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The Effects of Cognitive Strategy Instruction on the Mathematical Problem Solving of Adolescents With Spina Bifida

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Abstract

This study investigated the effects of cognitive strategy instruction on the mathematical problem solving of three adolescents with spina bifida. Conditions of the multiple-baseline across-individuals design included baseline, two levels of treatment, posttesting, and maintenance. Treatment 1 focused on one-step math problems, and Treatment 2 focused on two-step problems. All students substantially improved as measured by performance on criterion tests of math problem solving. Discussion centers on the need for intervention studies with students with spina bifida that specifically address their unique characteristics and the adaptations and accommodations that benefit these students.

Keywords

spina bifida, cognitive strategy instruction, math problem solving

Spina bifida myelomeningocele (SBM) is a congenital disorder associated with malformation of the spine and brain. As the most common severely disabling birth defect in North America, SBM affects approximately 4,000 newborns each year in the United States (Charney, 1992; Greenburg, James, & Oakley, 1983; Spina Bifida Association of America, 2004). SBM is a complicated series of neural insults that begin prior to birth resulting in physical impairments (i.e., disability of locomotion) with persisting effects on cognitive development (Dennis, Fletcher, Rogers, Hetherington, & Francis, 2002). The cause of SBM is not known with certainty, but it is believed to be multifactorial involving both environmental and genetic factors (Lutkenhoff, 1999).

Treatment involves surgical closure of the open myelomeningocele, which includes the neural elements and the surrounding bone and muscle tissue, within 24 to 72 hours after birth to return the spinal cord to its normal position and to prevent further damage. Surgery cannot, however, make the spinal cord function normally, and the neurological defect present at birth will persist throughout life (Lutkenhoff, 1999). Hydrocephalus is an additional neurological insult that is present in approximately 85% of children with SBM. Hydrocephalus results from an increased volume of cerebrospinal fluid (CSF) in the brain. When hydrocephalus occurs, a shunt (a mechanical device that allows drainage of the CSF) is surgically inserted into the ventricles (i.e., cavities) of the brain. The purpose of the shunt is to control CSF drainage so the rate of head growth is normal and damage to the brain is minimized (Sandler, 1997). Over the past 40 years, a number of important advances and technical innovations have improved the success rates of shunting from less than 50% to more than 90% (Sandler, 1997). However, despite these surgical improvements, the consequences of ventricular enlargement for the developing brain are complex and often adversely affect cognitive development, particularly nonverbal intelligence (Hommet et al., 2002; Riva et al., 1994).

Cognitive Characteristics of Children With SBM

Children with SBM are known to demonstrate significant individual differences in neurobehavioral functioning (Yeates, Enrile, & Loss, 1998). Congenital malformations (e.g., hydrocephalus) are clearly correlated with poorer outcomes in motor and perceptual skills (Ewing-Cobbs, Barnes, & Fletcher, 2003). Their verbal abilities, especially the more "crystallized" aspects of language and memory

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capacities, are usually intact (Wills, 1993). Comparisons on standardized intelligence tests show significantly lower scores on the nonverbal measures compared to verbal measures (e.g., Fletcher, Brookshire, Bohan, Brandt, & Davidson, 1995). Children with SBM also demonstrate memory retrieval problems (Scott et al., 1998; Yeates, Enrile, Loss, Blumenstein, & Delis, 1995). They are frequently strong on rote memory tasks but impaired in long-term storage and retrieval (Yeates et al., 1995). Calhoun and Mayes (2005 found that these children also had difficulties in effectively and efficiently processing and organizing information.

In addition, children with SBM have demonstrated dysfunctional executive processes including sequencing, visual planning, working memory, attention control, decision making, abstraction, and problem solving (Fletcher, Bohan et al., 1996; Roberts & Pennington, 1996; Snow, 1999). Executive functions are vital for setting goals and then determining what is necessary for their attainment (Singer & Bashir, 1999). Brewer, Fletcher, Hiscock, and Davidson (2001) found that children with SBM have difficulty shifting and refocusing attention in a flexible and adaptive manner. Their low level of arousal and alertness, inattentiveness, and lack of initiation, presumably because of a compromise of subcortical areas of the brain (Brewer et al., 2001), may be directly related to their characteristically poor performance on problem-solving tasks (Burmeister et al., 2005; Fletcher, Brookshire et al., 1996).

Academic Characteristics of Children With SBM

As a consequence of neurodevelopmental problems, children with SBM typically have academic problems (Wills, 1993) that are manifested particularly in reading comprehension and mathematics. These children frequently have adequate decoding skills but poor comprehension (Ayr, Yeates, & Enrile, 2005; Barnes & Dennis, 1992; Barnes, Dennis, & Hetherington, 2004; Barnes et al., 2002; Ewing-Cobbs et al., 2003; Fletcher et al., 1995). Children with this pattern in reading may also demonstrate relative strengths on mathematics tasks involving basic number knowledge, exact measurement, and arithmetic operations but have difficulty with tasks involving geometry, mental computation, and applied math skills such as estimation and problem solving (Barnes et al., 2006; Dennis & Barnes, 2002).

