A DOSE-RESPONSE CURVE ANALYSIS OF A COVER COPY COMPARE (CCC) INTERVENTION

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Abstract: While various approaches to academic intervention intensification exist, it is important to determine which methods actually strengthen the intervention by producing improved student outcomes. Common conceptualizations of intervention intensification include modifications such as increasing components, staff resources, or time. However, research indicates that these forms of intensification do not always produce a greater effect. To increase our understanding of academic interventions and how to strengthen them, it is important that we examine how intensifications affect student response. In medicine, researchers regularly evaluate treatment intensity in terms of the dose administered and the associated patient response. Similar studies in education may permit more precise intervention recommendations. Few academic intervention studies have applied the concept of dose in order to quantify changes made to an intervention to measure effects on student response. The present study demonstrates that increasing the frequency, or dose, of an evidence-based academic intervention, Cover Copy Compare (CCC), can produce associated increases in student response. Increased frequency of the CCC intervention produced associated increases in student growth rates with no maximum effective dose reached. This information is valuable to school staff responsible for remediating student deficits, because it provides insight not only into intervention intensity but also intervention strength. These findings also suggest that it may be possible to predict student growth rates based on the intervention, their grade level, and the target skill. Additional research is needed to understand how increased frequency of other evidence-based academic interventions impact student learning rate. Continuing this line of research may allow practitioners to prescribe evidence-based academic interventions with more precision so that basic skills deficits can be more efficiently and effectively remediated within available timeframes.

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CHAPTER I

INTRODUCTION

Increased accountability in schools has placed rising pressure on educators and administrators to identify and implement effective and efficient instructional strategies. Greater emphasis is placed on student outcomes, increasing the necessity for interventions that are highly likely to affect meaningful changes in student performance (Hawkins, 2010). As a result, there is a growing need for academic interventions that are effective and adaptable when attempting to meet diverse student needs (Lentz, Allen, & Ehrhardt, 1996).

An effective intervention has the capacity to produce a desired change, which has been referred to as the strength of the intervention (Yeaton & Sechrest, 1981). Gresham (1991) defined treatment strength as "the ability of a given treatment to change behavior in the desired direction" (p. 28). Academic intervention researchers have worked to identify the mechanisms underlying effective interventions. Findings indicate interventions that are generally effective for a majority of students make use of critical components based in principles of learning and behavior, such as measurement, modeling, opportunities to respond, immediate feedback, and reinforcement (Daly, Martens, Barnett, Witt, & Olson, 2007; Hawkins, 2010; Lentz, Allen & Ehrhardt, 1996; Skinner, 2008). Strong interventions are also appropriately matched to the topography of the target behavior, meaning each component functions meaningfully in relation to the desired outcome (Haring & Eaton, 1978).

There are various ways to adapt an evidence-based academic intervention in order to strengthen the effects of the intervention for a particular student or group of students not responding at expected levels. When an intervention is not effective or insufficiently effective for an individual or group of students, one possible approach to address this concern is to change the intervention.

When interventions are changed the interventionist may add additional intervention components to the existing intervention or employ a different intervention altogether. This approach consists of what is essentially a trial-and-error approach to intervention modification (Daly, Martens, Barnett, Witt, & Olson, 2007). While commonly practiced, this can result in time wasted and numerous failures to identify appropriate intervention conditions. Most problematic, a trial-and-error approach may inadvertently lead to a conclusion that the child simply cannot learn as expected due to inalterable variables within the child (i.e., a disability). An alternative approach to modification of an intervention is to strengthen the current intervention systematically until desired effects are produced.

Intensification

The strengthening of an intervention often occurs via intensification of the intervention. Barnett et al. (2004) described intensification in terms of implementation difficulty, necessary resources, and discrepancy from general education conditions. Various means of intensification have been explored across academic and behavior intervention literature. Mellard, McKnight, and Jordan (2010) organized intensification studies into the following categories: dosage, group size, immediacy of feedback, mastery requirements, response opportunities, transitions, curricular focus, and instructor specialties. Taken together, these categories combine into three major approaches to intensification which include altering the number of intervention components delivered, increasing the resources (personnel, materials, etc.) required for delivery, and increasing the time or duration of the intervention.

One way to intensify an intervention is to increase the number of components contained within an intervention package (Barnett, Daly, Jones, & Lentz, 2004). McComas et al. (1996) attempted to strengthen baseline reading and spelling interventions (oral reading and written spelling practice) in order to improve student performance on 10-item comprehension and spelling tests. The researchers intensified baseline interventions by systematically testing additional instructional components for each student. Components were ordered in terms of adult assistance required. Findings indicated that each participant's performance improved in response to different combinations of instructional components that varied both in terms of number and strategy. Daly, Martens, Dool, and Hintz (1998) intensified a baseline reading intervention (reading practice with reinforcement) by adding components theoretically ordered in terms of complexity. Components ranged from simple (i.e., a basic repeated readings intervention, listening passage preview) to complex (i.e., increasing content overlap across passages, modifying passage difficulty). Like McComas et al. (1996), findings indicated that each participant required a unique combination of components, ranging in complexity. Rhymer, Dittmer, Skinner, and Jackson (2000) evaluated the effectiveness of adding a performance feedback component to a multi-component peer tutoring intervention for math fluency. Three of four participants responded to the initial multi-component intervention and showed additional improvement following the addition of performance feedback.

The provision of additional components is an approach to intensification that has been shown to improve student performance in some cases. However, as indicated by Daly et al. (1998) and McComas et al. (1996) determining which combination of components is appropriate for each individual student can be a lengthy process. In addition, added components may require more effort but may not necessarily result in significantly improved outcomes (Duhon et al., 2009). In some cases, extra components may produce only modest gains, resulting in a less efficient intervention overall (Skinner, 2008). When researching the addition of components, Rhymer et al. (2000) also noted the difficulty in determining whether observed effects can be attributed to the added components or to practice effects related to repeated assessment.

Another way to intensify an intervention is to apply additional resources. For example, McMaster, Fuchs, Fuchs, and Compton (2005) compared reading interventions administered in peer tutoring (requiring minimal staff resources) to one-on-one and small group formats (requiring increased teacher time and/or specialized staff). Findings indicated no statistically significant differences in student reading fluency across conditions. Similarly, Begeny, Hawkins, Krouse, and Laugle (2011) measured intensity in terms of teacher time required to implement a reading fluency intervention, with participants receiving three alternating treatments (peer tutoring, small group, one-on-one) and a control (no treatment). Results indicated that while three of five participants responded better to the small group and one-on-one conditions when compared to peer tutoring, there were no significant differences in reading fluency outcomes detected between the small group and individual administration formats.

Increasing resources may be one way to intensify a treatment, but this method has not been consistently shown to result in improved outcomes. Because resources are often limited due to budget constraints, adding staff to intensify interventions via decreased student to teacher ratios may not be feasible in every case. In addition, the assumption that greater resources will improve outcomes can be problematic, because this may shift attention away from the selection of evidence based and appropriately linked intervention characteristics. For example, hiring an additional reading specialist may allow for more students to receive small group or one-on-one reading instruction, but if time spent with the reading specialist is not defined by high rates of responding, feedback, and reinforcement, then students may not receive additional benefit despite the added cost to the local education agency.

Academic interventions can also be intensified by increasing them along some dimension of time, such as duration, frequency, or opportunities to respond. Elbaum, Vaughn, Hughes, and Moody (2000) conducted a meta-analysis of reading research for students with disabilities and assessed outcomes related to increased duration in terms of the number of weeks the intervention lasted. They found no significant effects of increased duration, suggesting that similar outcomes could be achieved in a shorter number of weeks. Vaughn, Linan-Thompson, and Hickman (2003) assessed students' response to intervention following ten, twenty, and thirty weeks of intervention duration. Results indicated that all participants made the greatest gains during the first ten weeks of intervention, suggesting that merely extending the intervention duration did not result in significantly improved outcomes. Wanzek and Vaughn (2008) evaluated the impact of altering the frequency of a reading intervention package, comparing a 30-minute daily administration to two 30-minute daily administrations. Findings showed that doubling the daily dose of intervention did not significantly increase student performance when compared to the single dose. However, Duhon, Mesmer, Atkins, Greguson, and Olinger (2009) systematically increased the frequency of an explicit timing math intervention for non-responding participants. Intervention administration was increased from once daily, to five times daily, and lastly, to ten times daily. While some students required increased daily administrations of the intervention, all students met criterion.

Increased time in intervention, or attention to how this time is structured, may also permit higher rates of active responding or opportunities to respond (Hall, Delquadri, Greenwood, & Thurston, 1982). Greenwood et al. (1984) evaluated teacher-mediated versus peer-mediated instructional procedures to determine which condition allowed for the greatest opportunities for student engagement. They found that the peer-mediated procedures resulted in higher rates of student academic responding and were associated with improvements on weekly achievement measures. Albers and Greer (1991) measured the effects of increasing the number of three-term contingency trials (antecedent, behavior, consequence) during instruction. Findings indicated that increased three-term contingency trials resulted in increased rates of correct responding.

Ebbinghaus (1885) demonstrated that increased practice time can positively impact learning (as cited in Skinner, 2008). In many cases, students who are not responding to an effective academic intervention are learning, but not at the desired rate (Carroll, 1963; Gettinger, 1991; Skinner, 1998; Skinner, 2008). This suggests that increasing the amount of time a student spends in intervention may improve performance. However, it is also important to take into account the efficiency of the intervention, or the amount of learning that takes place per unit of time. These studies show that intensifying an intervention across some dimension of time may or may not produce improved student performance, depending on the degree and manner in which it was intensified.

When taken together, the above studies demonstrate that increasing the intensity of an intervention does not always result in a greater effect. Intensifying an intervention increases some aspect of the intervention, but strengthening has occurred only when increased learning rates associated with changes to the intervention provide evidence that intensification successfully improved intervention effect. To increase our understanding of academic interventions and how to modify them, it is important that we examine how modifications or intensifications impact student response.

Dose

In medicine, researchers regularly evaluate treatment intensity using a dose-response curve in which "dose" signifies the amount of treatment administered, and "response" represents the associated change in patient functioning (Holford & Sheiner, 1981). A graphic plot of dose against response results in a visual representation of the relationship between increases in treatment and associated patient outcomes. A dose-response curve produces a "therapeutic window" which consists of a threshold, or the lowest amount of treatment necessary for any effect to occur, and a plateau, at which increasing the dose produces no additional effects or, in some cases, toxicity. Psychological researchers have applied this model to psychotherapy in an attempt to evaluate the impact of increased sessions on patient outcomes. Howard, Kopta, Krause, and Orlinsky (1986) conducted a meta-analysis of outpatient clinic psychiatric data regarding total number of sessions and assessments of patient improvement throughout therapy. The researchers used this data to estimate dose-effect relationships and found that about half of the patients included in the study showed measurable improvement by eight sessions.

Few academic intervention intensity studies have used the concept of dose in order to quantify changes made to an intervention for the purpose of measuring effects on student response. Wanzek and Vaughn (2008) defined increased frequency of a reading intervention package in terms of dose, with a single dose of the intervention equaling one daily thirty-minute session, and a double dose of the intervention equaling two daily thirty-minute sessions, distributed over thirteen weeks. Findings indicated no significant differences in individual student response across the two dose levels. Duhon (2014) applied the dose-response model to evaluate the effects of different doses of an explicit timing math intervention package. Participants were assigned to eight dose levels ranging from no treatment to eight two-minute sessions daily. Findings indicated that the minimum effective dose was one session daily, and increased doses resulted in increased effects with no maximum reached. The changes in performance associated with each dose were used to predict the amount of growth that could be expected based on dose and days available to intervene.

