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Eye movement evaluation of Attention Deficit Disorder children

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Abstract

BACKGROUND: Very little is known about the eye movement performance (EMP) of children with Attention Deficit-Hyperactivity Disorder {ADHD), a syndrome involving attentional impairments, impulsivity, and typically, motor overactivity. Under achievement in reading and math has been shown to be associated with ADHD. Because ADHD children have been described as having slower response times, more topographical errors, and below age expected results on psychometric tests, we hypothesized that eye movement performance would also be below age expected. Since psycho stimulants reportedly decrease errors, variability, and response time with ADHD children, eye movement performance was sampled with and without their regularly prescribed medication.

METHODS: 36 children age 8 to 13 with normal eyesight and hearing and who were taking psychostimulant medication for ADHD, were recruited for this study. The Developmental Eye Movement Test (DEM), Groffman Visual Tracing Test (GVTT), Peabody Picture Vocabulary Test (PPVT), and the Visagraph Eye Movement Analysis (VEMA), were administered to all subjects. Several months later 18 original subjects were retested after not having taken their respective medication(s) for a minimum of 24 hours.

RESULTS: Mean DEM percentiles for the medicated ADHD group was: 44.18 vertical, 40.06 horizontal, 44.12 ratio, and 49.35 for errors. Mean PPVT percentile was 60.38. Horizontal DEM subtest performance was significantly better for the 18 subjects while non-medicated. VEMA, GVTT, and PPVT performance did not significantly differ between medicated versus nonmedicated conditions for these same subjects.

CONCLUSION: Based upon DEM results, Eye Movement Performance for the medicated ADHD group was slightly below normal. Above average mean PPVT auding vocabulary performance suggests that the reduced EMP was not due to reduced language ability. Surprisingly, horizontal subtest performance on the DEM was significantly better ($p<0.01$) while subjects were non-medicated. VEMA performance did not differ between the conditions.

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EYE MOVEMENT EVALUATION

OF ATTENTION DEFICIT DISORDER CHILDREN

By

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BIOGRAPHY

Dana Craig Ziskrout received his associate of science degree in ophthalmic dispensing at Cañada College and a bachelor of science degree in visual science at Pacific University. He earned his Doctor of Optometry degree from Pacific University College of Optometry in May 1997. He has been a nationally board certified and state licensed optician for the past 11 years. After graduation Dana will begin a post-doctoral Family Practice Residency program at the University of Houston College of Optometry. He plans to practice in the Western United States emphasizing primary care optometry and the diagnosis, treatment, and management of ocular disease.

Colleen Mariko Ichiyama earned her bachelor of arts degree in Japanese at University of Hawaii at Manoa. She has been involved with the ophthalmic industry as an optometric assistant for the past five years. She will receive her Doctor of Optometry degree in May 1997. Colleen plans to practice in her home state of Hawaii with an emphasis in contact lenses and primary care optometry.

ABSTRACT

BACKGROUND: Very little is known about the eye movement performance (EMP) of children with Attention Deficit-Hyperactivity Disorder (ADHD), a syndrome involving attentional impairments, impulsivity, and typically, motor overactivity. Under achievement in reading and math has been shown to be associated with ADHD. Because ADHD children have been described as having slower response times, more topographical errors, and below age expected results on psychometric tests, we hypothesized that eye movement performance would also be below age expected. Since psycho stimulants reportedly decrease errors, variability, and response time with ADHD children, eye movement performance was sampled with and without their regularly prescribed medication.

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KEY WORDS: attention deficit disorder, saccades, fixations, eye movements, hyperactivity

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INTRODUCTION

There are "3.5 million American youngsters, or nearly 5% of those under 18" [1] years old diagnosed with Attention Deficit Disorder with and without hyperactivity (ADD/ADHD). Attention Deficit Disorder is defined as a disorder of attention span, impulse control, motor activity and rule governed behavior beginning before the age of six or seven, persisting over time (6 months or more), pervasive (cross-situational though not necessarily uniform) and without obvious gross neurologic, sensory, motor or severe emotional impairment.[2] The diagnosis of ADHD stems from the American Psychiatric Association's "Diagnostic and Statistical Manual of Mental Disorders (DSM-III-R)(appendix 1). Based on this knowledge of problems with attention, we were curious to find out whether ADD/ADHD affects children's eye movements, since previous research has shown that eye movements correlate with academic performance, especially reading.[3] Since ADHD subjects were not differentiated from ADD subjects in this study, for the purpose of brevity in the remainder of this paper, they will be referred to as ADD subjects.

Presently, very little is known about the eye-movement ability of ADD children. However, it is widely known that attentional ability is closely related to eye movement ability, but there has been little published data how children with attentional deficit disorders perform on standard clinical eye movement tasks. Motivation for this research is a desire to educate eye care practitioners about the oculomotor skills of ADD/ADHD children.

The first goal of this investigation is to determine whether there are eye movement differences between ADD children and non-ADD children. The second question examines if there are potential eye movement differences between ADD children when medicated versus non-medicated. The final question asks how reliable are the clinical eye movement tests when ADD children are examined while medicated and non-medicated.

