

# Effects of a Strategic Intervention With iPad Practice on the Multiplication Fact Performance of Fifth-Grade Students With Learning Disabilities

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## Abstract

This study investigated the effects of explicit, strategic intervention with iPad application practice on the multiplication fact performance and strategy use of elementary students with learning disabilities (LD) using a single-case, multiple probe design across participants. Four fifth-grade students with LD received 15 1:1 intervention sessions in multiplication facts. Results indicated that all students made significant growth in multiplication fact performance across the study and maintained the intervention gains 2 weeks following the intervention. Overall, students increased their use of a doubling strategy taught during intervention and were able to retrieve facts automatically after intervention sessions. Social validity interview results indicated that participants had positive perspectives about the intervention. Implications for practice and suggestions for future research are discussed.

## Keywords

explicit, strategic instruction, iPads, mathematics, learning disabilities, multiplication facts

The ability to compute basic arithmetic facts fluently is a critical foundation skill for learning more difficult mathematics curriculum, such as fractions, ratios, and algebra (National Governors Association Center for Best Practices & Council of Chief State School Officers [NGA/CCSSO], 2010; National Mathematics Advisory Panel [NMAP], 2008). In addition, the Common Core State Standards for Mathematics (CCSSM; NGA/CCSSO, 2010) highlighted the importance of developing basic fact and computational fluency in the mathematics curriculum. Especially, multiplication is one of the essential domains in the mathematic curriculum for upper elementary grades; it is expected that students possess fluent multiplication computation skills with whole numbers by the end of the fifth grade (NGA/CCSSO, 2010; NMAP, 2008). Thus, fluency with multiplication facts is critical and necessary to foster computation of whole number multiplication problems.

Unfortunately, research findings have shown that students with learning disabilities (LD) often struggle learning arithmetic facts (D. P. Bryant, Bryant, & Hammill, 2000; Geary, 2004; Woodward, 2006). In particular, many students with LD experience difficulties mastering multiplication facts and developing computational fluency compared with the performance of their peers without disabilities. For example, students with LD usually exhibit slow fact retrieval and commit more errors than their typically

achieving peers when solving multiplication facts (Geary, 2011). In addition, these students may be performing developmentally at a lower grade level in computational skills, including fact retrieval, compared with their chronological grade (Shin & Bryant, 2015). Moreover, according to Rotem and Henik (2013), the performance of sixth- and eighth-grade students with LD on multiplication is similar to that of second-grade students without disabilities.

Students with LD tend to use developmentally immature strategies longer than typically achieving students who use more mature strategies (e.g., derived facts:  $5 \times 6 = 5 \times 5 + 5$ ), as they get older, for computing multiplication facts (Geary, 2004; Geary, Hoard, Nugent, & Bailey, 2011; Sherin & Fuson, 2005; Woodward, 2006). For instance, students with LD may use less efficient strategies (e.g., repeated adding:  $4 \times 3 = 4 + 4 + 4$ ) to solve a multiplication problem rather than more efficient strategies (e.g., count-by, derived facts, doubling) to find the product (Sherin & Fuson, 2005; Woodward, 2006). Unfortunately, the use of immature, inefficient strategies contributes to procedural

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delays and difficulties with automatic retrieval of facts (Geary et al., 2011).

Poor multiplication skills of students with LD often hinder the successful development of advanced mathematics skills (e.g., algebra). Poor performance could impact these students' success not only in school but also on measures for entrance into post-secondary education and future job performance (Adelman, 2006; Aunola, Leskinen, Lerkkanen, & Nurmi, 2004; Ritchie & Bates, 2013). Thus, it is imperative to provide effective instruction for supporting improved performance of students with LD on multiplication fact skills. Without effective intervention, students with LD will continue to experience mathematical challenges and frustration (Woodward, 2006) rather than demonstrate mathematics performance that begins to close the achievement gap (D. P. Bryant, Bryant, Powell, Soto-Pacheco, & Hou, 2015).

### Explicit, Strategic Intervention

Explicit instruction and strategy instruction have been consistently recommended as the most effective instructional approaches for teaching various academic skills including mathematics to students with LD (Gersten, Beckmann, et al., 2009; Swanson, Hoskyn, & Lee, 1999). Both classroom teachers and researchers can use these approaches for delivering interventions.

First, research has consistently reported that explicit instruction paired with various scaffolds and supports helps students with LD improve their performance on basic facts, computation, and problem solving skills; this instruction can also help students with LD maintain and generalize the skills (Gersten, Chard, et al., 2009; Swanson et al., 1999). Explicit instruction includes instructional components such as clearly stating goals and expectations, providing cumulative review of previously learned information, activating prerequisite skills/knowledge, and teaching logically sequenced skills (Coyne, Kame'enui, & Carnine, 2011). Other components include following a carefully planned sequence for instruction, using multiple examples, providing multiple opportunities to respond as well as immediate corrective feedback, teaching at an appropriate pace, and monitoring student progress (Archer & Hughes, 2010).