While too little or too much of an academic intervention is less likely to result in calamitous outcomes when compared to a medical treatment (e.g., a student is unlikely to die from excessive amounts of reading intervention), use of a similar approach within the realm of education may be one way to systematically evaluate intensification in terms of student outcomes. Changing an intervention in no other way but the number of times it is administered may be a feasible and effective way to improve intervention strength. Refining our understanding of empirically validated interventions could increase efficiency and improve decision-making, ultimately resulting in better outcomes for students and schools. Additional studies are needed to examine the impact of increasing the dose of various evidence-based academic interventions.

There are numerous studies supporting the use of Cover Copy Compare (CCC) as an evidence-based intervention across academic subjects and student demographics (Joseph et al., 2012; Poncy & Skinner, 2011; Skinner, Bamberg, Smith, & Powell, 1993; Skinner, Ford, & Yunker, 1991). CCC employs critical components based in learning and behavioral principles including modeling, practice, and immediate feedback. Problems are typically presented with a model of each problem and solution followed by a blank space for the student to cover the model, write the problem and answer, and compare his/her response to the modeled response. While widely considered a best match for students in the acquisition phase due to the modeling component (Haring & Eaton, 1978; Poncy, Skinner, & Jaspers, 2007), CCC has been shown to effectively enhance both accuracy and fluency (Skinner, Turco, Beatty, & Rasavage, 1989).

Accuracy refers to the ability to correctly respond to a given problem, while fluency is the ability to respond automatically with speed and ease (Daly, Lentz, & Boyer, 1996). According to the Instructional Hierarchy organized by Haring & Eaton (1978), accuracy is a prerequisite to fluency, which precedes more complex application of skills. Herrnstein's Matching Law (1961) suggests that increasing students' fluency results in decreased response effort and increased reinforcement, thereby increasing levels of engagement in the task (Skinner, 1998). Relatedly, fluent responding can increase students' endurance, motivation, and attitude toward school (Martens & Witt, 2004).

Curriculum Based Measurement (CBM) provides a means for assessing and tracking a student's level of performance on a given academic skill. The validity and reliability of CBM can provide a standardized measure for assessing students' responses to changes in intervention dose. These assessments are used to anchor a student's current performance against the levels expected of similar peers (Deno & Mirkin, 1977). In addition, CBM has been shown to be a more efficient way to measure academic achievement when compared to more comprehensive and time-consuming achievement tests (VanDerHeyden & Burns, 2009).

Current Study

The purpose of the present study is to apply the concept of dose to an empirically validated intervention (CCC) to examine how changes in intensity (defined by frequency of delivery) affect student performance and to determine the range of intensity that results in optimal student outcomes.

If simply modifying the frequency at which the CCC intervention is administered can produce increased growth rates, time-consuming trial-and-error approaches for identifying more effective interventions or more complex methods of intensification could potentially be avoided. Careful experimental evaluations of academic interventions in terms of dose and observed student response may aid in propelling the field of education toward status as a mature profession (Carnine, 2000).

Based on Duhon's (2014) existing dose-curve analysis of an explicit timing intervention, the following research questions will be examined in the present study: 1) What is the minimal effective dose of CCC? 2) What range produces an optimal result? 3) At what point does increased dose of CCC produce no additional return? It is hypothesized that like the explicit timing intervention, the minimum effective dose of CCC will be one session daily, and effective doses will range from once to eight times daily with no maximum effective dose reached.

CHAPTER II

REVIEW OF LITERATURE

While existing studies indicate which instructional strategies are generally effective for most students, students do not always respond as expected. Researchers must examine how to best strengthen interventions in order to provide guidance to educators when modifying standard approaches to meet the needs of all students. In existing studies, interventions have been increased, or intensified, along various dimensions including the number of components delivered, the resources required for delivery, and the time or duration of the intervention. Few researchers have studied the result of increasing only the frequency of intervention delivery. While increasing frequency alone may seem a simple approach to intervention modification, if increased growth rates result, other more time-consuming approaches could potentially be avoided.

Accountability in Schools

A variety of stakeholders, including local and federal government agencies, taxpayers, businesses, researchers, administrators, teachers, and parents take interest in what schools are doing to educate the next generation of Americans (Hardmann, McDonnell, & Welch, 1997). Education plays an important role in a society characterized by changing demographics, technological advances, and increasing global competition. American education is in a constant state of reform to meet changing needs.

The No Child Left Behind Act of 2001 (NCLB) is a federal policy that has significantly impacted American schools. This policy increased efforts to make schools accountable for student performance by requiring states to track student progress toward academic standards. Student outcomes were tied to federal funding for education, with underperforming schools first receiving increased support and then punishment for failing to meet objectives. The overarching goals of NCLB were to provide all children equal access to high-quality education and to promote effective educational practices (Paige, Hickok, & Neuman, 2002).

The Individuals with Disabilities Education Act (IDEA) was originally enacted in 1990 and was reauthorized in 2004. This act pertains to the appropriate provision of education services to children and youth with disabilities. IDEA is aligned with NCLB to require states to track progress of students with identified disabilities toward established performance goals. In addition, IDEA specified that students lacking appropriate instruction would not receive services via special education. The intention was to promote effective instruction and limit inappropriate labeling of poorly instructed students as disabled (U.S. Department of Education, 2007).

NCLB and IDEA have increased accountability in schools and placed rising pressure on educators and administrators to identify and implement effective and efficient instructional strategies. Greater emphasis is placed on student outcomes, increasing the necessity for interventions that are highly likely to affect meaningful changes in student performance (Hawkins, 2010). As a result, there is a growing need for academic interventions that are effective and adaptable when attempting to meet diverse student needs (Lentz, Allen, & Ehrhardt, 1996).

Behavior Analytic Perspective

Applied behavior analysis, the application of behavioral principles to produce socially meaningful changes in behavior (Baer, Wolf, & Risley, 1968), provides a framework for the improvement of student academic performance. Based in the scientific method, a behavior analytic perspective is an empirical approach to education that incorporates evaluation of procedures to ensure their effectiveness (Baer et al., 1968). A behavior analytic approach to education regards academic skills as behaviors that are a function of antecedent and consequent variables. Improving academic performance is a matter of effectively controlling associated variables to produce desired changes in behavior (Skinner, 2008).

Empirical studies have demonstrated that instructional approaches based in principles of behavior have been shown superior to other teaching methods. For example, a comprehensive longitudinal study titled Project Follow Through was conducted from 1967 to 1976 and compared direct instruction, based in behavioral principles, to four "child-centered" instruction models based in constructivist principles (Carnine, 2000). Findings indicated vast support for the direct instruction model. Students receiving direct instruction performed better than students in comparison groups across all academic subjects and measures of self-esteem. Similarly, in a study conducted by Klahr and Nigam (2004), a form of constructivism referred to as "discovery learning" was compared to direct instruction in science education. Results indicated that 15-23% of students taught with the constructivist approach learned how to solve the problems whereas 69-77% of students taught with the direct instruction approach achieved mastery.

Unfortunately, current research in education evidences lingering dissent among educators practicing from a behavior analytic perspective versus those practicing from a constructivist approach (Poncy, McCallum, & Schmitt, 2010). Although constructivist models of teaching have been shown less effective, they remain popular among many educators and psychologists (Carnine, 2000). A constructivist approach to education places the burden on students to construct their own understanding with minimal guidance, while a behaviorist approach places the burden on educators to employ effective techniques resulting in measurable growth in student performance (Poncy et al., 2010). When a student fails to progress as expected within a constructivist framework, the student is at risk for being blamed for his or her failure. On the other hand, when a student fails to progress within a behaviorist framework, educators take responsibility for student failure and amend their methods and/or environmental variables to produce desired outcomes.

Academic Interventions

An academic intervention is an instructional strategy applied to increase a student's performance on an academic skill, to lessen the discrepancy between a student's actual performance and expected performance as determined by an identified criterion or standard. A direct intervention is one that targets specific skills used in the natural environment, such as reading fluency or math fact accuracy (Shapiro, 2011). An indirect intervention is intended to target a supposed mediating cognitive process, such as processing speed or working memory, which cannot be directly observed or measured (Shapiro, 2011). On the other hand, specific skills used in the natural environment can be observed in terms of accuracy, frequency, and/or rate, resulting in a direct measure of a student's change in performance.

Curriculum Based Measurement

When monitoring student response, it is important that measurement tools are adequately sensitive so that they may validly and reliably detect changes in student performance (Ball & Christ, 2012; Daly, Martens, Dool, & Hintze, 1998). Curriculum Based Measurement (CBM) is a well-researched method of assessing and tracking a student's level of performance on a given academic skill. Examples of CBM tools include Dynamic Indicators of Basic Early Literacy Skills (DIBELS), AIMSweb, and System to Enhance Educational Performance (STEEP; Ball & Christ, 2012). CBM can provide a standardized measure for assessing students' responses to an intervention. These assessments are used to anchor a student's current performance against the levels expected of similar peers (Deno & Mirkin, 1977). In addition, CBM has been shown to be a more efficient way to measure academic achievement when compared to more comprehensive and time-consuming achievement tests (VanDerHeyden & Burns, 2009).

CBM consists of brief assessments of general outcome measures (GOM), such as reading fluency on a grade-level passage or computation fluency on a mixed grade-level math probe, or subskill mastery measures (SSM), such as nonsense word fluency or fluency on a sums-to-twenty math fact probe (Ball & Christ, 2012). GOM assessments are used for universal screening purposes to benchmark students periodically throughout the year and identify those in need of additional support. SSM assessments, on the other hand, measure basic component skills necessary to accomplish more complex GOM tasks. These more discrete measures can be used to task-analyze a student's deficit areas and design specific interventions to address individual student needs (Ball & Christ, 2012). SSM assessments are used more frequently to monitor a student's response to intervention and skill maintenance. Data produced from frequent SSM assessments can be used to change or titrate interventions to ensure satisfactory effects (Ball & Christ, 2012).

Intervention Strength

An effective intervention has the capacity to produce a desired change, which has been referred to as the strength of the intervention (Yeaton & Sechrest, 1981). Gresham (1991) defined treatment strength as "the ability of a given treatment to change behavior in the desired direction" (p. 28). Skinner (2008) referred to intervention strength as the ability to "cause larger learning level increases" in addition to increasing learning rates (p. 313). Academic intervention researchers have worked to identify the mechanisms underlying effective interventions. Findings indicate interventions that are generally effective for a majority of students make use of critical components based in principles of learning and behavior, such as measurement, modeling, opportunities to respond, immediate feedback, and reinforcement (Daly, Martens, Barnett, Witt,

& Olson, 2007; Hawkins, 2010; Lentz, Allen & Ehrhardt, 1996; Skinner, 2008). Strong interventions are also appropriately matched to the topography of the target behavior, meaning each component functions meaningfully in relation to the desired outcome (Haring & Eaton, 1978).

Daly, Martens, Barnett, Witt, and Olson (2007) indicated that strong academic interventions are adapted to students' level of skill proficiency and incorporate measurement to monitor student responding over time. Lentz, Allen, & Ehrhardt (1996) listed the following components as critical to effective academic interventions: high rates of responding, reinforcement for accurate responding, immediate feedback, appropriate use of pacing, error correction, modeling, and progress monitoring for decision making. Haring and Eaton (1978) researched stages of skill development and developed an Instructional Hierarchy to match appropriate interventions to student needs based on their current level of performance. For example, a student in the first stage of skill development, acquisition, has been shown to benefit from demonstration and modeling as he or she develops accuracy. A student in the second stage, fluency, has been shown to benefit more from drill, practice, and reinforcement as he or she moves from accurate to fluent responding.