Approximately 5% to 8% of the general population of school-aged children has mathematics disabilities (Geary, 2003). In contrast, about 25% of children with SBM have specific mathematics disabilities (Fletcher, 2004). Although the prevalence of math disability is much higher among children with SBM, the sources of their math difficulties may be similar to those of children in the general population (Agness & McClone, 1987; Barnes & Dennis, 2001; Barnes et al., 2006; Lollar & Reinoehl, 1990; Rourke, 1995; Snow, 1999). That is, like children with math disability in the general population, children with SBM are characterized by problems with attention, memory, and executive function and, therefore, have difficulty with mental tracking, fact retrieval, working memory, selective attention, sustained attention, and flexibility in shifting tasks and responses (Barnes et al., 2006; Wills, 1993). Children with SBM have brain dysmorphology in two regions, the posterior cortex and cerebellum, that are important for math tasks that require procedural knowledge and working memory (Hetherington, Dennis, Barnes, Drake, & Gentili, 2002). Dennis and Barnes (2002) found that problems in mathematics for these children persist into adulthood, which has serious implications for their functional independence.

It is important, however, that teachers be aware that not all children with SBM manifest cognitive difficulties that significantly impede their academic progress. That is, although some students with SBM will show pervasive impairment of cognitive functions, others will show unique profiles of strengths and weaknesses. A recent study of teacher knowledge and confidence in meeting the needs of children with chronic medical conditions including SBM found that special education teachers, compared to regular education teachers, reported being more knowledgeable about these conditions but not being more confident than regular education teachers in meeting the academic needs of these children (Nabors, Little, Akin-Little, & Iobst, 2008). With the move toward full inclusion in most school districts, it is imperative that teachers develop the knowledge, skills, and confidence to provide appropriate and high-quality instruction to children and adolescents with SBM in the context of the regular education classroom.

Cognitive Strategy Instruction and SBM

Swanson's meta-analysis of intervention research with students with learning disabilities (LD) indicated that direct instruction and cognitive strategy instruction were the most powerful interventions for these students (Swanson, 2002; Swanson & Sachse-Lee, 1999). Both instructional approaches involve the active presentation of information, clear organization, step-by-step introduction of content, multiple exemplars, demonstration and modeling, visual prompts, ongoing assessment of student understanding, alteration of the pace of instruction, and progress monitoring (Swanson, 2002). Cognitive strategy instruction, which directly addresses students' comprehension and problem-solving deficiencies, has improved the performance, strategic knowledge, and affective responses of students with LD across academic and social-emotional domains (for a review, see Wong, Harris, Graham, & Butler, 2003).

Montague (2003) developed a cognitive strategy instructional program (i.e., Solve It!) to improve mathematical problem solving for students with LD. She and her colleagues demonstrated the effectiveness of Solve It! with middle and secondary students with LD in resource programs and in general education math classrooms that include students with disabilities (Montague, 1992; Montague, Applegate, & Marquard, 1993; Montague & Bos, 1986; Montague, Enders, & Dietz, 2010). Solve It! is a comprehensive cognitive strategy instructional routine consisting of seven cognitive processes (i.e., read, paraphrase, visualize, hypothesize, estimate, compute, and check) and corresponding self-regulation strategies (i.e., self-instruction, self-questioning, and self-monitoring) in the form of a SAY, ASK, CHECK procedure. These processes and strategies are thought to facilitate linguistic and numerical information processing, formation of internal representations in memory, comprehension and integration of problem information, and development of solution plans.

Although research has begun to clarify the learning profile and cognitive manifestations resulting from underlying neurological dysfunction of children with SBM (Fletcher, 2004), our review found no research on effective instruction or interventions for this population. Given the similarities of cognitive processing problems in children with SBM and students with LD (i.e., attention, memory, and executive function problems), it seems only natural to explore whether interventions that have been successful with students with LD may be effective for students with SBM. The purpose of this study was to investigate the effects of an intervention, Solve It!, on the math problem solving of three adolescents with SBM. To our knowledge, this is the only intervention study to date that specifically targets students with SBM. The following research question guided this study: What are the differential effects of cognitive strategy instruction on the math problem-solving performance of three adolescents with SBM?

Method

Participants

A flyer was placed in the newsletter of a community Spina Bifida Association newsletter in a southeastern state inviting volunteers to participate in a research study on cognitive strategy instruction to improve mathematical problem solving for adolescents with spina bifida. Adolescent participants between the ages of 15 and 17 were recruited from families who responded to the request for participation in the study. Four participants met the following criteria for participation: (a) verbal intelligence quotient of 80 or more as measured by the *Kaufman Brief Intelligence Tests* (K-BIT; Kaufman & Kaufman, 1990), (b) a reading and math level of at least third grade as determined by the Letter-Word Identification, Passage Comprehension, Calculation, and Applied Problems subtests of the *Woodcock–Johnson Psycho-Educational Battery Tests of Achievement III* (WJ-III; Woodcock, McGrew, & Mather, 2001), (c) a diagnosis of SBM (the most severe form of spina bifida), and (d) evidence of shunted hydrocephalus within the child's first year.

The reliability of the K-BIT IQ composite ranges from .88 to .98 across ages. Bands of error for standard scores for the participants in this study at a 90% confidence interval resulted in a standard error of measurement around the individual's true score of ±6. Maria obtained a composite score on the K-BIT of 76 with a confidence interval score of 70 to 82. Given that her "true" score falls within this range, she was included in the study. The WJ-III subtests have reliabilities of .80 or higher.

Parents contacted their child's doctor to request the medical history including the type (i.e., meningocele, myelomeningocele) and location of the lesion (i.e., cervical, thoracic, lumbar, sacral) of the neural defect as well as information regarding the child's neurological status (e.g., history of hydrocephalus, shunt revisions, infections, etc.) and then completed a questionnaire about the child's medical history. Past medical records for one participant born outside the United States were unavailable, so no information regarding a specific neural anomaly (i.e., Arnold–Chiari II malformation) is provided. In addition, each child's cumulative school records were reviewed to examine the participant's current individualized education plan (IEP) and resultant academic and behavioral goals. The four adolescents who met criteria for participating in the study were randomly assigned either to the single-participant pilot study or to one of the three positions in the multiple-baseline study. Table 1 contains demographic information on the four participants.