Second, research findings have shown that strategy instruction can be an effective instructional approach to teach mathematics to students with LD who struggle with acquiring and using effective strategies (Montague & Dietz, 2009). According to Swanson (1999), strategy instruction includes the following instructional variables: (a) explicit explanations or verbal descriptions of task performance, (b) modeling and questioning of the strategy procedures by teachers, (c) systematic cues and prompts to use strategies, and (d) cognitive modeling using a think-aloud technique. Strategy instruction can help students with LD understand

and acquire mature and effective strategies that good learners use (Luke, 2006). Learning to use strategies could reduce students' burden of memorizing difficult basic facts. Strategies can also be helpful for long-term retention and direct retrieval of facts and effective for solving extended facts (e.g.,  $8 \times 6$  extends to  $80 \times 6$ ; Woodward, 2006). Through strategy instruction, students (a) learn the rationale for strategy use, (b) select and implement strategies, (c) practice the strategy systematically, and (d) evaluate their strategy usage (Swanson, 1999). Interestingly, Swanson and Hoskyn (1998) and Swanson et al. (1999) found that when explicit instruction (direct instruction) and strategy instruction were combined, their effect was higher than other instructional approaches for teaching students with LD. Thus, based on previous research findings, teachers should use a combination of explicit and strategic instruction when teaching mathematics to students with LD (Swanson, 2001).

### Technology and Mathematics Intervention

The use of technology in mathematics instruction has received widespread endorsement (National Council of Teachers of Mathematics [NCTM], 2000; NMAP, 2008). Technology is recommended as a viable instructional method for teaching mathematics to students with LD because it can provide more opportunities to practice mathematics ideas and potentially contribute to more success (Bouck & Flanagan, 2009). Computer-based instruction (CBI), using computer software for instructional purposes, is often recommended for mathematics instruction for students with LD (Bouck & Flanagan, 2009; Vaughn & Bos, 2009). Students can use CBI independently, or it can be incorporated into teacher directed instruction (TDI; Okolo, Bahr, & Rieth, 1993). Previous research results have shown that CBI can be used effectively for supporting students with LD to compensate for their challenges and increase interest in learning for a variety of academic areas including mathematics (e.g., Higgins & Raskind, 2005; MacArthur, 1998; Okolo, 1992). In addition, CBI allows for providing adapted and individualized instruction (e.g., set various goals for individual students, adjust difficulty levels and learning pace, provide more practice opportunities, record student's progress consistently) for students with disabilities based on their specific learning needs, which is often difficult for teachers to accomplish during whole-class or even small-group instruction (Dell, Newton, & Petroff, 2008). Due to these beneficial features, CBI has potential for teaching mathematics to students with LD, especially, to support them to improve their basic mathematics skills (Seo & Bryant, 2009).

Since the late 2000s, tablet computers have been gaining in popularity in society and more recently in the special

**Table 1.** Participants' Demographic and Testing Information.

Demographic	James	Kate	Amy	Perry
Age (years, months)	10.5	11.1	10.5	11.1
Grade	5	5	5	5
Gender	M	F	F	M
Race/ethnicity	Mixed race	Hispanic	Hispanic	Caucasian
Disability	LD	LD	LD	LD
Free/reduced lunch	Y	Y	N	N
ELL	N	Y	Y	N
Mathematics	84 <sup>a</sup>	87 <sup>a</sup>	103 <sup>b</sup>	93 <sup>b</sup>
Reading	98 <sup>a</sup>	78 <sup>a</sup>	98 <sup>b</sup>	81 <sup>b</sup>
Writing	92 <sup>a</sup>	78 <sup>a</sup>	97 <sup>b</sup>	72 <sup>b</sup>
Pre-test (DC/M)	13.5	13.5	5.5	16.5

Note. M = male; F = female; Y = yes; N = no; ELL = English language learner; DC/M = digit correct per minute.

<sup>a</sup>Woodcock-Johnson III Test of Achievement (Woodcock, McGrew, & Mather, 2001).

<sup>b</sup>Kaufman Test of Educational Achievement (2nd ed., Kaufman & Kaufman, 2004).

education field. Tablet computers are typically portable tablet-sized devices with touch-screen displays and Internet access features. In particular, the iPad is one of the most widely used tablet computers, and its use has rapidly increased in education even in the absence of a strong empirical base (Nirvi, 2011). The iPad could be a useful learning tool for students with disabilities because of its features (e.g., the availability of downloadable inexpensive apps for practice, touch-screen to reduce keyboarding issues, ability to individualize the use of the tablet [e.g., dictation, speak selection, adjustable fonts]). It has also been suggested that the use of iPad applications, which have features similar to educational computer software (e.g., programmable to meet individual needs of students, recordable students' progress) could be effective for teaching basic mathematics skills (Banister, 2010).

Findings from research studies (B. R. Bryant et al., 2015; Nordness, Haverkost, & Voberding, 2011) have shown promising effects for integrating iPads into mathematics interventions for students with LD. In a recent study, B. R. Bryant et al., 2015 compared the effects of only iPad application instruction (AI), only TDI (researcher delivered), and combined instruction (CI; AI with TDI) on the multiplication facts performance of students with LD. They found that both CI and only TDI conditions were more effective than only AI. Thus, based on the findings from these studies, it appears promising to integrate iPads into TDI mathematics interventions for students with LD.

## Purpose and Research Questions

This study investigated the effect of explicit, strategic intervention with iPad application practice on the performance of single-digit multiplication facts (factors of 4 and factors of 8) and strategy use of fifth-grade students with LD. The following research questions guided this study:

**Research Question 1:** What is the effect of explicit, strategic intervention with iPad application practice on multiplication fact fluency of fifth-grade students with LD?

**Research Question 2:** What is the effect of explicit, strategic intervention with iPad application practice on strategy use for solving multiplication facts of fifth-grade students with LD?

**Research Question 3:** What is the maintenance effect of explicit, strategic intervention with iPad application practice on multiplication fact fluency of fifth-grade students with LD?

**Research Question 4:** What are the perspectives of fifth-grade students with LD about explicit, strategic intervention with iPad application practice on learning multiplication facts?