Subjects

Thirty-four school age children, ages eight to thirteen, were recruited from within the greater metropolitan Portland, Oregon area for this study. This age range was selected based upon the normative parameters of the Developmental Eye Movement Test, Groffman Visual Tracings, and the Peabody Picture Vocabulary Test. Fliers, press releases, and referrals were utilized to identify the subjects. Prospective subject's parents contacted the researchers by phone and a ten minute screening interview was conducted to determine the child's eligibility. Participation in the study required that the subjects meet the following criteria:

1. Diagnosis of Attention Deficit Disorder by a licensed medical doctor or psychologist.
2. Age from eight to thirteen years old.
3. English as a first language.
4. Normal eyesight and hearing.
5. Two one hour visits to one of Pacific University's Family Vision Centers.

Subjects (con't)

Of the original 46 children who qualified for this study, 34 participated in the initial phase. Eighteen of the original 34 returned to complete the second and final phase. The average age of our 34 subjects was 10.2 years. Our sample of 34 children included seven females (20%), and 27 males (80%). The average age of the 18 subject subset was 10.9 years. This sample included two females (11%) and 16 males (89%). The ethnicity of our sample was predominantly Caucasian. The socio-economic status of families in our study was not investigated.

Grade level for subjects in our sample ranged from third to seventh grade, with a mean grade level of 4.8. Recent standardized academic achievement scores were obtained for each subject from their respective schools. Our subjects possessed a broad range of academic achievement; T.A.G. (talented and gifted) to learning disabled. The mean age equivalent of the subject's auding vocabulary was 11 years old as measured by the Peabody Picture Vocabulary Test.

Of the 34 subjects who came in for the first visit, 27 subjects were on single psychoactive medications, four subjects were on multiple psycho-active medications, and three subjects were on alternative medications/treatments which included various vitamins, minerals, and amino acids. Fifty percent of the subjects were taking Ritalin at the time of their visit. (See chart below)

Psychoactive Medications Taken On First Visit: (n = 34)

Name of Medication	Number of Children	Percentage of Children
Methylphenidate hydro chloride (Ritalin)	17	50.0
Dextro-amphetamine sulfate (Dexedrine)	5	14.7
Imipramine hydrochloride (Tofranil)	3	8.8
Pemoline (Cylert)	2	5.9
*Multiple Medications	4	11.8
**Alternative Medications	3	8.8

*Multiple Medications:

Subject #1: Pemoline (Cylert), Clonidine hydrochloride, and Paxil;
Subject #2: Zolaft and Methamphetamine hydrochloride (Desoxyn);
Subject #3: Prozac and Bupropion hydrochloride (Wellbutrin);
Subject #4: Clonadine and Zolaft

**Alternative Medications/Treatments: Kelp, Herbs, Spirulina, Nystatin powder, Niacinamide, Pyrdoxals phosphate, Theramins-M, Buffered Vitamin C, Magnesium Taurate, and various vitamins.

METHODS

This study was designed with two separate data gathering sessions. However, only about 18 of the participants (53%) returned for the second phase of data gathering.

METHODS (con't)

The first phase required subjects to come in for testing while currently taking their prescribed medications. Subjects were instructed to take their last dosage of medication 2 to 4 hours prior, or to take their regularly scheduled dosage before their first appointment. Data for the first phase of testing was gathered from June to September 1995.

The second phase required a return visit approximately 6 months after the first visit and the subject's parents were notified by the researchers to schedule a second visit. A requirement of the second visit was no ingestion of ADD medication(s) for at least 24 hours prior to testing. This requested time period without medication was required to eliminate the drugs effect within the blood plasma. The blood plasma $t_{1/2}$ of the medications varied from about 2 hours for Ritalin and 7-8.6 hours for Cylert. Dexedrine, based on urinary acidification to a pH of <5.6, yields a plasma $t_{1/2}$ of 7-8 hours. Imipramine is listed as having a "long $t_{1/2}$ life."[4] Four of the subjects were on Selective Serotonin Reuptake Inhibitors (SSRI) medications. All SSRI's half-life include the active metabolite norfluoxetine, which is used in figuring plasma half-lifes. The range of the SSRI's half-life used is 21-216 hours.[5]

The same test battery that was given in the first phase was readministered in the second phase using the same protocols. However, during the second visit, subject's parents were asked to complete a questionnaire addressing the "Effectiveness of Medication" (appendix IV).

With the exception of the P.P.V.T., the following tests were administered twice to each subject in both phases of the study (the Peabody was administered twice, once at the first session and again during the second);

Developmental Eye Movement Test (D.E.M.)
Groffman Visual Tracing Test (G.V.T.T.)
Peabody Picture Vocabulary Test (P.P.V.T.)
Ober/Visagraph Eye Movement Analysis (V.E.M.A.)

For all testing, the following general protocols were observed:

Subjects were comfortably seated next to a rectangular table in a well lit (fluorescent lighting) classroom at Pacific University College of Optometry. For most all subjects, a parent was seated adjacent, while the investigators sat facing the child throughout the testing battery. All the children were tested with their best visual correction (if needed). Each test was administered as faithfully as possible with the protocols specified in the respective test manuals.

