MATHEMATICAL PERFORMANCE AND BEHAVIOR OF CHILDREN WITH HYPERACTIVITY WITH AND WITHOUT COEXISTING AGGRESSION

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Summary—An analysis was made of a basic skill deficit and collateral behavior that could differentiate youth with hyperactivity from children with both hyperactivity and aggression. A total of 92 boys (with hyperactivity, with hyperactivity and aggression, and without disorders) were assessed for their timed performance and accuracy of computer-generated math operations. Response time differences documented between disordered and nondisordered groups, and between the diagnostic groups, were not explained by the group differences that were also observed in behavior or motor response speed (typing). Conclusions derived from these findings, and from prior work, indicated that speed of addition may be a marker of academic and social dysfunction. The overall importance of this assessment is related to the potential sensitivity of math fluency data for assessment and treatment monitoring.

It has been demonstrated that young children with hyperactivity (attention deficit hyperactive disordered, ADHD)† and learning disorders have poorer computational performance than that of comparison groups (e.g. Hasselbring, Goin & Bransford, 1988; Zentall & Shaw, 1980). Findings that provide convergent validity have been reported by Badian and Ghublikian (1983), who selected children with poor computational skill and reported associated inattention, disorganization, and social disorder. However, at advanced grade levels, accuracy is no longer a sensitive measure of this skill deficit (Hasselbring et al., 1988; Woods, Resnick & Groen, 1975), especially when IQ is factored out of the analysis (e.g. from math achievement test scores; Ackerman, Anhalt, Holcomb & Dykman, 1986). Because accuracy is no longer differentiating, it is not clear whether attention disordered children catch up or whether accuracy is an insufficiently sensitive measure across the age span.

The speed of producing correct responses (fluency) may be a better indicator of the degree to which basic skill has been attained. Slower computational speed in addition and subtraction has been documented for learning disabled (LD) and attention deficit disordered (ADD) groups relative to comparisons (Zentall, 1990). These deficits in computational speed were not explained by attention focused off-task, cognitive ability, or general activity, and were observed for seventh and eighth grade students, who should have achieved basic math skill. Kirby and Becker (1988) further demonstrated with a Sternberg method that the slower recognition-speed for correct computations by youth with LD relative to comparisons was not attributable to slower recognition of numbers or selection of correct operation.

Group differences in the slow speed of math-fact performance could be attributed to difficulty sustaining attention to rote tasks. Thus, computational speed could be viewed as a consequence of attentional disorder. Specifically what has been proposed is that children with hyperactivity fail to maintain attention to repeated stimulus presentations and thus fail to adequately overlearn stimulus properties (Zentall, 1990). This has been documented in related areas by (a) an inability to sustain attention to repetitive stimuli (e.g. Zentall, 1985, 1986); (b) avoidance of verbal rehearsal (repetition) unless reinforced at high rates (e.g. Hallahan, Tarver, Kaufman & Graybeal, 1978); and (c) increased activity and impulsive responding, especially during later trials of tasks that involve repeated exposure to stimuli of decreasing novelty (e.g. Zentall, 1985, 1986; Zentall & Zentall, 1976; Zentall, Falkenberg & Smith, 1985). The theorizing by Carver (1979, p. 1271)

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†In this article "hyperactivity" and attention deficit hyperactivity disorder are used interchangeably.
provides a related explanation. He states that performance of mental arithmetic tasks requires rejection of salient external sensory stimuli. In light of the evidence that children with hyperactivity are attracted to novel external stimulation (Copeland & Wisniewski, 1981; Radosh & Gittelman, 1981), mental arithmetic tasks would be particularly difficult.

In the present study we considered it important to also address a second disordered-group comparison. We selected related subgroups of children with hyperactivity (H) and with hyperactivity and aggression (H-A), because evidence has indicated greater attentional problems for the majority of youth with hyperactivity and social disorder (Madan-Swain & Zentall, 1990). Studies typically report that children with mixed disorders of attention and aggression (or conduct disorders) also demonstrate more academic problems, activity, and aggressive social behavior than either single type of disorder (attention or aggression) (McGee, Williams & Silva, 1984; Offord, Sullivan, Allen & Abrams, 1984; Walker, Lahey, Hynd & Frame, 1987). However, some researchers have failed to find differences among hyperactive, conduct disordered, and mixed diagnostic groups, using a full battery of laboratory tests (Koriath, Gualtieri, van Bourgondien, Quade & Werry, 1985) or using tests of cognitive style (for review see Stewart, Cummings, Singer & de Blois, 1981). Furthermore, at least one study has documented greater academic dysfunction on individually presented mathematics tests for children with hyperactivity than for a mixed hyperactive/conduct disordered group (Stewart et al., 1981).

