Self-Monitoring of Pace to Improve Math Fluency of High School Students with Disabilities

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ABSTRACT

This study illustrates how a behavioral self-management intervention, which combined tactile and visual cued self-monitoring, self-graphing, and goal setting, improved the math fluency of five high school students with various disabilities during independent math practice. The intervention helped students monitor, adjust, and increase the pace at which they produced answers to simple addition and subtraction problems during daily 3-minute sessions. Using the self-management techniques, the students systematically increased the number and pace of correct responses, and concurrently, kept the number of error responses minimal and maintained or improved accuracy of responses. The paper includes recommendations for teaching students how to monitor their own academic performances rather than relying on teachers.

Descriptors: Math fluency, pace, self-management, self-monitoring

Children with learning disabilities often have difficulty with fluency of math facts. Fluency means that students respond rapidly and accurately. However, some students have difficulties initiating, maintaining, and completing tasks; pacing their responses (e.g., they are quick but error-prone, or accurate but slow); and monitoring and correcting errors while responding (Woodward, 2006). Students who respond fluently, or with automaticity, are more likely to maintain the skills, resist distractions, and acquire more complex skills (Binder, 1993; Hartnedy, Mozzoni, & Fahoum, 2005; Johnson & Street, 2004; Singer-Dudek & Greer, 2005). Compared to fluent peers, students who are accurate but slow in completing problems that require basic math skills take longer to finish assignments, submit more incomplete assignments, and experience more difficulties when faced with complex math procedures for which mastery of those basic math skills is a prerequisite (Chiesa & Robertson, 2000). Precision teaching, goal setting, and efficient practice and feedback activities can improve student fluency of basic skills in math, reading, and other subjects (Burns, 2005; Carnine, 1989; Cates &

Rhymer, 2003; Lindsley, 1992, 1990). These fluency-building techniques can be combined with other procedures to further increase their efficacy.

Behavioral self-management techniques can be used with fluency-building exercises to improve math performance and other behaviors of students with disabilities (Glynn, Thomas, & Shee, 1973; Krosenbergen & Luit, 2004; McDougall, Skouge, Farrell, & Hoff, 2006; McLaughlin, 1976; O'Leary & Duby, 1979). Self-monitoring is the self-management technique that researchers have applied most frequently and with the most versatility in schools and other settings, whereas self-graphing is underutilized (McDougall et al., 2006). Self-monitoring consists of self-assessment (e.g., asking oneself, "Am I on-task?") followed by self-recording (e.g., circling "Yes" or "No" on a form) (Glynn et al., 1973). By self-monitoring, individuals stay aware, cognitively, of what, how, or how frequently they are performing a specific behavior, *while* performing a task. Then, they can adjust that behavior, as needed, in an ongoing manner. Reactivity, or responding behaviorally to one's own cognitions or awareness of a specific behavior, is the principle that underlies self-monitoring

(Meichenbaum, 1977).

By self-graphing, individuals obtain feedback *after* they complete a task. To self-graph, individuals record the frequency, duration, accuracy or rate of their own behavior, typically, on a bar or line graph. Self-graphing can be used in conjunction with goal setting to improve students' subsequent performance (McDougall et al., 2006). The importance of setting goals for student achievement has been documented in numerous studies (e.g., Peterson & Lezotte, 1991; McDougall, Saunders, & Goldenberg, 2007). Moreover, consistently measuring progress toward achieving educational goals has been shown to be positively related to improvements in students' academic outcomes (Brophy & Good, 1986).

An individual can use various cues to self-monitor behavior. An audible stimulus, such as a beep, buzz, or tape-recorded message, can be used to periodically prompt or remind an individual to self-assess (e.g., covertly ask oneself, "Am I working quickly?") then record a response to the self-assessed question (e.g., McDougall & Brady, 1998). However, the overt and public nature of audio cues can disrupt other students in the classroom. Consequently,

researchers and practitioners have suggested using less intrusive cues. For example, a visual stimulus, such as a printed reminder note or symbol, a printed list or picture or photo sequence of “to do” steps, or a flashing light or message, can be used to used to periodically prompt an individual to self-monitor.

