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Impact of Cover, Copy, and Compare on fluency outcomes for students with disabilities and math deficits: A review of the literature

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ABSTRACT

Fluency, a combination of response accuracy and speed, enables students to work efficiently through academic tasks. Students with disabilities and math deficits often struggle to learn math facts fluently. Although issues with fluency frequently coexist with a disability, problems gaining fluency also stem from a lack of practice and appropriate rehearsal activities routinely included in curricula. Absence of math fact fluency leads to future problems with higher level math curricula and tasks necessary for successful living and employment. Cover, Copy, and Compare (CCC), a self-managed intervention, has demonstrated promise toward increasing math facts fluency. The present literature review examines the implementation of CCC as a fluency intervention for students who have disabilities or who demonstrate skill deficits in math facts and its subsequent impact on such students' fluency outcomes. Results from the literature review indicate CCC increased fluency levels for all of the participants. The evidence suggests CCC interventions may help students acquire and practice diverse math content.

KEYWORDS

Cover, Copy, and Compare; learning disabilities; math facts; math fluency; special education

Students who enter school with learning difficulties and disabilities in mathematics often continue to struggle throughout their school careers (Bryant, Bryant, Gersten, Scammaeca, & Chavez, 2008; Geary, 2013; Gersten, Jordan, & Flojo, 2005). Data from the National Assessment of Educational Progress (NAEP, 2013) reports that only 41% of fourth-grade students and 34% of eighth-grade students performed at or above "proficient" in mathematics. The downward trend continues, with only 23% reaching proficiency by the end of Grade 12 (NAEP, 2007). Although many factors contribute to mathematical difficulties, trouble retrieving math facts from memory plays an essential role (National Mathematics Advisory Panel, 2008; Nelson, Burns, Kanive, & Ysseldyke, 2013).

Leading national organizations in mathematics have recognized the importance of teaching students to fluently retrieve math facts. The National Mathematics Advisory Panel (NMAP, 2008) standards require students to recall from memory the addition and subtraction of whole numbers by the end of third grade and the multiplication and division of whole numbers by the end of fifth grade. The Common Core State Standards Initiative for Mathematics (CCSSI, 2010) standards call for students to recall from memory sums of two one-digit numbers by the end of second grade and all products of two one-digit numbers by the end of third grade. Students who fail to meet the standards in the earlier grades will likely experience future problems in math curricula, including failed courses and low standardized test scores (Calhoon, Emerson, Flores, & Houchins, 2007; Mercer & Miller, 1992; Miller, Stringfellow, Kaffar, Ferreira, & Mancl, 2011, NMAP, 2008). The struggles also impact student retention and dropout rates (Duncan et al., 2007; Minskoff & Allsopp, 2003; Rhymer, Dittmer, Skinner, & Jackson, 2000).

Concern for mathematical competency stretches beyond school performance and graduation. Basic math skills such as counting money, estimating, and telling time represent essential aspects of successful independent living (Minskoff & Allsopp, 2003; Patton, Cronin, Bassett, & Koppel, 1997). Employability, potential income, and quality of life in an increasingly global job market depend on an even higher level of quantitative competency (NMAP, 2008; Rivera & Bryant, 1992). Despite the importance of math competency, NMAP (2008) reports that students in the

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United States cannot solve basic math facts as fluently as students from other countries.

Math facts fluency

Fluency refers to a student's ability to respond accurately, rapidly, and without hesitation (Binder, 1996, 2005; Dougherty & Johnston, 1996; Johnson & Layng, 1996; Kubina & Yurich, 2012; Wood, Burke, Kunzelmann, & Koenig, 1978). To reach a level of proficiency, students must correctly respond to problems at an identified level of difficulty within a fixed time period (Miller & Heward, 1992; NCTM, 2000). Students who lack fluency rely on inferior strategies to solve simple problems and struggle when transitioning to more complex problems. For example, students who use their fingers to solve one-digit plus one-digit addition facts (e.g., $3 + 3 = ?$) struggle to solve two-digit plus two-digit facts (e.g., $15 + 27 = ?$). The problem intensifies when students engage in long division and word problems (Rivera & Bryant, 1992). However, when students automatically retrieve math facts, they free working memory to operate on other components of a complex problem (Carr, Taasoobshirazi, Stroud, & Royer, 2011, Geary, 2004).

