

ADJUNCTIVE ROLE FOR IMMEDIATE FEEDBACK IN THE
ACQUISITION AND RETENTION OF MATHEMATICAL
FACT SERIES BY ELEMENTARY SCHOOL STUDENTS
CLASSIFIED WITH MILD MENTAL RETARDATION

ROBERTA E. DIHOFF
Rowan University

GARY M. BROSVIC, MICHAEL L. EPSTEIN, and MICHAEL J. COOK
Rider University

The effects of feedback on the acquisition and retention of mathematical fact series by elementary school students classified with mild mental retardation was examined in 4 studies. Immediate feedback was provided by either an educator or the Immediate Feedback Assessment Technique (IF AT), at the end of a test series by a review of correct solutions (delayed feedback), or for control purposes, with a Scantron form. Reductions in errors and inaccurate perseverative responding during intervention periods were higher, and the repetition of errors during maintenance test was lower, when feedback was provided by an educator in Study 1. These results were replicated and extended in Study 2 to the operation of subtraction. In Study 3, the concurrent presentation of both forms of immediate feedback was more effective than the presentation of either form separately. In Study 4, the adjunctive value of the IF AT to facilitate the teaching-learning process was established, with higher levels of independent learning and retention demonstrated when the IF AT was available. The IF AT, as a simple paper and pencil tool, can assist the educator through the provision of individualized performance feedback and the encouraging of students to continue responding while simultaneously promoting independent learning.

The past 20 years have witnessed considerable changes in educational policies and practices related to instruction of students with learning difficulties (Hitchcock & Noonan, 2000). The number of students with learning difficulties educated in regular classrooms increases annually, presenting new challenges to educators and prompting development of new methods of classroom instruction (Parker & Schuster, 2002). The design of instructional strategies for children with learning difficulties requires an effective set of teaching procedures (Noonan & McCormick, 1993), with most studies typically examining the effects of classwide peer tutoring (CWPT), constant time delay (CTD), and computer-assisted instruction (CAI) on a number of learning outcomes.

Address correspondence to Gary M. Brosvic, Department of Psychology, Rider University, Lawrenceville, New Jersey 08648. (E-mail: Brosvic@Rider.edu).

A central ingredient of CWPT, CDT, and CAI is the provision of immediate corrective feedback. There is little disagreement that feedback is an effective method for enhancing learning, but there has been relatively little agreement about the timing of its presentation (Bruning, Schraw, & Ronning, 1999; Robin, 1978). Kulik and Kulik (1988) reported that immediate feedback is more effective than delayed feedback for applied, but not laboratory, studies. Corrective feedback on objective examinations completed in the classroom, in the absence of computers, cannot be provided until the examination has been completed. In comparison, the conditions and equipment within the laboratory permit the immediate delivery of corrective feedback on an item-by-item basis. Until recently, the simple and practical means through which immediate feedback might be provided in the classroom in the absence of computers has not been available. In recent studies conducted in our laboratory, we have developed and validated a classroom assessment technique through which individualized performance feedback is coupled with the opportunity to answer until correct using simple paper and pencil media (Dihoff, Brosvic, & Epstein, 2003; Epstein, Brosvic, Dihoff, Lazarus, & Costner, 2003; Epstein, Epstein, & Brosvic, 2001; Epstein et al., 2002).

The tool that has been refined and validated in our classrooms and laboratories is the Immediate Feedback Assessment Technique, or IF AT, which manifests the theoretical and practical foundations of the teaching-testing machines described by Pressey (1950) and Skinner (1968), transforming the passive receiver of information into the active demonstrator of skills and knowledge. The IF AT form (see Figure 1) is a multiple-choice answer sheet with rows of rectangular answer spaces (e.g., A, B, C, D) that is nearly identical in layout to the ubiquitous machine-scored answer sheet available from Scantron Corporation. Participants scrape off an opaque, waxy coating covering an answer space on the IF AT form to record their answer. If a symbol (e.g., a star) is printed beneath the covering, the student receives instant feedback that a correct choice was made; the absence of a symbol provides instant feedback that an incorrect choice was made. However, rather than simply exiting the question, the student reviews the remaining response options, continues to respond until the correct answer is discovered (a self-correction procedure), and thus exits each question knowing the correct answer.