Brief descriptions of the tests are as follows:

D.E.M.:
The Developmental Eye Movement Test (D.E.M.) is an oculomotor test designed to assess saccadic-fixational eye movements. Tests A and B (two columns of vertically aligned numbers) represents a baseline measure of

METHODS (con't)

visual-verbal response time or automaticity. Test C (16 rows of horizontally spaced numbers) primarily represents a measure of horizontal saccadic eye movements and fixation ability. For the horizontal portion of the test (Test C), any additions, omissions, transpositions, and substitutions that the subject may have made are taken into consideration and the score is accordingly adjusted or compensated. These adjustments result in "true time-scores." Furthermore, "the ratio of the horizontal test to the vertical test provides an index of the processing time in the horizontal dimension relative to the vertical". [6]

The D.E.M. is age normed from ages six to 13 years 11 months. Recommended standardized testing protocol was followed when administering the D.E.M.[7]

G.V.T.T.:
"The Groffman Visual Tracing Test (G.V.T.T.) is a test of self-generated ocular pursuits in which the patient is required to visually trace lines that are embedded in other curving, tangled lines." [8] It is a considered primarily a visuo-spatial task which requires a minimal language ability but good figure ground perception. Age normed from seven to twelve, mean scores are based upon the speed and accuracy of the subject's response.

PPVT:
The Peabody Picture Vocabulary Test (P.P.V.T.) represents a measure of auding vocabulary ability. The value measured is then extrapolated to a standard score intelligence quotient based upon the subject's age. The P.P.V.T. is normed for subjects aged 2 years 6 months to 40 years 11 months.[9] For this test, subjects are asked to listen carefully and identify a word given verbally by the examiner. Subjects were instructed to point to one of four pictures that corresponded to the word; or call out the number of the picture in the test booklet that matched the spoken word. As recommended in the test manual, each subject was informed that at some point during the testing their current vocabulary ability would be exceeded and that best guesses would be appropriate.

OBER/VISAGRAPH:
The Ober/Visagraph Eye Movement Analysis Instrument (V.E.M.A.) measures eye position 60 times per second while a subject reads a standardized 100 word passage. Information from infra-red sensors in the goggles is transmitted to a computer program which reconstructs and tabulates the eye movements. The Visagraph records the following information: fixations/100 words, regressions/100 words, directional attack, average span of recognition (words), average duration of fixation (seconds), reading rate with comprehension (words/minute), rate adjusted for rereading (words/minute), relative efficiency, grade level equivalent, and a cross correlation value between the right and left eyes. Reading comprehension is estimated for each passage by having the subject answer 10 standardized oral questions given by the examiner. These data are compared to Taylor eye movement normative data incorporated into the Visagraph software. Results are then displayed numerically and also

METHODS (con't)

graphically. Thus, by evaluating these components an analysis is displayed by normed grade levels from grade one to grade 18 (college level).[10]

To choose an appropriate grade level reading passage for the Visagraph, subjects were asked what grade level they were currently in, and parents were asked if their child was reading at the appropriate grade level. Based on this information, subjects were asked to read aloud a sample passage to evaluate the appropriateness of the reading level demand for the test. Subjects were then asked 10 questions to see if they were able to comprehend what they had just read. If they read fluently and answered at least 7 of 10 questions correctly, that grade level demand was chosen for VEMA testing. However, if there was difficulty with comprehension or oral reading was not fluent, the reading demand level dropped down to a more appropriate level.

Grade level demand of the Visagraph paragraphs used ranged from second to seventh grade level. The average grade level demand of the paragraph read by the subjects was 4.2 versus the subject's actual grade placement which averaged 4.8 (age 10.5 years) . Overall, the subject's read passages slightly below their actual grade level placement.

To briefly recap the goals of this study, we posed three specific questions. 1. Are there eye movement differences between ADD children in our sample and non-ADD children? 2. Are there potential eye movement differences between ADD children when medicated versus non-medicated? 3. If so, how reliable are our clinical eye movement tests with ADD children and how well do the tests correlate when the children are medicated versus non-medicated?

RESULTS

QUESTION 1:
Are there eye movement differences between ADD children and non-ADD children?

DEVELOPMENTAL EYE MOVEMENT TEST RESULTS:
MEDICATED CONDITION- All Participants (n=34)

	MEAN	STANDARD DEVIATION
Vertical S.S.	96.74	19.31
Vertical %	44.18	35.08
Horizontal S.S.	94.88	17.66
Horizontal %	40.06	31.79
Ratio S.S.	97.24	13.90
Ratio %	44.12	29.86
Errors S.S.	99.59	15.51
Errors %	49.35	30.54

* [% = percentile, S.S. = Standard Score]Table 1: The normative means for the DEM Test are 100 for standard score and 50 for percentile. Means for our ADD sample were slightly below that reported for the normative population. The horizontal subtest yielded the lowest means for the ADD group.

DEM PERFORMANCE COMPARED TO THE HISTORICAL CONTROL GROUP: (n=34)

	Sample Mean	Historical Control Group	t- Value	Probability (2-tailed)
Medicated Vertical Time %	43.92	50	-1.07	0.2922
Medicated Vertical Standard Scores	94.58	100	-1.43	0.1622
Medicated Horizontal Time %	39.83	50	-1.98	0.0562
Medicated Horizontal Standard Scores	92.74	100	-2.03	0.0498
Medicated Ratio %	43.72	50	-1.30	0.2038
Medicated Ratio Standard Scores	94.92	100	-1.57	0.1245
Medicated Errors %	48.83	50	-0.24	0.8154
Medicated Errors Standard Scores	97.25	100	-0.80	0.4284

Table 2: A t-test comparison of the medicated ADD group to the historical control indicated that only the horizontal subtest standard score mean was significantly different from the population mean ($p<0.5$). The horizontal subtest mean percentile fell just short of being significant.