Despite the importance of mathematical fluency, the quality and quantity of practice in the American classroom does not generally support effective fluency instruction (NMAP, 2008). Few curricula include appropriate activities to increase math facts fluency (NMAP, 2008; Witzel & Riccomini, 2007). The problem is compounded by the absence of sufficient opportunities for students to practice basic math skills (Daly, Martens, Barnett, Witt, & Olson, 2007). In order to learn a new concept, students first focus on acquisition, quality, and accuracy (Binder, 2003). Students then practice toward the goal of fluency and endurance before applying the fluent element(s) into a compound behavior. Binder (2003) suggests that schools fail to produce mastery because students either skip the second stage or are prematurely pushed into the third stage before they can perform the element(s) behaviors fluently. Instruction, therefore, must include sufficient and appropriate practice (NMAP, 2008) to develop fluency.

Prior research supports the correlation between math fact practice and increased memorization and generalization (Daly et al., 2007; Rivera & Bryant, 1992). In a recent meta-analysis, Codding, Burns, and Lukito (2011) report interventions that include practice with modeling produce the largest effect size. Practice with modeling refers to interventions in which the student is exposed to a model of the problem and its correct answer before engaging in a practice opportunity. Practice with modeling proves most effective when the student is given multiple opportunities to respond successfully in a brief time period (Daly et al., 2007; Rivera & Bryant, 1992). Opportunities to respond denotes the number of instances students are prompted to deliver correct answers. Research has demonstrated that students who have high levels of responding display increased performance in accuracy, fluency, and maintenance (Greenwood, Delquardi, & Hall, 1984; Ivarie, 1986; Skinner & Shapiro, 1989). Opportunities to respond that offer immediate corrective feedback encourage repetition and reinforcement of correct responses rather than the reinforcement of errors (Burns, VanDerHeyden, & Boice, 2008; Daly et al., 2007; Rivera & Bryant, 1992).

Cover, Copy, and Compare

Students who self-manage practice opportunities often exhibit increased attention, motivation, and independence (Hughes, Korinek, & Gorman, 1991; McDougall, 1998; Reid, Trout, & Schartz, 2005). Self-management, similar to self-monitoring of performance (Mace, Belfiore, & Hutchinson, 2001; Reid, 1996, Reid et al., 2005), emphasizes the significance of a feedback cycle in which individuals methodically assess and evaluate their own performance (Pintrich, 2000; Zimmerman, 2000). During a feedback cycle, a student monitors the amount of completion or accuracy of their work either during or following the task (Reid et al., 2005). Self-monitoring provides an immediate consequence (Mace et al., 1988) or self-evaluation of performance, which results in a denser schedule of self-reinforcement and motivates behavior change (Webber, Scheuermann, McCall, & Coleman, 1993). Theoretically, self-management does not require external reinforcers (Zimmerman, 2000).

Cover, Copy, Compare (CCC), a self-managed math intervention, develops fluency through increased opportunities to respond, repeated exposure to problems and solutions, and immediate feedback for accuracy. Originally designed for spelling (Hansen, 1978), CCC was adapted by Skinner, Turco, Beatty, and Rasavage (1989) as a math facts acquisition and fluency intervention. In CCC, students complete many opportunities to respond in a brief period of time to associate problems with their solutions and to avoid the reinforcement of errors (Carr et al., 2011; Skinner, Fletcher, & Hennington, 1996). CCC involves repetition of a five-step sequence to complete a set of problems in a fixed time period. Skinner, McLaughlin, and Logan (1997) defined the five steps of CCC as follows: participants (a) look at the multiplication fact and solution on the left-hand side of the page, (b) cover the math fact and solution, (c) write the fact and solution on the right-hand side of the page, (d) uncover the original fact and answer, and (e) compare. If incorrect, the student may complete an error correction procedure (e.g., write the correct answer three times or repeat CCC). Since Skinner et al. (1989), researchers have used different mathematical computations and variations of CCC to enhance accuracy and fluency (Codding et al., 2011).

Researchers have implemented different iterations of CCC in math facts studies to investigate which combination is most effective when addressing the different student needs. The following is a description of three modifications made to CCC:

1. Verbal CCC (V-CCC): instead of writing the problem and answer during the third step, the participant vocalizes the problem and answer.
2. Cognitive-CCC (C-CCC): instead of writing the problem and answer during the third step, the participant subvocalizes a response.
3. Model-CCC (M-CCC): the participant looks at and then writes the problem and solution before covering the problem and solution during step two; the participant therefore writes the problem twice during the sequence.