Intervention Modification

Effective interventions are applied within a problem-solving framework. The problem is first identified and validated, and then an intervention is implemented and evaluated to determine whether meaningful outcomes have been produced. Evaluation should occur regularly throughout implementation in order to modify and titrate the intervention to produce adequate effects (Ball & Christ, 2002). There are various ways to adapt an evidence-based academic intervention in order to strengthen the effects of the intervention for a particular student or group of students not responding at expected levels.

When an intervention is not effective or insufficiently effective for an individual or group of students, one possible approach to address this concern is to change the intervention (Ball & Christ, 2012; Lentz, Allen, & Ehrhardt, 1996). When interventions are changed the interventionist may add additional intervention components to the existing intervention or employ a different intervention altogether. This approach consists of what is essentially a trial-and-error approach to intervention modification (Daly, Martens, Barnett, Witt, & Olson, 2007). While commonly practiced, this can result in time wasted and numerous failures to identify appropriate intervention conditions. Most problematic, a trial-and-error approach may inadvertently lead to a conclusion that the child simply cannot learn as expected due to inalterable variables within the child (i.e., a disability).

An alternative approach to modification of an intervention is to strengthen the current intervention systematically until desired effects are produced. Intervention researchers have taken numerous approaches to strengthening interventions. Daly et al. (2007) outlined possible methods for strengthening academic interventions including the use of measurement to track students' accuracy, fluency, and generalization; the use of appropriate instructional materials to promote stimulus control and generalization; the efficient use of intervention time; the use of changing reinforcement contingencies to support student engagement. Duhon, Mesmer, Atkins, Greguson, and Olinger (2009) suggested that adding supplementary components or increasing the frequency of the existing intervention might strengthen interventions.

Defining Intervention Intensity

Intensity has been defined in numerous ways across academic intervention literature. Barnett et al. (2004) described intensification in terms of implementation difficulty, necessary resources, and discrepancy from general education conditions. Daly et al. (2007) described intensity as dosage, frequency, and/or complexity of an intervention. Mellard, McKnight, and

Jordan (2010) organized intensification studies into the following categories: dosage, group size, immediacy of feedback, mastery requirements, response opportunities, transitions, curricular focus, and instructor specialties. Taken together, these categories combine into three major approaches to intensification which include altering the number of intervention components delivered, increasing the resources (personnel, materials, etc.) required for delivery, and increasing the time or duration of the intervention.

Components

One way to intensify an intervention is to increase the number of components contained within an intervention package (Barnett et al., 2004). McComas et al. (1996) attempted to strengthen baseline reading and spelling interventions (oral reading and written spelling practice) in order to improve student performance on 10-item comprehension and spelling tests. The researchers intensified baseline interventions by systematically testing additional instructional components for each student. Using a brief multielement design, they introduced one component at a time to evaluate effectiveness for each student participant. Components were ordered in terms of adult assistance required. Findings indicated that each participant's performance improved in response to different combinations of instructional components that varied both in terms of number and strategy. Daly, Martens, Dool, and Hintz (1998) intensified a baseline reading intervention (reading practice with reinforcement) by adding components theoretically ordered by complexity. Components ranged from simple (i.e., a basic repeated readings intervention, listening passage preview) to complex (i.e., increasing content overlap across passages, modifying passage difficulty). Like McComas et al. (1996), findings indicated that each participant required a unique combination of components, ranging in complexity. Rhymer, Dittmer, Skinner, and Jackson (2000) used an alternating treatments design to evaluate the effectiveness of adding a performance feedback component to a multi-component peer tutoring intervention for math fluency. Three of four participants responded to the initial multi-component intervention and showed additional improvement following the addition of performance feedback.

The provision of additional components is an approach to intensification that has been shown to improve student performance in some cases. Baer, Wolf, and Risley (1968), however, compared multicomponent procedures to a “shotgun” approach in need of further analysis to determine which components are actually effecting change (p. 95). As indicated by Daly et al. (1998) and McComas et al. (1996), determining which combination of components is appropriate for each individual student can be a lengthy process. In addition, added components may require more effort but may not necessarily result in significantly improved outcomes (Duhon et al., 2009). In some cases, extra components may produce only modest gains, resulting in a less efficient intervention overall (Skinner, 2008). When researching the addition of components, Rhymer et al. (2000) also noted the difficulty in determining whether observed effects can be attributed to the added components or to practice effects related to repeated assessment.

Resources

Another way to intensify an intervention is to apply additional resources. For example, McMaster, Fuchs, Fuchs, and Compton (2005) compared reading interventions administered in peer tutoring (requiring minimal staff resources) to one-on-one and small group formats (requiring increased teacher time and/or specialized staff). Findings indicated no statistically significant differences in student reading fluency across conditions. The authors commented that these findings could have resulted from a small sample size or the similarity of the intervention conditions despite the varied levels of individualization. Similarly, Begeny, Hawkins, Krouse, and Laugle (2011) measured intensity in terms of teacher time required to implement a reading fluency intervention, with participants receiving three alternating treatments (peer tutoring, small group, one-on-one) and a control (no treatment). Results indicated that while three of five participants responded better to the small group and one-on-one conditions when compared to peer tutoring, there were no significant differences in reading fluency outcomes detected between the small group and individual administration formats. The authors indicated that the limited number of sessions conducted during the study (5 per condition) may have restricted their ability to detect differences. While defining intensity in terms of required resources may seem practical, a drawback is

Increasing resources may be one way to intensify a treatment, but this method has not been consistently shown to result in improved outcomes. Because resources are often limited due to budget constraints, adding staff to intensify interventions via decreased student to teacher ratios may not be feasible in every case. In addition, the assumption that greater resources will improve outcomes can be problematic, because this may shift attention away from the selection of evidence based and appropriately linked intervention characteristics. For example, hiring an additional reading specialist may allow for more students to receive small group or one-on-one reading instruction, but if time spent with the reading specialist is not defined by high rates of responding, feedback, and reinforcement, then students may not receive additional benefit despite the added cost to the local education agency.

Time

Academic interventions can also be intensified by increasing them along some dimension of time, such as duration, frequency, or opportunities to respond. Elbaum, Vaughn, Hughes, and Moody (2000) conducted a meta-analysis of reading research for students with disabilities and assessed outcomes related to increased duration in terms of the number of weeks the intervention lasted. They found no significant effects of increased duration, suggesting that similar outcomes could be achieved in a shorter number of weeks. Vaughn, Linan-Thompson, and Hickman (2003) assessed students' response to intervention following ten, twenty, and thirty weeks of intervention duration. Results indicated that all participants made the greatest gains during the first ten weeks of intervention, suggesting that merely extending the intervention duration did not result in significantly improved outcomes. Wanzek and Vaughn (2008) evaluated the impact of altering the frequency of a reading intervention package, comparing a 30-minute daily administration to two 30-minute daily administrations. Findings showed that doubling the daily dose of intervention did not significantly increase student performance when compared to the single dose. However, Duhon, Mesmer, Atkins, Greguson, and Olinger (2009) systematically increased the frequency of an explicit timing math intervention for non-responding participants. Intervention administration was increased from once daily, to five times daily, and lastly, to ten times daily. While some students required increased daily administrations of the intervention, all students met criterion.

Increased time in intervention, or attention to how this time is structured, may also permit higher rates of active responding or opportunities to respond (Hall, Delquadri, Greenwood, & Thurston, 1982). Greenwood et al. (1984) evaluated teacher-mediated versus peer-mediated instructional procedures to determine which condition allowed for the greatest opportunities for student engagement. They found that the peer-mediated procedures resulted in higher rates of student academic responding and were associated with improvements on weekly achievement measures. Albers and Greer (1991) measured the effects of increasing the number of three-term contingency trials (antecedent, behavior, consequence) during instruction. Findings indicated that increased three-term contingency trials resulted in increased rates of correct responding.

Ebbinghaus (1885) demonstrated that increased practice time can positively impact learning (as cited in Skinner, 2008). In many cases, students who are not responding to an effective academic intervention are learning, but not at the desired rate (Carroll, 1989; Gettinger, 1991; Skinner, 1998; Skinner, 2008). This suggests that increasing the amount of time a student spends in intervention may improve performance. However, it is also important to take into account the efficiency of the intervention, or the amount of learning that takes place per unit of time. These studies show that intensifying an intervention across some dimension of time may or may not produce improved student performance, depending on the degree and manner in which it was intensified.

Outcome

When taken together, the above studies demonstrate that increasing the intensity of an intervention does not always result in a greater effect. Intensifying an intervention increases some aspect of the intervention, but strengthening has occurred only when increased learning rates associated with changes to the intervention provide evidence that intensification successfully improved intervention effect. To increase our understanding of academic interventions and how to modify them, it is important that we examine how modifications or intensifications impact student response.

Response-to-Intervention and Intensity

Response-to-intervention (RTI) is an approach to special education decision-making in which a student's basic skills deficits are identified and intervened upon with the goal of determining the amount of resources required to meet the student's instructional needs to produce desired rates of growth (Barnett et al., 2004). A RTI approach generally consists of multiple levels of intervention, referred to as "tiers", which are characterized by increasingly intense forms of intervention to remediate student deficits. Theoretically, students needing additional resources to address their educational needs move through the tiered system and may eventually be deemed eligible for placement in special education due to the intense form of intervention necessary to remediate academic concerns. To determine the appropriate amount of resources for optimal rates of learning, it is important to monitor the intensity of an intervention and associated growth rates (Barnett et al., 2004). However, our relatively limited understanding of intervention intensification makes it difficult to reliably make decisions related to intensity and intervention response (Mellard, McKnight, & Jordan, 2010).

Dose

In medicine, “dose” signifies the amount of treatment administered, and “response” represents the associated change in patient functioning. Advances in measurement technology have permitted more complex mathematical representations of drug dosage and patient response (Holford & Sheiner, 1981). A graphic plot of dose against response produces a visual representation of the relationship between increases in treatment and associated patient outcomes, typically resulting in a sigmoidal shape (Jackson, Jamieson, Johsnton, & Shepherd, 1987). The dose-response curve reveals a “therapeutic window” in which the treatment is effective. This window consists of a threshold, or the lowest amount of treatment necessary for any effect to occur, and a plateau, at which increasing the dose produces no additional effects or, in some cases, toxicity. For example, the commonly used pain reliever, acetaminophen (or Tylenol), is known to be severely toxic at high levels and can result in mild to severe liver failure (Mayhew, 2007).

Dose Concept in Medicine

A primary goal in pharmacology is to measure dose-effect relationships of drugs in order to determine which doses are maximally effective (Holford & Sheiner, 1981). An example of a dose comparison study is an evaluation of three doses of sustained-release fampridine, a drug used to treat multiple sclerosis (Goodman et al., 2008). The three doses examined were 10-, 15-, and 20-mg administered twice daily. Because the drug is intended to improve mobility, response was measured in terms of change in walking speed on a timed 25-foot walk assessment. Findings indicated that all three doses were generally well tolerated, although the risk of seizure may be increased at the highest dose. 8.5% of participants in the placebo group, 35% in the 10-mg group, 36% in the 15-mg group, and 39% in the 20-mg group showed consistent improvement in walking ability as measured periodically over 15 weeks. The authors concluded that the 10-mg twice-daily dose showed a promising “risk-to-benefit profile” and recommended further study (p. 71).

Dunn et al. (2005) evaluated the efficacy of four doses of exercise in the treatment of depression. Subjects were assigned to one of four groups that varied by total energy expenditure (a “low dose” of 7.0 kcal/kg/week or the “public health” recommended dose of 17.5 kcal/kg/week) and frequency (3 or 5 days per week). A placebo group received 15-20 minutes of stretching exercises 3 days per week. Response was measured periodically over 12 weeks using the Hamilton Rating Scale for Depression. Findings indicated that the low dose groups did not respond better than the placebo group across either frequency. The public health recommended dose administered at a frequency of five days per week produced the greatest response rate in terms of decreased symptoms of depression. The authors concluded that the low dose was not effective while the public health recommended dose produced improvements comparable to other treatments for symptoms of depression, such as medication or cognitive behavioral therapy.