## Method

### Participants

Four (two boys and two girls) fifth-grade students with LD participated in this study. To be eligible to participate, students needed to meet the following criteria: (a) enrolled in the fourth or fifth grade; (b) identified as having LD by their school district; (c) have Individualized Education Program (IEP) goals in mathematics; and (d) demonstrated low fluency on target multiplication facts, factors of 4 and factors of 8 (low fluency: scored at the frustration level: 0–19 digit correct per minute [DC/M]; Deno & Mirkin, 1977), on the pre-test. Table 1 shows participants' demographic and testing information, including age, grade, gender, ethnicity, free/reduced lunch status, English language learner (ELL) status, standardized scores (mathematics, reading, writing), and pre-test scores. Only fifth-grade students were identified for this study; no fourth-grade students met the criteria.

## Setting

This study was conducted in two elementary schools located in central Texas. James and Kate attended a public elementary school in a school district serving about 8,000 students. The school served 605 students in pre-K through fifth grade. Demographic data of the student population was as follows: 74% White, 12% Asian, 10% Hispanic, 2% Multi-race, and 1% African American. In addition, 10% of the students in the school were served in special education, 9% were gifted and talented students, 4% had limited English proficiency, and 1% was economically disadvantaged. Amy and Perry attended a state charter elementary school serving 305 students in pre-K through fifth grade. More than half (64%) of the students in the charter school were Hispanic, 19% were White, 15% were African American, and 1% was Asian. Moreover, 10% of the students in the school were served in special education, 7% were gifted and talented students, 8% had limited English proficiency, and 61% were economically disadvantaged. All sessions occurred within the participants' school, in small classrooms located near the participants' special education classroom.

## Research Design

A single-case, multiple probe research design across participants was employed. The design allows researchers the ability to collect baseline data intermittently, so it is considered as an efficient design for researchers when continuous measures could be impossible or unnecessary (Kennedy, 2005). The design is also ethically desirable because it does not require withdrawing potentially beneficial intervention for participants unlike other single-case designs such as ABAB design (Kennedy, 2005).

**Dependent variables.** Multiplication fact performance and strategy use were the dependent variables (DVs). Two multiplication facts (i.e., factors of 4 and factors of 8) were selected for instruction because the facts are considered to be harder than other facts (e.g., factors of 1, factors of 2, factors of 5; Stein, Kinder, Silbert, & Carnine, 2006; Woodward, 2006). In addition, the same strategy (i.e., doubling strategy) was used to solve both factors of 4 and factors of 8 multiplication facts. Previous studies (e.g., Flores, Houchins, & Shippen, 2006; McIntyre, Test, Cooke, & Beattie, 1991; Woodward, 2006) investigating the effects of explicit, strategic instruction and iPad-based instruction measured only mathematics performance (accuracy or fluency), not strategy use. These two DVs (i.e., multiplication fact performance for factors of 4 and 8, strategy use) were selected as dependent variables because it was expected that if students can use more effective, mature strategies for solving multiplication fact problems, their mathematics performance would improve.

**Independent variable.** The independent variable was explicit, strategic intervention with iPad application practice. The intervention consisted of three main parts: (a) explicit, strategic intervention for teaching multiplication facts (factors of 4 and factors of 8; i.e., warm-up, modeling, and guided practice); (b) independent practice with iPad application practice; and (c) daily progress monitoring probes and graphing data.

## Measures

**Pre-test.** Before starting the intervention, participants were assessed on their performance on the target skills. One of the five forms (A–E) developed as 2-min daily probes was used as a pre-test. Only students who scored at the frustration level (0–19 DC/M) were selected to participate in this study. The following survey level of assessments (Deno & Mirkin, 1977) was used for determining the students' performance level on the daily probes: (a) frustration level (0–19 DC/M): material is too challenging, (b) instructional level (20–39 DC/M): material is appropriately challenging, and (c) mastery level (40+ DC/M): material is mastered.

**Progress monitoring daily probes.** To answer Research Question 1, the researchers had the participants complete a 2-min curriculum-based measure (CBM), which was a daily probe on target multiplication facts (factors of 4 and factors of 8) at the end of each intervention session. Five alternate forms of the probe (A–E) were developed (Kratowchwill et al., 2010) and delivered in counterbalanced order. The researcher-developed paper-and-pencil-based probes contained 60 single-digit multiplication facts of the target facts (30 of each). All targeted facts were assigned an equal number of times across the five forms based on the recommendation to have "different but equivalent math sheets" as CBMs (Hosp, Hosp, & Howell, 2007, p. 98). DC/M was calculated by dividing the students' total digits correct by two and recorded to measure participants' progress (Shapiro, 2010).

**Strategy use test.** To answer Research Question 2, the researchers collected each participant's strategy use data three times (before, in the middle of, and after the intervention phase), and analyzed them to determine whether participants used the doubling strategy to solve the multiplication fact problems across the study. To compare changes in participants' strategy use across the study, three assessment forms (A, B, C) were used in counterbalanced order. The participants were asked to complete 10 multiplication problems randomly selected from the target multiplication facts daily probes for this study. Prior to the test, the participants were informed that they would be asked to solve each problem in 30 s and explain their strategies for solving the problems in the probe. After the 30 s, the participants were immediately asked to describe how they solved the problem; their answer was audio-recorded.

