level, the basic content is sensory-perceptual. It is suggested that the anatomical regions underlying some of these simpler functions mature earlier. At superior levels, "executive functions" (*i.e.*, multioperational cognitive activities) involve planning, establishing goals, and the ability to generate flexible alternatives and monitoring programs. Anatomical regions underlying these more complex functions present a later maturation (Stuss and Benson, 1986, 1987).

Biological and psychological development data are consistent with the concept that separate executive functions may present a different development rate over time. It has been suggested that executive functions can be modified by a conceptual feedback loop (Stuss, 1992). Most biological and psychological studies are consistent with the multi-operational executive theoretical construct which involves a differential and sequential development. Some of these cognitive operations may be learned or modified through different age levels. It is possible that five to six years-old children are able to plan better with concrete tasks. Temporal organization follows its developmental pattern from 6 to 12. Temporal organized tasks are impossible to perform before age six. High mental-control requires a slow and progressive development through childhood (Becker, Isaac and Hynd, 1987; Welsh and Pennintong, 1988). While much of the biological maturation is complete by puberty, there is evidence of continuing development in prefrontal areas in addition to parietal and temporal association areas. The corresponding psychological functions associated with these biological changes have not yet been clearly documented (Stuss, 1992).

EXECUTIVE FUNCTION AND ATTENTION DEFICIT HYPERACTIVITY DISORDER

Many children with attention deficit hyperactivity disorder (ADHD) have features of executive dysfunction. These include difficulty with the planning and sequencing of complex behaviors, inability to pay attention to several components at once, defects in the capacity for grasping the gist of a complex situation, low resistance to distraction and interference, and inability to sustain behavioral output for relatively prolonged periods

(Denckla, 1989, 1989; Benson, 1991). Several hierarchically organized prefrontal functions appear pertinent to the discussion about the role of executive dysfunction in ADHD: The “temporal gradient” as described by Fuster (1989) appears decreased in children with ADHD. It appears that there is a defective ability in handling serial information which represents an important characteristic of ADHD. Another dysfunction is that there is an increased drive, similar to that observed in patients with orbital or lateral polar frontal damage, which is responsible for increased reactivity in children with ADHD. A third prefrontal function altered in ADHD is the self-critical monitoring, including the unawareness of the potentials of physical or verbal responses. Lack of self-critical competency is almost a hallmark of children with ADHD. A delay in normal brain maturation may be postulated as a probable source of the syndrome. Delay in laying down myelin has been suggested as a potential explanation for the ADHD syndrome (Benson, 1991; Mattes, 1980). The symptoms observed in children with ADHD have been compared to those of frontal lesions in humans and animals (Barkley, Grodzinsky and Dupaul, 1992).

An abnormal performance in neuropsychological tests sensitive to frontal lobe damage have been reported in children with ADHD. Chelune and Baer (1986) administered the Wisconsin Card Sorting Test (WCST) to 105 children ages 7 to 12 year-old with average cognitive ability. Results indicated that the children made rapid gains in the number of categories obtained and significantly reduced the number of perseverative errors with advancing age. Similar results have been reported by Rosselli and Ardila (1993) in Spanish speaking children ages five to 12 years old. Chelune and Thompson (1987) observed that age was a significant factor in the performance level of the ADHD and control children evaluated with WCST.

Boucugnani and Jones (1989) reported significant differences between ADHD and normal control children in several tests sensitive to frontal lobe dysfunction, including some measures of the WCST (Heaton, 1981), the Trail Making Test (TMT) (Reitan and Wolfson, 1985) and the Stroop Color Word Test (Golden, 1978). Similar findings were reported by Chelune, Ferguson, Koon, and Dickey (1986). Gorenstein, Mammato and Sandy (1989) studied 21 children with inattention–overactivity (I–O) behavior, and 26 controls. It was found that I–O children performed in the direction of prefrontal-type deficits on the WCST (Heaton, 1981), a Matching Memory Task, Necker Cube Reversals, TMT (Reitan and Wolfson, 1985), and Stroop Color-Word Test (Golden, 1978; Stroop, 1935). Other researchers have also found similar results (Pineda, 1996; Reader, Harris, Schuerholz and Denckla, 1994; Riccio *et al.*, 1994; Shue and Douglas, 1992).