GROFFMAN RESULTS:
MEDICATED MEANS (n=34)

	A.E.	S.D.	Z-Score	%
Test A	7.98	3.51	8.43	>99.9
Test B	9.77	2.56	16.3	>99.9

* [A.E. = Age Equivalent In Years, S.D. = Standard Deviation, % = Percentile]
Table 3: The Groffman Visual tracing Test yielded A.E. scores below the mean (10.2 year) expected age for the ADD group. The A.E. and Z-score increased from Test A (given as the first trial) to Test B (given as the second trial), revealing that there was a practice effect for this clinical test. The extraordinarily high percentile score indicated a dramatic ceiling effect for this test.

RESULTS (cont)

VEMA MEANS (Second Trials)* (n=34)

	Mean	Expected Mean Based on Taylor Norms
Fixations	171.65	132.24
Span of Recognition	0.68	0.76
Regressions	48.41	28.76
Duration of Fixation	0.31	0.27
Rate Adjusted for Rereading	173.24	168.29
Relative Efficiency	0.87	1.07
Grade Level	3.89	**4.7
Comprehension	80.9	***

[*Two separate VEMA measurements were taken at each session. Only results of the second measurement are shown here because previous research has shown reliability to be higher for the second VEMA measurement.[11]

[** Grade level derived from Relative Efficiency Score]

[*** No expected mean based on Taylor norms available]

Table 4: For every single category of the VEMA, the ADD subjects did worse than expected based upon the Taylor norms.

QUESTION 2:

Are there potential eye movement differences or other differences in ADD children when in the medicated versus non-medicated states?

DEVELOPMENTAL EYE MOVEMENT TEST RESULTS: MEDICATED CONDITION AND NON-MEDICATED CONDITION (n=18)

	Phase One: Medicated		Phase Two: Non-medicated	
	MEAN	S.D.	MEAN	S.D.
Vertical S.S.	95.89	15.71	100.06	16.35
Vertical %	42.83	31.37	47.17	32.14
Horizontal S.S.	93.22	13.18	98.89	14.40
Horizontal %	36.72	26.76	47.22	30.93
Ratio S.S.	96.56	14.90	96.44	12.15
Ratio %	42.50	31.17	41.67	25.90
Errors S.S.	98.67	11.01	105.28	10.26
Errors %	48.61	24.00	61.33	19.42

Table 1: Comparing the 18 subjects while in the medicated and unmedicated states revealed that the subjects did better while in the non-medicated state in all areas except for the ratio scores.

RESULTS (cont)

DEM PERFORMANCE COMPARED TO HISTORICAL CONTROL GROUP (n=18)

	Sample Mean	Pop. Mean	t-Value	Probability (2-tailed)
Non-Medicated Vertical Time %	47.17	50	-0.37	0.7130
Non-Medicated Vertical SS	100.06	100	0.01	0.9887
Non-Medicated Horizontal Time %	47.22	50	-0.38	0.7079
Non-Medicated Horizontal SS	98.89	100	-0.33	0.7473
Non-Medicated Ratio %	44.67	50	-1.37	0.1900
Non-Medicated Ratio SS	96.44	100	-1.24	0.2312
Non-Medicated Errors %	61.33	50	2.48	0.0241*
Non-Medicated Errors SS	105.28	100	2.13	0.0434*
Medicated Vertical Time %	42.51	50	-1.27	0.2740
Medicated Vertical SS	92.10	100	-1.56	0.1359
Medicated Horizontal Time %	36.64	50	-2.36	0.0294**
Medicated Horizontal SS	89.53	100	-2.23	0.0381**
Medicated Ratio %	41.95	50	-1.22	0.2390
Medicated Ratio SS	92.46	100	-1.45	0.1632
Medicated Errors %	47.75	50	-0.44	0.6668
Medicated Errors SS	94.56	100	-1.14	0.2677

[* = better than normative population ($p<0.5$); **= worse than normative population ($p<0.5$)]
TABLE 2: Eye movement performance for subjects both medicated and non-medicated were compared to published normative data provided with the DEM test. In general, medicated subjects performed worse than the published means, especially on the horizontal subtest. Horizontal subtest performance while medicated was significantly worse than that expected for the historical control group. When non-medicated, the 18 subjects in phase two did better, nearly as well as the normative population. In the case of errors, they performed significantly better than the historical control group.

******Bonferoni adjustment - suggestive but not statistically significant***

RESULTS (cont)

DEVELOPMENTAL EYE MOVEMENT TEST RESULTS:
MEDICATED VERSUS NON-MEDICATED CONDITIONS (TWO TAILED T-TEST) (n=18)

	Mean X-Y	Paired T- Value	Probability (2 Tailed)
SS Mean Vertical Time Medicated vs. SS Mean Vertical Time Non-Medicated	-4.17	-1.56	0.1382
Medicated Vertical Time % vs. Non-Medicated Vertical Time %	-4.33	-0.76	0.4587
SS Mean Horizontal Time Medicated vs. SS Mean Horizontal Time Non-Medicated	-5.67	-2.94	0.0091*
Medicated Horizontal Time % vs. Non-Medicated Horizontal Time %	-10.50	-2.89	0.0102*
SS Medicated Ratio vs. SS Non-Medicated Ratio	0.11	0.03	0.9772
Medicated Ratio % vs. Non-Medicated Ratio %	0.83	0.11	0.9148
SS Medicated Errors vs. SS Non-Medicated Errors	-6.61	-2.23	0.3950
Medicated Errors % vs. Non-Medicated Errors %	-11.06	-1.91	0.0736

[SS = Standard Score; % = percentile ($p<0.5$)]
[*=significant value]

Table 3: The means for the Developmental Eye Movement test were compared using a two tailed T-test. Horizontal subtests differed significantly between the medicated and non-medicated conditions, using both SS and % values. When non-medicated, the subjects took less time and called out the numbers more rapidly. The means of the vertical time ratio and errors did not differ significantly, although there was a trend of better performance in the non-medicated condition.