Tactile cues or vibrations that a person feels provide another means for prompting an individual to self-monitor (Amato-Zech, Hoff, & Doepke, 2006; McDougall et al., 2006). For example, the “Gentle Reminder” (Davidson, 1995) and other types of vibrating pagers have been used with children and teenagers with autism to prompt verbal and social initiations and requests for assistance when lost (Shabani et al., 2002; Taylor, Hughes, Richard, Hoch, & Coello, 2004; Taylor & Levin, 1998). Recently, Seligson-Petshcer and Bailey (2006) used vibrating pagers and self-monitoring forms to improve job performance of instructional assistants in a self-contained classroom for students with severe behavior disorders. Amato-Zech et al. (2006) implemented an intervention with a similar type of tactile cueing device, called the MotivAider® (Levinson, Kopari, & Fredstrom, 2002), to improve students’ on-task behavior during an academic subject. Because tactile cues are silent, devices like the MotivAider® have the potential advantage of being less intrusive than other types of cues in settings where audio and visual cues might be disruptive or impractical. As such, additional empirical demonstrations of this strategy would advance the field.

Although many studies have illustrated how students can self-monitor attention or productivity, no studies to date have examined the impact of teaching students to self-monitor the pace at which they produce academic responses. As noted previously, research has shown benefits for students who respond fluently on basic academic tasks, such as addition and subtraction problems (Singer-Dudek & Greer, 2005).

Table 1: Participant Characteristics

Student	Age	Gender	Race	Qualification for Services	Medication	WJ MathSS	
						Broad	Fluency
Jeff	15	M	Caucasian	SED, ADHD Bi-polar	Concerta Risperdal	81	NA
Ronnie	15	F	Caucasian	SLD in Math	None	77	84
Anisa	15	F	Caucasian	SLD in Math		86	82
Shaun	14	M	Caucasian	ADHD Tourette's	Adderall	88	67
Peter	15	M	Caucasian	SLD in Math	None	63	62
Max	15	M	Caucasian	SLD in Math	None	74	76

M = male; F = female; ADHD = attention deficit hyperactivity disorder;
 SED = serious emotional disturbance; SLD = specific learning disability; WJ = Woodcock-Johnson;
 SS = standard score with mean of 100 points and standard deviation of 15 points; NA = not available

Thus, we designed an intervention that aimed to improve students’ fluency by helping students self-monitor the pace at which they produced answers during daily skills practice in math. We employed two types of cues because self-monitoring of pace is procedurally more complicated than self-monitoring of attention or productivity. Tactile cues in the form of vibrations emitted by the MotivAider® prompted the students to self-assess their pace and visual cues in the form of colored highlights on their worksheets helped the students to determine whether they were on, behind, or ahead of pace to reach a particular goal.

The purpose of the current study was to extend the previous literature by combining tactile and visual self-monitoring cues to improve the math fact fluency performance of high school students with disabilities. The intervention package included self-monitoring embedded within fluency building exercises, self-graphing of daily results, and informal goal setting. The study applied a novel variation of self-monitoring of productivity — that is, self-monitoring of pace — whereby students periodically determined whether they were on, behind, or ahead

of pace to produce a predetermined range of responses during daily skills practice sessions in math.

Method

Participants

The participants were six 9th-grade students who qualified for special education services according to state guidelines. Table 1 includes pseudonyms for the participants, as well as their ages, genders, races, special education qualifications (disability), and Broad Math and Math Fluency scores from the Woodcock-Johnson Revised (WJ-R; Woodcock & Johnson, 1989) or Woodcock Johnson-III (WJ-III; McGrew & Woodcock, 2001).

Adults involved in this study included the participants’ math teacher (i.e., first author), who served as the primary data collector for math fluency and social validity, an educational assistant who collected procedural integrity data via classroom observations, and the second author, who assessed reliability of math fluency data and who collected data on one aspect of procedural integrity. The teacher was a licensed special educator with 7 years of teaching experience. The educational assistant had 3 years of

classroom experience.

For the purpose of collecting social comparison data on math fluency, 23 students enrolled in a general education Algebra I class at the same high school as the aforementioned six 9th-graders, took part during two days of this study—once at the beginning of the study and once at the end of the study. These 23 students were the same ages as the 6 participants, but they did not qualify for special education services.