Since 1989, researchers have shown that CCC is a useful self-managed intervention approach to improving math facts fluency. Although CCC has been investigated in other reviews and meta-analyses (Burns et al., 2008; Codding et al., 2011; Joseph et al., 2012), there has not been an extensive analysis of CCC and the criteria and procedures used to improve fluency in students with disabilities and mathematics deficits. Selecting the appropriate fluency criteria and procedures allows teachers to modify instruction, instructional materials, and assessment that enable students to effectively execute practice at a specific level of performance (Burns, Codding, Boice, & Lukito, 2010; Daly & Martens, 1994; Daly, Martens, Kilmer, & Massie, 1996; Kubina, 2005; VanDerHeyden & Burns, 2005, 2008). Conversely, a mismatch can lead to student boredom, frustration, and low performance outcomes (Burns et al., 2006; Daly et al., 1996; Gravois & Gickling, 2002). Therefore, the following question guides this review: how does the Cover, Copy, and Compare intervention and the related measurement and assessment practices researchers used to evaluate student performance affect math facts fluency with students who demonstrate skill deficits in mathematics? In order to explore the topic, the review also asks the following subquestions:

1. How did the researchers measure fluency? How was fluency calculated?
2. What fluency criteria was used in each study? How were the assessments designed?
3. What variations of CCC were used in the studies? What were the participant fluency outcomes?

Method

Inclusion criteria

The following inclusion criteria determined which studies qualified for review. The study had to (a) include participants diagnosed with a disability or identified by teachers as having math deficits or at risk (functioning below grade level or in need of additional supports), (b) include students from primary, elementary, middle, and/or high school, (c) include a dependent measure for fluency, (d) disaggregate data for each participant in order to evaluate how the fluency criteria, practice, and assessment procedures directly impact student performance, (e) investigate effects of CCC or a variation of CCC, and (f) be published in a peer-reviewed journal and available in English.

To locate articles for review, searches were conducted of four academic databases (Academic Search Complete, ERIC, ProQuest PsycINFO, and ProQuest Educational Journals) and one Internet search engine (Google Scholar) using combinations of the terms *cover, copy, and compare; math facts; math fluency; learning disabilities; math difficulties;* and *special education*. The time span of the search includes the years 1989 (year the first study implemented CCC for math facts) to 2015. An ancestral search was conducted from the references of three meta-analyses (Burns et al., 2008; Codding et al., 2011; Joseph et al., 2012). Fourteen studies were identified using CCC with math facts. Only eight articles contained a measure of fluency and therefore qualified for this review. All of the selected studies were single-case design.

Results

The results section is divided into two sections. The first describes how the previous researchers measured and calculated fluency as well as the study's specific assessment characteristics. The second section includes the different iterations of CCC implemented, the criterion used to demonstrate fluency, and fluency outcomes. Table 1 lists the characteristics of CCC without additional over-correction procedures, Table 2 presents a summary of the participants, and Table 3 outlines the sequence of steps used to implement CCC in each study.

Fluency measures, fluency criteria, and assessment design

Digits correct per minute

Across all studies researchers recorded digits correct per minute (DCPM) as the fluency measure. Seven out of the eight studies (Lee & Tingstrom et al., 1994; Poncy, Skinner, & Jaspers, 2007; Skinner, Bamberg, Smith, & Powell, 1993; Skinner et al., 1989; Skinner, Belfiore, Mace, Williams-Wilson, & Johns, 1997; Skinner, Ford, & Yunker, 1991; Stone, McLaughlin, & Weber, 2002) transformed raw scores to calculate DCPM. DCPM was calculated as number of digits correct multiplied by 60 seconds. The answer was then divided by the number of seconds it took to complete the assessment (e.g., 15 correct multiplied by 60 seconds divided by 45 seconds to complete the assessment equals 20 DCPM). Only one study (Becker, McLaughlin, Weber, & Gower, 2009) did not transform the originally measured scores. Of the eight reviewed studies, only Becker et al. (2009) and Stone et al. (2002) reported digits incorrect per minute (DICPM).

Table 1. Characteristics of CCC without additional procedures.

