COMPUTERIZED VS. CONVENTIONAL REMEDIAL INSTRUCTION FOR LEARNING-DISABLED PUPILS[1]

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Recent advances in microelectronics and computer software have rekindled enthusiasm for applications of computer-assisted instruction (CAI) The more salient features of CAI are highly compatible with the major instructional and curricular principles recommended for learning-disabled children. To assess the relative effectiveness of computerized over conventional remedial methods with handicapped learners, 205 learning-disabled first- through sixth-grade children were assigned to either a mathematics CAI or spelling CAI treatment group or to a conventional-instruction control group. After 1 school year, posttest achievement indices were gathered through individually administered and group-administered standardized tests. Posttest performance was covaried for initial group differences in pretest achievement, IQ, and time in remedial instruction. Separate repeated-measures analyses for individually assessed and group-assessed achievement indicated that gains for the 3 groups were essentially equivalent It was found that certain popular achievement measures may be insensitive to achievement gains in the learning disabled

Educational applications of computer technology have spanned well over 2 decades. Early computer-assisted instruction (CAI) was delivered on large, centrally located, mainframe computers. High cost, low reliability, and lack of convincing evidence regarding effectiveness resulted in a general lack of acceptance by the educational community. The situation remained static until recently when technological advances in microelectronics produced small, powerful, and relatively inexpensive microcomputers. The advent of microcomputers has fueled an explosive growth in educational computer usage. Chambers and Bork (Note 1) reported that 90% of American school districts currently use computers and projected that CAI will, by 1985, be used by more districts than any other type of computer application.

The expansion of computers into American education has been relatively unguided. Articles and news releases dealing with CAI have often been based upon speculation and conjecture rather than upon sound empirical evidence (Atkinson, 1968). The accumulated data of 10 CAI studies led Visonhaler and Bass (1972) to

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conclude that "in the controlled studies applying drill and practice to language arts and mathematics, there appears to be rather strong evidence for the effectiveness of CAI over traditional instruction where effectiveness is measured by standardized achievement tests" (p. 30). Jamison, Suppes, and Wells (1974) reviewed a wider range of CAI research and concluded that "at the elementary-school level, CAI is apparently effective as a supplement to regular instruction" (p. 55). Edwards, Norton, Taylor, Weiss, and Dusseldorp (1975) found that CAI used to supplement regular instruction was uniformly effective, but results were equivocal when CAI was a substitute for traditional instruction. Thus, the evidence regarding CAI with nonhandicapped students is positive, but not overwhelmingly so.

The use of CAI with handicapped children has been neglected, with application to hearing-impaired children receiving the most attention. After 2 years of research that involved 3,000 hearing-impaired children, Suppes, Fletcher, Zanotti, Lorion, and Searle (1973) noted that CAI led to substantial increases in mathematical computation skills. Mentally handicapped children have received CAI in several settings but evaluative efforts have been deficient in both internal and external validity (e.g., see Hallworth, & Brebner, 1978; Nelon, 1972; Vitello & Bruce, 1977). A review of the literature (Winters, Hoats, & East, Note 2) revealed only one study that employed an experimental design to determine the efficiency of CAI where mentally handicapped children were compared with non-CAI and nonhandicapped children.

Investigations of CAI with learning-disabled children are the rarest. Chiang (1978) compared matched groups of learning-disabled students in order to test the effectiveness of CAI in mathematics and reading. Significant differences in favor of the CAI treatment resulted in both achievement areas with junior high school students but not with elementary school students. More recently, however, Sandals (Note 3) reported the results of a study that provided CAI in arithmetic and spelling to junior high school students with a "wide variety of learning disorders." When compared with non-CAI students, no significant posttest differences were detected.