Setting and Materials

The setting was a basic math skills classroom in a high school located in an upper-middle socioeconomic suburb of a major city in the western United States. Only six students (i.e., the participants) attended this class and students sat at individual desks. Baseline and intervention sessions consisted of a 3-min “warm up” (i.e., independent practice) at the beginning of math class, Mondays through Fridays.

Materials used by participants included 21.6 by 27.9 cm worksheets with addition and subtraction money problems, tactile cueing devices (i.e., one MotivAider® per participant), and 21.6 by 27.9 cm graphing paper. Each worksheet included eight rows of five problems numbered consecutively from “1” through “40.” Each problem was arranged in vertical format and included three-digit by three-digit addition and subtraction problems (e.g., $\$1.91 - 0.13$; $\$0.54 + 0.94$). The teacher used a computer software program (“Mathematics Worksheet Factory”) to generate worksheets of equivalent difficulty (School House Technologies; <http://www.schoolhousetech.com>). Difficulty of worksheets remained consistent throughout the study. Each worksheet also contained colored highlights to assist participants in determining whether they were on pace, behind pace, or ahead of pace during the sessions (see *Intervention* for further description). All participants completed the same worksheet on a particular session, and the same worksheet was

never used during more than one session.

The MotivAider® measured 6.35 by 6.03 by 1.59 cm and weighed 3 ounces with one AA battery. The MotivAider® can be set to emit vibrations on a fixed or variable interval schedule. These vibrations are not audible to others when the MotivAider® is clipped to a person’s waistline. The MotivAider® allows users to vary the strength and duration of the vibrations, as well as the time that elapses between vibrations. The self-graphing grid paper that participants used had an x-axis labeled “Sessions” and a y-axis labeled “Digits,” as well as a key with triangles that symbolized correct digits and circles that symbolized incorrect digits.

Research Design

The single-case research design combined a multiple baseline design across participants design (Kazdin, 1982) with a modified changing criterion design, called a “range-bound changing criterion design” (McDougall, 2005). For a typical changing criterion design, the practitioner or researcher sets a single performance criterion during each intervention phase (e.g., a student must produce 12 or more correct responses in a prescribed period of time to receive reinforcement). In contrast, the performance criterion in a range-bound changing criterion design has an upper and lower limit (e.g., a student is expected to produce at least 12 but not more than 15 correct responses in a prescribed period of time).

Response Measurement

The dependent variable, or target behavior, in this study was math fluency, which included three elements—correct digits, incorrect digits, and accuracy. We operationally defined a correct digit as a numeral written by a participant in the answer space of a math problem on a worksheet that matched the corresponding answer key; an incorrect digit was defined as a numeral written by a participant in the answer space of a

math problem on a worksheet that did not match the corresponding answer key, or a blank space where the participant should have written a numeral; accuracy was defined as the percentage of digits written correctly (i.e., number of correct digits divided by number of correct and incorrect digits multiplied by 100%). The teacher (primary scorer) measured and recorded data for correct digits, incorrect digits, and percentage correct after each session throughout the study.

Procedures

Baseline. Prior to each 3-min session, the teacher directed the students to write answers to as many problems as possible while keeping errors at or near zero. The teacher also timed each session and told the students when to start and stop writing. The teacher did not provide praise statements or reinforcement based on how much or how well students completed their math problems.

Training. After the last session of baseline, but before the first session of the initial intervention phase for each participant, the teacher worked individually with the students for 30 min to 45 min to teach them how to use the tactile cues from the MotivAider® and visual cues on the worksheets to monitor the pace at which they produced answers and how to self-graph their daily performance. The teacher modeled and explained to the students that whenever they felt a vibration, if they were (a) on pace, then they should continue at that pace; (b) behind pace, then they should quicken their pace; and (c) ahead of pace, then they should consider slowing their pace. Participants were also shown and informed that if they finished all of their stipulated math problems before the 3-min period elapsed, they should “go back and check” their completed problems for errors, rather than continuing to answer subsequent math problems on their worksheet. Following these explanations and demonstrations by the teacher, each student practiced the procedures while the teacher observed and provided feedback. Training ended

when participants performed each of the required steps of the training protocol for three consecutive 3-min practice sessions. None of the participants required more than three practice sessions..