Design

A pilot study was conducted with one student prior to implementation of the multiple-baseline across-individuals study in which the remaining three participants were randomly assigned to one of three positions. The experimental phases included baseline, two levels of treatment, posttesting, and maintenance. Treatment 1 focused on one-step math problems, Treatment 2 on two-step problems. After establishing baselines, staggered application of the independent variable (the intervention, Solve It! instruction) across students permitted demonstration of the reliability of the dependent variable (i.e., tests of math problems). The modifications made to the Solve It! intervention as a result of the pilot study are described next.

Modifications to Solve It!

The first modification was to control the type of problem and to reduce the number of problems on the criterion-based

Table 1. Characteristics of the Participants

Variable	Pilot	James	Frank	Maria
Gender	Female	Male	Male	Female
Race	Hispanic	Hispanic	Hispanic	Hispanic
Age (years)	17	17	15	16
Grade	10	10	10	9
WJ-III Applied Math Problems GE		7.2	3.8	3.1
WJ-III Math Calculations GE	6.2[a]	7.3	4.9	6.2
WJ-III Letter Word-Identification GE		9.1	12.7	17.3
WJ-III Passage Comprehension GE	10.0[a]	10.1	8.9	5.1
K-BIT Verbal IQ (SS)	99	89	88	79
Performance IQ (SS)	100	79	78	77
Full-scale IQ	99	82	81	76
Type of spina bifida	SBM	SBM	SBM	SBM
Level of lesion	Thoracic-8	Lumbar-2	Lumbar-5	Lumbar-5
Shunted for hydrocephalus	Yes	Yes	Yes	Yes
Age	4 days	10 days	5 days	7 days
Shunt revisions	Yes	Yes	Yes	Yes
Number	4	1	2	3
Arnold–Chiari II malformation of the brain stem	Yes	Information unavailable	Yes	Yes
If so, has the child had decompression surgery?	Yes	No	Yes	No
Age	9 years		11 years	
Agenesis or partial agenesis of the corpus callosum	Yes	Information unavailable	Yes	No
Any history of infections in the brain	Yes	No	Yes	No
If yes, what type	Meningitis	No	No	Meningitis
Age	4			3

Abbreviations: WJ-III, *Woodcock–Johnson Psycho-Educational Battery Tests of Achievement III*; GE, grade equivalent; K-BIT, *Kaufman Brief Intelligence Tests*; SS, standard score; SBM, spina bifida myelomeningocele.
[a]Pilot student was administered only the WJ-III Calculation and Passage Comprehension subtests.

measures. Solve It! uses progress monitoring measures consisting of 10 one-, two-, and three-step textbook-type word problems. The pilot study with one student with SBM suggested that the measures were too long and too difficult. As a result, two levels of treatment were planned. The first level consisted of daily lessons focusing on one-step word problems. Criterion measures of 5 one-step problems drawn from the Solve It! problems were developed for Treatment 1. The criterion for mastery was established at 4 correct of 5 problems. The second level consisted of daily lessons focusing on two-step word problems. Criterion measures of 5 two-step problems, also drawn from Solve It!, were developed for Treatment 2. Again, the criterion for mastery was 4 correct of 5 problems. Following mastery at Treatment 2, a 10-problem posttest including 5 one-step and 5 two-step problems was administered. The criterion for mastery on the posttest was 7 correct of 10 problems.

A second modification was to delete the estimation process from the Solve It! routine. Estimation requires flexible thinking, which Snow (1999) identified as a weakness for children with SBM. The student in the pilot study had considerable difficulty with estimation, and teaching estimation would have required additional instructional time. Following discussion, the researchers decided to eliminate this element of the routine. A third modification was to assist the student in visually representing the problem, an essential cognitive process in problem solving (Montague & van Garderen, 2003). Because of the visuospatial and visuomotor characteristics of children with SBM (Ewing-Cobbs et al., 2003), and based on the difficulty the student in the pilot demonstrated in drawing a picture to represent the problem, the researchers decided that assistance in creating an image to represent the problem was necessary. Therefore, a schematic representation was provided by the researcher–instructor for students in the intervention study.

Fourth, research has established that children with SBM tend to have poor oculomotor problems such as squinting, strabismus, nearsightedness, and poor visual tracking as a result of the malformation of cranial nerves and the malformation of the cerebellum (Dennis et al., 1981). During the pilot study, a one-page, double-spaced work sheet was used as the master chart to review the cognitive processes daily with the student. However, the student in the

Math Problem Solving Processes and Strategies

READ	(for understanding)
Say:	Read the problem. If I don't understand, read it again.
Ask:	Have I read and understood the problem?
Check:	For understanding as I solve the problem.
PARAPHRASE	(your own words)
Say:	Underline the important information. Put the problem in my own words.
Ask:	Have I underlined the important information? What is the question? What am I looking for?
Check:	That the information goes with the question.
VISUALIZE	(a picture or a diagram)
Say:	Make a drawing or a diagram. Show the relationships among the problem parts.
Ask:	Does the picture fit the problem? Did I show the relationships?
Check:	The picture against the problem information.
HYPOTHESIZE	(a plan to solve the problem)
Say:	Decide how many steps and operations are needed. Write the operation symbols (+, -, x, and /).
Ask:	If I …, what will I get? If I …, then what do I need to do next? How many steps are needed?
Check:	That the plan makes sense.
COMPUTE	(do the arithmetic)
Say:	Do the operations in the right order.
Ask:	How does my answer compare with my estimate? Does my answer make sense? Are the decimals or money signs in the right places?
Check:	That all the operations were done in the right order.
CHECK	(make sure everything is right)
Say:	Check the plan to make sure it is right. Check the computation.
Ask:	Have I checked every step? Have I checked the computation? Is my answer right?
Check:	That everything is right. If not, go back. Ask for help if I need it.