The question presented by these findings is whether the inconsistency in findings is due to insensitive measurement. Response speed may be a more sensitive measure than traditional laboratory or normative accuracy measures. In support of this possibility, Ackerman et al. (1986) reported that out of all learned automatic skills (i.e. naming speed, number combinations, writing speed) and when IQ was partialled out of the analysis, only the computational tasks were sufficiently sensitive to differentiate groups with reading disabilities and attention disorders (ADD) (with and without hyperactivity) relative to controls. To indicate the heuristic value of factors underlying math response speed, the speed of simple computations has provided the strongest single predictor of reading recognition achievement (Ackerman et al., 1986) and of correct math problem solving performance (Zentall, 1990).

Finally, the present study attempted to rule out visual-motor skill as an explanation for slower computational speed. We considered this important, given the visual-motor deficits documented for these children (e.g. Stevens, Stover & Backus, 1970; Zentall & Kruczek, 1988) and the lack of control for this variable in past research.

METHOD

Subjects

Boys, whose parents granted permission (77%), were selected from 20 classes (grades 2 to 5) in three suburban schools. Specifically selected were all the boys with hyperactivity, with both hyperactivity and aggression, and a larger random sample of their nondisordered classmates. Hyperactivity status was primarily determined by teachers’ ratings on the SNAPz* (see Zentall, 1990 for further validity data). Criterion scoring of 8 out of 14 behavioral items rated “considerably more than other children of the same mental age,” was used to determine hyperactive status (DSM-III-R, American Psychiatric Association, 1987). Reliability of group status was determined either (a) by the same teacher on a subsequent rating of the IOWA Conner’s Teacher Rating Scale (a score of 11, Loney & Milich, 1982) or (b) by a parent rating on the Werry-Weiss-Peters Activity parent-rating scale (WWP) using the Routh, Schroeder and O’Tauma (1974) criteria, which classifies children if they are 2 SD above the mean for children of their age group. In general the WWP does

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* An adapted form of the Swanson, Nolan and Pelham (SNAP) Checklist (see Pelham & Bender, 1982, p. 370, for reliability and validity data). Adaptations of the SNAP for DSM-III-R included changing the criterion level of behavioral frequency from a 5-point to a 3-point scale (i.e. considerably less, about the same, and considerably more) to force the raters to make clinical judgments of severity “relative to other children of the same mental age.” Significant agreement was observed between the labeling decisions of the SNAPz DSM-III-R and DSM-III grouping decisions [phi = 0.80, \( \chi^2(1, N = 122) = 77.47, P < 0.01 \)]. These comparisons could be made because of the item overlap of the two scales within the adapted form. Ratings were to be made from a retrospective examination of the child’s behavior over the last 6 months, as per DSM-III-R criteria.
not correlate well with objective measures of activity (see Werry, 1978, for review); however, it does correlate with conduct disturbance (Shaffer, McNamara & Pincus, 1974). H-A group status was determined by a score of at least seven on the aggression (A) subscale of the IOWA scale.

After dropping two children (1 hyperactive and 1 comparison) due to equipment failure, 92 boys, ages 7-12 were designated into three groups: (1) nondisordered comparisons (n = 57, 2 students were receiving services for LD, 14% of the total were nonwhite), (2) hyperactive (n = 22, 3 were receiving services for LD, 8% were nonwhite). Statistically significant mean differences (P < 0.05) were yielded between the two groups of youth with hyperactivity [hyperactive (H), H-A] and the nondisordered comparison children (C) on each of the behavioral ratings (see Table 1). Additionally, the H-A group differed from the H group on the IOWA (A) subscale of aggression and on the DSM-III-R items of the SNAPz—and its subscales of sociability and school functioning (“Poor school work…”). From an examination of Table 1, it can be concluded that the H-A group was more severely disordered than the H group, with a greater number of problems in teacher-rated social and school functioning, aggressive behavior, and more items rated of the DSM-III-R characteristics [but not the teacher-rated IOWA Hyperactivity (IO) subscale or the parent-rated WWP Activity scale]. Data were not available for these children for IQ or parental economic status. However, prior work (Zentall, 1990) has shown that partialling IQ out of the analysis has not altered the effects observed in computational performance.