The paucity of sound CAI research with learning-disabled pupils is unfortunate, since the attributes of CAI closely parallel teaching techniques recommended by experts in special education (i.e., Gearheart, 1976; Wallace & McLaughlin, 1979; Wiederholt, Hammill, & Brown, 1979). Vitello and Bruce (1977), Caldwell and Rizza (1979), and Watkins (1981) have enumerated some of these attributes: (a) frequent and immediate feedback, (b) individualized pacing and programming, (c) modularized and hierarchical curriculum, (d) outcomes stated as performance objectives, (e) a mastery learning paradigm, (f) clarity of presentation, (g) motivation, (h) a multisensory learning format, and (i) personalized instruction. The present study was designed to fill partially the evidential lacuna by testing the effectiveness of well-designed mathematics and spelling CAI with learning-disabled pupils at the elementary school level.

METHOD

Subjects

Children participating in this study comprised the entire population of 250 learning-disabled students initially enrolled in elementary grades 1 through 6 of a suburban Southwestern school district. All participants were diagnosed as learning disabled by school psychologists, teachers, and other educational specialists in accordance with state and federal guidelines. Basically, identification as learning disabled required evidence of a child's normal (as opposed to retarded) general intellectual ability associated with a significant discrepancy between the expected level of academic performance (as determined through individually administered intelligence tests) and actual levels of achievement in major areas of academic endeavor (as reflected in individual and group achievement-test indices).

For the study's final sample, Full Scale IQs for the Wechsler Intelligence Scale for Children-Revised (WISC-R) ranged from 72 to 126 with a mean of 93. Expected vs. actual performance discrepancies were evidenced by average differences between WISC-R predicted and Wide Range Achievement Test (WRAT) obtained standard scores > one standard error of estimate (see Thorndike & Hagen, 1977, for further details on regression criteria in assessment of academic underachievement). In addition, discrepancies between expected and observed performance could not be secondary to a child's mental retardation, emotional disturbance, cultural deprivation, or sensory or communication handicap.

Eight special education teachers from two of the district's seven elementary school volunteered to conduct the CAI portion of the project. Thus the 96 learning-disabled students attending those schools were randomly assigned to either a Mathematics CAI or Spelling CAI experimental group. The district's remaining 154 learning-disabled students, assigned to 19 other special teachers in five schools, served as a pool for a control condition receiving Conventional Instruction in remedial mathematics and spelling.

Instrumentation and procedure

Prior to implementing instructional activities, students' mathematical and spelling skills were evaluated using the arithmetic and spelling tests of the WRAT and mathematical-computation and spelling subtests of the California Achievement Test (CAT), levels 11 to 16 (CTB, 1979). Children's levels of intellectual functioning were based upon IQs from the most recently administered WISC-R (with none dated earlier than 1 year preceding the instructional program). Between the time of such pretest assessments in August 1980 and subsequent posttest assessments in June 1981, the original 250 student subject pool was reduced to family relocations, interdistrict transfers, and continuous absenteeism. Table 1 displays demography and obtained IQs for the final sample ($N = 205$) consisting of 38 Mathematics CAI students, 41 Spelling CAI students, and 126 Conventional Instruction students.

The experimental instruction was provided individually to pupils through multilevel-multifunctional microcomputer programs covering the range from fundamental to advanced elementary mathematics and word-spelling skills. The programs, known respectively as The Math Machine and The Spelling Machine (Watkins, Johnson, & Bloom, 1981a, 1981b), were specially tailored for and delivered through Apple II microcomputers. Teachers carrying out the CAI segments of the project received comprehensive inservice training on the uses of microcomputer hardware and software and possible applications of CAI with learning-disabled children. Moreover, the students' approved individual educational plans specified teachers' objectives in adopting computerized vs. conventional mathematics or spelling instruction.