Reed et al. (2007) discussed the importance of measuring dose when researching and implementing nursing interventions in order to determine what interventions are effective and how much of an intervention is necessary to achieve desired outcomes. The authors outlined issues surrounding the measurement of dose within the field of nursing, defining dose in terms of amount, frequency, and duration (p. 123). One concern raised was the frequent reliance on a categorical approach to dose in nursing, meaning that the intervention was either delivered or not delivered, leaving the actual amount of intervention unknown. This can result in poor intervention integrity, because it is impossible to consistently implement an intervention that is not well defined in terms of its amount. The authors also described the difficulty in comparing two different interventions that are administered inconsistently in terms of dose, because it is unclear whether any differences in outcomes are due to differences in intervention components or doses administered. Finally, the authors proposed simplified statistical methods (representing dose as categories based on percentiles) for evaluating dose-response relationships in the field of nursing.

Dose Response Curve in Psychotherapy

Psychological researchers have applied the dose-response concept to psychotherapy in an attempt to evaluate the impact of increased sessions on patient outcomes. Howard, Kopta, Krause, and Orlinsky (1986) conducted a meta-analysis of outpatient clinic psychiatric data regarding total number of sessions and assessments of patient improvement throughout therapy. The researchers used this data to estimate dose-effect relationships and found that about half of the patients included in the study showed measurable improvement by eight sessions. Kopta, Howard, Lowry and Beutler (1994) studied the dose-response relationship in psychotherapy by tracking the number of sessions and assessing patient progress as measured by periodic self-reports of symptoms on a standardized checklist. Results indicated that 75% of patients in the sample recovered from their symptoms following 58 once-weekly therapy sessions, while 50% of patients recovered following 11 sessions.

In a similar study, Barkham et al. (1996) studied subjects diagnosed with depression receiving 8 or 16 sessions of therapy. Results indicated that 59% of the subjects who received 8 sessions and 72% of the subjects who received 16 sessions showed clinically significant change in self-reported symptoms. These authors discussed the possibility that patient response to dose varies according to the severity of presenting problems, suggesting that patients are likely to discontinue treatment when a “good enough level” (GEL) of improvement is reached. Baldwin, Berkeljon, Atkins, Olsen, and Nielsen (2009) compared a dose-effect model (which predicts a constant rate of change related to total number of sessions) to the GEL model (which predicts that rates of change will vary and may decrease over longer durations due to discontinuation by more rapid responders when "good enough levels" of improvement have been reached). These authors concluded that without random assignment of subjects to various dose levels to control for other sources of variance, it is difficult to make conclusions concerning the impact of dose on patient response.

Quantifying Academic Interventions by Dose

Few academic intervention intensity studies have used the concept of dose in order to quantify changes made to an intervention for the purpose of measuring effects on student response. Wanzek and Vaughn (2008) defined increased frequency of a reading intervention package in terms of dose, with a single dose of the intervention equaling one daily thirty-minute session, and a double dose of the intervention equaling two daily thirty-minute sessions, distributed over thirteen weeks. The intervention package consisted of instruction in phonics and word recognition, fluency, and comprehension. Components were identical across the two dose levels, the only exception being that the group receiving the double dose received two sessions daily. An analysis of covariance was conducted to compare groups on each dependent measure in the study. These included three subtests (Word Identification, Word Attack, and Passage Comprehension) from the Woodcock Reading Mastery Test and two subtests (Nonsense Word Fluency and Oral Reading Fluency) from curriculum based Dynamic Indicators of Basic Early Literacy Skills. Findings indicated no significant differences in individual student performance on dependent measures across the two dose levels. The authors concluded that more of the same intervention did not strengthen the intervention for initially poor responders. Limitations discussed included the exclusive focus on low responders, which limited the number of participants eligible for the study, and the inability to inhibit the control group from receiving reading services outside of the study.

Duhon (2014) applied the dose-response model to evaluate the effects of different doses of an explicit timing math intervention package. The purpose of the study was to aid in the determination of the proper amount of treatment required to produce a desired change in student performance, and methods were derived from procedures used in the medical field when conducting dose-response analyses. To determine the effective range of dosages, several different doses of an explicit timing math intervention package were evaluated, including: 1) no treatment (control), 2) every other week, 3) once per week, 4) every other day, 5) once per day, 6) twice per day, 7) four times per day, 8) eight times per day. Participants were randomly assigned to one of these eight levels of frequency. The explicit timing intervention package was delivered for four consecutive weeks in accordance with group assignment. Student performance was evaluated using a pre-test, post-test measure consisting of three two-minute assessments on basic multiplication facts. Findings indicated that the minimum effective dose was one session daily, and unlike outcomes observed in the above study by Wanzek and Vaughn (2008), increased doses resulted in increased effects with no maximum reached. Duhon (2014) concluded that these results were a first step toward the "prescription" of academic interventions (much like the prescription of medication), and changes in performance associated with each dose were used to predict the amount of growth that could be expected based on dose and days available to intervene.

While too little or too much of an academic intervention is less likely to result in calamitous outcomes when compared to a medical treatment (e.g., a student is unlikely to die from excessive amounts of reading intervention), use of a similar approach within the realm of education may be one way to systematically evaluate intensification in terms of student outcomes. Changing an intervention in no other way but the number of times it is administered may be a feasible and effective way to improve intervention strength. Refining our understanding of empirically validated interventions could increase efficiency and improve decision-making, ultimately resulting in better outcomes for students and schools.

Additional studies are needed to examine the impact of increasing the dose of various evidence-based academic interventions.

Math Interventions

According to the National Mathematics Advisory Panel (2008), effective mathematics education is essential to the continued safety and prosperity of our nation. Quantitative skills are important for daily living and fundamental to careers in science, technology, engineering, and mathematics (STEM) fields. Research indicates that accurate and rapid responding to basic math facts is fundamental for later development and mastery of more advanced math skills (Poncy, Skinner, & O'Mara, 2006). Numerous intervention strategies have been used to increase basic math fact fluency. A growing research base has provided guidance regarding evidence-based mathematics interventions. Continued research is needed to refine our understanding of which interventions are most effective and under what circumstances.

Some examples of math interventions designed to increase performance on basic math facts include explicit timing (ET), taped problems (TP), and cover, copy, compare (CCC). These interventions employ drill and practice, immediate feedback, and reinforcement. ET has been demonstrated to increase the rate at which students (who have already developed accuracy) are able to correctly respond to math facts (Codding et al., 2007; Van Houten & Thompson, 1976). During an explicit timing intervention, students are timed while they engage in math fact practice for a pre-determined interval. At the end of the interval, the student receives feedback regarding how many facts he or she was able to complete correctly during the interval. The TP intervention has been demonstrated to increase basic fact accuracy and fluency (McCallum, Skinner, & Hutchins, 2004; Poncy, Skinner, & Jaspers, 2007). TP procedures consist of the student listening to an audio recording of a series of math facts that corresponds to a worksheet containing the same problems. The student is instructed to write the correct answer on the worksheet before the answer is provided via the audio recording, providing immediate feedback to the student regarding the accuracy of his or her response.

Cover Copy Compare

There are numerous studies supporting the use of Cover Copy Compare (CCC) as an evidence-based intervention across academic subjects and student demographics, which indicates high external validity (Joseph et al., 2012; Poncy, McCallum, & Schmitt, 2010; Poncy & Skinner, 2011; Skinner, Bamberg, Smith, & Powell, 1993; Skinner, Ford, & Yunker, 1991). CCC is a self-managed intervention employing critical learning and behavioral principles. Modeling, repetition, and feedback are embedded within the CCC procedures. Essential components of a CCC intervention include an academic stimulus item, a space to prompt an academic response, and an opportunity to compare the academic response with the original stimulus to check for accurate responding (Skinner, McLaughlin, & Logan, 1997).

When used as a math fact intervention, problems are presented with a model of each math fact followed by a blank space for the student to cover the model, write the problem and answer, and compare his or her response to the original model. If the student responds incorrectly, he or she is instructed to repeat the CCC procedure until producing an accurate response (Skinner, McLaughlin, & Logan, 1997). While widely considered a best match for students in the acquisition phase due to the modeling component (Haring & Eaton, 1978; Poncy, Skinner, & Jaspers, 2007), CCC has been shown to effectively enhance accuracy, fluency, and maintenance (Skinner, McLaughlin, & Logan, 1997; Skinner, Turco, Beatty, & Rasavage, 1989).

Skinner, Turco, Beatty, & Rasavage (1989) evaluated the effectiveness of CCC as an intervention for multiplication fact fluency in four behavior disordered students. Using a within subjects multiple baseline design across three mutually exclusive sets of ten single-digit multiplication facts, the researchers found that rates of correct responding increased across problem sets for all four subjects. The authors commented that CCC procedures were not only effective but also inexpensive and provided numerous opportunities to respond with corrective feedback and minimal teacher assistance. Poncy, McCallum, and Schmitt (2010) employed an alternating treatments design to compare CCC to a constructivist math intervention using "fact families." The researchers examined which procedures produced greater improvement in second-graders' performance on basic subtraction facts. Data indicated that CCC produced immediate and maintained subtraction-fact fluency gains across students while the constructivist method resulted in minimal gains, comparable to the no instruction condition. Poncy et al. (2010) suggested that gains produced via the CCC intervention were likely attributable to the incorporation of models, frequent opportunities to respond, and immediate feedback.

Joseph et al. (2012) conducted a meta-analysis of 31 CCC studies. 17 of these studies examined the use of CCC as a spelling intervention, 12 studies examined CCC as a math intervention, and two studies examined CCC as a content intervention (i.e., geography and science). Mean percentages of non-overlapping data (PND) were calculated using results of each study, with a PND of 70 to 100 indicating intervention effectiveness. Mean PND for math and spelling interventions ranged from 61.5 to 91.9. For geography and science studies, PND were 100% across both studies. Some variations in CCC procedures, such as extra opportunities to copy the correct response or reinforcement for accurate responding, resulted in increased performance. Overall, findings indicated that CCC is "a recommended scientifically supported method that can be used in multiple settings" (p. 135). The authors described CCC as a straightforward and efficient intervention that has been successfully used to instruct students with and without disabilities.

Fluency

Accuracy refers to the ability to correctly respond to a given problem, while fluency is the ability to respond accurately *and* automatically with speed and ease (Daly, Lentz, & Boyer, 1996). Educators tend to emphasize accuracy, but once a student can correctly respond to a task, increasing his or her rate of task performance is also important (Skinner, Fletcher, & Henington, 1996). Procedures designed to increase fluency emphasize repeated practice and reinforcement to promote overlearning and provide motivation needed to engage in repetitive practice (Haring & Eaton, 1978).

According to the Instructional Hierarchy organized by Haring and Eaton (1978), accuracy is a prerequisite to fluency, which precedes more complex application of skills. These authors stated, "It is not enough merely to perform a skill; one must be able to perform it fluently and competently if the skill is to serve one well in all circumstances" (p. 27). The ability to perform a skill at a rapid rate is also thought to be associated with retention of that skill (Haring & Eaton, 1978). Fluency with keystone skills is also considered to promote progression to more complex skills and procedures (Skinner, Fletcher, & Henington, 1996). For example, a student who can respond automatically to basic addition facts (e.g., 8 + 6 = 14, 5 + 8 =13) can apply this basic knowledge to a more procedurally complex double-digit multiplication task requiring these numbers to be added during an intermediate step (e.g., 98 x 76 = 7448).