Figure 1. Math problem-solving processes and strategies

pilot study said the print was too small and asked that it be held up so she could see the chart. Therefore, an 8 in. × 11 in. freestanding flipchart with laminated pages was created to display the Solve It! processes and strategies.

Finally, children with SBM have impaired visuospatial and serial ordering skills and other problems (e.g., attention and memory) that affect their ability to do arithmetic (Wills, 1993). The Solve It! program recommends that students be taught how to use and be allowed to use calculators whenever possible to circumvent retrieval problems that characterize children with LD and also, in this study, children with SBM. Therefore, students used calculators in the study.

Materials

Dependent measures. Criterion-referenced tests of 5 one-step math problems and 5 two-step math problems were used to assess mastery during Treatment 1 and 2. Tests of 10 one-step and two-step math problems were used for baseline and posttesting.

Intervention materials. Materials for the study included a freestanding flip chart to display the Solve It!cognitive processes and the self-regulation strategies (i.e., the SAY, ASK, CHECK routine), an individual Solve It! booklet for the student to use at home, one-step and two-step math problem worksheets, daily graphs, and baseline and posttests. The math problems were drawn from the Solve It! program (Montague, 2003). Individual graphs were used to record each student's progress during baseline, the two treatment phases, posttesting, and maintenance. Other materials included pencils, pens, highlighters, and a calculator.

Procedures

James, Frank, and Maria (pseudonyms) participated in the intervention study. The students were removed from an elective course to participate in the study. The course that the student missed because of the intervention was mutually agreed on by the student, the student's parents, and the school's exceptional student education specialist. Space was limited in all three schools. James received instruction in a guidance office, Frank in a private room in the library, and Maria in a quiet corner of the library.

Three baseline tests consisting of 5 one-step and 5 two-step math problems were administered to students during 1 month to establish baseline for each student (see Figure 1). On evidence of a stable baseline for James, the first student, the intervention was introduced. Progress monitoring measures consisted of tests of 5 one-step problems for Treatment 1 and 5 two-step problems for Treatment 2. On evidence of an upward trend and performance stability of at least 4 correct of 5 problems during Treatment 1, James advanced to Treatment 2. At that time, Treatment 1 was introduced for the second student, Frank. During this interval, the third student, Maria, remained in baseline. The intervention was introduced to Maria after Frank reached the criterion of 4 correct of 5 problems during Treatment Level 1. When students met criterion in Treatment 1 (one-step problems), they entered Treatment 2 (two-step problems). On reaching criterion in Treatment 2, students completed a posttest consisting of 10 one-step and two-step problems. The criterion for mastery was preset at 7 correct of 10 problems.

Solve It! Instruction

In Lesson 1, each student was provided with an overview of Solve It!, and the goal of instruction, to improve math problem solving, was discussed. Scores received during baseline were reviewed with emphasis on improving those scores on subsequent progress measures. Mathematical problem solving and why it is important to be a good problem solver were discussed. The six cognitive processes were displayed for the student on the flipchart, defined, and discussed interactively. The student learned the mnemonic for the processes (reading, paraphrasing, visualizing, hypothesizing, computing, and checking [RPV-HCC]) and practiced the routine by verbalizing the processes and strategies using the chart with prompts by the researcher as needed to attain mastery (i.e., 100% recitation of the cognitive processes from memory). The researcher modeled thinking aloud as she solved three one-step problems using the Solve It! routine, which included the cognitive processes (RPV-HCC) and the self-regulation strategies (SAY, ASK, CHECK). The researcher then verbalized the Solve It! Routine, followed by the student independently verbalizing the processes and strategies. The student was provided with an individual study booklet of the routine to review for homework. Figure 1 presents the modified Solve It! routine.

In Lesson 2, the routine was reviewed and verbally rehearsed using the following steps. First, the researcher and the student read the processes and strategies from the flipchart. The student was then cued to recite the names and descriptions of the processes using the mnemonic RPV-HCC. Second, the researcher modeled solutions for two problems while the student listened and observed. Each worksheet contained only two problems to provide sufficient workspace. Third, the researcher modeled problem solving as the student recited the strategy while solving the problem with the researcher. In addition, the student independently underlined important information and assisted the researcher in paraphrasing the problem. Fourth, the student verbally rehearsed the routine prior to solving a problem and then independently solved a one-step problem while thinking aloud. The schematic representation of the word problem was provided to the student, or the student could draw one with the researcher's assistance. Fifth, the student completed the computation and checked the calculation with the use of a calculator. Finally, the student attempted to independently solve a mastery check consisting of five problems while thinking out loud. If the student requested help on the mastery check, the researcher assisted the student by rereading the process and by modeling the correct solution out loud to solve the word problem. However, if the student required assistance on the mastery check, the item was not counted as a correct response toward the criterion for mastery. The mastery check was scored, and the results were graphed daily.