GROFFMAN RESULTS:
MEDICATED AND NON-MEDICATED MEANS (n=18)

	Medicated				Non-medicated			
	A.E.	Std. Dev.	Z-Score	%	A.E.	Std. Dev.	Z-Score	%
Test A	8.36	3.61	10.26	>99	9.6	3.22	-1.01	16
Test B	9.68	3.07	16.54	>99	10.28	3.06	1.03	84

[*A.E.=Age Equivalent, Std. Dev.=Standard Deviation, % =percentile]

Table 4: The mean age for the 18 subjects was 10.3 years in phase I, and 10.9 in phase II. Test A Groffman mean AE score improved from 8.4 years medicated to 9.6 years non-medicated. AE scores for test B similarly increased from 9.7 years medicated to 10.3 years non-medicated. Performance improved from Test A (given as the first trial) to Test B (given as the second trial) in both the medicated and non-medicated states, again revealing a large practice effect. The Z-score and percentile means of test A and test B could not be meaningfully analyzed because of the apparent ceiling effect seen in this group with the Groffman test.

RESULTS (con't)

GROFFMAN TWO TAILED T-TEST (n=18)

	Mean X-Y	Paired T- Value	Probability (2 Tailed)
Medicated total points (1st run) vs. Non-Medicated total points (1st run)	-5.11	-1.78	0.0924
Medicated total points (2nd run) vs. Non-Medicated total points (2nd run)	-4.67	-1.72	0.1031
Medicated Age Equivalent (1st run) vs. Non-Medicated Age Equivalent (1st run)	-1.25	-1.63	0.1205
Medicated Age Equivalent (2nd run) vs. Non-Medicated Age Equivalent (2nd run)	-0.60	-0.90	0.3780
Medicated Z-score (1st run) vs. Non-Medicated Z-score (1st run)	10.71	3.84	0.0012
Medicated Z-score (2nd run) vs. Non-Medicated Z-score (2nd run)	15.51	6.06	<0.0001

Table 5: This table indicates that when the means were compared between the two groups, performance did not differ significantly. Only the Z-scores were found to be significant both for the medicated first run vs. non-medicated first run and the medicated second run vs. non-medicated second run. However, the magnitude of these values due to ceiling effect makes this comparison meaningless.

VEMA 1st TRIALS- TWO TAILED T- TEST (n=18)

	Mean X-Y	Paired T- Value	Probability (2 Tailed)
Medicated Fixations** vs. Non-Medicated Fixations	51.94	1.78	0.0923
Medicated Span of Recognition vs. Non-Medicated Span of Recognition	-0.05	-0.75	0.4629
Medicated Regressions vs. Non-Medicated Regressions	26.83	2.69	0.0155*
Medicated Duration of Fixation vs. Non-Medicated Duration of Fixation	0.03	1.17	0.2585
Medicated Grade/Level vs. Non-Medicated Grade/Level	-0.64	-0.76	0.4588
Medicated Comprehension vs. Non-Medicated Comprehension	-0.28	-0.53	0.6020

[*= significant value; **= fixations/100 words]

TABLE 6: The VEMA computerized eye movement assessment was administered to each of the 18 subjects a total of four times. During the first phase, two separate VEMA measurement samples were taken. This procedure was repeated for phase II. This table compares the first sample on the first visit and the first sample on the second visit. Results of this comparison indicated that only regressions differed significantly between the medicated and non-medicated conditions ($p<0.5$). Significantly more regressions were made while medicated than non-medicated. Fixations, span of recognition, duration of fixation, measured grade level, and comprehension did not differ between the two conditions.

RESULTS (con't)

VEMA 2nd TRIALS- TWO TAILED T-TEST

(n=18)	Mean X-Y	Paired T- Value	Probability (2 Tailed)
Medicated Fixations vs. Non-Medicated Fixations	-20.89	-0.94	0.3602
Medicated Span of Recognition vs. Non-Medicated Span of Recognition	0.06	1.06	0.3053
Medicated Regressions vs. Non-Medicated Regressions	6.67	0.76	0.4589
Medicated Duration of Fixation vs. Non-Medicated Duration of Fixation	0.01	0.89	0.3862
Medicated Grade/Level vs. Non-Medicated Grade/Level	0.40	0.50	0.6248
Medicated Comprehension vs. Non-Medicated Comprehension	-0.06	-0.12	0.9054

TABLE 7: This table compares the second VEMA measurement from phase I to the second VEMA measurement from phase II. VEMA results for the second measurement from each phase comparing medicated versus non-medicated conditions indicated that there were no significant differences in between the conditions for either fixations, span of recognition, duration of fixation, extrapolated grade level, or comprehension.

PEABODY PICTURE VOCABULARY TEST:
All Participants:
Medicated Group Means (n=34)

S.S.	Std. Dev.	%	Std. Dev.	Age Equivalent	Std. Dev.
104.71	18.76	60.38	27.26	10.87	3.02

TABLE 8: Shows that the mean SS and % for all 34 medicated subjects was above average.