TABLE 1
DEMOGRAPHY AND INTELLECTUAL FUNCTIONING LEVEL FOR 205 LEARNING-DISABLED STUDENTS BY INSTRUCTIONAL METHOD

Variable		Method of instruction: Mathematics CAI (*n* = 38)	Spelling CAI (*n* = 41)	Conventional (*n* = 126)	Total (*N* = 205)
Sex	Male	27	31	84	142
	Female	11	10	42	63
Age	*M*	10.08	10 17	9.90	9.98
	SD	1.60	1.18	1.45	1.43
Race	White	35	37	123	195
	Nonwhite	3	4	3	10
Full Scale IQ	*M*	93.92	91.76	93.13	93.00
	SD	10.36	10.79	13.36	12.33
Verbal IQ	*M*	91.66	90.39	91.40	91 25
	SD	11.39	10.73	14.57	13.28
Performance IQ	*M*	97.42	95.78	96.18	96.33
	SD	10.74	12.96	15.40	14.12

The experimental and control instructional programs proceeded from September 1980 through May 1981. A program clerk maintained records of student time in CAI or Conventional Instruction. Time was measured in *day* units corresponding to the amount of instructional time devoted to mathematics or spelling during the average school day. The instructional program was terminated for each student following an average of 139.02 days, with mean days for the Mathematics CAI group being 140.53 (*SD* = 28.43), mean days for the Spelling CAI group being 138.10 (*SD* = 29.01), and mean days for the Conventional Instruction group being 138.87 (*SD* = 17.06).

Data analysis

The experimental format constituted a pretest–posttest nonequivalent control-group design in which the Spelling CAI group functioned as a placebo contrast for the Mathematics CAI group, and vice versa for the Mathematics CAI group, and in which two types of criterion measures were taken: i.e., individually assessed achievement in mathematics and spelling, and group-assessed achievement in those same subject areas. Data were analyzed in several ways (as recommended by Cook & Campbell, 1979, and Greenwald, 1976) including independent analyses of covariance on posttest-achievement raw scores and repeated-measures analyses of covariance using standard-score achievement indices. Since the respective results were nearly identical, treatment of only standard-score measures is reported here. Finally, *t* tests for correlated means were applied to evaluate overall pretest-posttest achievement gains (as per Reynolds & Gentile, 1978).

RESULTS

Separate analyses were performed on the individually assessed WRAT posttest standard scores and CAT posttest normal-curve equivalent scores. Each analysis comprised a two-way ANCOVA, with the first factor having three levels corresponding to the three methods of instruction; the second factor held as a within-students effect with two levels representing the mathematics and spelling criteria, respectively; and posttest scores covaried for initial group differences in days of instruction, WISC-R Full Scale IQs, and pretest criterion performance. Therefore, for each analysis, the desired effect (should the CAI procedures excel) would be reflected by a significant method of instruction × subject area (MI × SA) interaction, with Mathematics CAI students excelling on the mathematics criterion, Spelling CAI students on the spelling criterion, and both groups outperforming the Conventional Instruction group.

Table 2 presents the ANCOVA summary analysis for WRAT achievement and Table 3 for CAT achievement. In neither case does a significant MI × SA interaction effect emerge, thus lending no support to the greater effectiveness of CAI over regular remedial instruction. For both individual and group methods of measuring achievement, a significant effect was discovered for the repeated measure. This simply indicates that standardized posttest scores for all students in aggregate were better in individually assessed spelling ($p < .05$) and group-assessed mathematics ($p < .01$).

Posttest differences in WRAT achievement were attributed largely to initial pretest differences where the pooled regression coefficient between pretest and posttest scores was .72 ($p < .001$), as compared with regression coefficients for days of instruction ($r = .01$) and IQ ($r = .02$). This makes sense in view of the fact that the overall pretest–posttest differences in WRAT achievement scores were minimal (*M* gain = 2.06 points) and statistically insignificant; it suggests that the item pool on the WRAT is perhaps too small and differential difficulty between items too great to detect increments (across 1 academic year) within samples of learning-impaired youngsters.