Based on observation of a participant's behavior, written solutions on the probe, and verbal self-description, the investigator recorded the participant's strategy use on the researcher-developed observation form. The observation form was developed using a taxonomy of strategies for single-digit multiplication (Sherin & Fuson, 2005), procedures for solving simple multiplication problems (Mabbott & Bisanz, 2008), and children's characteristics in arithmetic (Geary, 2004), which were combined and modified for the strategy categories on the form. The taxonomy of strategies for single-digit multiplication (Sherin & Fuson, 2005) was primarily used. The following are the eight strategy categories on the observation form:

1. Guess: participants noted they guessed the answer,
2. Count-all: participants counted from 1 to the product,
3. Additive calculation: participants solved multiplication facts using understanding of addition,
4. Count-by: participants used sequenced counting to solve the multiplication fact,
5. Pattern-based: participants used rules-based strategies,
6. Learned product (also known as automatic retrieval): participants recalled the product automatically,
7. Hybrids: participants used mixed strategies such as a doubling strategy, and
8. Other: an ambiguous answer that does not fit any category.

The accuracy of solving the problems on the probe (the number of correct items divided by the number of items attempted) was recorded. In addition, the percentage of use of each strategy (the total number of times each strategy was used divided by the total number of items on the probe and multiplied by 100) was recorded. Specifically, for recording the use of the doubling strategy, even though the investigator marked "X" in the Hybrids category when participants used mixed strategies, it was noted what specific strategies were used.

**Maintenance tests.** To answer Research Question 3, the researchers had participants complete maintenance tests 2 weeks following the intervention phase to determine whether the level of performance during intervention was maintained over time. Two of the 2-min daily probes were used; for example, if participants used Form C in the last intervention session, they were assessed with Forms D and E for the maintenance test. The average DC/M of the two tests was calculated and recorded.

**Inter-scoring agreement.** All tests—including the pre-test, daily probes, maintenance test, and strategy use test—were double-scored by two other researchers independently.

Overall, inter-scoring agreement was 99%; a discussion between the scorers and the investigator occurred until they reached 100% agreement. Inter-scoring agreement was calculated by using the formula, number of agreements of participant's responses divided by the number of agreements plus disagreements multiplied by 100.

**Social validity interview.** To answer Research Question 4, the researchers developed interview questions and individually administered them to participants after their last intervention session. The interview included 20 questions investigating their perspectives about each intervention component (e.g., explicit, strategic instruction; independent practice using an iPad application) and overall intervention. Each interview took approximately 15 min.

### Procedures

**General procedures.** The study adhered to the following procedures: (a) pre-training, (b) baseline, (c) intervention, and (d) maintenance. Prior to the study, 30 min of pre-training (a brief overview of the study and iPad application training) was provided to participants. During the baseline phase, 2-min daily probes were administered to measure participants' fact fluency; no instruction was provided. During intervention phase, the staggered intervention, explicit, strategic intervention with iPad application practice, was introduced across participants (Kratochwill et al., 2010). Each student received fifteen 30-min one-to-one intervention sessions for 5 days a week over a 3-week period. At the end of each session, students completed a 2-min daily probe. To understand participants' strategy use, students completed strategy use tests three times across the study (before, in the middle of, and after intervention phase). After the intervention phase, the investigator conducted a social validity interview. During the maintenance phase (after 2 weeks following intervention phase), participants' fact fluency was measured with two of the 2-min probes; students received no instruction. Total duration across all phases was approximately 10 weeks.

**Intervention instructional features.** Explicit, strategic intervention with iPad application practice was designed to help students with LD improve their multiplication fact fluency. To design an effective intervention for teaching target facts, critical features of effective research-based instruction for teaching students with LD mathematics—such as explicit strategic intervention, CBI, the Concrete-Representative-Abstract (CRA) routine, and distribution of data and feedback to students—were employed to design the intervention (Gersten, Chard, et al., 2009; Jayanthi, Gersten, & Baker, 2008).

Participants received a total of 15 lessons (Lessons 1–5: factors of 4; Lessons 6–10: factors of 8; Lessons 11–15: a

mix of factors of 4 and factors of 8). The target fact skills were broken down into smaller sets (two new facts for each lesson) as well as sequenced (teaching factors of 4 before factors of 8; Archer & Hughes, 2010). Participants also repeatedly reviewed the target facts systematically through cumulative review opportunities in each lesson (Woodward, 2006). All lessons were systematically organized; the instructional routine for each lesson consisted of (a) warm-up (3 min): reviewed prerequisite skills/knowledge (e.g., review factors of 2, addition required for using a doubling strategy) and skills and knowledge (e.g., facts, vocabularies) taught in previous lessons, (b) modeling (8 min): provided explicit modeling designed to develop both conceptual and procedural understanding of a doubling strategy to solve factors of 4 and factors of 8, (c) guided practice (7 min): practiced the target facts with worksheets under the investigator's guidance, (d) independent practice using an iPad application (5 min): practiced the target facts independently using Math Evolve, (e) daily probe (2 min): completed probes, and (f) graphing daily data and providing feedback (3 min): scoring the probe, graphing their daily data, and obtaining feedback on performance.

The doubling strategy taught included the following steps: (a) break apart 4 to 2 and 2 or break apart 8 to 2, 2, 2, 2; (b) multiply each 2 with the other factor; and (c) add the products. The doubling strategy was selected based on findings from previous studies (Pfannenstiel, 2011; Wood & Frank, 2000; Woodward, 2006). The studies reported positive effects of using the doubling strategy for teaching students with LD target multiplication facts similar to this study (i.e., factors of 4 and factors of 8). A think-aloud approach and CRA routine (concrete: connected cubes; representational: a picture of dots; abstract: numbers) were also used for teaching the strategy (Gersten, Chard, et al., 2009). Throughout all lessons, participants were asked to respond frequently, their performance was monitored carefully, and immediate and corrective feedback was provided (Archer & Hughes, 2010).