Some conflicting results, however, have also been observed. Staton and Beatty (1989) in a study with 20 ADHD and 20 control children reported that the hypothesis of frontal lobe related disturbances in children with ADHD was not supported by their results. Fischer *et al.* (1990) arrived to a similar conclusion. These studies assume that the right parietal system is responsible for sustained attention, as it was proposed by Posner and Petersen (1990). According to this theory, the capacity in visuoperceptual functioning is also significantly impaired in children with ADHD, pointing to a right hemisphere dysfunction.

PURPOSE OF THIS RESEARCH

A further analysis of neuropsychological test performance in children with ADHD is presented in this research study. A transversal, clinical and correlational-factorial analysis of the executive functions in a group of children with ADHD is used. Factor analysis represents a strong and relatively sophisticated statistical tool in measure research. Factorial analysis allows to deduce underlying factors accounting for variance in individual tests. Communality, and in consequence, "relative distance" among different subtests can be deduced. One of the purposes of this research was to attempt a further step in the component analysis of executive functions in normal and ADHD children.

The authors in this study will attempt to integrate different theoretical points of views: Fuster's (1981, 1989) temporal integration of behavior; Shallice's (1978) information processing model; Luria's (1973) neuropsychological interpretation of behavioral and cognitive control; Stuss and Benson's (1986) self-control model; Passler, Isaac, and Hynd's (1985) functional development multistage process theory; and Stuss's (1992) biological-psychological maturation feedback loop theory.

METHOD

Subjects

One hundred and twenty-four male children ages 7 to 12 years-old were selected using a non-probabilistic approach. The subjects in this research were selected from a database containing 100 ADHD children and 72 normal children. ADHD children were referred by the public schools of

Medellin city (Colombia) with the purpose of assessing their behavioral problems and academic difficulties. Normal controls were taken from the very same schools. They voluntarily accepted to participate with the purpose of normalizing some psychological and neuropsychological tests. All of the subjects were in a low socioeconomic status. Table I presents the general characteristics of the sample.

The sample was divided into two groups following the DSM III-R (American Psychiatric Association, 1987) clinical guidelines for ADHD: The first group was composed of children with ADHD. The second group contained normal control children (N-ADHD). Each group included 62 subjects.

Subjects in each group were matched using the WISC-R (Wechsler, 1974) Full Scale IQ, Spanish version. The Spanish version was translated and adapted by De La Cruz, Lopez, and Cordero-Pardo (Wechsler, 1993). This version of the WISC has been previously standardized and normalized in Spain. No statistically significant differences were found between the groups WISC-R Full Scale IQs. Full Scale IQs in ADHD children ranged from 85 to 126, whereas in N-ADHD subjects they ranged from 88 to 119. Maximum Full Scale IQ difference between matched subjects was 8 points.

School grade was lower in the ADHD group than in the N-ADHD groups. In the Colombian educational system, a child can fail a school grade, and to be required to repeat it. Because of this, school grade was in average lower in the ADHD group. This difference in school grade corroborates that ADHD subjects were poorer students than N-ADHD children.

Testing was performed by graduate neuropsychology students from San Buenaventura University, under the supervision of a professor. The evaluators were not blind to the hypotheses and purposes of the research. Evaluation was performed in three sessions, each one lasting about 40 minutes. Tests were administered in the following sequence: WISC-R, verbal

TABLE I General characteristics of the sample

	<i>N-ADHD</i> (<i>n</i> = 62)	<i>ADHD</i> (<i>n</i> = 62)	<i>F-ratio</i>	<i>p</i>
Age	9.6 ± 1.5	9.5 ± 1.8	0.690	NS
School level	4.1 ± 1.5	3.0 ± 1.7	13.218	.001
Full Scale IQ	103.3 ± 7.2	100.8 ± 11.5	2.107	NS
Verbal IQ	109.0 ± 10.1	108.7 ± 13.1	0.019	NS
Performance IQ	96.4 ± 9.9	91.7 ± 12.2	5.577	.05

Note: Means and standard deviations are presented.

fluency, and WCST. No subject had been on medication during the week prior to the testing.

ADHD Criteria

All subjects in the group with ADHD met the following criteria:

1. Developmentally inappropriate degree of inattention, impulsiveness and hyperactivity following the DSM III-R (American Psychiatric Association, 1987) criteria for ADHD. All subjects in this group presented a minimum of 8 of the 14 behavioral disturbances, listed in DSM-III-R criteria A for at least eight months. The average number of behavioral disturbances presented by this group is shown in Table II. The onset of symptoms were before the age of six and none of the children had indication of autism, psychosis, thought disorder, epilepsy, brain damage or mental retardation:
2. Hyperactive symptoms were reported by parents and teachers based on Conners' Behavioral Scales (Conners, 1979a, 1979b). Two different forms were used: Conners' Parent Rating Scale and Conners' Teacher Rating Scale. The parents and the teachers of the children were actually interviewed in order to fill the Conners' Behavioral Scales and obtain some additional developmental and behavioral information. A Hyperactive Index is included in this measurement. Normative data proposed by Goyette, Conners and Ulrich (1978) were used. The cutoff score used for the ADHD children was 1.5 standard deviations above the mean obtained in the normal children, as proposed by Kirby and Grimley (1992) and Kendal and Braswell (1985) and.