Herrnstein's Matching Law (1961) suggests that increasing students' fluency results in decreased response effort and increased reinforcement, thereby increasing levels of engagement in the task (Poncy, Skinner, & Jaspers, 2007; Skinner, 1998). Cognitive processing theories propose that attending to multiple tasks simultaneously can overload our cognitive capacity. However, tasks that have been practiced to automaticity require less cognitive time or effort, freeing up cognitive resources (Poncy, Skinner, & Jaspers, 2007). Relatedly, fluent responding can increase students' endurance, motivation, and attitude toward school (Martens & Witt, 2004).

Rationale

The purpose of the present study is to apply the concept of dose to an empirically validated intervention (CCC) to examine how changes in intensity (defined by frequency of delivery) affect student performance and to determine the range of intensity that results in optimal student outcomes. If simply modifying the frequency at which the CCC intervention is administered can produce increased growth rates, time-consuming trial-and-error approaches for identifying more effective interventions or more complex methods of intensification could potentially be avoided. Careful experimental evaluations of academic interventions in terms of dose and observed student response will help us to understand how level of frequency affects performance, better informing treatment recommendations and predicting effects. These evaluations may also aid in propelling the field of education toward status as a mature profession (Carnine, 2000).

Research Questions

Based on Duhon's (2014) existing dose-curve analysis of an explicit timing intervention, the following research questions will be examined in the present study: 1) What is the minimal effective dose of CCC? 2) What range produces an optimal result? 3) At what point does increased dose of CCC produce no additional return? It is hypothesized that like the explicit timing intervention, the minimum effective dose of CCC will be one session daily, and effective doses will range from once to eight times daily with no maximum effective dose reached.

CHAPTER III

METHODOLOGY

Participants and Setting

Participants included 65 students from an elementary school in a large, urban school district in the Midwest. Participants were distributed across four second-grade classrooms and represented 60% of the entire second grade population. Each classroom contained approximately 25 students, containing male and female students and a variety of ethnicities. Students had already received instruction in basic subtraction facts prior to the start of the study.

Materials

Materials for this study included individualized student folders, a digital timer, single skill subtraction fluency pre- and post- assessments (see appendix A), CCC intervention packets (see appendix B) or control packets (see appendix C), progress monitoring assessments administered every three days of intervention (see appendix D), assessment and intervention protocols and integrity recording sheets (see appendix E and appendix F), and self-graphing paper (see appendix G). Individualized student folders were labeled with student names and color-coded to indicate which experimental or control group the student was placed into by random assignment. Student folders were removed from the classroom daily to score progress-monitoring assessments when conducted and to prepare with materials for the next day of intervention or assessment.

Single skill subtraction pre- and post-test fluency assessments consisted of basic subtraction problems to complete in two minutes (see appendix A). The assessments were created using an Excel spreadsheet designed to generate random numbers of a given range to quickly and easily produce multiple, equivalent assessments. Progress monitoring assessments were created in the same manner (see appendix D). The set of subtraction problems used in the study included 15 unique problems with minuends less than 20. The set was designed to exclude problems containing zeroes, ones, and reciprocals. The following problems were included within the set: 15-9=6, 13-6=7, 14-7=7, 8-3=5, 11-3=8, 10-2=8, 6-3=3, 17-9=8, 11-6=5, 13-9=4, 7-5=2, 14-9=5, 12-9=3, 12-6=6, 7-3=4.

CCC intervention packets were formatted to contain modeled problems followed by the problem written without the answer for students to look at the model, cover it, write the answer from memory, and uncover the model to check that they have responded accurately (see appendix B). Students were trained on the CCC procedures before the start of the study (see appendix H); however, some students required additional prompting to whisper the entire problem to themselves before covering the model and writing the answer in the blank provided. This modification was added to ensure the students were engaging in the CCC procedures instead of merely copying the answer from the model. For students who were assigned to a group not participating in a given session, an alternative activity was selected with teacher input. The purpose of the alternative activity was to occupy these students while other groups received intervention. Students engaging in the alternative activity were instructed to write sentences incorporating spelling words provided (see appendix C).

Assessment and intervention protocols and integrity-recording sheets contained scripted step-by-step instructions used during assessment administration and intervention implementation. Each step included a space for experimenter to initial after completion (see appendix E and appendix F). For 25% of the intervention sessions an additional researcher observed administration and monitored integrity using the integrity-recording sheet by initialing each step administered correctly. Self-graphing paper was included in student folders to provide performance feedback to students based on their digits correct per minute performance on progress monitoring assessments (see appendix G).

Dependent Variable

The dependent variable measured was student subtraction fact fluency on two-minute assessment probes. Randomized versions of the probes were used for pre-, post-, and progress-monitoring assessments. The dependent variable was measured on a total of 11 occasions including the pre- and post-assessments. The same assessment procedures were used for all assessments. Fluency was calculated as digits correct per minute (DCPM) by totaling the number of digits correct on each two-minute assessment then dividing by two. Progress monitoring took place prior to intervention sessions every three days using a single two-minute fluency assessment. Fluency on this assessment was calculated as digits correct per minute.

Experimental Design

Pre-Tests

The experimenter administered pre-tests in each classroom using scripted step-by-step instructions based on standardized curriculum based measurement procedures (Shinn, 1989). A single fluency pre-test score was collected for each student. Each fluency assessment consisted of a set of 15 basic subtraction problems in a randomized order to complete in two minutes. Assessments were scored for fluency as measured by total digits completed accurately per minute during a two-minute assessment, or the number of digits correct per minute (DCPM; Shinn, 1989).

Group Assignment

In order to randomly assign students to treatment groups while controlling for initial fluency levels, students were first rank ordered according to their single pre-test fluency scores. Next, students were randomly assigned to one of five levels of intervention frequency: 1) one intervention session once per day, 2) two intervention sessions per day, 3) four intervention sessions per day, 4) eight intervention sessions per day, 5) no intervention control. A stratified randomized sample was used to ensure equal representation of math skill in all five groups, and treatments were randomly stratified across each classroom to control for classroom-related effects. The duration of each intervention session was two minutes, so total instructional minutes per day ranged from zero to 16 minutes. Student folders were color-coded to indicate which experimental or control group each student was placed into, and corresponding intervention packets were placed into folders based on group assignment.

Procedures

Experimental procedures consisted of eight two-minute CCC intervention sessions where students received the CCC intervention based upon group assignment. The experimenter administered interventions in each classroom using scripted step-by-step instructions. The first four daily intervention sessions occurred during a morning administration, and the second four sessions occurred in the afternoon. To minimize the potential effects of massed versus distributed practice, all intervention sessions were evenly distributed across morning and afternoon administrations to the greatest extent possible. For example, for students receiving two intervention sessions per day, one took place in the morning and the other took place in the afternoon, and students assigned to receive four sessions per day received two sessions in the morning and two in the afternoon. Because some students received the intervention during all eight administrations and others received the intervention fewer times daily or not at all, those not participating in a given session were instructed to complete an alternative spelling/writing activity decided upon with teacher input.

Progress Monitoring Assessment

The experimenter administered progress-monitoring assessments every three days prior to intervention sessions in each classroom using scripted step-by-step instructions based on standardized curriculum based measurement procedures (Shinn, 1989). A single fluency assessment was used to generate the progress monitoring score for each student. The purpose of the progress-monitoring assessments was to collect data to be used to analyze change over time. It was believed that progress monitoring would not significantly affect performance because a dose-response analysis of an explicit timing intervention indicated that no statistically significant growth occurred as a result of two-minute explicit timing administrations once weekly or every other day (Duhon, 2014).

Post-test

Following 32 school days of intervention implementation, a post-test was administered to all participants. The post-test was administered in the same manner as the pre-test (as described above). Pre-test, progress monitoring, and post-test scores were used for statistical analysis of intervention effects.

Interrarter Agreement and Procedural Integrity

To check reliability of measurement throughout the study, a second rater re-scored 25% of all math probes collected. Inter-rater agreement (IA) was calculated by dividing the DCPM in agreement by total agreements plus disagreements on each probe multiplied by 100. The average of IA for all probes was calculated at the end of the study to find the overall interrater agreement. Overall reliability of scoring was 99.80% (range 89-100) agreement on an item-by-item analysis.

Procedural integrity was evaluated daily throughout the study using procedural checklists. A second experimenter observed procedures for 25% of sessions and calculated procedural integrity by dividing the number of procedural steps completed correctly by the total number of steps, and then multiplying by 100. Overall integrity was 99.75% (range 99-100).

Analysis of Results

Pre- and post-test results were analyzed using hierarchical linear modeling (HLM; Raudenbush & Bryk, 2002). Pre-test, progress-monitoring, and post-test fluency scores were used to analyze growth trajectories and distinguish treatment differences across groups at various time points.

CHAPTER IV

RESULTS

Data for the current study were analyzed using HLM (Raudenbush & Bryk, 2002) with time nested within students. This statistical technique is used to evaluate growth trajectory differences both within and between groups and is useful for distinguishing treatment differences across groups at various time points. Results were analyzed using HLM with restricted maximum likelihood estimators. By considering observation points (level-1) as nested within individual students (level-2), HLM controls for violations of independence, permits examination of differences in student growth over time, and allows the modeling of slope and level differences in relation to various predictors (Raudenbush & Bryk, 2002). Observation points included the baseline time point through the post-test (11 observations per student). The final two-level model was defined as

Level-1 Model: $SCORE_{ti} = \pi_{0i} + \pi_{1i}*(QUADCEN_{ti}) + e_{ti}$

Level-2 Model: $\pi_{0i} = \beta_{00} + \beta_{01}*(D2_i) + \beta_{02}*(D3_i) + \beta_{03}*(D4_i) + \beta_{04}*(D5_i) + r_{0i}$

$$\pi_{1i} = \beta_{10} + \beta_{11}*(D2_i) + \beta_{12}*(D3_i) + \beta_{13}*(D4_i) + \beta_{14}*(D5_i)$$

where $SCORE_{ti}$ is equal to an individual student's fluency score *i* at each time point *t*. Group assignment was dummy coded so that the 1x-per-day group is referred to as D1, the 2×-per-day group as D2, the 4×-per-day group as D3, the 8x-per-day as D4, and the control group as D5.

Note that the model was rerun with all possible group contrasts until all pairwise comparisons had been calculated. The parameter π_{0i} was centered at the post-test and represents the final performance occasion for each student while π_{1i} defines the slope of growth over time. β_{11}, β_{12}, β_{13}, β_{14}, and β_{15} represent the time invariant group membership dummy codes that permit contrasts of student trajectories across instructional groups. Group differences were modeled at Level-2 for both π_0 and π_1, allowing for comparisons of post-test performance and slopes.

Descriptive data from the five groups are presented in Table 1 and Figure 1 for average pretest and posttest scores. The student mean performance and variance were roughly equivalent at baseline across groups. For these measurement periods there were no missing data. However, across the nine observation points in between there were 11 missing datum points distributed across groups: two from D1, three from D2, three from D3, one from D4, and two from D5. These disparities were not significantly different from what would be expected, suggesting that they were missing at random.