In addition to these data, subtest scores in math (math computation, applications, and total scores) on the Comprehensive Test of Basic Skills (CTBS, 1987) were available for most of the children. The group differences are reported in Table 1. Newman-Keuls analyses yielded significant differences between the disordered and nondisordered groups on each math test and on the total battery, which included math, language arts, science, and social studies. Equivalent age scores were documented across groups. From an examination of each child’s school records it was noted that cognitive, sensory and severe language disorder were not present.

**Tasks**

Four tasks were programmed to randomly generate one digit problems for the three arithmetic tasks (addition, subtraction, multiplication, each 10 min) and to generate random numbers (-9 to 81) for the copying numbers task (typing practice) presented by the microcomputer. To control for individual motor response times, the copying task assessed number recognition and time to select a number key. This was presented “8 = ” or “−8 = ”; addition was presented “8 + 1 = ”, subtraction problems were presented either “7 − 2 = ” or “2 − 7 = ”; and multiplication problems were presented “6*2 = ”. Three types of feedback were provided horizontally on the bottom of the screen: (a) for correct answers: “Time: 2:12 sec. Ready?”; (b) for incorrect answers: “Wrong answer: Entered 7 instead of 6. Time: 2:12 sec. Ready?” and (c) for nonnumeric answers “Nonnumerical answer in input. Ready?”

Table 1. Group comparisons on measures of hyperactivity and aggression (Rating Scale Scores), and on measures of achievement and age

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>F</th>
<th>P</th>
<th>Comparison Mean (C)</th>
<th>Hyperactive Mean (H)</th>
<th>Hyperactive/aggressive Mean (H-A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating Scale Scores</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SNAPz</td>
<td>2.91</td>
<td>290.88</td>
<td>0.001</td>
<td>0.74</td>
<td>&lt; 8.50</td>
<td>&lt; 10.15</td>
</tr>
<tr>
<td>Sociability</td>
<td>2.91</td>
<td>24.49</td>
<td>0.001</td>
<td>(0.12)</td>
<td>&lt; 0.64</td>
<td>&lt; 2.08</td>
</tr>
<tr>
<td>School functioning</td>
<td>2.91</td>
<td>46.72</td>
<td>0.001</td>
<td>0.05</td>
<td>&lt; 0.68</td>
<td>&lt; 1.31</td>
</tr>
<tr>
<td>IOWA subscales</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggression (A)</td>
<td>2.91</td>
<td>123.62</td>
<td>0.001</td>
<td>0.79</td>
<td>&lt; 2.50</td>
<td>&lt; 9.08</td>
</tr>
<tr>
<td>Hyperactivity (IO)</td>
<td>2.91</td>
<td>131.19</td>
<td>0.001</td>
<td>2.11</td>
<td>&lt; (10.00)</td>
<td>&lt; 11.00</td>
</tr>
<tr>
<td>WWP</td>
<td>2.80</td>
<td>7.71</td>
<td>0.001</td>
<td>6.61</td>
<td>&lt; (11.84)</td>
<td>&lt; 10.18</td>
</tr>
<tr>
<td>Achievement Test Scores</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computation</td>
<td>2.89</td>
<td>6.03</td>
<td>0.004</td>
<td>70.55</td>
<td>&gt; (52.81)</td>
<td>47.69</td>
</tr>
<tr>
<td>Application</td>
<td>2.89</td>
<td>7.54</td>
<td>0.001</td>
<td>74.69</td>
<td>&gt; (58.08)</td>
<td>56.82</td>
</tr>
<tr>
<td>Math total</td>
<td>2.89</td>
<td>7.32</td>
<td>0.001</td>
<td>74.15</td>
<td>&gt; (55.27)</td>
<td>53.69</td>
</tr>
<tr>
<td>Total battery</td>
<td>2.65</td>
<td>12.32</td>
<td>0.001</td>
<td>77.26</td>
<td>&gt; (54.88)</td>
<td>49.27</td>
</tr>
<tr>
<td>Age in months</td>
<td>2.91</td>
<td>0.37</td>
<td>0.694</td>
<td>113.64</td>
<td>&gt; 114.91</td>
<td>117.92</td>
</tr>
</tbody>
</table>