TABLE II Diagnostic criteria for ADHD

	<i>N-ADHD</i> (<i>n</i> = 62)	<i>ADHD</i> (<i>n</i> = 62)	<i>F-ratio</i>	<i>p</i>
<u>DSM-III-R</u>				
Number of				
behavioral disturbances	1.03 ± 1.1	11.59 ± 1.6	1,669.3	0.001
<u>Conners Parent Rating Scale</u>				
Behavioral disorders	0.21 ± 0.2	1.67 ± 0.7	265.4	0.001
Learning disorders	0.20 ± 0.3	1.64 ± 1.1	102.7	0.001
Hyperactivity Index	0.26 ± 0.2	2.35 ± 0.4	1,229.0	0.001
<u>Conners Teacher Rating Scale</u>				
Behavioral disorders	0.19 ± 0.3	1.73 ± 0.7	264.3	0.001
Hyperactivity Index	0.20 ± 0.2	2.33 ± 0.4	1,170.8	0.001
Hyperactivity	0.17 ± 0.3	2.03 ± 0.5	631.1	0.001

Note. Means and standard deviations are presented.

3. A full scale IQ in the normal range based on the WISC-R, Spanish version (Wechsler, 1993).

N-ADHD Criteria

All subjects in the control group (N-ADHD) had:

1. No history of behavioral problems;
2. No current complaints from parents or teacher of attention of hyperactive behaviors;
3. Scores were in the normal range on the Conners' Rating scales.
4. No fulfillment of the DSM-III-R criteria for ADHD and
5. No evidence of psychiatric disorders or mental retardation.

The full scale IQ in the normal range, based on the WISC-R (Wechsler, 1974) Spanish version was used to match intelligence level between both groups (see Tab. II).

Instruments

The following tests were individually administered to the experimental and control subjects:

- (1) Wisconsin Card Sorting Test (WSCT) (Heaton, 1981). Areas scored were categories achieved, perseverative errors, non perseverative errors, and failure to maintain set. This test has been previously normalised in Spanish-speaking children (Rosselli and Ardila, 1993) and has been found to be sensitive to frontal lobe pathology (Lezak, 1995).
- (2) Verbal fluency (phonologic – /f/, /a/, and /s/; and semantic-animals and fruits). Verbal fluency was measured by the number of words produced in a particular category within a one minute time limit. This test has also been normalized in 233 five to 12 year-old Spanish-speaking children of different socioeconomic status (Ardila and Rosselli, 1994). The verbal fluency test has been describe in the clinical neuropsychology literature as an ability easily disrupted by frontal lobe injuries (Ardila, Rosselli and Puente, 1994).
- (3) WISC-R, Spanish version (Wechsler, 1993), Picture Arrangement subtest. Past research has theorized Picture Arrangement's sensitivity to executive dysfunctions. Walsh's (1987) research discusses the difficulties patients with frontal lobe damage have in making appropriate solutions on the Picture Arrangement subtest.

RESULTS

For all the test scores statistically significant differences were found between both ADHD and N-ADHD groups. Differences were particularly strong on the WCST.

Two separate factor analyses were performed, using the normal control group and the group with ADHD. Seven test scores and 62 subjects were included in each factor analysis. Factor components were obtained using varimax (orthogonal) rotated factor matrix in both groups, as it demonstrates clearer factorial grouping.

Table IV presents the factors obtained for the control group, the eigenvalues, and the percentage of the variance accounted for. Four factors are well defined for N-ADHD group, which accounted for 85.7% of the variance. In the normal control group Factor 1 is composed of the WCST's Perseverative Errors and Categories Achieved scores. This factor accounts for 34.5% of the variance. Considering that the WCST may be interpreted as an abstraction test, and perseverative errors are pointing to defects in shifting responses, this factor might be interpreted as an Abstraction and Flexibility Factor (AFF).