Each remaining lesson followed the same format; that is, the student reviewed the master chart with the researcher and was cued to use the routine. The student was required to think aloud to solve a math problem and then apply the strategy to 5 one-step word problems. This procedure continued until the student met the criterion of 4 correct of 5 one-step problems in Treatment 1. On reaching criterion for Treatment 1, each student progressed to Treatment 2, which focused on two-step problems using the same procedures as in Treatment 1.

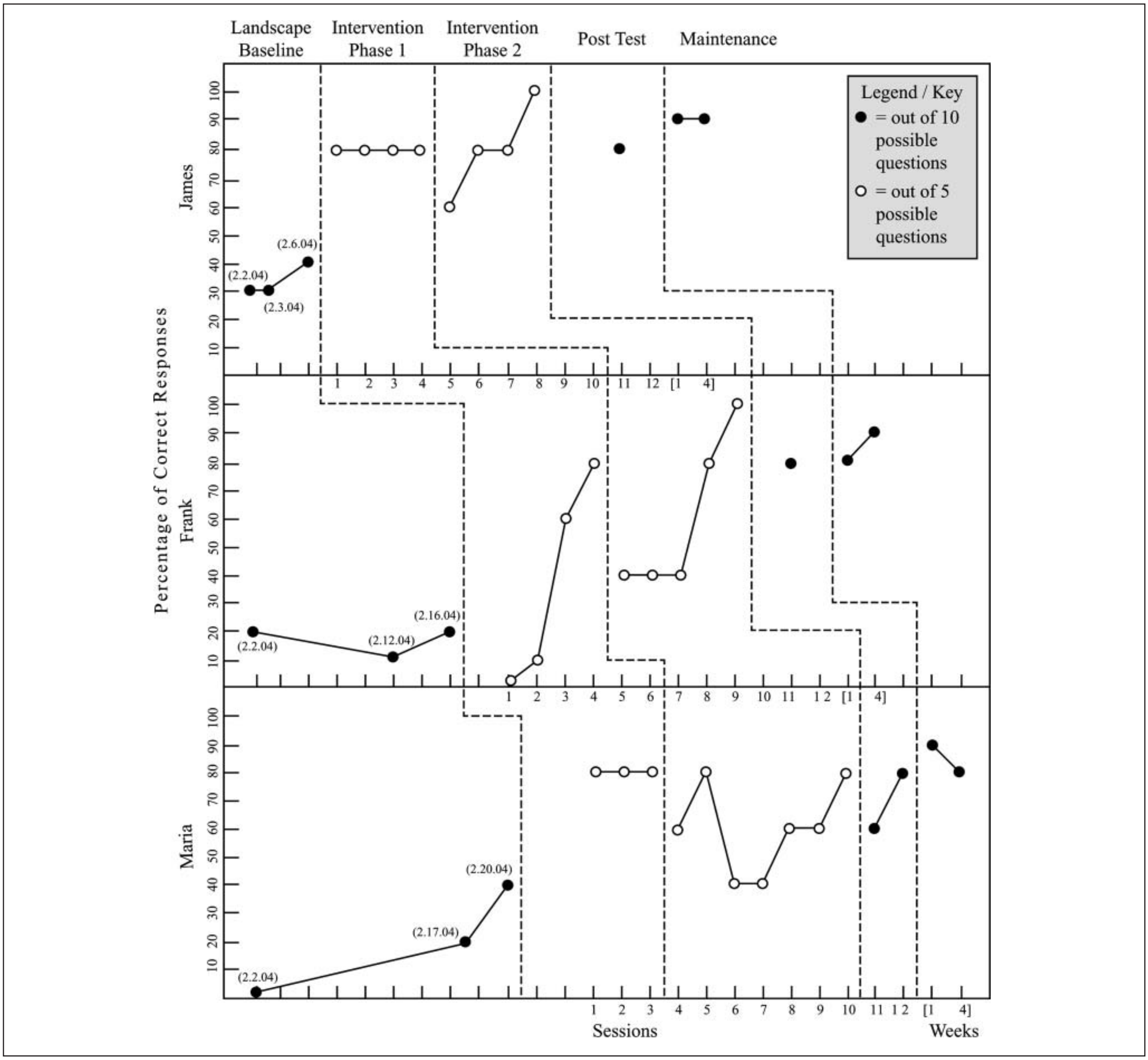

Figure 2. Line graphs for all three participants

When mastery was met for Treatment 2, the student completed a posttest consisting of 10 mixed one-step and two-step problems. Immediate feedback was provided, and the student graphed his or her score. The criterion for mastery was 7 correct of 10 problems. If the student did not demonstrate mastery on the posttest, a booster lesson consisting of 1 day of review and guided practice was provided. Students varied on the amount of time needed to achieve mastery for each level of treatment.

A maintenance test of 10 one-step and two-step problems was administered 1 week following the intervention. If the participant failed to achieve at least 7 correct on the maintenance test, the student practiced verbalization of the strategy steps and a review session was provided prior to retesting during this phase. The student was tested again 1 month later to measure long-term maintenance. If the student did not attain mastery, the same procedure was followed. When a score of 7 or better on the maintenance tests was achieved, the study ended for that student.

Treatment Fidelity

The first author–researcher was the instructor. All lessons were scripted. The instructor noted any variations from the script following each lesson with each student. Both researchers reviewed the notes and determined that the variations were simply additional reinforcement of Solve It! components, additional explanations of solutions, or additional practice. Thus, the researchers concurred that the intervention was implemented with 100% fidelity across the three students.