For independent practice with an iPad application, Math Evolve (Zephyr Games, 2012) was used. Math Evolve is an educational game-type drill and practice application, which is designed to build mathematics basic fact fluency. Users need to solve problems to fight against enemies coming down from the top of the screen to the bottom. The application was selected because the features included progress monitoring data, immediate and corrective feedback, error correction, multiple practice opportunities, and customizable settings; all of which are considered to be effective practices for students with LD (Boone & Higgins, 2007). The application provided cumulative and distributed practice opportunities; participants practiced both facts previously and newly taught (Archer & Hughes, 2010). In addition, the application provided immediate and corrective feedback as well as error correction opportunities to

participants. The correct answer was given if participants made a mistake twice in a row; only after they inserted the correct answer could they go back to solve the next problem. Moreover, the investigator set up settings for the application in regard to the number of problems, theme, color, sound, speed, arrangement of problems, and error correction assistance so that all participants practiced solving fact problems under the same conditions. Participants were able to adjust sound volume while working with the application. The investigator closely monitored participants' performance and provided guidance, or technical support, if needed.

### Fidelity of Implementation

Three researchers assessed fidelity of the implementation for 20% of all intervention sessions across participants (12 lessons; 4 for each participant). A checklist developed for the fidelity of implementation contained 20 items that assessed procedural fidelity on implementation of the intervention (e.g., materials, instruction [warm-up, modeling, guided practice, independent practice, feedback/support], CRA routine, daily probes, and graphing daily data). For example, to assess fidelity of implementation for warm-up, the following three items were checked: (a) the objective of the lesson was stated to the student, (b) the teacher completed the review of prior knowledge/skills, and (c) 3 min were spent to adhere to the time limit. Fidelity was measured using a 3-level points system (0 = behaviors not observed, 1 = inconsistent level of implementation, 2 = high level of implementation). To calculate the fidelity, the points of behaviors observed by the investigator were divided by the total possible points of all planned behaviors in the checklist and multiplied by 100. The fidelity of implementation calculated was 98% overall (James, Kate, Perry: 98% and Amy: 100%).

### Social Validity

After completing the intervention phase, participants were interviewed individually to identify their perspectives toward the intervention. The investigator read aloud all 20 interview questions, and participants verbally responded to the questions. The questionnaires consisted of 16 questions using a 5-point Likert-type scale (1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, 5 = strongly agree) and four open-ended questions. The questions were designed to determine participants' perspective toward (a) explicit, strategic instruction, (b) independent practice using iPads, (c) daily probes and graphing daily data, and (d) the overall intervention. In addition, participants responded to the following four open-ended questions:

1. What method do you prefer to practice multiplication facts (flashcards/worksheets vs. iPad application)? Why?

2. What did you like best about our tutoring time? Why?
3. What aspects of tutoring time did you dislike? Why?
4. Do you have any other comments or suggestions regarding tutoring time?

## Results

To understand the effects of the intervention on the multiplication fact fluency of participants with LD, a visual analysis of data regarding level, trend, variability, and immediacy of effect (Kratochwill et al., 2010) was conducted. In addition, two effect sizes, percentage of non-overlapping data points (PND; Scruggs & Mastropieri, 1998) and Tau-U (Parker, Vannest, Davis, & Sauber, 2011), were computed.

### Research Question 1: Effects of Explicit, Strategic Intervention With iPad App Practice

**Visual analysis.** Figure 1 displays DC/M scores on the progress monitoring probes for each participant across all phases.

**James.** The scores for James were constant at low and stable levels during the baseline phase ( $M = 10.06$ , range = 9.5–13 DC/M). After the intervention was implemented, his fluency scores immediately increased ( $M = 25.87$ , range = 16.5–36.5 DC/M) and stayed high and at increasing levels for the rest of the intervention phase. He maintained the intervention gains 2 weeks following intervention phase ( $M = 22$  DC/M). His fluency scores were at the frustration level during baseline, but his scores improved and were at the instructional level during both intervention and maintenance phases; his highest score (36.5 DC/M) closely approached mastery level. The trend showed that James' fluency scores did not change during baseline phase (slope of 0), but did increase (slope of 1.09) during the intervention phase. In addition, 65% of the immediacy of effect was observed.