Phase One:
Medicated Group Means (n=18)

Phase Two:
Non-Medicated Group Means (n=18)

S.S.	Std. Dev.	%	Std. Dev.	A.E.	Std. Dev	S.S.	Std. Dev.	%	Std. Dev.	A.E.	Std. Dev.
101.9	22.2	57.0	31.8	10.6	3.4	105.4	15.0	61.7	30.8	11.7	2.9

Table 9: The means of both medicated (n=18) and non-medicated (n=18) standard score and percentiles were slightly above that expected for the historical control group. However, non-medicated standard score, percentile, and age equivalent means were higher than when medicated. The subject's chronological age ranged from 8 to 13 years. Mean A.E. for the 18 medicated subjects was 10.6 years and 11.7 years when non-medicated. This reflects an A.E. increase of 1.1 years. Chronological age differed by 4.5 months between the two conditions.

RESULTS (con't)

QUESTION 3:

How reliable are clinical eye movement tests with ADD children and how well did they compare when the children were medicated versus non-medicated?

CORRELATION COEFFICIENT:

	Medicated 1st Trial vs. Medicated 2nd Trial (n=34)	Medicated 1st Trial vs. Medicated 2nd Trial (n=18)	Non-Medicated 1st Trial vs. Non-Medicated 2nd Trial (n=18)
DEM Vertical SS	0.92	0.80	0.93
DEM Vertical Time %	0.77	0.77	0.81
DEM Horizontal SS	0.90	0.79	0.94
DEM Horizontal Time %	0.75	0.75	0.86
DEM Ratio SS	0.29	-0.19	0.77
DEM Ratio %	0.38	0.04	0.38
DEM Errors SS	0.67	0.27	0.92
DEM Errors %	0.85	0.24	0.85
Groffman Ave. (Z-score)	0.76	0.80	0.65
VEMA Fixations	0.56	0.45	0.45
VEMA Span of Recognition	0.39	0.79	0.75
VEMA Regressions	0.40	0.20	0.29
VEMA Duration of Fixation	0.88	0.65	0.47
VEMA Grade Level	0.62	0.90	0.71
VEMA Comprehension	0.74	0.71	0.44
VEMA Rate Adjusted for Rereading	0.44	0.91	0.83

Table 1: For the 34 medicated subjects, the DEM correlation was moderate to high with the vertical standard score (0.92) and horizontal standard score (0.90). Repeatability of the ratio standard score was poor with a correlation of only 0.29. Reliability between Groffman versions A and B was 0.76. VEMA correlations overall had a reliability less than DEM and the Groffman tests with a range from 0.88 (duration of fixation) to 0.39 (span of recognition).

The smaller medicated sub-set group (n=18), yielded similar but lower patterns of correlations as did the larger medicated group, with four exceptions: Groffman, VEMA span of recognition, grade level, and rate. The DEM correlations ranged from 0.80 (vertical standard scores) to -0.19 (ratio standard scores). The Groffman had a moderately high correlation between test A and test B of 0.80. VEMA correlations ranged from 0.20 to 0.91.

Non-medicated, the smaller group (n=18) had a similar pattern of moderate to high correlations on DEM subtests. The DEM correlations ranged from a high of 0.93 (vertical standard scores) to a low of 0.38 (ratio percentage). The Groffman correlation was shown to be moderate (0.65). VEMA correlations were very similar medicated and non-medicated.

Although the apparent trend was higher reliability while non-medicated for most all subtests, statistical comparison of reliability coefficients medicated versus non-medicated indicated that only VEMA reading rate differed significantly between the two conditions.

RESULTS (con't)

PEABODY PICTURE VOCABULARY TEST CORRELATION COEFFICIENT: (n=13)

	Correlation
Medicated Standard Score vs. Non-Medicated Standard Score	0.23
Medicated Percentile vs. Non-Medicated Percentile	0.59
Medicated Age Equivalent vs. Non-Medicated Age Equivalent	0.63

Table 2: The highest PPVT correlation was seen with the age equivalent score, while the lowest correlation was found with the standard score. The percentile showed moderate correlation. These P.P.V.T. correlations represent only 13 subjects as a result of misplaced scores.

GROFFMAN MEDICATED CORRELATION COEFFICIENT:

(n=34)	Correlation Coefficient
Test A Age Equivalent vs. Test B Age Equivalent	0.60
Test A Z-Score vs. Test B Z-Score	0.76

Table 3: Moderate correlation was found between the Groffman age equivalent and Z-Score between test A and test B.

GROFFMAN MEDICATED AND NON-MEDICATED CORRELATION COEFFICIENT: (n=18)

	Correlation Coefficient
Test A Age Equivalent Medicated vs. Test B Age Equivalent Medicated	0.70
Test A Z-Score Medicated vs. Test B Z-Score Medicated	0.80
Test A Age Equivalent Non-Medicated vs. Test B Age Equivalent Non-Medicated	0.91
Test A Z-Score Non-Medicated vs. Test B Z-Score Non-Medicated	0.65

Table 4: For the medicated state, there was moderate correlation between age equivalence for test A vs. Test B, while the Z-score registered a moderate to high value. Conversely, the non-medicated state revealed a high correlation between test A vs. Test B of the age equivalent. The non-medicated Z-score showed a low correlation.

DISCUSSION

This study was centered around three questions:

The *first* question examined if there were eye movement differences between ADD children and non-ADD children. The trend was for poorer eye movement performance with all the clinical eye movement tests, however, few of these mean differences were signficant. Significant differences were seen on the horizontal subtest of the DEM, with ADD subjects performing worse than the historical normative control group.