Intervention. Prior to each session, the teacher reported to individual participants the number of correct and incorrect digits they had written during the previous session. The participants then graphed their results from the previous session on a line graph. Two parallel lines (similar to the upper and lower criterion lines displayed in intervention phases in *Figure 1*), previously inserted by the teacher on the graph paper, indicated the minimum and maximum number of digits to be completed. Next, the teacher reminded students to work quickly to hit their goal while keeping errors at or near zero. The graphing procedures were intended to serve two functions - to provide feedback on the prior session and to clarify the goal for the impending session.

Next, participants clipped a MotivAider® to their waistlines. They turned on the MotivAider® when the teacher stated “Begin” and wrote answers on their math worksheets. During all intervention sessions, the MotivAider® emitted a mild vibration once every 45 s; thus, 4 vibrations segmented the 3-min sessions into 4 equal intervals. The teacher programmed each student’s MotivAider® to this equal interval schedule at the start of the study, and this schedule remained the same throughout all intervention sessions. When participants felt each of the first three vibrations, they circled the math problem on which they were working, ascertained whether they were on pace, behind pace, or ahead of pace, then resumed writing answers to their math problems. Participants were able to determine whether they were on pace, behind pace, or ahead of pace, by comparing the problem they just circled (i.e., where they were on the worksheet at the time of a tactile cue) to the colored highlights (i.e., visual cues), which the teacher had previously inserted on their worksheets. The colored highlights

indicated the specific math problems that they should have reached at the time that the MotivAider® emitted each of the four vibrations during a session (sample data sheet is available at <http://www.abainternational.org/BAinPractice.asp>). When participants felt the fourth vibration, they immediately placed their pencils on their desktop. If participants completed all of their assigned problems before the fourth (final) vibration, they self-checked the accuracy of their answers (without an answer key) until they felt the fourth vibration, rather than writing answers to additional problems that appeared on their worksheets.

For the initial intervention phase, the lower performance criterion of the range was set at or slightly above the highest number of correct digits a participant had achieved during any baseline session *when his or her accuracy was at least 95%*. The upper criterion of this range was set a few digits above the lower criterion, typically 3 digits, which was the equivalent of one full math problem. The teacher then highlighted, in color, answer spaces of problems on individual participants’ worksheets based on a pacing schedule that would permit them to meet their goals. Specifically, the upper criterion of the range was divided by 4 to determine which answer spaces to highlight. For example, if a participant was expected to write 37 to 40 digits during a session, the teacher divided 40 by 4 and colored the answer spaces on the worksheet where the 10th digit (yellow), 20th digit (purple), 30th digit (green), and 40th digit (orange) would be written; this showed the participant where he or she should be at the time of the 1st (45 sec), 2nd (1:30), 3rd (2:15) and 4th (3:00) tactile cue. The teacher also highlighted the answer space of the problem that corresponded to the lower limit of their performance criterion for the entire 3-min probe. Thus, in this example, the teacher highlighted, in orange, the answer space in the math problem for the 37th digit to indicate the lower criterion of the range, as well as the 40th digit to indicate the upper criterion

of the range.

The performance criterion was raised whenever individual participants “hit their target,” that is, produced the number of digits prescribed by their range bound criterion for that intervention phase (e.g., 37 to 40 digits), with $\geq 95\%$ accuracy for three consecutive sessions, or a cumulative mean of $\geq 95\%$ accuracy across three or more consecutive sessions. Typically, we raised the criterion for each participant such that (a) the lower boundary of the new criterion was at least one digit above the upper boundary of the prior criterion, and (b) the upper boundary of the new criterion was at least three digits (the equivalent of one full math problem) above the lower boundary of the new criterion (e.g., changed the prior range bound criterion from 37 to 40 digits to 41 to 44 digits). As in baseline, the teacher did not provide praise statements or reinforcement based on how much or how well students completed their math problems.