Factor 2 was formed by the phonological verbal fluency and the WISC-R Picture Arrangement subtest. It accounts for 19.7% of the variance. Picture Arrangement is testing the ability to organize and sequence events. Verbal fluency requires a time-dependent verbal production. This factor might be named as Temporal Sequence Factor (TSF). Factor 3 integrated by the WCST's Failure to Maintain Set scores explains 16.8% of the variance. Failure to Maintain Set appears to assess an attentional ability, and in

TABLE III General results in the different neuropsychological tests

	<i>N-ADHD</i> (<i>n</i> = 62)	<i>ADHD</i> (<i>n</i> = 62)	<i>F-ratio</i>	<i>p</i>
<u>WICS-R</u>				
Picture arrangement	26.2 ± 4.9	23.3 ± 7.7	6.224	0.05
<u>WCST</u>				
Categories	4.7 ± 1.5	3.4 ± 1.9	17.294	0.001
Errors	36.4 ± 18.6	56.6 ± 22.9	29.105	0.001
Non persv errors	18.6 ± 8.3	24.3 ± 14.1	7.495	0.01
Perseverative errors	15.8 ± 13.0	25.7 ± 18.8	11.677	0.001
Failure to maintain the set	0.5 ± 0.7	1.2 ± 1.2	14.304	0.001
<u>Verbal fluency</u>				
Phonologic	16.7 ± 5.1	13.85 ± 5.8	8.476	0.005
Semantic	23.9 ± 6.7	20.9 ± 7.2	6.008	0.05

Note: Means and standard deviations are presented.

TABLE IV Factor analysis control group ($n = 62$)

Factor	Eigenvalue	Percentage of variance	Cumulative variance percentage	Item	Correlation
1	2.4178	34.5	34.5	Perseverative errors Categories	-0.93 0.91
2	1.3812	19.7	54.2	Phonol verbal fluency Picture arrangement	0.84 0.76
3	1.1789	16.8	71.0	Failure to maintain set	0.88
4	1.0294	14.7	85.7	Non perseverative errors	0.89

consequence, it represents an Attentional Factor (AF). Factor 4 included only the WCST's Non-Perseverative Errors score, which determined the 14.7% of the variance. It may be assumed that high scores are due to a failure in organizing, programming and planning the responses. This factor could be interpreted and referred as a Preplanning Factor (PF).

The group with ADHD exhibited a factorial structure of executive functions is quite similar to the N-ADHD group, except for the absence of Factor 1 (Abstractions and Flexibility Factor) (See Tab. V).

DISCUSSION

All the tests used to assess executive functions in our study established statistically significant differences between ADHD and control children. These results are believed to support the hypothesis of an executive dysfunction in children with ADHD and are in agreement with other authors' results (Chelune *et al.*, 1986; Parry, 1973; Shue and Douglas, 1989; Weyandt and Willis, 1994).

Differences in the WISC-R Picture Arrangement subtest were mild, even though statistically significant. Full Scale IQ were used to match groups and no major differences in subtest scores were in consequence expected. Nonetheless, it was assumed a dispersion in subtest scores. Decreased

TABLE V Factor analysis. ADHD group ($n = 62$)

Factor	Eigenvalue	Percentage of variance	Cumulative variance percentage	Item	Correlation
1	3.1187	44.6	44.6	Phonol verbal fluency Picture arrangement	0.84 0.76
2	1.2497	17.9	62.5	Failure to maintain the set	0.87
3	1.0791	15.4	77.9	Non perseverative errors	0.89

subtest scores may point to some underperforming cognitive areas. Departing from available literature (see Walsh, 1987), Picture Arrangement subtest was selected as a measure of executive function and specially analyzed, but indeed other WISC-R subtest (*e.g.*, Block Design) could have been also selected. Direct clinical observation corroborated that the performance of children with ADHD on the Picture Arrangement subtest was characterized by an increased number of errors, a tendency to make responses without thinking, and the absence of self-correction. This behavior is similar to what has been describe in individuals with frontal lobe damage (Luria, 1966). Walsh (1987) suggests that the difficulties frontal lobe individuals exhibit on the Picture Arrangement subtest is due to the tendency these subjects have in making hypotheses, impulsively and uncritically, which are often based on first impressions without analyzing the entire situation.

The ADHD group performed significantly lower than the control group on the phonologic part of the verbal fluency test. The differences on the semantic section, although significant, were smaller. Semantic verbal fluency is somehow akin to lexical access, whereas phonological verbal fluency requires certain level of abstraction (phonological abstraction). Interestingly, this is a tasks almost impossible to perform for illiterate people (Rosselli, Ardila and Rosas, 1990). On the semantic verbal fluency, on the other hand, one can efficiently find words that are semantically linked using concrete strategies (*e.g.*, visualizing animals, foods, *etc.*). On the phonological verbal fluency, there are just not that many strategies to choose from the individual with EF problems might have trouble coming up with those strategies that do indeed work.