*a*Sum of SNAPz items 17-23.  
*b*Sum of SNAPz items 24-25.  
**Note.** Inequalities indicate significant differences (P < 0.05) according to Neuman-Keuls comparisons.
Procedures

Testing schedules were pre-arranged with principals and teachers. Occasionally, children had to
be re-scheduled the following day due to absences or school related duties (e.g. testing, special
programming). Each child was individually escorted to the testing area and told that he would be
doing simple math on a computer in order to see which types of problems he could do fast and
which types were harder and would take longer. The experimenter assisted the child with entering
simple information (e.g. name, age, gender, school, town, state) on the computer, with reading the
instructions, and understanding the examples for the tasks presented on the microcomputer. The
child was instructed to type his answer as fast as he could and then press the return key quickly,
which produced a bell tone and stopped the timer. He was then to press the return key again or
enter “y” (yes) to go on to the next problem at the prompt “Ready?” The experimenter returned
to the area behind the screen where another microcomputer was set up, signaled to the child to
begin the task, and proceeded to record the child’s behavior. The child continued working until four
bells in succession. This cued the end of that task and signaled the experimenter to stop observation,
come around the screen, and start the next task. At the end of the four tasks, the child was thanked
and given a small prize.

Design

The copying task was presented first to each of the children, so they would acquire the same
amount of practice on the keyboard prior to the computational tasks. Order of computational tasks
(addition, subtraction, multiplication) was random for each S. Two sessions, each 40 min long,
were separated by a 2 to 3 week time interval, such that 2 samples of all 4 tasks were collected
to increase the representativeness of these data. Equipment failure or unforeseen school events (e.g.
firedrrils, power outages) were responsible for the loss of data for specific tasks or sessions.

Experimental area

The tasks were presented to individual children in one of the three school working-areas: (a) a
partitioned area within a classroom (2.55 x 3.43 m), (b) a storage room (1.80 x 4.50 m), or (c) an
anteroom (2.40 x 3.00 m). Sound level ranged from 50-70 dB (relative to 0.002 dynes/cm², Sound
Level Meter, Gen Rad No. 1565-B). The child was seated in front of a microcomputer monitor.
Separating him from the experimenter was a three panel screen (1.62 m high and 0.42 m wide) with
a one-way mirror in the center panel. Overhead and clamp-lights were adjusted for optimal visibility
for the observer and student.

Measures

Two observers independently used an event recorder hooked up to a second microcomputer to
record specific types of behavior observed through the one-way mirror. Training of behavioral
observation for the observers was done using video recordings of a child performing tasks.
Percentage agreement for durations were: Bottom/Torso movement (71%), Leg movement (94%),
Head movement (86%), and Vocalizations (77%). Whatever differences were extant between the
two observers would be expected to contribute to variability and thus reduce the probability of
obtaining significance. However, these differences would not be expected to contribute to systematic
differences between groups.

Behavior. Durations of: (a) Bottom/torso movements, where the normal sitting position deviated
by having one or both buttocks off the chair. This included any forward, backward, or 90° twisting
motions. (b) Leg and feet movement were noted only for repetitive swinging or tapping. (c) Head
turns off-task consisted of turns 45° or more away from the computer. (d) Vocalizations/noise were
clearly audible spontaneously generated noises and words, excluding involuntary noises such as
coughs or sneezes.