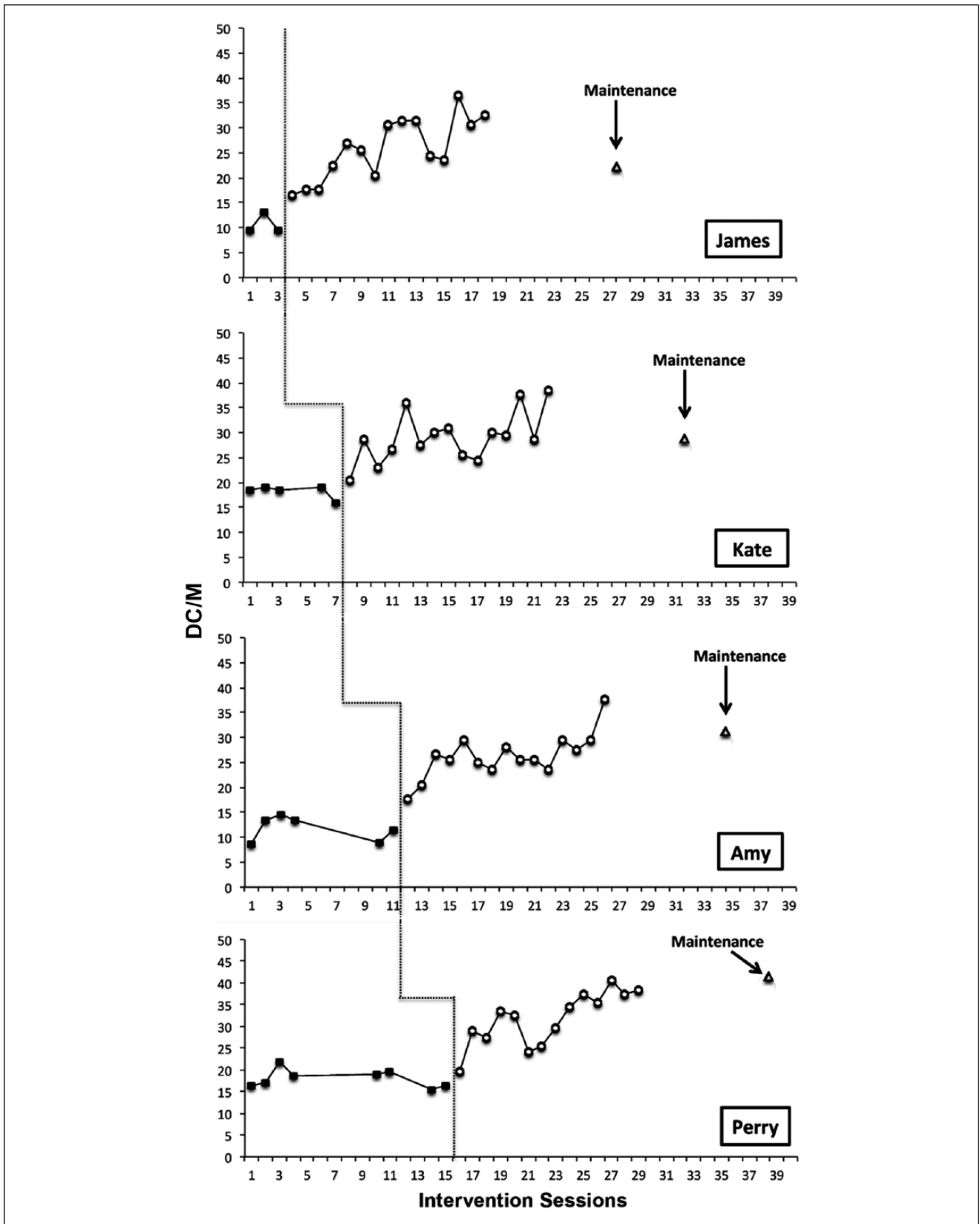
**Kate.** The fluency scores for Kate were initially low during baseline and were constantly at low and stable levels during the baseline phase ( $M = 18.20$ , range = 16–19 DC/M). Her scores promptly increased after the intervention was implemented and continued at relatively high and increasing levels for the rest of the intervention phase ( $M = 29.13$ , range = 20.5–38.5 DC/M); she also maintained the intervention gains after the removal of the intervention ( $M = 28.25$  DC/M). Her fluency scores were at the frustration level during baseline but at the instructional level during both intervention and maintenance phases; her highest score (38.5 DC/M) closely reached mastery level. Regarding the trend, the fluency score decreased by 0.29 DC/M during baseline

whereas Kate's performance increased by 0.65 DC/M during intervention phase; the data for Kate showed a 61.70% immediacy effect.

**Amy.** The scores for Amy were initially low and stayed low constantly during the baseline phase ( $M = 11.75$ , range = 8.5–14.5 DC/M), but her scores promptly increased after the intervention was introduced and continued at relatively high and increasing levels for the rest of the intervention phase ( $M = 26.50$ , range = 17.5–37.5 DC/M). She also maintained her intervention gains ( $M = 30.5$  DC/M) after the intervention was removed. Her scores were at the frustration level during baseline whereas they were at the instructional level during both intervention and maintenance phases; her highest score (37.5 DC/M) closely reached the mastery level. The data for Amy demonstrated a downward trend (–0.16) during the baseline phase but an upward trend (0.74) during the intervention phase. In addition, 101.70% of the immediacy of effect was observed.

**Perry.** The fluency scores for Perry were low initially and were constant at low and stable levels throughout the baseline phase ( $M = 18.29$ , range = 16.5–22 DC/M). After the intervention was implemented, his scores improved and continued at relatively high and increasing levels for the rest of the intervention phase ( $M = 32.50$ , range = 19.5–42.5 DC/M); he also maintained the intervention gains ( $M = 41$  DC/M) after the removal of the intervention. His fluency performance was at the frustration level during baseline but at the instructional level during intervention phase; his scores even reached mastery level twice (40.5 and 42.5 DC/M) during the intervention phase. Perry also maintained the intervention gains at the mastery level. Perry's trend data demonstrated that his fluency score decreased by 0.21 DC/M during baseline whereas his performance increased by 1.22 DC/M during intervention phase. In addition, 81.70% of the immediacy of effect was observed; one data point overlapped between baseline and intervention data. According to a visual analysis of data, it was evident that there was a causal relation between explicit, strategic intervention with iPad application practice and participants' multiplication fact fluency performance (Kratochwill et al., 2010).