Follow-Up

Short-term follow-up probes were conducted 1 and 2 weeks after the last session of the final intervention phase. During these probes, participants used the same procedures that they used during the final intervention phase.

Social Validity

The participant’s teacher collected social validity data using the social comparison and subjective evaluation methods (Kazdin, 1982). For social comparison data, two math warm-up probes—one at the beginning of the study and the other at the end of the last intervention phase—were administered to 23 students enrolled in a 9th-grade, general education Algebra class at the same school as the participants. We collected these data to determine if, by the end of the study, the intervention had eliminated the math fluency gaps that had existed between the participants and their same-grade peers at the start of the study. For subjective evaluation,

Table 2: Items on Subjective Evaluation Questionnaire

1. Did participating help you/increase your speed, or did it hurt you/make you slow down?*
2. Did participating help or hurt you to become more accurate/make fewer errors?*
3. Did you like or dislike being apart of this research study?*
- 4 (& 10). What specifically did you like most (least) about participating in the research study?*
5. Did the self-graphing hurt you or help you?*
6. Was the MotivAider easy or hard to use?*
7. Did you ever hear any other MotivAiders go off during the study? If so, did it bother you, or did it not bother you?*
8. Did the highlights on your worksheets help or hurt you pace yourself during each session?*
9. Did circling the problem whenever you felt a vibration help or hurt the pace at which you did problems during each session?*
11. How did you feel/what did you think about when you graphed your results each day before you were about to do your math warm-up problems? What did you think about when you found out (marked your graph for days when) you did or did not make your range?
12. Describe a specific task or activity that you do in school, at home, or anywhere else, for which you might be able to use the MotivAider to help you improve how you perform.
13. When you felt the vibrations from the MotivAider®, did you check to see/notice whether or not you were on pace, behind pace, or ahead of pace? Most of the time when you felt the cues, were you (select one) way ahead, a little bit ahead, right on, a little behind, or way behind pace?
- 14 (& 15). At the beginning (end) of the study, how do you think your performance on warm-up problems compared to the performance of students in [name of teacher's] Algebra Part I class on the same type of math problems before (after) you used the MotivAider?
16. Is there anything else you want to say? Are there any specific things that might have helped you perform better/answer even more problems during the daily 3-minute math warm-ups?

* = Items for which the teacher used follow up probe, as needed, such as: How so? Why? Explain. Can you give specific examples?

the teacher interviewed each participant individually at the end of the study and wrote participants' oral responses to each of 16 items (see Table 2) on a social validity questionnaire, which was developed jointly by the teacher and second author.

Interscorer Agreement

Near the end of the study, the teacher (primary scorer) faxed copies of participants' completed worksheets to the secondary scorer. The secondary scorer used an answer key and recorded whether each digit written on the worksheets by participants was correct or incorrect. Then, the secondary scorer compared these results with those previously and independently recorded by teacher. Mean item-by-item interscorer agreement for all worksheets completed during baseline, intervention, and follow-up sessions was 99.71% for correct digits and 98.28% for incorrect digits for the 6 participants. Mean

interscorer agreement for the worksheets completed by the 23 students in the general education Algebra class during the first and second social comparison probes was 99.29% for correct digits and 98.35% for incorrect digits.

Procedural Integrity

The educational assistant used 7-item, 5-item, and 8-item observational checklists, respectively, to collect data on procedural integrity during 100% (5 of 5) of sessions during training, 72% (57 of 72) of sessions during baseline, and 72% (54 of 75) of sessions during intervention, respectively (sample checklist is available at <http://www.abainternational.org/BAinPractice.asp>). Procedural integrity during training, baseline, and intervention sessions was 100% across all phases. When conducting these checks for procedural integrity, the educational assistant directly observed the teacher and participants and checked "yes" or "no" for each item on

the checklists. Examples of items printed on the procedural integrity checklists were as follows: "Did the teacher state verbatim the directions on the script? Did students clip the MotivAider® to their waistlines? Did the students shift the "on" switch on the MotivAider® when the teacher stated, "Ready, start?" Did students stop immediately after 3 minutes? Did the students graph the number of correct and incorrect digits from their previous session?"