Frontal lesions regardless of the side tend to depress verbal fluency scores, with left frontal lesions resulting in lower word production (Lezak, 1995). The use of this test in children with ADHD has exhibited contradictory findings. Fischer, Barkley, Edelbrock, and Samllish (1990); Loge *et al.* (1990) and McGee *et al.* (1989) found no significant impairments relative to normals on a word fluency test. Felton, Wood, Brown and Campbell (1987) found impairments on their group with ADHD, and Grodzinsky and Diamond (1990) report reduced scores only on the phonological section of the test in the group with ADHD when compared to normal children. Our results point to more significant defect on the phonological section of the test. Other authors (*e.g.*, Fisher, Barkley, Adelbrock and Smallish, 1990; McGee, Williams, Moffitt and Anderson, 1989) have not found fluency tests to be impaired in the hyperactive groups when compared with the control groups. The conflicting pattern of these findings may a result of the degree

to which learning disabilities coexist with ADHD in the different samples (Fisher, Barkley, Adelbrock and Smallish, 1990). Furthermore, we assume that both conditions (semantic and phonological) are evaluating somehow different abilities.

The WCST has been traditionally believed to be the most sensitive test to frontal lobe pathology (Barkley, Grodzinsky and DuPaul, 1992; Drewe, 1974; Milner, 1963). In most studies in which children with ADHD are compared with normal controls on WCST measures (Categories, Perseverative responses and Perseverative errors) significant deficits are observed in the group with ADHD (Parry, 1973; Chelune *et al.*, 1986; Shue and Douglas, 1989). Boucagnani and Jones (1989), however, did not find differences in the perseverative responses and errors between children with ADHD and normals. These negative findings were also observed by Loge *et al.* (1990). The failure these authors had in finding differences on the WCST could be due to the smaller sample size used (less than 30 per group).

It has been suggested that age of the subjects may be an important variable in the performance of children with ADHD on the WCST (Barkley, Grodzinsky and DuPaul, 1992; Denckla, 1996). Chelune, Ferguson, Koon and Dickey (1986) and Grodzinsky and Diamond (1992) found that older subjects with ADHD were less deviant from normals than their younger counterparts. Unfortunately, we did not compare age groups, but this is a point deserving further research and analysis.

Results in our factorial analyses are similar to the executive function multi-operational approach proposed by Stuss and Benson (1986). Current results point to at least four different operative activities related to executive function in N-ADHD children, each one associated with a theoretical neurobehavioral factor (or “devide”): AFF, TSF, AF, and PF. Each factor is theorized to participate in the mental control in a somewhat different way. Further, these basic executive factors may theoretically be related to basic frontal functions associated with damage in different prefrontal areas. Perseveration may be observed especially in cases of left convexital damage. In addition, attentional disturbances can be particularly found in patients with orbitofrontal damage, *etc.* (Luria, 1973; Stuss and Benson, 1986).

The factor structure presented some similarities in both groups: Factors 2, 3 and 4 in the control group correspond to factors 1, 2 and 3 in the ADHD group. Nonetheless, in the ADHD group Factor 1 (Abstraction and Flexibility Factor) was absent. Factor 1 was measured by WCST Perseverative errors and Categories scores. It may be proposed that the abilities required in these two test scores were underdeveloped in ADHD children. The children with ADHD may present abnormalities in “abstraction and

flexibility". Their cognitive activities may be driven mainly by some basic categorical cues, including perceptual cues, resulting in a higher probability of error. This observation supports Stuss' statement (1992) about the importance of cognitive age-related managing on the development of the executive function. Stimulus-bound behavior and perseveration are expected in this group of children.

The Temporal Sequence Factor suggests representing a kind of time and space organizer, which would work with perceptual-external-cues and use them into a basic categorical frame to organize the solving problem strategies. This is similar to the same device named "temporal structuring of behavior" which has been proposed by (Fuster, 1980, 1989) as a specific function of the frontal lobes. It would function to anticipate through a provisional (working) memory, which may maintain small bits of information for later response. It appears to also exert a strong control on the interferences. There is evidence that suggests that this might be related to the activity of the dorsolateral aspects of both frontal lobes.