From our data it is obvious that not all ADD children demonstrate poor eye movement performance. The ADD children in this study spanned a broad range of eye movement performance and academic ability (from talented and gifted to learning disabled). For the clinical eye movement measures that were selected, the mean standard deviations were very large which may have obscured poor performance by a subgroup of ADD subjects. Therefore, looking only at mean data may not reveal the presence of an ADD subgroup with poor eye movements. Future analyses will examine whether the majority of our subjects performed slightly below expected, or if there exists a small subgroup of individuals whose eye movements were far worse than that of the other subjects.

If the horizontal subtest of the DEM differentiated ADD subjects from non-ADD subjects, why was that difference not seen with the GVTT and the VEMA measures? Although the VEMA indicated poorer mean eye movement performance by ADD children in nearly every category, it was not possible to statistically compare the performance of our ADD subjects with those of the VEMA normative group given the limited VEMA normative data available. Based upon GVTT results, eye movement skills were less than expected. These results need to be interpreted with caution given the dramatic test ceiling effect seen with these subjects. Alternatively, both the VEMA and GVTT may sample different eye movement sub-skills than the horizontal subtest of the DEM. The GVTT reportedly measures "self-generated pursuit eye movements," VEMA measures eye movement efficiency during reading (with heavy linguistic processing), whereas the horizontal subtest of the DEM is a saccadic-fixation task with a limited linguistic demand.

The *second* question investigated if there were potential eye movement differences (and PPVT differences) in ADD children when medicated versus non-medicated. For the 18 subjects who were tested both medicated and non-medicated, the mean DEM horizontal standard score and percentile was significantly worse when medicated. A comparison of this medicated subgroup to the historical control group indicated that mean horizontal DEM subtest performance was significantly worse than the historical control group. When non-medicated however, mean performance for these same individuals was not significantly different from that of the historical control group. In other words, this subset of ADD subjects demonstrated a deficit on the horizontal subtest of DEM only when medicated. Other DEM subtests, PPVT, VEMA, and Groffman

DISCUSSION (cont)

values did not yield significant differences when medicated versus non-medicated. There were also no significant differences in PPVT results medicated versus non-medicated.

For both questions one and two, the horizontal subtest of the DEM was the only clinical test to detect significant differences. Why didn't other DEM subtests detect these differences? Is the horizontal subtest a more sensitive eye movement measure than the other subtests?

The vertical subtest of the DEM is described by the test authors[12] as a measure of visual-verbal response time, or automaticity. The vertical subtest is said to tap different neurological skills than those needed for the horizontal subtest. If the DEM vertical subtest samples automaticity and language ability, it is not unreasonable to expect that ADD individuals would not show differences in rapid naming ability as compared to non-ADD children. Further, ADD medications would not be expected to alter visual-verbal performance.

There are several possible explanations for why there were no significant differences in mean horizontal/vertical subtest ratios medicated versus non-medicated. Lack of significant differences in the ratio score may be due to the inherent variability of the score itself.[13] Because the ratio is a derived score that amplifies the variability of two subtests from which it is calculated, it can not reliably detect subtle differences in performance. As reported by the test authors[14] the intrasubject test-retest reliability of the ratio score was only 0.57. Other investigators have reported even lower reliability co-efficients with children[15]. Similarly, the test authors also reported a large amount of variability in the normative error findings, so DEM error performance is not a reliable developmental measure.[16]

An alternative explanation may be that horizontal DEM differences were due to chance or that they reflect increased maturation between test sessions. It is important to keep in mind that at the first testing session all subjects were medicated. Eighteen subjects returned for the second non-medicated testing session. These sessions were separated by a mean of 4.5 months, (range of 2 to 6 months). This time interval may reflect a period of increased maturation, and perhaps better eye movement performance based on development alone. DEM horizontal age equivalent scores would argue against this explanation. Although the sessions were separated by a mean of 4.5 months, subject's mean horizontal subtest age equivalent performance increased from 9.72 years to 10.74 years from the first to the second session. This age equivalent improvement was much larger than that expected from the intersession interval alone.

The vertical subtest of the DEM indicated no differences between medicated and non-medicated conditions. This indicates that it wasn't a basic language processing problem causing the difference in eye movements nor was it an automaticity or visual verbal response type of problem.

DISCUSSION (cont)

From our findings there was no clear indication of improved eye movement performance while they were taking their regularly prescribed medication(s). Stated another way, eye movement performance was not significantly improved by the ADD medications. In fact, our results showed the reverse, improved overall eye movement performance when non-medicated.

The *final* question asked how reliable were the tests when the ADD children were medicated versus non-medicated. Except for VEMA reading rate, there were no differences in test reliability between conditions. Although the general trend was greater reliability in the non-medicated state, surprisingly, the only significant medicated versus non-medicated reliability difference found was opposite to this overall trend. VEMA reading rate reliability was significantly better when medicated (r=0.91 vs 0.83). It should be pointed out that better readers usually demonstrate more variability in their reading rates than do retarded readers because good readers are better able to adapt to the demands of the text.

A review of ADD literature suggests that its effects are not entirely isolated only to attentional abilities. Previous investigations have associated ADD with central nervous system disorders. For example, ADD individuals can manifest gross and fine motor control delays (affecting 50% of ADD children), developmental delays, obsessive-compulsive disorders (OCD), and TIC Syndromes. Approximately 20% of children with ADD have Tourette's although 40-60% of children with Tourette's have ADD.[17]

Since CNS disorders are known to be related to attentional deficits, we theorize that not only do the subject's CNS psychotropic and Selective Serotonin Reuptake Inhibition (SSRI) medications influence specific target areas of the brain, but there is also an antagonistic effect on other neurological systems. In fact, poor eye movements may be a representation of decreased chemically induced neuronal innervation to specific cranial nerves, thereby interfering with the fluidity of ocular motility.