Performance. Response-times to each correct problem were measured in hundredths of a second,
averaged within each of the two sessions. Additional measures were number of problems attempted
and percent of error. Errors were divided into typographical errors (i.e. nonnumeric data) and
numerical errors.
Mathematical performance

Table 2. Univariate analyses and planned contrasts for group differences in the performance data

<table>
<thead>
<tr>
<th>Measure</th>
<th>Task</th>
<th>LS mean contrasts*</th>
<th>LS original log means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C (2,175)</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.57</td>
<td>&lt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.09</td>
<td>&lt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.72</td>
<td>&lt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.47</td>
<td>&lt;</td>
</tr>
<tr>
<td>Log M SD scores</td>
<td></td>
<td>0.62</td>
<td>&lt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.95</td>
<td>&lt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.15</td>
<td>&lt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.29</td>
<td>&lt;</td>
</tr>
<tr>
<td>Log percent errors</td>
<td></td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>14.13</td>
<td>&lt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.22</td>
<td>&lt;</td>
</tr>
<tr>
<td>Log number attempted</td>
<td></td>
<td>128.80</td>
<td>&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>117.49</td>
<td>&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100.00</td>
<td>&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>104.71</td>
<td>&gt;</td>
</tr>
</tbody>
</table>

*The means are presented more meaningfully by converting the logged data used in the analyses to seconds by an inverse-log procedure.

**Differences between two groups are reported at the 0.05*, 0.01**, 0.001*** level.

RESULTS

Performance

To correct for the observed positive skew in the response time data, which is common to response time distributions (Kirby & Becker, 1988), the response speed data \((x + 1)\) were transformed by log base 10 prior to analysis.* This transformation was applied to the other performance measures, as it most consistently resulted in normality and homogeneity of variance for unequal number of observations across the cells (group × grade level × session). Grade level was used as a covariate in the overall analysis, even though the groups did not differ in grade placement or age, due to the spread of grades. Using a Multivariate Analysis of Covariance (MANCOVA) and the Wilk's criterion for the nonrepeated factor of group (H, H-A, and comparisons) and the 2 repeated sessions factor, an assessment was made of log problem response-times and the spread of these scores (i.e., SD of the individual mean scores), log percent correct and numerical/nonnumerical errors, and the number of problems attempted for each of the four tasks (MANCOVA per 6 variables per task). Equality of regression slopes of the age covariate was assessed in a group by session interaction. Homogeneity of regression slopes was yielded for each computation (addition, subtraction, multiplication) to indicate the appropriateness of the covariate analysis for these data.

MANCOVA was selected as the appropriate control for the overall alpha level (Bray & Maxwell, 1982), and the SAS GLM procedure was selected to correct for unequal number of subjects per group.† Orthogonal planned contrasts were specified as (a) the comparison group versus both hyperactive groups (H/H-A) and (b) a disorder contrast (H vs H-A). As indicated by Keppel (1982, pp. 146–147) the number of planned comparisons was restricted to 1 less than the number of groups and evaluated at the standard level of significance.

*The data were transformed by log base 10, instead of selecting the procedure that more severely alters the nature of the data by cutting off response times over 10 sec (Hasselbring et al., 1988; Woods et al., 1975) or over 16 sec (Ackerman et al., 1986).

†Number of Ss per group was not altered by randomly dropping Ss because Tabacknick and Fidell (1989, p. 47) have stated: "In nonexperimental work, unequal n often results from the nature of the population. Differences in sample size reflect true differences in nature. To artificially equalize the n's is to distort the differences and lose generality."
The MANCOVA analysis yielded a main effect of group for the log mean response times \( F(8, 330) = 3.57, P < 0.0005 \) and for the log mean SD scores \( F(8, 326) = 4.91, P < 0.0001 \). Planned contrasts yielded differences between the hyperactive and comparison children on all four tasks for response times and SD scores (see Table 2). These findings indicated that the spread of scores was greater and the response times were slower for children with hyperactivity for each task (including typing numbers) than it was for their classmates. Also, addition scores for both measures differentiated between youth with hyperactivity and with mixed disorders of H-A (see Table 2). The largest variability and longest times were observed for the group with H-A.

A supplementary analysis was conducted with typing-response time a second covariate (i.e. to partial out from the analysis the slower typing-response speeds of the hyperactive children). Equality of regression slopes of the typing and age covariates was assessed in a group by session interaction. Homogeneity of regression slopes was yielded for each computation. Even with these adjusted scores, response time differences remained for addition facts (comparison versus hyperactive groups and the inter-disorder contrasts). When the data for the second graders were removed from the analysis (i.e. floor effects due to second graders lack of exposure to multiplication and the difficulty they had with the negative number concept in the subtraction problems), control versus experimental group differences in response speed scores were also observed for the subtraction and multiplication tasks. Although visual motor response times were significant in each analysis, processing speed differences among groups remained.