**Effect sizes.** Table 2 shows effect sizes computed for each participant. The effect size results (PND and Tau-U) indicated there was a significant large effect of the intervention on improving the target fact fluency of all participants (Parker et al., 2011; Scruggs & Mastropieri, 1998). According to the effect size data (PND: James, Kate, Amy: 100%, Perry: 93.33%; Tau: James, Kate, Amy: 1.0, Perry: 0.98), all participants improved their fluency scores (PND: between 93.33% and 100%; Tau: between 98% and 100%) from baseline to the intervention phase. The Tau-U data also



**Figure 1.** DC/M scores across the baseline, intervention, and maintenance phases for participants.  
 Note. DC/M = digit correct per minute.



**Table 2.** Effect Sizes Computed.

Participants	PND (%)	Tau-U		
		Tau	90% CI	p value
James	100	1.00	[0.38, 1.62]	<.01 (.0077)
Kate	100	1.00	[0.50, 1.50]	<.01 (.0011)
Amy	100	1.00	[0.53, 1.47]	<.01 (.0005)
Perry	93.33	0.98	[0.55, 1.40]	<.01 (.0002)

Note. PND = percentage of non-overlapping data; CI = confidence interval.

demonstrated the result was statistically significant (all  $ps < .01$ ; Parker et al., 2011).

### Research Question 2: Strategy Use

Regarding accuracy, overall all participants improved their fact accuracy on the strategy usage test across the study (before, in the middle of, after intervention phase; James: 40%, 70%, 90%; Kate: 70%, 90%, 100%; Amy: 70%, 70%, 100%; Perry: 80%, 100%, 100%). In addition, regarding the percentage of strategy use when solving fact problems on the strategy use test, participants employed a variety of strategies (e.g., count-all, count-by, simple additive calculation, learned product). None of the students used the doubling strategy before the intervention phase. However, in the middle of the intervention (after Lesson 7), they used the doubling strategy for solving the facts or were able to recall the facts automatically. All participants except Perry improved using the doubling strategy from before intervention (all participants: 0%) to the middle of the intervention (James: 40%, Kate: 30%, Amy: 40%, Perry: 0%). Even Perry was able to recall all the facts automatically, but he did not use the doubling strategy. After intervention phase, none of them used the doubling strategy, but all participants were able to recall the facts automatically; they only used the learned product strategy. Table 3 shows the percentage of strategy use across the participants.

### Research Question 3: Maintenance Effect of the Intervention

According to the data (see Figure 1), all participants maintained the intervention gains 2 weeks following the intervention phase. Three students maintained their fluency scores at the instructional level (between 22 and 30.5 DC/M); Perry's performance during the maintenance phase was at the mastery level (41 DC/M). Regarding changes between levels of intervention and maintenance phases, James and Kate decreased a level (James: 3.87, Kate: 0.88 DC/M) while Amy and Perry increased a level (Amy: 4.12, Perry: 8.5 DC/M).

### Research Question 4: Participants' Perspectives on the Intervention

The results of the social validity interviews indicated that overall, all participants expressed positive perspectives toward explicit, strategic intervention with iPad application practice (average score: 4.7 out of 5); for example, they noted they enjoyed the tutoring time and that the instruction helped them learn multiplication facts. The intervention appeared to motivate students and engage them in learning. Regarding what they liked about the intervention, two students said learning target facts, one said using iPads (fun to use), and one said working on the mini-board for practicing the strategy.

Regarding what they disliked about the intervention, two of them said none, one student said working on worksheets, and one said she needed to leave early from her class for the tutoring. None of them noted any other suggestions regarding the intervention. Regarding the doubling strategy, participants' perspectives varied; James and Kate strongly liked it, Amy neither disliked nor liked it, and Perry strongly disliked it. Perry said he did not like it because it took a long time for him to use the strategy to solve fact problems. During intervention sessions, it was often observed he did not like to use the strategy. According to his performance data, it seems like he was already more knowledgeable at target facts than the other participants, but he was very slow to recall the facts; this might have impacted this result.

Overall, participants thought the strategy was easy to learn and use for solving the facts (4), it helped them to get better in the facts (4.5), and they said they would like to recommend using the strategy to their friends (4). Even Perry agreed the strategy helped him to do better on the facts. Second, all participants had positive perspectives toward using Math Evolve for independent practice (average score: 4.3 out of 5); it was noted that they liked using iPads to practice facts (4.75), it helped them learn the facts (4.5) as well as motivate them to practice facts (4), and they would like to recommend using iPads for practicing facts to their friends (4). Interestingly, it was found that although all of them liked using Math Evolve, all participants except one (Perry) preferred flashcards or worksheets to using iPads for practice; they liked the interaction with the investigator rather than using the application independently. Last, all participants noted they liked graphing their daily data (4.5) and obtaining the teacher's feedback on their performance (4.75); they thought it motivated them to learn and work harder (4.75).

### Discussion

This study examined the effects of explicit, strategic intervention with iPad application practice on the multiplication fact fluency and strategy use of fifth-grade students with

**Table 3.** Percentage of Strategy Use for Strategy Use Tests.

Participant	Percentage of strategy usage		
	Before intervention	Middle of intervention	After intervention
James	Learned product: 40% Other (I don't know): 40% Count-by: 20%	Learned product: 60% Hybrids (doubling strategy): 40%	Learned product: 100%
Kate	Additive calculation: 70% Learned product: 30%	Learned product: 70% Hybrids (doubling strategy): 30%	Learned product: 100%
Amy	Count-by: 30% Other (I don't know): 30% Hybrids: 20% (learned product + count-all: 10% & count-all + count-by: 10%) Count-all: 10%	Learned product: 60% Hybrids (doubling strategy): 40%	Learned product: 100%
Perry	Learned product: 60% Hybrids (learned product + additive calculation): 30% Guess: 10%	Learned product: 100%	Learned product: 100%