Confirmation or disproval of this theory may require a randomized prospective crossover study, where non-ADD children would be administered a temporary regimen of the aforementioned psychotropic medications. Once the medications have reached proper blood plasma levels, the testing battery used for this study could be imposed. Pre and post analysis of medicated versus non-medicated eye movement performance results would then be compared with the results from children diagnosed with attentional deficit disorders. Future studies may provide a better understanding of the potential relationship between ADD medications and ocular motility.

Future studies should also be directed at exploring alternative treatment methods that have been reported to be effective with ADD. These methods include dietary intervention including megavitamins and mineral supplements, anti-motion sickness medications, candida yeast, EEG biofeedback, applied

DISCUSSION (cont)

kinesiology, and vision therapy. To date, there have been few rigorous scientific studies to substantiate claims for these therapies.[18] Symptomology, severity, academic performance, and interpersonal relationships are so variable in this population that we feel there is no perfect treatment modality... yet. So how do we best treat this population? It is essential that professionals familiarize themselves with the challenges that ADD presents, and prepare accordingly, keeping in mind that they are all special individuals--but diverse as a group. Further studies should be undertaken because the condition is so epidemic, and so many questions remain to be answered.

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APPENDIX A

ATTENTION DEFICIT HYPERACTIVITY DISORDER: DIAGNOSTIC CRITERIA

ADHD is defined when exhibiting at least 8 of 14 specific behaviors for a period longer than 6 months and that its appearance presented before age seven. However, attentional deficit disorder does not require hyperactivity, in fact, up to 30% of children with ADD are not hyperactive.

The behaviors are as follows:

1. Often fidgets with hands or feet or squirms in seat (in adolescents, maybe limited to subjective feeling of restlessness).
2. Has difficulty remaining seated when required to do so.
3. Is easily distracted by extraneous stimuli.
4. Has difficulty awaiting turn in games or group situations.
5. Often blurts out answers to questions before they have been completed.
6. Has difficulty following through on instructions from others (not due to oppositional behavior or failure of comprehension) (e.g., fails to finish chores)
7. Has difficulty sustaining attention in tasks or play activities.
8. Often shifts from one uncompleted activity to another.
9. Has difficulty playing quietly.
10. Often talks excessively.
11. Often interrupts or intrudes on others (e.g., butts into other children's games).
12. Often does not seem to listen to what is being said to him or her.
13. Often loses things necessary for tasks or activities at school or at home (e.g., toys, pencils, books, assignments).
14. Often engages in physically dangerous activities without considering possible consequences (not for the purpose of thrill seeking) (e.g., runs into street without looking).

Appendix B

PRE- TEST QUESTIONS

Parent's
Name:_____Phone:_____

Address:_____

Child's
Name:_____DOB:_____Age:____

Prenatal Complications: Yes No
If yes:_____

Were there any complications during birth: Yes No
If yes:_____

Any significant trauma to the head: Yes No
If yes:_____

High Fever: Yes No
If yes:_____

Loss of Consciousness: Yes No
If yes:_____

Is The Child On Any Medications: Yes No
Name of Medication:_____
Dosage:_____"x"/day_____Effectiveness:_____

What Age Did They Begin With The Medication?:_____

School History:_____

Involved with Chapter One or LRC: Yes No
Currently Receiving Special Education In School: Yes No
Learning Disabilities (type):_____
Diagnosed as ADD: Yes No
By Whom:_____When_____

Appendix C

EYE MOVEMENT ASSESSMENT- SECOND VISIT

DATE:_____

CHILD'S
NAME:_____

MEDICATION HISTORY:

Regular dosage and time of day taken:_____

As of today's visit, how many hours has it been since your child has taken their last dosage:_____

How long have they been taking their medication(s):_____

Has the dose been changed since your last visit with us:_____
If so, please explain:_____
_____

In addition to the ADD/ADHD medications currently being taken, are there any other prescribed or over the counter medications being taken:_____

Have you noticed any behavioral changes while on their respective medications. For example: Ability to stay on regular tasks, complete assignments at school, maintaining their grades, etc:_____

Is your son/ daughter taking their medication(s) during the;

a. weekends:_____. If so, is it the same dosage regimen that they receive during the school week?_____

b. summers:_____. If so, is it the same dosage regimen that they receive during the school year?_____

Appendix D

EFFECTIVENESS OF MEDICATION-SECOND VISIT

This scale is to measure the difference between the medicated vs. Non-medicated state (5=Most difference; 1=Least difference; 0=Has not been a problem prior to medication)

Academic Performance:	5	4	3	2	1	0
Behavior at home and the ability to get along with family members:	5	4	3	2	1	0
Ability to stay on task at <u>home</u> with school work:	5	4	3	2	1	0
Ability to stay on task at <u>school</u> with school work:	5	4	3	2	1	0
Ability to get along with peers:	5	4	3	2	1	0
Impulsivity/distractibility:	5	4	3	2	1	0
Regular sleeping cycles:	5	4	3	2	1	0
Personal organization: (i.e. not losing items, etc.)	5	4	3	2	1	0