The effectiveness of the IF AT has been demonstrated in a number of studies conducted in our classrooms and laboratories, with enhancements in student performance observed during cumulative assessments (Epstein et al., 2002, 2003). In these studies, the provision of corrective information during classroom and laboratory tests reduced the likelihood of incorrect perseverative responding on subsequent item administrations presented in their original or with a modified wording (Dihoff et al., 2004). The correction of initially inaccurate responses was maintained across retention intervals of 2 to 10 weeks and across populations ranging from preschool children with developmental delays (Epstein et al., 2002) to university students preparing for classroom examinations (Dihoff et al., 2004). Similar gains were not

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2	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
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9	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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Figure 1. Sample portion of the Immediate Feedback Assessment Technique (IF AT) form. Patent is held by E3 Corporation.

observed when responses were recorded with Scantron forms, and only intermediate gains were observed when feedback was provided either after the completion of a test or after a 24-hour delay (Dihoff et al., 2003). Students without known learning difficulties (elementary school students through college students) reported that immediate feedback and the opportunity to respond until correct provided realistic assessments of performance, more involvement in the testing process, and the opportunity to exit an item with the correct solution. Students with diagnosed learning difficulties reported that immediate feedback enhanced the acquisition of basic academic materials (e.g., colors, shapes), enhanced rote

memorization once a concept and the function of that concept were grasped (e.g., learning multiplication skills in discrete units), and that the answer-until-correct procedure enabled the completion of each test item as a discrete unit that could be resolved before approaching the next test item.

Among the most common advantages of the IF AT reported by educators with special needs children in their classrooms and resource rooms was that the IF AT not only provided feedback, but that the answer-until-correct procedure prompted students to continue to respond until the correct solution was attained. This latter advantage was not achieved when feedback was provided by an educator, as students required continuous prompting to maintain responding. When the IF AT was used, feedback coupled to the opportunity to answer-until-correct could be provided to an entire class, whereas an educator could provide this combination to only one student at a time, which suggests a tremendous potential for the IF AT as an adjunctive tool with special-needs learners under appropriate classroom conditions. For example, the IF AT would not be effective for teaching concepts and their applications and functions, but it would be highly effective for assisting learners during rote memorization drills, such as those used while rehearsing mathematical fact series. The concept and function of an arithmetic operation, in keeping with NCTM 2000 principles and standards (National Council of Teachers of Mathematics, 2000), must be presented by an educator. However, the encouragement of active learning, the provision of immediate feedback, and the use of an answer-until-correct procedure that maximizes time on task, are three cardinal principles of pedagogy (Rickey, 1995), and they are easily employed with the IF AT.

The present studies were undertaken to determine how immediate feedback and the opportunity to answer until correct could assist the learning of students classified with mild mental retardation. Each child had participated in early intervention and preschool intervention services, repeated at least one grade, received the majority of instruction in regular classrooms, and presented considerable learning difficulties in the area of mathematics. A review of each student's mathematics examinations indicated high rates of inaccurate perseverative responding, while observation of their learning environments indicated that each student required high rates of verbal prompting to maintain responding. These learning difficulties and classroom behaviors suggested the opportunity to evaluate the adjunctive potential of the IF AT. The four studies described below included more participants than reported in prior studies employing single-subject procedures, and all teaching and testing occurred within the regular classrooms and resource rooms in which the students received instruction.

Study 1 compared the effects of immediate feedback provided by an educator with immediate feedback provided by the IF AT, delayed feedback, and the absence of feedback on the acquisition of an arithmetic fact series. Study 2 compared the effects of immediate feedback, provided by either an educator or the IF AT, separately, on the acquisition

of a fact series for addition, subtraction, division, and multiplication. Study 3 compared the interactive effects of immediate feedback, provided by an educator and the IF AT, on the acquisition of fact series for the operations of addition, subtraction, division, and multiplication. Study 4 examined the adjunctive utility of the IF AT during the teaching process.