LD. The results of this study indicated that the intervention is a promising instructional method for supporting students with LD to improve, as well as maintain, their fact fluency. The intervention was designed with various research-evidenced instructional variables, such as explicit and strategic instruction, use of iPads, the CRA routine, and provision of data and teacher's feedback to students. The findings of this study were consistent with those from previous research on effects of these instructional strategies for teaching students with LD (B. R. Bryant et al., 2015; Gersten, Chard, et al., 2009; Mancl, Miller, & Kennedy, 2012). The intervention also is promising for helping students with LD to learn and use more mature, efficient strategies for mathematics, as indicated in previous studies (Iseman & Naglieri, 2011; Woodward, 2006). It was observed that students with LD tend to use developmentally immature, inefficient strategies (e.g., count-all, simple additive calculation) rather than more mature strategies (e.g., doubling strategy, automatic retrieval) for solving multiplication facts before the intervention, but they improved in using the more mature, efficient strategies across the study.

The students with LD also reported positive perspectives about the intervention; they liked using the doubling strategy and iPad application practice for learning the targeted facts. Regarding use of iPads, students also thought it supported their learning of the facts and motivated them to practice more, so they would recommend it to their friends. Finally, the investigators found that it was easy to use iPads during intervention sessions. With a short training session (5–10 min), students were able to use the iPad application. The iPad provided correct feedback and kept students engaged during practice; thus, it has potential to be an effective independent practice tool. Given that many students come to school with multiple technology experiences,

integration of tablet computers into interventions seems to be worthwhile.

### *Limitations and Future Research*

There were four limitations in this study. First, explicit, strategic intervention with iPad application practice was a multi-component intervention. It was designed with several empirical validated instructional strategies for teaching mathematics for students with LD. Even though findings were promising for students with LD, it is difficult to identify the effects of each instructional component on the participants' fact fluency performance. Thus, it is necessary to conduct studies to identify the effect of each instructional component, especially using iPads. For example, future research should compare the effects of using flashcards/worksheets versus using iPad applications for independent practice on fact skills. Also, examining the effects of using iPads and applications for teaching other mathematics domains (e.g., division, fractions) and different types of students (e.g., various grade levels) is important. In addition, it is necessary to examine the effect of other mathematics applications available on the market. Future research also should include measuring engagement and motivation data when students use iPads to identify if there is a relationship between their engagement and motivation in learning and mathematics performance. Finally, it would be interesting to compare student performance on iPads during independent practice time with their performance on a paper-based test.

Second, only a one-time short-term interval maintenance effect was assessed; it is necessary to investigate a longer-term interval (e.g., 8 weeks) maintenance effect of the intervention. The maintenance effect of the intervention should

be interpreted cautiously. It was found that Amy and Perry, who were attending a public elementary school, were provided some instruction on multiplication skills during the maintenance phase, while James and Kate were not provided any instruction. This might have had an impact on the results of the maintenance effect; the data for Amy and Perry showed that their levels of maintenance phase data improved compared with the levels of the intervention phase, whereas James and Kate decreased their levels. Thus, future research should verify that no instruction on target skills was provided during the maintenance phase. Other external variability that might have an impact on the maintenance effect should be controlled.

Third, only researcher-developed daily probes were used to assess participants' fluency performance. Although the probes were developed based on recommendations for mathematics CBM design (Hosp et al., 2007), the reliability and validity of the probes were not adequately assessed. The internal consistency reliability of the probes should be measured, and future research should include additional standardized tests to assess participants' performance. This would provide more convincing results and assess how participants could generalize the skills taught.

Last, when assessing participants' percentage of strategy use, the researchers asked the participants to solve each problem on the test in 30 s. However, it was not timed exactly to see how long it took to solve the problem. If the time were measured, the information would have helped to better understand their strategy usage. For example, Perry used the learned product strategy for solving all problems on the test both in the middle of the intervention and after intervention, and he solved all problems correctly. If how long it took him to solve the problems was measured, we could better understand if his speed of recall of the facts increased from the middle of the intervention to after the intervention. Thus, future research should measure the exact time that participants take to solve the problems using the strategies.

### Implications for Practice

This study has several implications for practice. First, the findings suggested that explicit, strategic intervention using an iPad application is a promising practice for teaching multiplication facts to students with LD. A researcher delivered the intervention, so generalization of the findings to teacher delivery of this intervention must be viewed cautiously. We anticipate that teachers can use the strategies embedded in the intervention (e.g., explicit, strategic instruction, using iPads to practice) for multiplication fact instruction for their students with LD; replication of the findings when the intervention is delivered by teachers is warranted.

Second, although the findings of this study indicated the effects of teaching the doubling strategy for teaching multiplication facts, teachers should cautiously recognize that the strategy might not be effective for all students with LD. For students such as Perry who already know facts but need to improve the speed of recall, other fluency building instruction might be warranted. Teachers should identify the needs of their students first to see if the strategy would be beneficial for them.

Finally, when teachers use technology-based lessons, they should be cautious. Technology is a vehicle to deliver instruction; instructional strategies embedded in the technology programs are important for effective instruction (Clark, 1983). Effective instructional variables embedded in Math Evolve might have an impact on the results of this study; therefore, teachers need to select applications that include effective instructional design for teaching students with LD (Ok, Kim, Kang, & Bryant, in press). In addition, integrating iPads into interventions might be more effective than using iPads solely to provide instruction (B. R. Bryant et al., 2015; Howell, Sidorenko, & Jurica, 1987).

### Authors' Note

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