Iteration	Verbal	Nonverbal	Written	Nonwritten	# of trials
W-CCC		X	X		3+
C-CCC		X		X	3+
M-CCC		X	X		4+
V-CCC	X			X	3+

Fluency criteria and assessment design

Three of the eight studies reported using a fluency criteria. Lee and Tingstrom (1994) and Skinner at al. (1989) implemented a fluency criteria of 40 DCPM and 90% accuracy during assessment without a time limit to complete 10 and 12 problems, respectively. Skinner et al. (1993) subsequently implemented a fluency criteria of 40 DCPM and 100% accuracy during assessment and also implemented a 60-second time limit to complete 22 or 23 problems. The balance of the studies did not report using a criteria for fluency; however, timings on assessments were limited to 60 seconds. Stone et al. (2002) included 27–36 problems on each assessment, Poncy et al. (2007) included 24 problems, and Skinner, Belfiore, et al. (1997) and Skinner et al. (1991) included 12 problems. Participants in the previous seven studies had the opportunity to complete the problems on their assessment in under one minute. One assessment (Becker et al. 2009) included more problems (90–100) than could have been answered in 60 seconds.

Intervention implementation and outcomes

Cover, Copy, and Compare

Three studies (Lee & Tingstrom, 1994; Poncy et. al., 2007; Skinner et al., 1989) implemented CCC through the use of the original sequence of steps noted in the introduction. Two of the studies (Lee & Tingstrom, 1994; Skinner et al., 1989) created three separate sets of math facts of similar difficulty (A, B, C). Lee and Tingstrom (1994) included 10 problems in each set and Skinner et al. (1989) included 12 problems. Each of the three sets included (a) three assessment sheets of all the problems used in packets A, B, and C, and (b) three CCC training sheets for either set A, B, or C. During the session, the participants completed the three separately timed assessment sheets for the dependent measure (i.e., DCPM). As noted previously, a fluency criteria was implemented, but a time limit was not imposed. The participants then completed the three CCC training sheets. Participants repeated the same process the next day. The process was repeated throughout the entire study. When a participant reached criteria on assessment A, B, or C (40 DCPM & 90% accuracy), the participant "mastered" that set and then transitioned to the next set.

Both studies reported measurable gains in DCPM, with only one participant not meeting the fluency

Table 2. Summary of studies.

Source	Participants	Disability	Setting	Experimental design/Operation	Outcomes
Becker, McLaughlin, Weber, and Gower (2009)	1 Female: 10 fourth grade	LD Math Reading	Resource room	ABC single case design; Multiplication	CCC: Increase in corrects and a decrease in errors; CCC + error drill: Further decrease in errors
Lee and Tingstrom (1994)	3 females: 10, 1 male: 10, 1 male: 11	Chapter 1	Regular ed. classroom	Multiple baseline design; Division	4 out of 5 participants met 40 DCPM and 90% accuracy; 1 participant did not meet criteria on one set; 2 participants did not make follow-up phase for one set of problems
Poncy, Skinner, and Jaspers (2007)	1 Female: 10	MMR	Classroom	Alternating treatments design; Addition	Final maintenance test reported 25 DCPM for the TP set of problems, 22 DCPM for CCC, and 4 DCPM for control.
Skinner, Bamberg, Smith, and Powell (1993)	Joe (Male): 12, Phil (Male): 12, Pat (Male): 9	BD	Private school for BD; classroom	Within-subjects multiple baseline design; Division	3 out of 3 participants met 40 DCPM and 100% accuracy. Learning trials increased significantly using the C-CCC procedure; participants did not master Lists A, B, and C quicker than the participants in Skinner et al. (1989).
Skinner, Belfiore, Mace, Williams-Wilson, and Johns (1997)	Bill (Male): 10, Jack (Male): 11	BD	Residential school; classroom	Multiphase alternating treatments design; multiplication	Both participants demonstrated an increase in DCPM. Response rate significantly greater during VCCC. Fluency improved for Bill after four sessions.
Skinner, Ford, and Yunker (1991)	1 male: 9, 1 male: 11	BD	Testing room; empty classroom	Alternating treatments design; multiplication	Participant one: mean of 38.5 DCPM during VCCC and 27.8 DCPM during WCCC; participant two: mean of 17.8 DCPM during VCCC and 13.1 DCPM during WCCC
Skinner, Turco, Beatty, and Rasavage (1989)	1 female: 4th, 1 male: 4th, 2 males: 10th	BD	Classroom; small office	Within-subjects multiple baseline design; multiplication	4 out of 4 met 40 DCPM and 90% accuracy; instructional level to mastery level for each set in a little over 3 minutes per day for 3–7 days
Stone, McLaughlin, and Weber (2002)	1 Female: 10	Math deficits	Home setting	Multiple baseline design; division	Participant steadily increased DCPM on each list; − made largest increase during the flash cards + rewards intervention

Note. BD: behavioral disability; LD: learning disability; MMR: mild mental retardation.