Study 1 Analysis of the Effects of Timing of Feedback on the Acquisition of a Multiplicand

Method

Participants. Twelve male and four female students meeting the criteria for the diagnosis of mild mental retardation (AAMR, 2002) and enrolled in an urban public elementary school served as voluntary subjects. The representative student was either an African-American or a Caucasian male, of lower socioeconomic status (United States Department of Health and Human Services, 2002), 10.5 years of age, had participated in early intervention and preschool intervention services, currently enrolled in second grade after repeating at least one academic year, and received the majority of instruction in regular classrooms. Three students were being treated for mild seizure disorders, two were being treated with antidepressants, and one was classified with Down syndrome. The median score on the WISC-III was 66 (range: 59 to 69) and the median developmental standing on the Vineland Adaptive Behavior Scale (Sparrow, Balla, & Cicchetti, 1984) was 7.1 years (range: 6.05 to 8.9).

Materials. Multiplicands of four served as the test stimuli. Materials included 3- x 5-inch index cards for the presentation of multiplicands, with four solutions (marked A, B, C, D) presented in multiple-choice format. For each member of the fact series there was one card (e.g., 4×0) and four solutions from which to select. The solutions were presented in multiple-choice format (e.g., A = 4, B = 8, C = 2, D = 0), with the solutions for each member of the fact series printed on separate sheets of paper. Responses were recorded on either Scantron answer sheets using a pencil to darken the appropriate circle or the Immediate Feedback Assessment Technique form (E3 Corporation).

Design and procedure. Thirty test sessions were completed by each participant, with five sessions completed daily during the baseline and the intervention periods; during the maintenance period, only one session was completed per day on each of five consecutive days. Each test session consisted of the presentation of 10 single-digit multiplication facts with a multiplier of 4 (i.e., 4×0 through 4×9), each time in a random order. After completion of the baseline period, 1 female and 3 male participants were randomly assigned to complete the intervention period using one of four feedback procedures. Participants in the four feedback conditions were matched for scores on the WISC-III, the Vineland Adaptive Behavior Scale, and overall classroom performance (e.g., grades in mathematics, overall class grades, participation, and

attendance). The participants reviewed the multiplicands of one through three, received instruction on the concept and function of the multiplicand of four, and then transitioned to resource rooms for experimental participation; all participants were taught by the same educator. Answers in the control condition were recorded with a pencil on a Scantron form. Answers in the end-of-test-feedback condition were recorded on a Scantron form, but after the completion of the test session, all pencils were removed and the participants were permitted to review the multiplicand series, the correct solutions, and their original answers for 10 minutes; these participants could review their work, but could neither discuss it with other participants nor ask questions about their solutions. Participants in the other conditions remained seated during this time and worked quietly on non-course materials under educator supervision. Participants in the immediate feedback condition scraped off the opaque, waxy coating covering an answer space on the IF AT form to record each answer. If a symbol (e.g., a star) was printed beneath the covering the student received instant feedback that a correct choice was made; the absence of a symbol provided instant feedback that an incorrect choice had been made. Answers in the educator-feedback condition were recorded on a Scantron form, and verbal feedback was provided by the educator. Correct responses were reinforced with "that is correct, 4 x 1 is 4"; incorrect responses were met with "that is not correct" and a verbal prompt to make an additional response. A maximum of two additional responses was permitted before the correct solution was provided by the educator, and thus the maximum number of responses permitted and the performance information provided in the IF AT and educator-feedback conditions was comparable.

Participants in the four conditions rated confidence in the accuracy of their solutions on a 100-point scale ranging from 1 (no confidence) to 100 (complete confidence) after each response during the baseline, intervention, and maintenance periods. Upon the conclusion of the intervention period, each participant completed a 15-item questionnaire assessing ease of understanding and of completing response requirements, perceived fairness of and preference for an answer-until-correct procedure, and involvement in the test-taking process, as described previously by Epstein and Brosvic (2002).

Results

The results of ANOVAs with feedback condition as the between-subjects factor indicated that scores on the WISC-III and the Vineland scales, as well as on the measures of classroom performance, did not differ, all $F < 1$, all $p > .87$.