Results

The data demonstrated the effectiveness of cognitive strategy training on the mathematical problem-solving performance of three adolescents with SBM. Visual analysis of Figure 2 indicates that all three students made substantial progress following Solve It! instruction. James achieved a baseline mean score of 3.3 correct of 10 problems and had 8 correct problems on the 10-problem posttest, an increase of 4.7 problems correct. James received four lessons in Treatment 1 and reached criterion on the daily mastery tests (4 correct of 5 one-step problems). In Treatment 2, he reached the criterion (4 correct of 5 two-step problems) on the second lesson; two additional lessons were provided to reinforce performance on two-step problems. James received a total of eight lessons and eight daily mastery checks across the two treatment levels. On the posttest, he obtained a score of 8 correct of 10 problems, which met the criterion for mastery. We can conclude that Solve It! instruction was successful for improving James's math problem solving.

Frank had a baseline mean of 1.6 correct responses and scored 8 correct of 10 problems on the posttest, an increase of 6.4 correct responses. Frank required four lessons in Treatment 1 to reach criterion and four lessons in Treatment 2 to meet criterion for mastery. He received a fifth lesson to reinforce performance and had all 5 problems correct. Frank received a total of nine sessions and nine mastery checks across the two levels of treatment. Frank obtained a score of 8 correct of 10 problems on the posttest, meeting the criterion for mastery. Again, we concluded that Solve It! instruction was effective for Frank.

Maria achieved a baseline mean of 2 correct responses and scored 8 correct of 10 problems on the posttest, an increase of 6 responses. Maria had 3 lessons in Treatment 1 and reached criterion on each mastery test (i.e., 4 correct of 5). She required 7 lessons in Treatment 2 to reach the criterion of 4 correct of 5 problems. On the posttest, Maria achieved 6 correct of 10 problems, which did not meet the criterion of 7 out of 10 correct responses established for mastery. Therefore, further intervention in the form of a practice session was provided for Maria, followed by a second posttest on which she scored 8 correct of 10 problems, thus meeting criterion. In all, Maria received 10 lessons across the two levels of treatment. We concluded that Solve It! instruction was effective for Maria.

Maintenance

Figure 2 illustrates that all three students met or exceeded the criterion established for mastery during the maintenance checks 1 week and then 4 weeks following instruction. The criterion for mastery was again 7 correct of 10 one-step and two-step problems. James had 9 correct responses at both time periods. Frank had 8 correct and then 9 correct at the 1- and 4-week time points. Maria had 9 and then 8 correct on the maintenance checks. Thus, all students met the criterion for mastery during the maintenance phase of the study.

In sum, the adolescents with SBM in this study were successful in learning how to apply Solve It! when they solved math problems. Their problem solving improved as indicated by the 47% to 64% increase in problems correct on the mastery tests. All three students reached the criterion for mastery on the posttest and maintained performance at least 1 month following instruction.

Discussion

To our knowledge, this is the first intervention study conducted with students with SBM. Because children with SBM exhibit some learning difficulties that are similar to those demonstrated by children with LD (Fletcher, 1998; Rourke, 1995; Snow, 1999), we thought it only natural to investigate an intervention designed for and validated as effective for children with LD. Consequently, we investigated the effects of a modification of a cognitive routine for solving math problems, Solve It!, an intervention that improved math problem solving for middle and secondary school students with LD (Montague, 2003). The results of this study have implications for how we assess and teach students with SBM and their educational outcomes. Successful school performance of these students has implications for their everyday functioning at home, in the community, and in the work place.

Results of the study indicated that all three students demonstrated substantial improvement in math problem solving following cognitive strategy training, using an adaptation of Solve It!, and maintained performance gains 1 month following instruction. This study adds validity to the hypothesis that interventions that have been successfully implemented with students with LD may be appropriate, with modifications, for students with SBM. Like many children with LD, children with SBM are poor math problem solvers because of their inability to select and organize relevant information, visually represent the problem, and develop an appropriate solution path (Barnes et al., 2002). Many of the errors demonstrated by the students in this study were process errors. The most prevalent errors were using the wrong operation and completing only one step of a two-step problem.

The modification of Solve It! focused on teaching students six cognitive processes important for solving math problems: reading, paraphrasing, visualizing, hypothesizing, computing, and checking (i.e., RPV-HCC). Instruction incorporated the following eight teaching strategies that have been found to be effective for teaching students with LD (Swanson, 2002): (a) sequencing (a series of short activities, prompts such as a mnemonic to enhance memory), (b) consistent practice and review as needed, (c) parsing the skill into smaller units (graduated instruction from easy to difficult), (d) directed questioning and responses (asking process-related questions, engaging the student in thinking aloud, prompting the student to ask questions), (e) controlling the pace of instruction, (f) technology (structured text, scripted lessons, emphasis on schematic representations, displaying the cognitive routine, calculators), (g) supplement to teacher involvement (daily review and homework), and (h) cues and prompts (students were cued to use the SAY, ASK, CHECK self-regulation strategies and required to think aloud as they solved problems during practice sessions).

The processes that seemed most effective were related to problem representation, (e.g., rereading, paraphrasing, and visualizing the problem). Controlling the pace of instruction and providing students with immediate and corrective feedback on performance were also effective. Process modeling (i.e., thinking aloud while solving a problem and using the self-regulation strategies) also seemed to guide students as they solved problems. Maria had difficulty choosing the correct operation for this problem: "Karla bought 8 used CDs for $8.00 each. How much did she pay for them?" The researcher instructed her to reread the problem aloud. When she heard the word *each,* she realized that *each* meant each CD, and she then knew what to do. The aural presentation seemed to facilitate understanding. In addition, providing a schematic representation of the problem for the students rather than having them create their own also seemed to be an effective modification of the routine. Frequently that accommodation was sufficient for the student to make a plan to solve the problem. Finally, controlling the pace of the instruction by introducing one-step problems to mastery before advancing to two-step problems allowed the students to graduate from one level of mastery to the next. Daily graphs of their performance on the mastery checks provided immediate and positive reinforcement. The students seemed eager to attempt harder problems to "beat" the previous day's score.