In addition to these differences in computational speed, the microcomputer tasks did assess accuracy group differences. The MANCOVA yielded differences among hyperactive and comparison groups for log percent error (the number of incorrect numerical answers divided by the number of problems attempted) \( F(8, 332) = 3.29, P < 0.001 \). Planned contrasts documented group differences in percent errors between hyperactive and comparison groups in the specific operations of subtraction and multiplication (see Table 2 and Fig. 1). These two operations were more difficult than addition \((M = 9.55\%\) errors). Multiplication was the most advanced computation \((M = 14.13\%\) errors); subtraction included answers with negative numbers* \((M = 20.42\%\) errors). For this reason, these error data were sufficiently sensitive. The greater percent of errors for the youth with hyperactivity may be related to the fewer problems attempted by these children, as assessed by the MANCOVA analysis on all four tasks \( F(8, 332) = 1.99, P < 0.047 \) see Fig. 1.

Across all tasks, log number of typographical (nonnumeric) errors also differentiated among the hyperactive and comparison groups \( F(4, 166) = 2.62, P < 0.05 \). Also in the MANCOVA analysis was an effect of session \( F(4, 166) = 6.94, P < 0.0001 \). Specifically typographical errors increased from session 1 to 2 in the copying task \[M_1 = 0.51, M_2 = 0.74, F(1, 169) = 21.05, P < 0.001\] and in the addition task \[M_1 = 0.56, M_2 = 0.74, F(1, 169) = 4.46, P < 0.05\]. That errors increased with each successive presentation of these easier tasks typically indicates that they required sustained attention.

### Collateral behavior

MANCOVA analyses were conducted per type of behavior repeatedly assessed across the four tasks. We did not analyze different behavior per task, as we had for performance, because it was possible that some types of behavior would be greater for youth with hyperactivity (torso/bottom) and some would be less (e.g. noise/vocalization might have been task relevant, and leg swinging has not previously differentiated between groups). We did use the same design, tests, and transformations as described for the performance data.

Even with the transformations, the behavioral data were not normally distributed. For this reason, supplementary Wilcoxon Ranks nonparametric analyses were performed for the effects of group. The MANCOVA yielded an overall effect of group for log torso/bottom movement durations \( F(8, 264) = 2.87, P < 0.01 \) across the four tasks. Planned contrasts yielded shorter durations of movement for comparisons than for children with hyperactivity during each task (see

*It may have been possible to analyze subtraction problems with negative numbers separately from those with positive numbers. Nevertheless, carryover effects from negative to positive number problems would have made actual distinctions between types of problems impossible. Furthermore, prior work with only positive answer subtraction problems and older youth yielded equivalent findings (Zentall, 1990).
Additionally, we found that children with hyperactivity and coexisting aggression moved for longer durations during copying numbers and multiplication than did their peers without aggression. The nonparametric procedure replicated the main effects of group for all four tasks. Thus, comparable conclusions can be drawn from the parametric and nonparametric analyses.

MANCOVA analysis of leg swinging produced no significant difference or trend. Trends were observed in the MANCOVA analysis for group differences in head durations (off task) \( F(8, 264) = 1.86, P = 0.066 \) and for noise/vocalization \( F(8, 264) = 1.78, P = 0.083 \). Planned contrasts yielded hyperactive vs comparison group differences for these two types of behavior during addition, subtraction and multiplication (see Table 3).

Fig. 1. Least squared means of percent of correct answers for subtraction and multiplication tasks (top graph) and of numbers of problems attempted for copying, addition, subtraction, and multiplication tasks (bottom graph).
Table 3. Univariate analyses and planned contrasts for the log behavior duration group differences

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Task</th>
<th>F(2,141)</th>
<th>C</th>
<th>H</th>
<th>H-A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<tr>
<td>Head duration</td>
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<tr>
<td>Vocalization</td>
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<td></td>
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</table>

*p < 0.05 level.