The Attentional Factor is evidently related with the ability to sustain cognitive activity on a task for a long period of time. It is necessary to inhibit irrelevant stimuli. This attentional factor is present in children with ADHD as in N-ADHD children. The results suggest that it is related to activity of the reciprocal right prefronto-parietal systems, as proposed by Petersen *et al.* (1988); Posner (1988), and Posner and Petersen (1990). This activity appears to be initiated by the norepinephrine (NE) system arising in the locus coeruleus (Posner and Petersen, 1990).

The Preplanning Factor appears to be related to a kind of anticipatory device, or trial and error managing system. The underlying brain structure for this cognitive operation suggests involvement from diffuse and reciprocal connections from the prefrontal regions to the posterior cortical areas, especially to right parietal alerting areas, as proposed by Posner (1978) and Posner and Petersen (1990). The alert state mediated for this system produces more rapid responding, however this increase is accompanied by a higher error rate Posner and Petersen (1990).

In brief, our research study supports the assumption of the presence of executive function deficits in children with ADHD. Different cognitive factors may be affected. These defects may be associated with some brain maturational delays.

Our results in the factor analysis are partially coincidental with previous factor analytic studies on executive function measures in children. Welsh, Pennington and Groisser (1991) administered a battery of executive function tasks to 100 subjects ranged from 3 to 12 years old. The measures clustered

in three different factors account for 69% of the total variance. These factors reflected speed responding (best measured with verbal fluency test), set maintainance (best measured with reaction time in the Matching Familiar Figures Test), and planning (Tower of Hanoi Test). Levin *et al.* (1991) studied 52 children and adolescents ranged from 7 to 15 years old. Several cognitive and memory tests purported to reflect frontal lobe functioning were administered. A principal components analysis revealed a three factor solution: a semantic association/concept formation factor (California Verbal Learning Test), a freedom from perseveration factor (Wisconsin Card Sorting Test), and a planning/strategy factor (Tower of London Test). Our factor solution is quite similar to Welsh *et al.* (1991) factor analytic study: Factor 1 (AFF) corresponds to their Planning factor, Factor 2 (TSF) may correspond to Speed responding, and Factor 3 (PF) to Set maintainance. Factor 4 (PF), however, does not seem easy to match with any Welsh *et al.*, factors. To compare our factor analytic results with Levin *et al.* (1991) findings does not seem easy. It should be emphasized, nonetheless, that the tests were rather different. For example, we did not include any memory test. Freedom from perseveration and Planning/strategy factor might partially correspond to our AFF and PF factors.

Despite the commonalities of symptoms among children with ADHD, there is also heterogeneity. These differences have been proposed in the DSM-IV (American Psychiatric Association, 1994) to distinguished three subtypes among children with ADHD. The subtypes are: Inattentive, Hyperactive–Impulsive and Combined. There seems to be clear behavioral distinctions among them even though their cognitive and neuropsychological differences have not been clearly defined. Greater learning disabilities have been reported in individuals with ADHD-inattentive subtype (Barkley, Grodzinsky and DuPaul, 1992). In many cases hyperactivity scores are unrelated to inattention, academic and cognitive skill (Reichenbach, Halperin, Sharma and Newcorn, 1992). This implies that overactive normal children may not present an executive dysfunction; as overactivity *per se* is not necessarily related with executive function deficits. The few studies that have compared neuropsychological performance in children with ADHD, both with and without hyperactivity have disclosed mixed results (Carlson, Lahey and Neeper, 1986; Trommer, Hoepfner, Lorber and Armstrong, 1988; Johnson, 1991). Johnson (1991) reports more perseverative responses on the WCST and in the Trail Making Test time in the subgroup ADHD (hyperactive subtype). On the other hand, Carlson, Lahey and Neeper (1986) were unable to find differences in the Stroop test, between children with ADHD with and without hyperactivity. Barkley, Grodzinsky and Paul

(1992) compared the two groups of children with ADHD on different executive function tests. No significant differences were observed in most of the tests. The only differences between the two groups were in the Stroop, the Continuous Performance Test and in verbal fluency tests. The group with ADHD-inattentive subtype performed significantly lower in the verbal fluency tests, as well as in some Stroop measures and presented a higher number of errors in the Continuous Performance Test. These results may be preliminary due to the small sample size. Unfortunately, our sample was collected before the DSM-IV was published, therefore, no ADHD subtypes were considered. There may be potential neuropsychological differences in particular aspects of executive functions among the ADHD subtypes (American Psychiatric Association, 1994) that need further research.

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