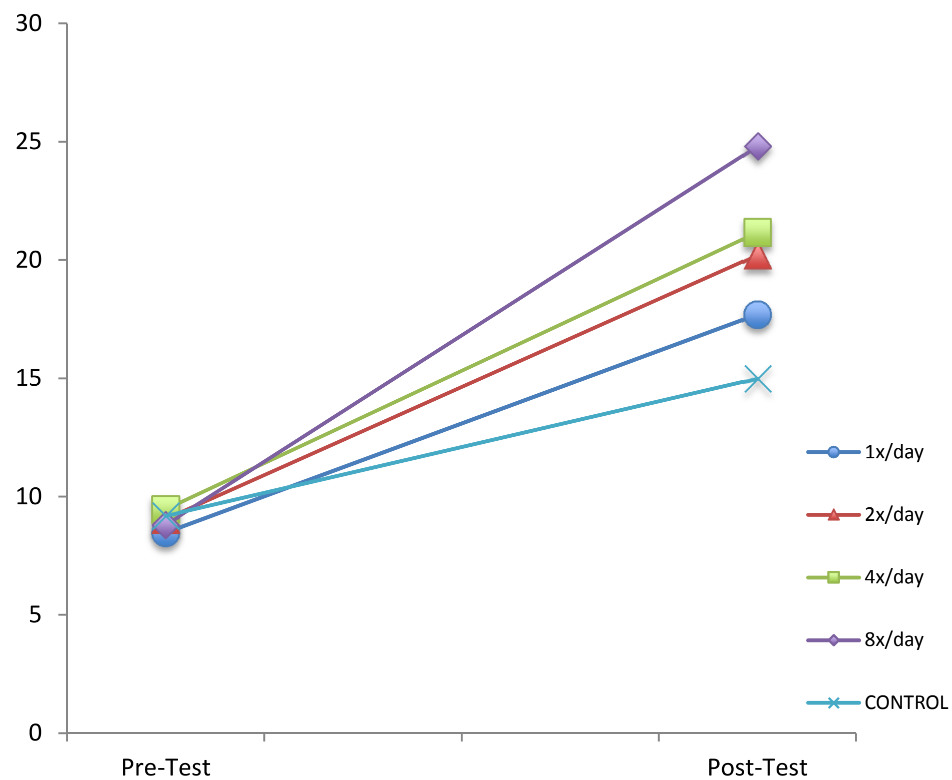
Table 1.

Descriptive Statistics Across Phases and Groups

	Pretest			Posttest		
Group	*n*	*M*	*SD*	*n*	*M*	*SD*
1x-per-day (D1)	15	8.47	5.09	15	17.70	14.79
2x-per-day (D2)	12	9.04	5.61	12	20.21	12.84
4x-per-day (D3)	12	9.46	6.62	12	21.17	11.46
8x-per-day (D4)	13	8.81	6.47	13	24.80	12.01
Control (D5)	13	9.19	7.96	13	15.00	8.46

Figure 1.

Group Fluency Growth in DCPM After Intervention



Two unconditional models were first tested to examine whether linear or quadratic trend best explained the pattern of results. It was found that a quadratic model best explained overall growth when linear growth was controlled for, $t(637) = -3.09$, $p = .002$. Table 2 presents post-test performance and slope results from the final model. An alpha of .05 was used for all tests of statistical significance of parameters.

Post-test performance results indicate students in the 8x-per-day group performed on average 9.87 DCPM higher than the control group. The difference was statistically significant, $t(60) = -2.65$, $p = .010$. Slope results indicate students in the 1x-per-day group improved on average .02 DCPM more per assessment session than the control group. The difference was statistically significant, $t(634) = -2.03$, $p = .043$. Students in the 2x-per-day group improved on average .02 DCPM more per assessment session than the control group. The difference was statistically significant, $t(634) = -2.01$, $p = .045$. Students in the 4x-per-day group improved on average .03 DCPM more per assessment session than the control group. The difference was statistically significant, $t(634) = -2.43$, $p = .016$. Students in the 8x-per-day group improved on average .07 DCPM more per assessment session than the control group. The difference was statistically significant, $t(634) = -5.47$, $p < .001$. Students in the 8x-per-day group improved on average 0.04 DCPM more per assessment session than the 1x-per-day group. The difference was statistically significant, $t(634) = 3.61$, $p = <.001$. Students in the 8x-per-day group improved on average .04 DCPM more per assessment session than the 2x-per-day group. The difference was statistically significant, $t(634) = 3.33$, $p < .001$. Students in the 8x-per-day group improved on average .04 DCPM more per assessment session than the 4x-per-day group. The difference was statistically significant, $t(634) = 2.91$, $p = .004$.

Table 2.

HLM Results of Group Post-Test Performance and Slope Comparisons

Model Parameters	Coefficient	*SE*	*t*	*df*	*p*
β_{00}	19.20	2.45	7.84	60	<.001
1x/day vs. 2x/day	2.28	3.67	0.62	60	.537
1x/day vs. 4x/day	2.95	3.68	3.59	60	.425
1x/day vs. 8x/day	6.19	3.59	1.72	60	.090
1x/day vs. control	-3.68	3.59	-1.02	60	.310
2x/day vs. 4x/day	0.67	3.87	0.17	60	.863
2x/day vs. 8x/day	3.91	3.80	1.03	60	.307
2x/day vs. control	-5.96	3.80	-1.57	60	.122
4x/day vs. 8x/day	3.24	3.80	0.85	60	.397
4x/day vs. control	-6.63	3.80	-1.75	60	.086
8x/day vs. control	-9.87	3.72	-2.65	60	.010
β_{10}	0.07	0.01	8.38	634	<.001
1x/day vs. 2x/day	0.00	0.01	0.09	634	.926
1x/day vs. 4x/day	0.01	0.01	0.52	634	.602
1x/day vs. 8x/day	0.04	0.01	3.61	634	<.001
1x/day vs. control	-0.02	0.01	-2.03	634	.043
2x/day vs. 4x/day	0.01	0.01	0.41	634	.684
2x/day vs. 8x/day	0.04	0.01	3.33	634	<.001
2x/day vs. control	-0.02	0.01	-2.01	634	.045
4x/day vs. 8x/day	0.04	0.01	2.91	634	.004
4x/day vs. control	-0.03	0.01	-2.43	634	.016
8x/day vs. control	-0.07	0.01	-5.47	634	<.001

Note. Final model summary: $o^2 = 15.92$, $\tau^2 = 83.17$. τ^2 was statistically significant, $\chi^2(3464.57)$, p < .001. Model includes unstandardized coefficients.

In summary, analysis of post-test performance revealed a statistically significant difference between 8x-per-day and control group performance. The 8x-per-day group performed on average 9.87 DCPM higher at post-test than the control group. Analysis of slope indicated statistically significant differences in growth trajectories between the control group and all other groups. Students in the 1x- and 2x-per-day groups improved on average 0.02 DCPM more per occasion than the control group. Students in the 4x-per-day group improved on average 0.03

DCPM more per occasion than the control group. Students in the 8x-per-day group improved on average 0.07 DCPM more per occasion than the control group and 0.04 DCPM more per occasion than the 1x-, 2x-, and 4x-per-day groups.

CHAPTER V

DISCUSSION

The purpose of the current study was to apply the concept of dose to an empirically validated intervention (CCC) to examine how changes in intensity (defined by frequency of delivery) affect student performance and to determine the range of intensity that results in optimal student outcomes. To do this, participants were stratified based on initial performance and randomly assigned to one of five levels of intervention frequency: 1) one intervention session per day, 2) two intervention sessions per day, 3) four intervention sessions per day, 4) eight intervention sessions per day, 5) no treatment control. Each intervention session was two minutes in length, so across the duration of the study (32 days), the 1x-per-day group engaged in 64 total instructional minutes, the 2x-per-day group engaged in 128 total instructional minutes, the 4x-per-day group engaged in 256 total instructional minutes, the 8x-per-day group engaged in 512 total instructional minutes, and the control group engaged in zero total instructional minutes (the control group engaged in an alternative learning activity). All sessions were distributed across the day to the greatest extent possible to minimize massed versus distributed practice effects.

Research Questions

First, it was hypothesized that the minimum effective dose of CCC, like the explicit timing (ET) intervention examined in Duhon's (2014) dose-response curve analysis would be one session daily. While the present study did not include any dose less than one session daily, results indicated that one two-minute CCC session daily was effective, resulting in a statistically significant difference of 0.02 DCPM greater growth per occasion on average when compared to the control group. Second, it was hypothesized that effective doses would range from once to eight times daily with no maximum effective dose reached. Results indicated that all treatment groups, ranging from once to eight times daily, demonstrated greater growth trajectories when compared to the control group. Differences were statistically significant for all groups when compared with the control group, indicating no maximum effective dose was reached. Finally, it was hypothesized that increased dose of CCC would continue to produce additional return. Overall growth on average from pre-test to post-test continued to increase as dose increased, with the 8x-per-day dose performing 9.87 DCPM higher on average when compared to the control group at post-test. However, an examination of growth per instructional minute revealed a diminished return in terms of gains per instructional minute with increased frequency of sessions per day. Excluding the variation present within the first three assessments (which may have resulted from re-learning effects), average growth per instructional minute was fairly consistent across time. These results suggest a relatively stable average learning rate associated with intervention frequency, although some drop-off in growth per instructional minute was observed across groups toward the end of the study.

Table 3.

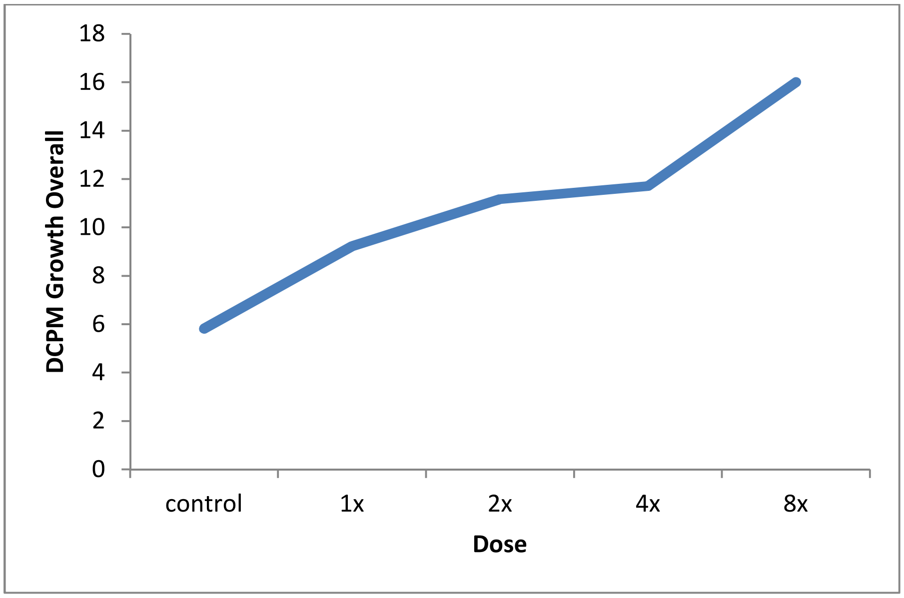
Growth in Digits Correct Per Instructional Minute Across Assessment Sessions

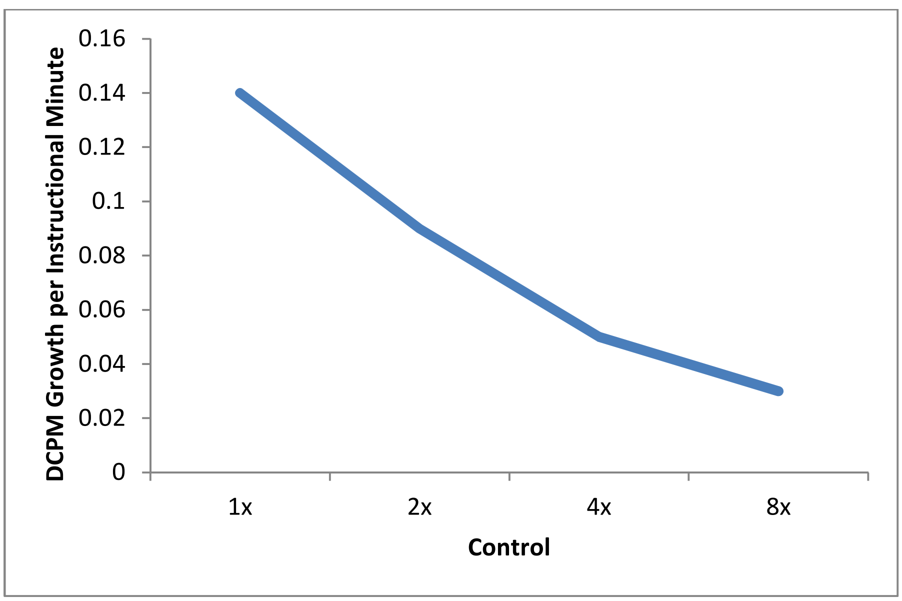
Group	1	2	3	4	5	6	7	8	9	10
1x/day	0.52	0.43	0.16	0.20	0.20	0.18	0.14	0.17	0.16	0.14
2x/day	0.28	0.16	0.19	0.15	0.15	0.14	0.10	0.10	0.08	0.09
4x/day	0.20	0.08	0.08	0.07	0.07	0.06	0.05	0.05	0.04	0.05
8x/day	0.10	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
0x/day	0.02	0.02	0.00	0.02	0.02	0.00	0.01	0.01	0.01	0.01