Table 3. Cover, Copy, and Compare session summary.

Source	Presequence assessment	CCC Type	CCC: 1st	CCC: 2nd	CCC: 3rd	CCC: 4th	CCC: 5th	Correction/over corr.	Post sequence assessment	Error drill	Fluency criteria
Becker et al. (2009)	N/A	MCCC + Error drill	Looks at fact Looks at problem and solution	Writes problem and solution Writes problem	Covers columns 1 + 2 Covers columns 1 + 2	Writes the problem and solution Writes the problem and solution	Uncover/ compare Uncover/ compare	Write 3× if incorrect Write 3× if incorrect	One minute probe: 90 mult. facts One minute probe: 90 mult. facts	N/A Error drill: recite several times write the fact	Y
Lee and Tingstrom (1994)	Assessment for Sets A, B, C; $n = 30$	CCC $n = 30$	Looks at problem and solution	Cover problem	Writes problem	Uncover/compare	N/A	N/A	N/A	N/A	Y
Poncy et al. (2007)	N/A	CCC + error drill $n = 4$	Looks at problem and solution	Covers problem	Writes problem	Uncover/compare	N/A	If correct, verbalize 3× If incorrect, write problem and answer	N/A	One minute sprint drill work sheet; if incorrect write the correct answer	N
Skinner et al. (1993)	Assessment for each set A, B, C; $n = 36$	C-CCC $n = 72$	Looks at problem and solution in 1st column	Covers problem in 1st column	Sub-vocalize problem	Uncover/compare	N/A	N/A	N/A	N/A	Y (cont.)
Skinner, Belfiore, et al. (1997)	Assessment for one set at a time, A, B, or C; $n = 12$	CCC Timed: $n =$ AMAP, V-CCC Timed: $n =$ AMAP	Looks at problem Looks at problem	Covers problem in 1st column Covers problem	Writes problem Verbalizes problem	Uncover/compare	N/A	If incorrect, repeat procedure If incorrect, repeat procedure	N/A	N/A	N
Skinner et al. (1991)	N/A	CCC $n = 12$, V-CCC $n = 12$, NT	Looks at problem and solution in 1st column Looks at problem and solution in 1st column N/A	Covers problem in 1st column Covers problem in 1st column N/A	Writes problem right of 1st column Verbalizes problem N/A	Uncover/compare N/A	N/A	If incorrect, repeat procedure If incorrect, repeat procedure N/A	Assessed on CCC problems $n = 12$ Assessed on VCC problems $n = 12$ Assessed on NT problems $n = 12$	N/A	N
Skinner et al. (1989)	Assessment for each set A, B, C; $n = 30$	W-CCC $n = 30$	Looks at problem	Covers problem	Writes problem	Uncover/compare	N/A	If incorrect repeat procedure	N/A		Y
Stone et al. (2002)	Assessment from each set A, B, C; $n = 27–36$	M-CCC $N = ?$	Looks at the problem	Writes the problem and verbalizes	Covers the problems	Writes the problem	Uncover/ compare	If incorrect, repeat the procedure			N

criteria for Set C (Lee & Tingstrom, 1994). Three of the five participants in Lee and Tingstrom (1994) reached criteria on all three sets within 14 sessions and continued to increase DCPM during follow-up measures on the assessment sheets; the other two participants did not reach the follow-up phase by the last session (29) due to the amount of time it took to reach criteria on all three packets. Skinner et al. (1989) reported that participants increased performance from instructional level to mastery level for each set in a little over three minutes per day for 3–7 days. Participant one reached criteria on all three sets in 17 sessions, participant two in 23 sessions, and subject three in 19 sessions.

Poncy et al. (2007) used an alternating treatments design to compare CCC and taped problems (TP). The researchers created three sets of problems (A = CCC, B = TP, C = Control) consisting of three sheets with four addition problems each. The first was a CCC practice sheet to practice the four addition problems five times each. The second sheet introduced an overcorrection component; it featured a math sprint of the problems just practiced. If the student made a mistake during the math sprint, the student rewrote the problem and correct answer. The third sheet was a 60-second timed assessment probe (to calculate DCPM) that contained 24 problems. During the intervention, the participant completed either the TP or CCC procedure, followed by the math sprint and the assessment probe. Poncy et al. (2007) did not assign a fluency criteria. Although TP demonstrated an immediate and rapid increase in DCPM (and in 30% less time), the participants completed a higher number of DCPM with CCC by the end of the intervention sessions. However, data from the final maintenance test reported 25 DCPM for the TP set of problems, 22 DCPM for CCC, and 4 DCPM for the control.