Mean errors per session are plotted in Figure 2 as a function of feedback condition and test session. Potential differences in mean errors were analyzed using an ANOVA with feedback condition as the between-subjects factor and test session as the within-subjects factor, with significance observed for each main effect and their interactions, all $F > 21.21$, all $p < .0001$. Scheffe comparisons indicated that errors did not

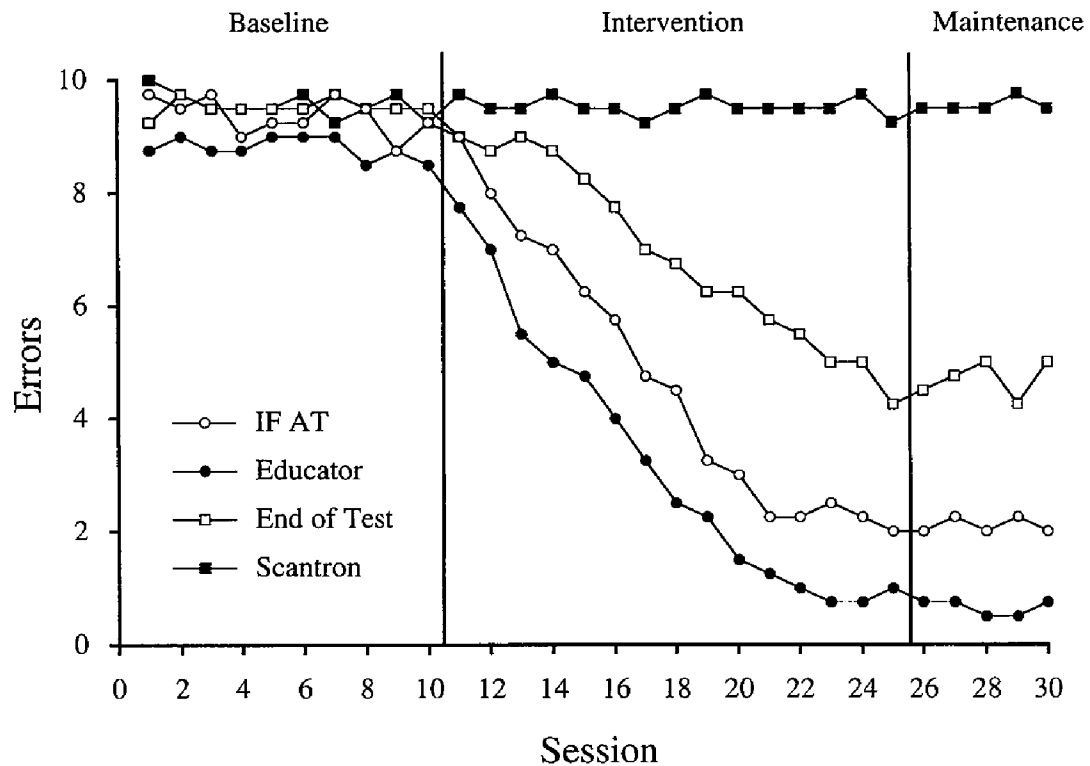


Figure 2. Errors committed across test sessions as a function of feedback condition in Study 1.

differ between the feedback conditions during baseline, and thus the outcomes described below cannot be attributed to preexisting differences in multiplication skills. Scheffe comparisons also indicated that errors were (a) lowest for the educator-feedback condition, (b) lower for the IF AT than for the end-of-test and Scantron conditions, and (c) lower for the end-of-test than for the Scantron condition, all $p < .001$.

Mean confidence ratings are plotted in Figure 3 as a function of feedback condition and test session. Potential differences in confidence ratings were analyzed using an ANOVA with feedback condition as the between-subjects factor and test session as the within-subjects factor, with significance observed for each main effect and their interactions, all $F > 19.02$, all $p < .0001$. Scheffe comparisons indicated that confidence ratings were higher for the (a) educator-feedback and the IF AT conditions than for the end-of-test and Scantron conditions, and (b) the end-of-test than for the Scantron condition, all $p < .001$.

Mean responses on the scales (see Table 1) measuring test anxiety and time requirements did not differ as a function of feedback condition, all $F < 1$, all $p > .5$. Mean responses on the scales measuring satisfaction with response format, clarity of response requirements, the desirability of the response form, and the benefits of testing differed significantly as a function of feedback condition, all $F > 23.78$, all $p < .0001$. Scheffe comparisons indicated that mean scores on these latter four scales were higher when feedback was provided by either an educator or the IF AT than when either end-of-test feedback or a Scantron form was provided, all $p < .001$.