Descriptively, the 8x-per-day condition showed the most growth across the 32 sessions with an average increase of 16.00 DCPM; however this condition also showed the lowest growth rate with an average overall learning rate of .03 digits correct per instructional minute (DCPIM). The 2x-per-day and 4x-per-day conditions showed similar overall growth across the 32 sessions with average increases of 11.17 and 11.71 DCPM, respectively. The average growth rate observed for the 2x-per-day group was .09 DCPIM, and the average growth rate for the 4x-per-day group was .05 DCPIM. Finally, the 1x-per-day group showed the least growth overall with an average increase of 9.23 DCPM; however, this group demonstrated the highest average growth rate at .14 DCPIM. All instructional conditions showed significantly higher increases in DCPM compared to the control group, which grew an average of 5.81 DCPM overall at an average rate of .01 DCPIM. These findings raise an important question concerning the significance of intervention efficiency. While the 1x-per-day group was shown most efficient in terms of growth per instructional minute, at the end of the day, the 8x-per-day group evidenced the most growth overall. Figure 2 demonstrates this contrast, comparing average overall growth versus average growth per instructional minute. Students' fact fluency did not increase at a rate comparable to the effort required to implement the intervention.

Figure 2.

Comparison of Average Growth Overall vs. Average Growth per Instructional Minute





The present study validates CCC as an effective intervention and provides additional information regarding the differential effects of dose. Literature has examined various ways to modify the intensity of an intervention, but little attention has been given to simply increasing the frequency, or dose, of an evidence-based intervention in order to strengthen its effects. This study indicates that increasing the dose of a CCC intervention produces associated increases in learning outcomes. Furthermore, results demonstrate that intervention doses may produce stable average growth in digits correct per instructional minute (DCPIM). DCPIM data were used to calculate dose-specific growth per day and project expected growth based on available days to intervene. Projected growth rates are presented in Table 4. Duhon (2014) reported projected growth for an Explicit Timing (ET) intervention targeting fourth graders' multiplication fluency and suggested dose-response curve analyses of evidence-based interventions provide a first step toward research-based "prescriptions" to remediate academic deficits.

Table 4.

Projected Growth for CCC Subtraction Fluency Intervention

		Available Days to Intervene				
		10	20	30	40	50
Dose	Daily DCPM Growth	Projected Growth				
1x/day	0.28	2.8	5.6	8.4	11.2	14.0
2x/day	0.36	3.6	7.2	10.8	14.4	18.0
4x/day	0.40	4.0	8.0	12.0	16.0	20
8x/day	0.48	4.8	9.6	14.4	19.2	24.0

Implications for Practice

Research is needed to guide practitioners when an evidence-based intervention is insufficiently effective for an individual or group of students. While existing literature indicates numerous methods of intensification (Daly et al., 2007; Barnett et al., 2004; Mellard et al., 2010), such as adding components or increasing teacher support or involvement of specialized staff, these methods often require additional resources not always available, are difficult to evaluate systematically, and have not been shown to reliably increase student outcomes (Duhon et al., 2009; Skinner, 2008).

To increase our understanding of how to strengthen academic intervention effects, we must systematically examine how intensification impacts student response. In medicine, researchers regularly evaluate treatment intensity using a dose-response curve in which "dose" signifies the amount of treatment administered, and "response" represents the associated change in patient functioning (Holford & Sheiner, 1981). However, in education, few researchers have systematically evaluated intensification in terms of dose and student outcomes.

The present study applied the concept of dose to an empirically validated intervention (CCC) to examine how changes in frequency of delivery impacted student performance. Because increased frequency of the CCC intervention produced associated increases in student growth rates with no maximum effective dose reached, results suggest that altering an evidence-based intervention in no other way but the number of times it is administered each day may be a feasible and effective way to increase the strength of an evidence-based intervention. Results of this study indicated that increasing frequency (ranging from two to sixteen minutes per day) produced increases in student outcomes, indicating that this method of intensification resulted in a greater effect. This information is valuable to school staff responsible for remediating student deficits because it provides insight not only into intervention intensity but also intervention strength.

In addition, data from this study were used to create a table projecting student growth based on the dose of CCC received. Tables such as these may allow school staff to more precisely select interventions with increased probability for student success within available timeframes. For example, a student with a subtraction fluency deficit may respond to basic subtraction facts at a baseline rate of 15 digits correct per minute (DCPM), which falls well below mastery range (40 DCPM; Deno & Mirkin, 1977). In order to remediate the student's subtraction fluency deficit by increasing performance to mastery level (approximately 40 DCPM), the interventionist could benefit from having a table projecting student growth based on intervention dose. The interventionist could calculate the discrepancy between the student's current and expected performance (40 – 15 DCPM = 25 DCPM) and use the table to determine the appropriate dose to remediate the student's deficit within the available timeframe. If the interventionist has 10 weeks available to intervene using a CCC intervention 8x-per-day, he or she may expect the student's performance to approach the expected level within the given timeframe.

With this type of data for varying dose levels of evidence-based interventions, practitioners could more precisely draw intervention aim lines and more rapidly increase intervention strength as needed based on whether the student's response aligns with the predicted growth trajectory. School administrators and staff may more efficiently allocate available resources when appropriate doses of evidence-based interventions are matched to individual student deficits. Students with minor deficits could receive smaller intervention doses, freeing up time for instructional staff to provide students evidencing major deficits with larger intervention doses. In the current study, results demonstrated that students' basic subtraction fact fluency grew significantly from intervention doses ranging from just two to 16 minutes per day in a class-wide format and distributed across brief morning and afternoon sessions.

Within a response-to-intervention (RtI) framework, simply increasing the frequency of delivery of an evidenced-based intervention could permit more efficient alignment of instructional resources with student need. Studies that quantify the effects of intervention intensification could reduce the guesswork involved in effectively matching instruction to student deficits and monitoring student response. If this prescriptive approach is used to intervene on basic skill deficits as early as possible, this might reduce the number of students unnecessarily referred for more intensive tier three supports and/or evaluation for special education services.

Limitations and Future Research

Although this study contributes to our understanding of intervention strength, there are several limitations that should be taken into account. As noted previously, this study examined dose levels including one, two, four, and eight two-minute sessions daily providing growth trajectory data for these levels only. All four doses showed statistically significant growth over the control group, but doses less than once daily, more than eight times daily, or doses such as three or six times daily were not examined. As a result, the minimum and maximum effective dose levels were not determined. Future studies could examine additional dose levels to explore the minimum and maximum effective doses and the sensitivity of student growth in relation to minor dosage differences. Similarly, this study involved only second-grade students engaging in a single academic intervention (CCC) to build basic subtraction fact fluency, which may limit generalizability to different grade levels, interventions, or skills. Additional studies are needed to examine the interactions between dose and variables such as these.

Second, while this study was designed to reduce effects of massed versus distributed practice to the greatest extent feasible given the applied classroom setting, sessions were distributed across morning and afternoon administrations only. A study of four levels of massed versus distributed practice indicated increased distribution produced increased learning rates, but the authors noted that the definitions and parameters of distributed practice are still tentative due to the limited levels of distribution studied (Schutte et al., 2015). In other words, the impact of the amount of time permitted to elapse between distributed practice sessions is still unclear. For example, in the current study, it is unknown whether the two-minute breaks in between intervention sessions for the 4x-per-day group provided a sufficient amount of time between sessions to produce the benefits of distributed practice. A related concern is the extent to which growth rates for the 8x-per-day group were impacted by massing four two-minute sessions in the morning and four in the afternoon. Future studies could more precisely examine the interaction between dose and various distribution levels.

Third, this study examined student fluency gains on a set of fifteen subtraction facts. The set size for this study was limited to fifteen problems in order to minimize the duration of the study while promoting the likelihood of statistically significant growth across groups. Future research could investigate the potential interaction between various set sizes and dose levels to evaluate the most efficient pairings that will maximize learning rates.

Finally, due to the nature of applied research, unforeseen disruptions to the intervention schedule occurred as a result of weather related school closures. Although the study was extended to accommodate these closures, it is possible that disruptions to the routine introduced unexpected variation in student performance. In addition, had the study continued for several more weeks, it is possible that the groups receiving one, two, and four intervention sessions daily may have evidenced statistically significant growth at the final post-test. Considering that all groups demonstrated statistically significant growth trajectories, it is possible that students would have continued to progress at steady rates had more time been available to intervene. While future studies might plan to implement the intervention at various doses for a longer duration overall, time constraints are a common obstacle in applied research.

Summary

While various approaches to intervention intensification exist, it is important to determine which methods actually strengthen the intervention by producing improved student outcomes. Common conceptualizations of intervention intensification include modifications such as increasing components, staff resources, or time. However, research indicates these forms of intensification do not always produce a greater effect (McMaster, Fuchs, Fuchs, & Compton, 2005; Begeny, Hawkins, Krouse, & Laugle, 2011; Elbaum, Vaughn, Hughes, & Moody, 2000; Vaughn, Linan-Thompson, & Hickman, 2003; Wanzek & Vaughn, 2008). To increase our understanding of academic interventions and how to strengthen them, it is important that we examine how intensifications affect student response. In medicine, researchers regularly evaluate treatment intensity in terms of the dose administered and the associated patient response. Similar studies in education may permit more precise intervention recommendations.

Few academic intervention intensity studies have applied the concept of dose in order to quantify changes made to an intervention to measure effects on student response. The present study demonstrates that increasing the frequency, or dose, of an evidence-based academic intervention can produce associated increases in student response. These results are consistent with those found by Duhon (2014) in which increased frequency of an explicit timing intervention resulted in associated increases in third grade students' fluency on multiplication facts. Taken together, these findings suggest that it may be possible to predict student growth rates based on the intervention, their grade level, and the target skill. Additional research is needed to understand how increased frequency of other evidence-based academic interventions impact student learning rates. Continuing this line of research may allow practitioners to prescribe evidence-based academic interventions with more precision so that basic skills deficits can be more efficiently and effectively remediated within available timeframes.