Cover, Copy, and Compare versus verbal Cover, Copy, and Compare

Two studies (Skinner, Belfiore, et al., 1997; Skinner et al., 1991) compared CCC to V-CCC. Similar to Poncy et al. (2007), both studies used an alternating treatments design with three different sets of 12 problems to compare the two interventions and a control set (A, B, C). During baseline sessions, participants in both studies completed all three sets of problems until they reached near-equal performance on any two of the sets. The two sets were then assigned to either CCC or VCCC; the third set became the control. During the intervention session, participants completed both the CCC and V-CCC sheets. Both studies collected DCPM data from a 60-second timed assessment, which was presented either immediately after the intervention (Skinner et al., 1991) or the next day before the intervention (Skinner, Belfiore, et al., 1997). Each assessment (V-CCC, CCC) contained the same 12 problems as in the intervention. Neither study contained fluency criteria. In both studies, participant fluency increased at a faster rate with V-CCC due to more opportunities to respond. Skinner et al. (1991) reported mean DCPM for fluency. At the end of the study, participant one demonstrated a mean of 38.5 DCPM during V-CCC and 27.8 DCPM during W-CCC. Participant two demonstrated a mean of 17.8 DCPM during V-CCC and 13.1 DCPM during WCCC. Fluency rates were only available from Skinner, Belfiore, et al. (1997) on a line graph; exact rates were unavailable.

Cognitive—Cover, Copy, and Compare

The V-CCC intervention created noise and distraction and therefore limited its applicability and social validity in the classroom (Skinner et al., 1996). In order to alleviate concerns with verbal responding and still maintain a higher response rate than CCC, Skinner et al. (1993) replaced the written/vocal step of CCC/V-CCC with a subvocal response. The study replicated Skinner et al.'s (1989) and Lee and Tingstrom's (1994) use of CCC in a multiple baseline design. The criteria for fluency on each set of problems was 40 DCPM and 100% accuracy. Practice problems increased in each set to 22 or 23 problems from the inverse of 12 problems. Baseline data was conducted on all three sets for a minimum of three sessions until performance stabilized on each set. Assessment data (DCPM) was collected for 12 problems from each set before the practice phase. Similarly to V-CCC, opportunities to respond increased significantly using the C-CCC procedure because the sequence does not require writing. The three participants reached the fluency criteria for all three sets in 16, 17, and 22 sessions, respectively.

Model—Cover, Copy, and Compare

Becker et al. (2009) compared the M-CCC sequence to the same M-CCC sequence plus an error drill (MCCC + D) in an ABC design (A: baseline; B: MCCC; C: MCCC + D). During the error drill, the researcher modeled an incorrect math fact and the participant repeated the fact several times out loud. Baseline (A) lasted for four sessions, during which the participant completed a one-minute timed worksheet of 90–100 multiplication problems. M-CCC (B) lasted for seven sessions. During the intervention the student practiced 10 multiplication problems and then completed a one-minute probe worksheet with 90–100 multiplication problems. M-CCC + D (C) lasted for 10 sessions and repeated the same process as in the B phase. Results throughout the study showed a gradual decrease in mean errors ($M = 56.0$ at baseline to M = 6.6 at M-CCC + D) and an increase in mean correct responses ($M = 34.0$ at baseline to $M = 83.4$ at M-CCC + D).

Stone et al. (2002) compared M-CCC + rewards (M-CCC + R) to flashcards + rewards in a multiple baseline design. The researchers generated three lists of different division facts (A, B, C). The number of facts in each set ranged from 27–36, and the answers were all single digit. Each list received both interventions. The participant completed a timed 90-question pretest before the study and a posttest at the end of the study in order to compare fluency rates. During baseline, the researcher instructed the participant to complete as many problems as she could from each list in order to collect DCPM. The study lasted for 39 sessions of approximately 40 minutes each, during which overlapping interventions were used.