Their confidence seemed to improve as well. Frank's performance on the following problem illustrates this point: "Kimberly packs an average of 180 cartons a day for five days. She is paid $.30 for every carton she packs. How much will she earn in five days?" Frank correctly solved the problem and then expanded on it by multiplying the amount by 4 to find out how much Kimberly earned in a month. He then asked how many months were in a year but answered his own question stating, "Oh, I know. 12." Next, he multiplied the amount she earned each month by 12 to find out how much she made in a year. He was quite proud of himself, stating, "I just did four steps by myself!" Finally, he said, "How many years in a decade? No, I better not go that far." He then looked up and said, "Wow, I couldn't do that before." This example provides evidence that Frank was using metacognition as he solved the problem and was extending or generalizing his learning. In addition, students with SBM have difficulty retrieving math facts because of memory problems and speed of processing (Fletcher, Brookshire et al., 1996). Using the calculator allowed students to focus on the process of problem solving as opposed to retrieving math facts.

Each student began to adapt the strategy. At first, all of the students used all six cognitive processes during strategy acquisition and application but over time began to work more independently. They became more flexible and selective during application of the Solve It! routine. For example, James usually did not draw a picture but represented the problem mentally. In contrast, Maria attempted to draw a picture of the problem and often asked the researcher for help. Frank tended to be impulsive and at first often chose the wrong operation. He demonstrated varying levels of proficiency in his use of the SAY, ASK, and CHECK strategies. On several occasions, he exhibited signs of the mental inflexibility described by Snow (1999) characteristic to children with SBM. He was quite confident that his answers were correct and would strongly disagree with the researcher when illustrating the correct procedure to solve a problem. For example, on the following problem, "If there were 500 grizzly bears in the woods and twice as many black bears, how many black bears were there?" the researcher provided a visual representation, but he still did not solve the problem correctly. The researcher then modeled the correct solution to the problem to which Frank replied, "No, Miss, that's not right." Frank was quite rigid in his thinking, which made it difficult at times to advance to the next problem in the lesson.

One hypothesis or explanation for these students' performance is that the ability to acquire and select appropriate strategies is affected by what has been described by Fletcher (2004) as a modal cognitive profile for students with SBM. The participants in this study displayed remarkably similar cognitive profiles to each other and to the modal cognitive profile described by Fletcher (2004) including a verbal intellectual quotient greater than the performance intellectual quotient, a discrepancy between mathematical calculation and applied mathematical ability, and a large discrepancy between reading decoding and reading comprehension, a pattern that is frequently found in children with SBM.

Implications for Assessment and Education of Students With SBM

According to Lollar and Reinoehl (1990), to effectively identify the learning strengths and weaknesses of children with SBM, it is imperative to go beyond the typical psychological evaluation, which evaluates intelligence, academic levels and basic learning levels, and neuropsychological functions. These functions include attention, perceptual motor processes, reasoning and problem solving, organization, sequencing skills, and memory. Baseline neuropsychological assessment will allow for the detection of altered neuropsychological functioning that will enable educators to develop appropriate educational interventions for individual children. When the information is integrated, a learning profile (i.e., current level of performance) can be developed for each student (Lollar & Reinoehl, 1990). The individual learning profile is fundamental in developing an IEP that is truly individualized and addresses the unique neurological disorders commonly found in children with SBM. The behavioral problems that characterize many children with SBM (i.e., inattention, passivity) tend to be underidentified and untreated. In fact, these problems are often manifestations of cognitive difficulties that are secondary to their underlying neurological disorder. Educators must recognize and understand the characteristic learning deficits of children with SBM. One way to ensure that the neurological component of their disorder is recognized is to make certain that the child is classified to receive special education services under the category of other health impaired, which includes children with neurological disorders. As previously mentioned, these children are frequently misidentified as lazy and unmotivated because of these common behavioral characteristics. Teachers may misperceive their distractibility, disorganization, and difficulty staying on task (Burmeister et al., 2005; Rourke, 1995) as passivity and lack of interest in learning.

The researcher reviewed the school cumulative files for James, Frank, and Maria. The IEP goals for all three students included specific goals to increase motivation, on-task behavior, and task completion. The IEP for James contained goals to improve task management, time management, work attitudes, and assignment completion. Similar statements were found in the IEP for Maria, stating that she demonstrated poor sustained mental effort and lacked concentration and the ability to focus. All three students' IEPs contained goals to improve motivation. The review of the students' files established that none of the students had received a psychological exam at school or privately in the past 5 years, nor had any student received a neuropsychological evaluation recommended as best practice for establishing the current level of performance for students with SBM (Lollar & Reinoehl, 1990). Therefore, it is presumed that the goals written in the IEP to improve motivation were developed on the basis of teacher observation and/or misinformation, not from empirical data.