DISCUSSION

Predictions of this study were that children in general education classes with characteristics of hyperactivity and attentional disorder would demonstrate slower computational speed than their classmates. We predicted slower speed as a cumulative effect of having avoided repeated exposure to similar stimuli and tasks. It was further hypothesized that children with hyperactivity and additional aggressive characteristics would demonstrate poorer performance than children with hyperactivity but without aggression, due to the greater attentional problems documented for these children. Prior work in this area with youth demonstrating attention deficit disorder, learning disabilities, and reading disabilities indicated that response-speed differences among groups existed, while controlling for cognitive skill differences. In the present study we considered it important to also determine whether slower copying (visual-motor speed) or behavior could explain the slow speed of math facts.

Although there are several limitations of this study (e.g. a relatively small number of Ss for the between disorder-group comparisons, and lack of data on socioeconomic status), our findings were that youth with hyperactivity and attentional disorder were slower, their response times more variable, and they attempted fewer problems in all four tasks. The fewer number of problems attempted by the children with hyperactivity could be attributed to a combination of more off-task attention, slower fact response times, and slower typing (visual-motor speed). In general, it may be factors such as these that contribute to the observed failure of these children to complete classroom tasks. Additionally, youth with hyperactivity demonstrated a greater percent of errors—but only with the difficult multiplication and subtraction facts with negative numbers. Thus, accuracy is sufficiently sensitive for younger elementary aged children but only for the more difficult operations, whereas speed is sensitive across the age span and type of operation.

Specific behavioral differences between the disordered/nondisordered groups, which were supported by a significant MANCOVA, were longer durations of general activity (torso-bottom movements) in each of the four tasks. These observational data are consistent with objective assessments, using acceleration-sensitive devices, documenting greater activity for youth with hyperactivity than comparisons during math classes (Porrino, Rapoport, Behar, Sceery, Ismond & Bunney, 1983). Visual-motor deficits were also demonstrated for both hyperactive groups by slower motor-response speed (copying numbers) and more typographical errors (summed across the copying and operation tasks). This replicates visual-motor control and speed deficits previously reported for these children. As a test of the independence of computational speed, we partialed
motor-response times out of the overall analysis, and group effects of computational speed remained.

In this study, children with both hyperactivity and aggression moved for longer durations than youth with only hyperactivity during copying and multiplication tasks. This finding supports prior observations of greater activity for youth with mixed disorder than with only hyperactivity (Loney & Milich, 1982; Madan-Swain & Zentall, 1990). Additional disorder-comparison findings were that youth with hyperactivity and aggression exhibited slower fact response times during the performance of addition facts than children with hyperactivity but without aggression—even while partialling out visual-motor speed. Because this performance finding is specific, it indicates this is not simply a question of overall disorder severity across measures. Furthermore, this finding is not related to task difficulty, because addition facts produced the smallest percent-of-error scores. Easy tasks, such as addition, may rely on retrieval of previously stored answers, whereas multiplication and subtraction with negative numbers may require more effortful processing. Our finding with addition facts is of particular interest because response speed of addition facts (while controlling for cognitive ability) similarly was the only performance measure that differentiated between two related disorders of seventh and eighth grade youth with LD as distinct from youth with ADD (Zentall, 1990).

Slower addition-speed scores may be a marker of the poorer additional and academic performance of the youth with mixed hyperactivity and aggression. Validation in this study is also provided by the teachers, who rated mixed disorder children as demonstrating poorer academic functioning than the children with only hyperactivity. Based on the present findings and on prior findings with more severely disordered youth with learning disabilities (two thirds of whom had attentional disorders), we propose that slowed response speed of addition facts may be a better measure than many laboratory tasks or normative tests. Thus, the overall importance of this assessment is related to the potential sensitivity of math fluency data for assessment and treatment monitoring.

Response-speed is a sensitive enough measure to assess group differences even when more basic differences often exist among groups, such as IQ (Werry, Elkind & Reeves, 1987). Tasks that are sensitive may be those where performance has reached asymptote. Simple math computations require speeded processing and elicit slow and sometimes inaccurate performance. This differs from tasks that require slow, careful performance and delayed responding and that elicit inaccurate and fast (impulsive) responding for youth with ADHD (see Zentall, in press).

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REFERENCES


Shaffer, D., McNamara, N. & Pincus, J. (1974). Controlled observations on patterns of activity, attention and impulsivity in brain damaged and psychically disturbed boys. Psychological Medicine, 4, 4-18.