Only baseline was implemented for the first three sessions. On session four, the participant began List A using the MCCC + R intervention for six sessions. During session six, researchers introduced the flashcards + rewards intervention, which continued for the remaining sessions. The M-CCC + R intervention was first used on List B during the 23rd session, and continued for three sessions. On the 25th session, the researchers implemented flashcards + rewards for List B for the remaining sessions. The process was repeated for list C, with M-CCC + R introduced during session 32 for three sessions and flash cards + rewards introduced for the last five sessions. Stone et al. (2002) did not report why M-CCC + R was used in 12 sessions while flash cards + rewards was used in 30 sessions. The participant steadily increased DCPM on each list through each phase and made the largest increase during the flash cards + rewards intervention. The participant scored 9.7 DCPM and 2.48 DICPM on the pretest and 42.9 DCPM and 0.97 DICPM on the posttest.

Discussion

Results indicate that each variation of CCC helped students with disabilities and math deficits by increasing their performance in simple mathematics computation. The increased rate of responding from V-CCC and C-CCC had the most impact on DCPM. Skinner et al. (1997) reported students completing up to three times as many learning trials using V-CCC versus CCC; one student completed up to approximately 90 learning trials in under two minutes (Skinner et al., 1991). By eliminating the written component, students worked more efficiently (Grafman & Cates, 2010), completing more learning trials in similar fixed periods of time (Skinner, Belfiore, et al., 1997).

The findings also suggest students with disabilities and math deficits can successfully self-manage CCC without mediation from teachers or researchers. For students with behavioral and attention issues, high levels of reinforcement from multiple learning trials in a short time span encourage students to stay on task versus engaging in competing conditions that historically delivered higher levels of reinforcement (Banda, Matuszny, & Therrien, 2008; Lee, 2006; Nevin, 1992). Repetitive, uninterrupted movement throughout the intervention indicates that the students experienced momentum during the sequence (Lee, 2006). As the rate of responding increases, the rate of reinforcement elevates (Banda & Kubina, 2009; Lee, Belfiore, Scheeler, Hua, & Smith, 2004). Prior research shows that an increase in learning trials and reinforcement also leads to a higher probability of assignment completion and access to the benefits of academic achievement (Lee, 2006). The findings correlate with previous studies in which increasing opportunities to respond while decreasing the time to complete tasks improves fluency; (Sutherland, Alder, & Gunter, 2003; West & Sloane, 1986).

The combination of CCC and timed assessments provides the learner opportunities to practice two key components in hierarchical models of learning: accuracy and fluency (Binder, 1996; VanDerHeyden & Burns, 2005). Immediate feedback during the CCC sequence ensures accuracy. Thus, accurate performance prevents students from practicing incorrect responses, thereby decreasing the likelihood of a student learning incorrect answers (Goldman & Pellegrino, 1987; Siegler & Shrager, 1984). Immediate feedback followed by the error-correction procedure within CCC increases the probability of correct responses in future learning trials. Furthermore, as the intervention delivered immediate feedback, the students continued to respond with accuracy while completing a high number of problems. Performance outcomes within the set of studies—in particular the studies that measured performance in DCPM and an accuracy component—support previous research that interventions designed for speed do not diminish accuracy (Carr et al., 2011).

Students with learning and intellectual disabilities as well as behavioral disorders require additional opportunities to respond and opportunities to correct errors (Butler, Miller, Lee, & Pierce, 2001; Sutherland & Wehby, 2001). Error correction and overcorrection procedures provide students with additional opportunities to fix incorrectly answered problems and practice the correct form. In six of the eight studies, the researchers designed the procedures within the CCC sequence. Variations consisted of repeating the sequence or verbalizing or rewriting the problem and correct answer up to three times. In two studies, however, the student completed an error correction procedure after a post-CCC sequence assessment. When the additional error correction procedure follows the assessment, the researcher/teacher has to immediately correct the assessment in order to identify the incorrect answers the student is to correct prior to proceeding. As a consequence, the length of the session increases.

Fluency criteria and assessment methodology varied among the studies. Three out of the eight studies used a fluency criteria that included a rate and accuracy component (e.g., 40 DCPM with 90% accuracy). The balance of the studies used rate without an accuracy component. The number of problems assessed during the intervention sessions fluctuated (i.e., 10, 12, 24, 27–36, 90). Researchers assessed student fluency with untimed, one-minute, and three-minute probes. Studies have shown that students who solve a varying number of problems over different periods of time tend to perform differently (Binder, Haughton, & Van Eyk, 1990; Skinner, 2010). Six out of the eight studies converted scores to arrive at DCPM. Although CCC improved student performance, the variation in fluency and accuracy criteria, number of problems, and timings makes it difficult to establish the criteria and assessment format that works best.