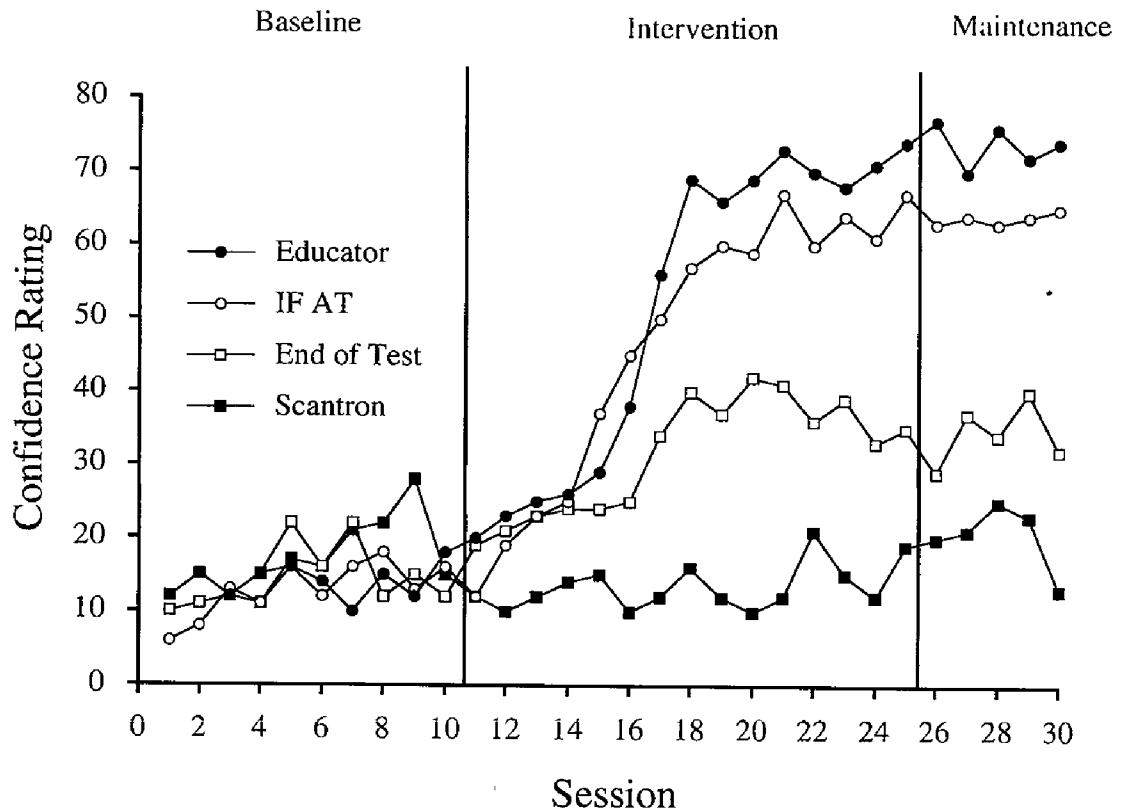


Figure 3. Mean confidence ratings as a function of feedback condition in Study 2.

Table 1

Posttest Measures Assessing Perceptions as a Function of Feedback Condition in Study 1		Educator	IF AT	End of Test	Scantron
Test	<i>M</i>	2.76	2.56	2.99	3.01
Anxiety	<i>SD</i>	0.98	0.87	1.01	0.99
Time		3.44	3.32	3.35	3.39
Requirements		1.55	1.42	1.66	1.23
Satisfaction With		4.35	4.31	2.87	2.66
Response Format		1.91	1.66	1.44	1.26
Clarity of Response		4.65	4.56	2.54	2.67
Requirements		1.64	1.32	1.19	1.23
Benefits of		4.34	4.45	2.56	2.34
Testing		1.14	1.01	1.42	0.87
Desirability of		4.65	4.52	2.23	2.43
Response Format		1.25	1.53	0.78	0.54

Study 2 Effects of Timing of Feedback on the Acquisition of Multiple Mathematical Operations

Rationale: The results of Study 1 indicated that the fewest errors were made when feedback was provided by an educator, and that fewer