TABLE 2
MULTIPLE COVARIANCE ANALYSIS OF INDIVIDUALLY ASSESSED ACHIEVEMENT (WRAT) VIA COMPUTERIZED AND CONVENTIONAL INSTRUCTION

Source	*df*	*MS*	*F*	β
Between students				
Method of Instruction (MI)	2	29.61	.38	
Days of Instruction covariate	1	17.58	.22	.01
IQ covariate	1	10.94	.14	01
Mathematics Pretest covariate	1	18105.74	229.30**	.77
All covariates	3	6470.50	81.95**	
Students within groups	199	78.96		
Within students				
Subject Area (SA)	1	188.25	5.89*	
MI × SA	2	55.15	1.73	
Spelling Pretest covariate	1	5182.09	162.27**	.66
Repeated measure × students within groups	201	31.93		

Note $N = 205$
*$p < .05$.
**$p < .001$

TABLE 3
MULTIPLE COVARIANCE ANALYSIS OF GROUP-ASSESSED ACHIEVEMENT (CAT) VIA COMPUTERIZED AND CONVENTIONAL INSTRUCTION

Source	*df*	*MS*	*F*	*β*
Between students				
Method of Instruction (MI)	2	96.40	36	
Days of Instruction covariate	1	3067.89	11.39*	.18
IQ covariate	1	619.44	2.30	.05
Mathematics Pretest covariate	1	15957.44	59.22***	49
All covariates	3	7029.32	26.09***	
Students within groups	199	269.44		
Within students				
Subject Area (SA)	1	1690.00	8.82**	
MI × SA	2	103.88	.54	
Spelling Pretest covariate	1	4241.18	22.13***	.38
Repeated measure × students within groups	201	191.62		

Note. $N = 205$.
*$p < .05$.
**$p <$ 01.
***$p < .001$.

In contrast, tests for overall pretest-posttest differences in CAT performance revealed significant improvement for the combined instructional groups in mathematics (i.e., M gain = 7.31 points, $t = 6.14$, $df = 204$, $p < .001$) and spelling (M gain = 4.22 points, $t = 3.36$, $df = 204$, $p < .001$). Whereas the welter of CAT posttest differences are attributed primarily to pretest performance (pooled $r = .44$, $p < .001$), the contribution of the days of instruction covariate was significant as well ($r = .13$, $p < .01$), with IQ continuing to have no demonstrable effects ($r = .09$). This finding, in company with the more discernible CAT pretest–posttest increments, may suggest the greater sensitivity of the group-administered method to changes in achievement over the school year.

DISCUSSION

Although methodologically flawed, earlier research (Chiang, 1978; Sandals, Note 3) has indicated that CAI holds no clear advantage over traditional remedial instruction for elementary and junior high level children who are learning impaired. The present findings confirm this general conclusion and, at once, generate alternative hypotheses. The work by Edwards et al. (1975) with "normal" learners suggests that when CAI is used as a supplement to rather than a replacement for traditional teaching, levels of summative criterion achievement are consistently higher than for either instructional method of isolation. It is possible that combinations of computerized and conventional remedial instruction may work as well with problem learners and that success will vary as a function of the severity of the learning disorders and differential styles of learning.

CONCLUSIONS

When using standardized indices of performance in elementary mathematics and spelling, the effectiveness of computerized and conventional instruction with learning-disabled children appears equivalent. This would seem to suggest that the two methods may be substituted for one another as instructional procedures. Assuming similar degrees of effectiveness and efficiency, it might be reasonable (a) to assign such pupils to CAI programs whenever it appears that this will reduce the motivational deficits and resistance so often detected among problem learners, and (b) to recommend special teacher-instructed programs whenever affiliative needs and social conditioning are deemed priorities.

Future research is best directed to test the efficacy of various combinations of computerized and conventional remedial instruction with learning-impaired children and to relate the results to the severity and duration of impairment, motivation levels, learning styles, and other pertinent characteristics. Researchers should be careful to select criterion measures that are adequately sensitive to achievement gains in handicapped learners.

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