In addition, the second author examined copies of all worksheets that participants used during all intervention and follow-up sessions and evaluated the extent to which participants circled problems based on occurrences of tactile cues emitted by the MotivAider®. With one exception, each participant circled one problem for each of the first three tactile cues emitted during all sessions. Overall, participants adhered to this procedure for 99.58% (239 of 240) of the cues emitted by the MotivAider®.

Figure 1. Correct and incorrect digits during baseline, intervention, and follow-up sessions for Jeff and Ronnie. Parallel, horizontal, solid lines depict upper and lower limits of the range-bound criteria that defined minimum and maximum number of digits the participant was expected to produce. Sessions when percentage of correct digits fell below the 95% accuracy standard associated with fluent performance are marked <95%. C and I indicate correct and incorrect digits for invalid worksheet (simpler than usual problems) used only on session 6. Sessions without data points indicate that the student was absent.

Results

Results of the intervention for the six participants are displayed in Figures 1, 2, and 3. Similar results were obtained across all students with the exception of Max, who was not exposed to the intervention. During each intervention phase, the five participants met or exceeded the lower limit of the performance criterion in nearly every session. The mean number of correct

digits in each phase exceeded the previous phase, while the mean number of incorrect digits remained at or below baseline levels. Thus, the increase in pace was not associated with a decrease in accuracy. In fact, most of the participants also increased the overall percentage of digits completed accurately relative to their baseline levels. These improvements generally maintained during the follow-up probes for all participants. Shaun, having broken his writing hand a few

Figure 2. Correct and incorrect digits during baseline, intervention, and follow-up sessions for Anisa and Shaun. Parallel, horizontal, solid lines depict upper and lower limits of the range-bound criteria that defined minimum and maximum number of digits the participant was expected to produce. Sessions when percentage of correct digits fell below the 95% accuracy standard associated with fluent performance are marked <95%. C and I indicate correct and incorrect digits for invalid worksheet (simpler than usual problems) used only on session 6. Sessions without data points indicate that the student was absent.

days prior, did not complete the second follow-up probe.

As shown in the bottom panel of Figure 3, the number of correct digits for Max continued to increase throughout baseline and did not stabilize by the end of this study. Thus, intervention was not implemented. Max also was not present for either of the follow-up probes.

Results of the social comparison evaluation indicated that the improvements in the participants' math

Figure 3. Correct and incorrect digits during baseline, intervention, and follow-up sessions for Peter, and correct and incorrect digits for Max, who did not require intervention. Parallel, horizontal, solid lines depict upper and lower limits of the range-bound criteria that defined minimum and maximum number of digits the participant was expected to produce. Sessions when percentage of correct digits fell below the 95% accuracy standard associated with fluent performance are marked <95%. C and I indicate correct and incorrect digits for invalid worksheet (simpler than usual problems) used only on session 6. Sessions without data points indicate that the student was absent.

fluency across the study substantially exceeded those of the comparison peers. Furthermore, participants' performance was similar to or better than the performance of these peers at the end of the study. Means for the 23 students in the comparison group, at the beginning of this study, were 47.7 for correct digits, 4.7 for incorrect digits, and 91 % for accuracy. At the end of the study, the means were 53.3 for correct digits, 13.2 for incorrect digits, and 80% for accuracy. Means for the five students

who received the intervention were 53 for correct digits (range, 41.8 to 72.7), 1.3 for incorrect digits (range, 0 to 3.3), and 97.6% for accuracy (range, 93% to 100%) during the final intervention phase. While peers in the comparison group increased the mean number of correct digits by 5.6 digits, or 11.7%, from the first to the second social comparison probe, the participants increased their mean number of correct digits during the same five-week time period by 23.9 digits (range, 12.8 to

32.5 across students), or 77% (range, 44% to 89% across students).

Finally, all participants reported that they "liked" the intervention and that it helped them improve their performance on math warm-ups. Shaun reported, "It kept me on my toes." When asked what they liked *best*, three participants alluded to "getting faster" or "getting better," including Anisa, who stated, "having a great warm-up with zero errors." Two other participants, Ronnie and Jeff, specifically identified the MotivAider® as what they liked best. In addition, each participant reported that the MotivAider® was easy to use.