Consider the following example, which illustrates a teacher's impression of James's work habits. When the researcher arrived at James's class to take him for instruction, the teacher told the researcher, within earshot of James, that he was failing art class because he did not care about the class and was "unmotivated and lazy." Art class requires fine motor skills and visual perceptual abilities that research has verified to be common deficits in children with SBM (French, 1995; Snow, 1999). The motor disorders are because of the malformation of the cerebellum and result in deficient depth perception, which could exacerbate difficulties with tasks such as drawing (Dennis & Barnes, 2002; Wills, 1993). James was placed in a class that emphasized the very skills known to be impaired in children with SBM. Moreover, James was not provided with the necessary modifications for educational success but suffered from a regrettable misunderstanding of the cognitive effects of the neurological impairments common to children with SBM and was consequently perceived by his teacher as lazy. James stated that people do not understand him, think he is stupid, and put him down for doing poorly in school and being lazy. He said he did not participate in art because he cannot draw and felt that the teacher did not like him. This example illustrates how vital it is for educators to have knowledge and understanding of the neurological component of SBM and to recognize it as part of the disability (Fletcher, 1998).

In addition, teachers must understand the affective variables that interact with achievement. Children with SBM and other physical disabilities frequently have poor self-esteem (Kazak & Clark, 1986). According to Bandura (1975), how people behave can often be predicted by the beliefs they hold about their own capabilities (i.e., their self-efficacy). The assumption is that the beliefs that individuals create and develop and hold to be true about themselves are vital forces in their success or failure in all endeavors including performance in school. The students in this study reported feeling good about themselves as they improved in math problem solving. For example, James said, "Now I know how to do math. No one ever showed me before. My teacher even called my mother and told her how much better I am doing. People always told me I couldn't do it, but now I see I can and I feel better about myself." Frank commented, "Look, Miss, I just did a four- step problem and I'm only supposed to do two. I'm working my way up." Maria acknowledged, "Now I can figure it out."

James seemed more positive about school in general and more motivated to learn. This may be because of improved self-esteem as a result of participation in this study. His mother told the researcher that she received a phone call from James's science teacher praising his recent improvement in effort and grades in science class. His mother reported that in fall 2003 James had received an F in all of his classes. He participated in this intervention program during February and March 2004. At the end of March, he received an interim report card that showed a change in grades from all Fs to Cs and one D. James attributed his progress to his ability to apply the cognitive strategy he learned in his general education classes and to his improved self-esteem. At the conclusion of the intervention program, he thanked the researcher for helping him to learn how to solve word problems as well as for the impact the improved performance made on his self-esteem. His statement to the researcher was,

> You really helped me with my self-esteem, and I needed that. I really had a problem with that. People made me feel stupid, but you showed me that I'm not and that I can do it. I'm going to keep on trying to do better in school. I now know that I can do it.

Limitations

A major limitation of single-participant research is that the findings may not be generalizable to individuals outside of the study. However, Kazdin (1982) stated that direct replication of an experiment (e.g., applying the same procedures across a number of different participants) strengthens external validity. Because this study was a multiple-baseline across-subjects design, it is regarded as a direct replication for single AB designs, and the treatment effects may be generalizable to individuals with characteristics that are similar to those of the participants in the study. A second limitation of the study is in establishing homogeneity of the participants. Every effort was made to examine each individual on cognitive and academic status as well as to identify similar congenital malformations of the brain and spine. The participants in this study appear to possess similar congenital malformations, and they exhibit a cognitive modal profile characteristic to students with SBM (Fletcher, 2004; Wills, 1993). However, there is a wide variability in neurological status and cognitive functioning of children with SBM. Thus, the findings cannot be generalized to all children with SBM but only to those with similar neurological disorders and cognitive characteristics. It would also have been beneficial to investigate strategy generalization. Although the students said they used the strategy in other classes, generalization was not systematically studied.

Future Research

There are at least five directions for future research. First, researchers should explore other research-based programs and practices that may be effective for children with SBM. This study modified an intervention that was developed for students with LD. This may be a promising avenue to pursue to improve learning for these children. Second, children with SBM need to be taught problem-solving skills from early on. Given the importance of math problem solving for success in school and in the community, instruction in math problem solving should begin in elementary school and be maintained as an educational goal throughout high school. Third, this study established the effectiveness of cognitive strategy training for students with SBM when taught in a one-to-one setting. One-to-one instruction provided the scaffolding, that is, the support necessary to assist students with SBM to become effective problem solvers. It is expected that, because of their unique cognitive profile, students with SBM will continue to require scaffolding in some form or another to effectively acquire and apply cognitive strategies. Providing effective one-to-one instruction to students with SBM in the school setting is not realistic in most school settings. Alternative instructional groupings should be explored. For example, cross-age peer tutoring has been found to be effective for improving students' math problem solving (e.g., Fuchs, Fuchs, & Karns, 2001). In addition, peer tutoring has contributed to a higher rate of academic achievement as well as the social and adaptive functioning of students with disabilities (Bierne-Smith, 1991; Maheady, 1999; Schloss, Kobza, & Alper, 1997). Finally, critically important for student success is the need to investigate professional development to improve teachers' knowledge of SBM and the skills needed to effectively teach students with SBM.

In sum, more research is needed with respect to evaluation and classification issues and effective instructional strategies specific to the unique modal cognitive profile of children with SBM. The current study should be replicated and cognitive strategy training should be studied as an intervention for these children in other academic domains. Solve It! proved effective for improving math problem solving for the three adolescents with SBM in this study and seemed to have a positive effect on their affective attributes as well. Improving mathematical performance for students with SBM should be a primary goal as it has been demonstrated to be the single biggest predictor of future adult independence for these students (Dennis & Barnes, 2002). This study represents a starting point for improving school performance and, ultimately, postschool outcomes for students with SBM.

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