Implications for practice

Effective implementation of CCC involves matching the student with the appropriate iteration that produces the most opportunities to respond, provides immediate feedback, and is performed with fidelity. Each iteration of CCC has distinctive characteristics that affect performance (see Table 1 below). For instance, V-CCC yields the highest response rates without a written component, yet increases classroom volume. Although students who exhibit issues with distractibility and behavior may have difficulty with classroom volume, results from the review indicate that only one student with a behavior disorder completed the intervention unsuccessfully. The written component of W-CCC and M-CCC reduces the number of learning trials; however, the two iterations operate as quiet activities that produce a permanent product to evaluate for accuracy and fidelity of treatment. During M-CCC, the student writes the problem twice within the first three steps of the sequence, further reducing the rate of response. Yet, students may also find the writing component of W-CCC and M-CCC cumbersome and aversive (Skinner, McLaughlin, et al., 1997). Students with behavioral issues, dysgraphia, or other writing difficulties may also find it difficult to complete the task and to keep up with peers, reducing their potential for reinforcement in future sessions.

Teachers organize the intervention and differentiate content based on the needs of each student. However, as the size of the group increases, maintenance of instructional material and data also increases. A plausible direction includes students self-managing assessment data by checking answers from a key and recording scores. From that point, the students can input correct and incorrect responses as they create the next day's CCC practice sheet. Teachers can refer to prior research to determine the appropriate ratio of correct to incorrect problems for the next day's practice (Skinner, 2002). In addition, students have the opportunity to earn reinforcement by graphing and monitoring their own progress as they compete against their prior performance(s).

With limited empirical evidence to support numerical markers and standard practices for fluency, educators have a wide range of criteria and methods of measurement to choose from. As a consequence, a lack of efficiency and instructional ineffectiveness may stem from inadequate source(s) of information. Moreover, educators may have to make arbitrary decisions as to what qualifies as a fluent performance resulting in extended periods of trial and error and the reinforcement of inadequate teaching practice. Replicating methods and procedures from studies in the review provide a foundation until research establishes best practice for disabilities.

Directions for future research

Limitations within the group of studies include a small representation of disabilities. The majority of participants (11 out of 18) had an emotional/behavioral disorder. Only two participants qualified as having either a low-incidence disability or a learning disability. The remaining participants attended a Chapter 1 classroom. Additional studies among both students with low-incidence and high-incidence disabilities would lend more reliability to CCC as an evidence-based fluency practice. Further replication of each iteration with different student populations would offer more data indicating the intervention's effectiveness within different types of disabilities. For instance, only one study (Poncy et al., 2007) focused on intellectual disabilities. In the study, the researchers assigned four problems per set with a verbal overcorrection procedure. Although the intervention proved successful in 11 sessions, Poncy et al. (2007) reported that the student could have handled more problems due to how quickly the student reached the performance goal. Future replication can explore an increase in number of problems, different timings for assessment, and whether the overcorrection procedure provided a benefit for the additional time expended during the intervention session.

Explicit timing has been shown to increase both accuracy and speed on simple computation mathematics problems (Rhymer et al., 2000). Fluency criteria with an accuracy component represents both speed and accuracy, thereby providing students, educators, and researchers with performance objectives. Both can also signify benchmarks that indicate a specific level of achievement when compared to similar age students with similar disabilities. In the set of studies, three incorporated similar fluency and accuracy criteria resulting in the most transparent method to evaluate and report performance in students with behavioral disorders (Lee & Tingstrom, 1994; Skinner et al., 1993; Skinner et al., 1989). Future studies that include both fluency criteria and accuracy measures can potentially provide more information detailing the nuances of a student's performance. Information from manipulating length of time (e.g., 20 seconds, 30 seconds, 60 seconds) as well as the number of problems per assessment may also pinpoint best assessment practices.

Conclusion

Cover, Copy, and Compare (CCC) successfully increases fluent performance in students with disabilities and math deficits. With interventions that build fluency such as CCC, students learn to automatically retrieve math facts that lead to inproved performance when attempting more complex problems. CCC demonstrates that when students engage in higher rates of responding and receive immediate feedback within the intervention sequence, performance increases. V-CCC and C-CCC proved the most effective and efficient iterations of CCC due to elevated opportunities to respond. With further replication of studies and more precise measurements and assessment of fluency, CCC has the potential to generalize across disabilities and to be developed into a practical choice teachers could use to build fluency.

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