Participants provided explicit descriptions that confirmed the intended pacing function served by combining tactile and visual cues. When asked whether the colored highlights on worksheets, as well as circling the current problem when the MotivAider® vibrated, helped or hurt their performance, each participant indicated that comparing where they were to the colored highlights helped them see if they were behind, ahead, or on pace. Peter stated, "It told me to either check over the problems if I had time, or move faster if I was behind pace." Anisa noted, "I tried to beat the MotivAider® by using the highlights. It helped [me] to see where I'm going. When I'm behind and circling the problem, I'm thinking to myself that I better pick it up." Ronnie added, "The last highlights helped me to stop." When asked whether they ever had time "left over" during math warm-up sessions and what they did with such time, participants responded that they "sometimes" finished the maximum number of digits specified by the upper performance criterion before three minutes elapsed. Participants indicated that they used the left over time to "check my answers," "look over my problems," or correct their answers.

When describing their reactions to self-graphing their results "on days when you did or did not make your range," participants' verbal responses suggested that self-graphing served feedback, reinforcing, and goal setting functions. Participants indicated, "I felt good"

and “I felt proud of myself,” when they were able to chart that they were in their range. When self-graphing results for sessions when they fell short of their stipulated range of digits, participants reported that the information was a signal that they could and should “do better” during the next session.

When asked how they thought their math fluency changed during the study, each participant indicated that he or she closed or erased a math fluency gap that they believed had existed between themselves and the comparison students in the Algebra class. This subjective belief was consistent with objective social comparison data.

Conclusions and Guidelines for Best Practice

These results suggest that the multiple component self-management intervention helped improve math fluency for five of six participants. The other participant's math fluency improved without the intervention. For the five participants exposed to the intervention, accuracy was maintained while pace of responding (i.e., the number of correct digits during daily 3-min sessions) increased. These findings are important because achieving accurate and fast responses via brief practice sessions promotes automaticity and other educational outcomes. Students who do not perform fluently on basic skills, such as math facts and sight words, frequently have difficulties with more complex skills (Carnine, 1989; Cates & Rhymer, 2003; Chiesa & Robertson, 2000; Singer-Dudek & Greer, 2005; Woodward, 2006). The gains in math fluency also appeared to be socially valid in that participants improved their math fluency more than non-participant peers. In fact, as a result of the intervention, their performances either matched or exceeded that of the non-participant peers by the end of the study. Finally, participants reported enjoying the procedure and finding it useful.

The study had several limitations, however. Most notably, we cannot conclude that the intervention components were responsible for gains

in the participants' math performance. It is possible that each participant increased the number of correct digits through daily practice alone. In fact, results for Max suggested that merely practicing each day was enough to improve his math fluency. Baseline responding of another participant, Jeff, also was increasing when the intervention was introduced, suggesting that these improvements may have continued through daily practice alone. It should be noted that Jeff's baseline data appeared to be stable before we assessed interscorer agreement near the end of the study. Agreement checks, however, identified errors in reporting correct digits for Jeff during baseline. Correcting these errors revealed an ascending trend and variable performance that had not yet stabilized at the end of baseline. The simple but important lesson, here, is that researchers and practitioners should conduct reliability checks for permanent products, such as worksheets, immediately after each session, rather than waiting until later.

One way to separate the effects of daily practice from the self-monitoring intervention would be to periodically reduce the performance criteria. A corresponding decrease in the production of correct digits would suggest that the self-monitoring intervention was responsible for the outcomes. We did not implement such reversals because it seemed impractical and counter to educational goals to ask students to produce *fewer* correct digits after they had already achieved a quicker pace. Future research could implement such reversals for purposes of demonstrating experimental control.