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APPENDICES

Appendix A

Example Pre-/Post-Assessment Format

Form A, Side 1 **Name:**__________________________

14 - 7	12 - 9	17 - 9	14 - 9	13 - 6	7 - 5
13 - 9	12 - 9	15 - 9	11 - 6	13 - 6	10 - 2
8 - 3	12 - 9	6 - 3	11 - 6	14 - 7	11 - 3
15 - 9	14 - 7	6 - 3	7 - 3	7 - 5	15 - 9
17 - 9	15 - 9	11 - 3	14 - 9	15 - 9	10 - 2
11 - 6	11 - 3	10 - 2	12 - 6	13 - 6	12 - 6
6 - 3	8 - 3	14 - 7	11 - 6	12 - 6	13 - 9

Appendix B

Example CCC Intervention Worksheet Format

CCCB: 1A1 Name:____________________ Date:_________

12 - 9 3	12 - 9	7 - 5 2	7 - 5	17 - 9 8	17 - 9
14 - 9 5	14 - 9	8 - 3 5	8 - 3	10 - 2 8	10 - 2
13 - 9 4	13 - 9	11 - 6 5	11 - 6	14 - 7 7	14 - 7
14 - 9 5	14 - 9	13 - 6 7	13 - 6	12 - 9 3	12 - 9
7 - 3 4	7 - 3	11 - 3 8	11 - 3	13 - 9 4	13 - 9
11 - 3 8	11 - 3	7 - 5 2	7 - 5	10 - 2 8	10 - 2

Appendix C

Example Control Worksheet Format

Spelling Practice: 2A1 Name: ____________________ Date: _____________

beach
became
begin
between
block
board

Appendix D

Example Progress Monitoring Format

PM 5, Side 1 Name:__________________________ Date: ______________________

14 - 9	6 - 3	11 - 3	12 - 6	11 - 3	17 - 9
6 - 3	13 - 9	12 - 9	10 - 2	13 - 6	12 - 6
10 - 2	11 - 6	14 - 7	11 - 6	12 - 6	14 - 7
13 - 9	6 - 3	11 - 3	8 - 3	10 - 2	17 - 9
12 - 6	14 - 9	14 - 7	10 - 2	17 - 9	12 - 6
14 - 9	14 - 7	11 - 3	13 - 9	10 - 2	13 - 6
6 - 3	7 - 3	17 - 9	12 - 9	10 - 2	11 - 3

Appendix E

Example Assessment Protocol and Integrity Recording Sheet

Pre- and Post- Assessment Protocol

Date___________ Start Time__________ End time__________

Follow the script, but be enthusiastic. Initial in the provided space when you complete a step in the intervention.

1. Pass out the assessment packets to students and instruct them to write their name and date at the top of the packet. ____
2. Read the following directions, "Here is your math worksheet. Some of the problems may be easy and some may be difficult. Work across the page. Don't work ahead and don't skip problems. If you come to a problem you do not know, put an X through it after you have tried it, and go to the next problem. You will have 2 minutes to complete as many problems as you can. Ready? Begin." ____
3. Walk around the room to make sure students are completing the worksheets correctly and are not working ahead. ____
4. After 2 minutes, say, "Stop. Put your pencils down and turn to the next page. You will have 2 more minutes to complete as many problems as you can. Ready? Begin." ___
5. Repeat step 3. ____
6. After 2 minutes say, "Stop. Put your pencils down." ____
7. Collect the assessment worksheets. ____

Appendix F

Example Intervention Protocol and Integrity Recording Sheet

Daily Intervention Protocol

Date___________ Teacher _____________

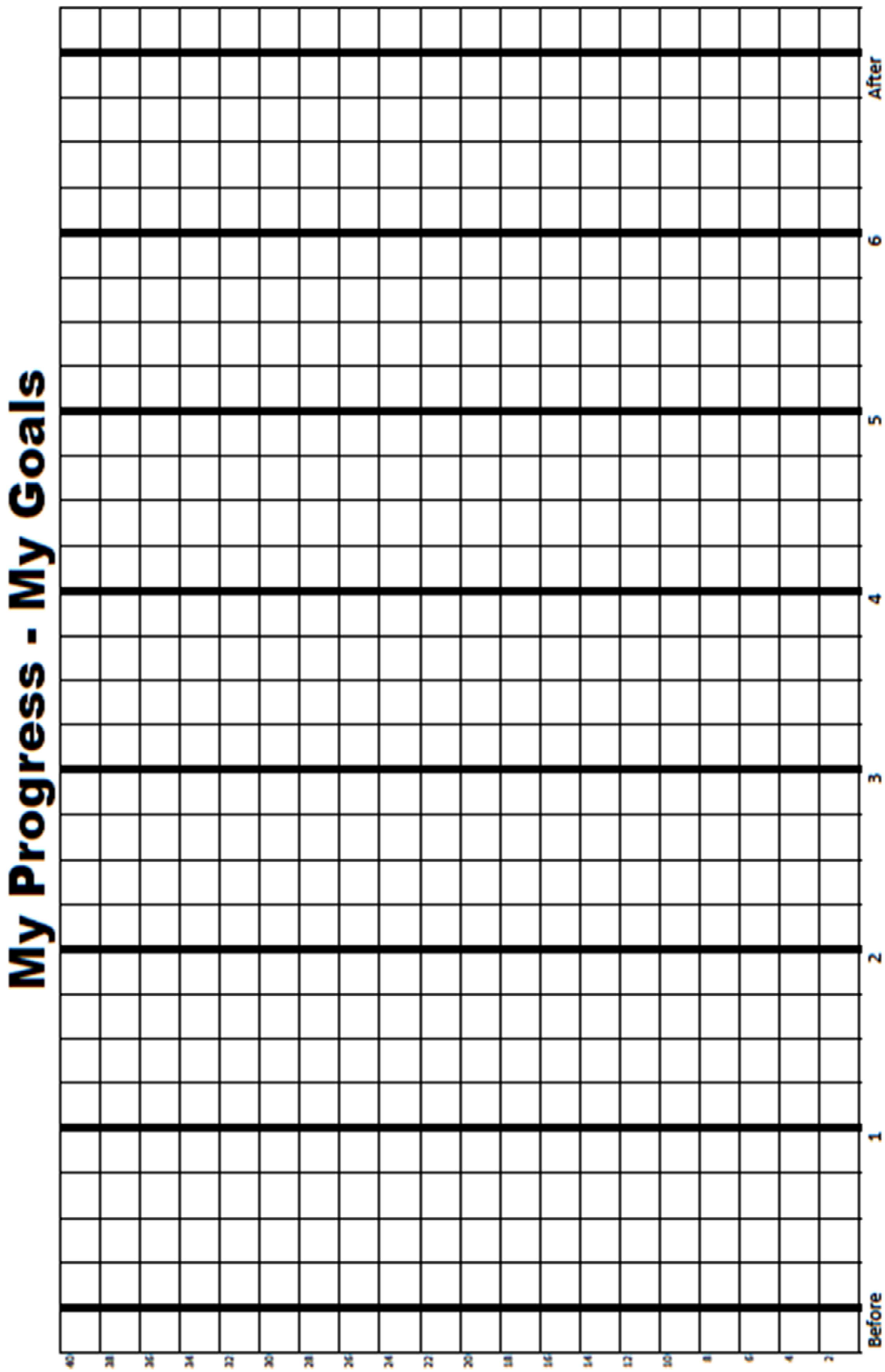
Follow the script, but be enthusiastic. Initial in the provided space when you complete a step in the intervention. Pass out the folders to students and instruct them to take out their packet and write their name and date at the top of the packet. Ask the students to place their folders so that you can see each student's colored dot. ____

(All) Morning Sessions – Start Time__________ End time__________
Morning Session 1
CCC: Red, Green, Blue, Yellow
Spelling: Pink

1. Read the following directions, "Look at the first page of your packet. You will see subtraction problems or spelling words. If you see subtraction problems, you will be working on the Cover, Copy, Compare activity for two minutes. If you see spelling words, you will be working on writing sentences using these words. Please do your best to work quickly and carefully. If you finish the first page, turn to the back of the page and keep working. If you finish the back of the page, please raise your hand and I will bring you another page to continue working until time is up." ____
2. Walk around the room to make sure students are on the correct page of their packet (a 1 in the top left corner for session 1) and that they will be engaging in the correct activity as indicated by the colored dot on their folders (as described in the bold text above). ____
3. Say: "You will have 2 minutes to complete as many items as you can. Ready? Begin." ____
4. Walk around the room to make sure students are completing the worksheets correctly and to give encouragement if needed. Provide extra worksheets (that match the activity they are assigned for this session) as needed. ____
5. After 2 minutes, say, "Stop. Put your pencils down and turn to the next page."
6. Walk around the room to make sure students have put their pencils down and turned to the correct page. ____

Appendix G

Example Self-Graphing Paper



Appendix H

Example Student Training Materials

CCC – Student Training Protocol

Use this to train students how to use CCC: Answer Only procedures. This training script was written for a class-wide application; however, it should be fairly easy to adapt to either a small group or individual student. The steps are as follows:

1. Pass out the CCC sheets to students and instruct them to write their names at the top of the paper.

2. Read the following directions, "Today we are going to do something new. We are going to do math problems using something called Cover, Copy, and Compare: Answer Only. (Pause) Look at your worksheets. On the worksheet you will see columns of math problems with an empty space next to each problem, you are going to use Cover, Copy, and Compare to complete these".

3. Continue reading, "Doing Cover, Copy, and Compare: Answer Only is easy. Look at the first problem. It is (read problem & answer). When doing Cover, Copy, and Compare you begin by looking at the problem and saying it to yourself. With this problem it is (read problem & answer). Next, you cover the problem and answer with your hand, everybody cover it. After it is covered, then you write the answer to the problem next to it, now everybody write the answer. After you have written the answer uncover it and check to see if what you wrote is correct. (Pause) Did everyone write the correct answer? If you have written the wrong answer then cross it out and write in the correct answer. Does anyone have any questions? (Pause)

4. Continue reading, "Now let's try the next problem it is (read problem & answer). Remember look at the problem, say it to yourself, and then cover it. Next, write the answer (Pause for students to complete the step). Lastly, uncover the problem to see if you did it correctly. When you have answered the problem correctly then go to the next problem. Complete these until you have finished the sheet.

5. If anyone has any questions, or is unsure of how to do Cover, Copy, and Compare: Answer Only then raise your hand and I will come to your desk and show you how to do this.

6. Repeat as necessary

This training script is generally successful for a majority of students. As you are reading the directions cycle though the room to check for adherence to protocol. In addition, point out students who are doing the steps correctly and provide behavior specific praise for correctly implementing CCC: Answer Only steps.

Appendix I

Institutional Review Board Approval Letter

Oklahoma State University Institutional Review Board

Date:	Wednesday, February 04, 2015
IRB Application No	ED14139
Proposal Title:	A Dose-Response Curve Analysis of a Cover Copy Compare (CCC) Intervention
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved   Protocol Expires: 2/3/2018

Principal Investigator(s):

Kathryn Moore	Gary J Duhon
1606 S Springfield St	423 Willard
Stillwater, OK 74074	Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1.Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms
2.Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3.Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of the research; and
4.Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Cordell North (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Hugh Crethar, Chair
Institutional Review Board

VITA

Kathryn Elaine Moore

Candidate for the Degree of

Doctor of Philosophy

Thesis: A DOSE-RESPONSE CURVE ANALYSIS OF A COVER COPY COMPARE (CCC) INTERVENTION

Major Field: Educational Psychology (Option: School)

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy in Educational Psychology (Option: School) at Oklahoma State University, Stillwater, Oklahoma in July 2016.

Completed the requirements for the Master of Science in Educational Psychology (Option: School Psychometrics) at Oklahoma State University, Stillwater, Oklahoma in 2012.

Completed the requirements for the Bachelor of Arts in Sociology and Spanish at The University of Tulsa, Tulsa, Oklahoma in 2008.

Experience:

August 2015-July 2016 – Pre-Doctoral Intern at Houston Independent School District, Psychological Services Department
June 2014-July 2015 – Systems-Level Consultant for Oklahoma Tiered Intervention Systems of Support (OTISS), State Dept. of Education
June 2014-May 2015 – 600 Hour Clinic-Based Practicum at School Psychology Center, Oklahoma State University
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