Practitioners planning to implement this intervention to improve fluency should consider several issues. First, the benefits of using a range-bound performance criterion rather than a single-point performance criterion should be considered. A range-bound changing criterion may be preferable when rapid increases in performance — well beyond the magnitude specified by a single-point criterion — might produce deleterious consequences (e.g., increased errors) that sabotage systematic and

enduring changes. For example, Stecker, Whinery, and Fuchs (1996) discovered that establishing a single-point criterion for previously late-arriving students to “beat” while walking from a computer lab to their next classroom, while helpful, had an undesirable result. By single-point criterion, we mean, for example, that a child must take no longer than 50 s to complete a task, such as the aforementioned one. In this case, one participant began running to get to the next classroom on time. Although the participant met and exceeded the single-point criterion, he engaged in unacceptable and potentially dangerous behavior (i.e., running in the hallway) to do so. The authors recommended, “In actual classroom application, teachers may need to modify the procedures by setting a goal range [rather than a single point criterion] in which times that are too high or too low are not accepted” (p. 145).

Practitioners and educators also must consider how much to increase the criterion over time. Small, incremental increases were sought to ensure the likelihood of participant success, that is, to maximize the probability that participants would not only meet the criterion for increasing the number of correct digits, but also keep errors low. The criterion was also set so that students who paced themselves effectively would have a brief amount of time left over to check the accuracy of their responses. Many benefits accrue from having students self-correct their work (Morton, Heward, & Alber, 1998; Okyere, Heron, & Goddard, 1997). Thus, we recommend that teachers make explicit the expectation that ‘left over’ time should be used to check work if students do not do so as a matter of habit.

Practitioners might also consider making explicit the expectations for both the number of correct and incorrect responses. In the current study, performance expectations for participants were relatively explicit for total digits to be completed, as indicated by two parallel lines drawn on participants' self-graphing forms and the visual cues on the

worksheets. Performance expectations for participants were less explicit for the number of incorrect digits. The teacher simply stated, "Make zero or as few errors as you can." Although gains were demonstrated without providing participants explicit criteria for accuracy, the research literature suggests that making performance criteria explicit enhances benefits associated with goal setting (Watson & Tharp, 2002; Wehmeyer, Yeager, Bolding, Agran, & Hughes, 2003).

The tactile cues illustrate one way that teachers can help students to cue themselves to self-monitor their behavior in a way that could be less intrusive than audio cues, visual cues, and teachers' verbal reminders. In this study, participants and their teacher reported that the tactile cues emitted by the MotivAider® were not audible, even to the student who was wearing the device. The sole exception was when the device, which students attached to their waistline, inadvertently contacted a hard surface, such as a chair or desk. Consequently, we recommend that practitioners: (a) use tactile cues in contexts where audio or visual cues might prove to be disruptive, distracting, or impractical; and (b) teach individuals, if necessary, to avoid placing the device against a hard surface. For additional guidance and considerations, Flaute, Peterson, Van Norman, Riffle, and Eakins (2005) have identified 20 practical ways the MotivAider® can be used to improve students' performance.

A few additional practical recommendations for teachers are as follows. First, we recommend that teachers use self-monitoring of pace, selectively, with students whom are likely to benefit rather than with the entire class. The procedures would be most useful for students who respond (a) accurately, but too slowly; (b) inaccurately as a result of answering too quickly; or (c) erratically, that is, alternating between being on-task and off-task. Additionally, we recommend that teachers expend the time necessary to: (a) initially train students, individually or in small groups, how to use the MotivAider®; (b) establish

appropriate pacing targets for students; (c) provide performance feedback to students, including self-graphing of daily results; and (d) increase gradually and systematically performance criteria for individual students. Indeed, the teacher in this study reported that the time he invested in teaching students to self-monitor their pace paid dividends beyond having the students' math fluency improve. From the teachers' perspective, he and the students saved time allocated previously to reminding students to stay on task, as well as extra time, beyond the 3-min daily practice sessions, that students used to complete and correct the math problems assigned to them.

In closing, we identify additional considerations for practitioners regarding use of the MotivAider®. First, we found that learning how to operate and, subsequently, using the MotivAider®, were relatively easy. The device includes printed directions that are easy to follow. The controls and display window on the device function well, too. We believe that many teenagers and children could operate the device. However, at approximately \$60 per device, the MotivAider® might cost too much for some practitioners. Given rapid advancements in technology, as well as trends whereby electronic devices become more compact, more versatile, and less expensive over time, use of devices like the MotivAider® might become more widespread when per unit costs decrease.

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