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Improving spelling for at-risk kindergartners through element skill frequency building

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Abstract

A student's ability to spell affects literacy outcomes. Students profit from explicit spelling instruction but may also benefit from frequency building or systematic practice. The method of frequency building leads toward effortless performance or behavioral fluency. Reaching certain frequencies of behavior produces a critical learning outcome called application. The current study focused on the effects of building element spelling behaviors for at-risk kindergartners and the subsequent application to a compound spelling skill. Visual and quantitative analysis suggest a clear experimental effect between the attainment of performance criterion for letter sounds, letter naming, and sequencing on students' spelling behavior. A discussion of the results precedes future research directions.

KEYWORDS

application, at-risk, behavioral fluency, precision teaching, spelling

1 | INTRODUCTION

Spelling has importance for both reading and writing. For example, misspelled words adversely impact the ease of reading and also lead readers to negatively view the writer's message (Graham & Santangelo, 2014). Furthermore, teachers who encounter misspelled words in papers grade the quality of ideas more harshly than papers without spelling errors (Graham, Harris, & Hebert, 2011). Spelling also plays a pivotal role in writing. Spelling words slowly taxes the emerging writer leading to a greater focus on the spelling of a word rather than composing text (Berninger, 1999; Graham, Berninger, Abbott, Abbott, & Whitaker, 1997; Graham & Perin, 2007). Furthermore, spelling errors occur at a greater frequency in students with learning disabilities than those without (Graham, Harris, & Larsen, 2001).

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Whereas some typically developing students experience difficulties learning to spell, students with, and those at-risk for, disabilities will likely have problems spelling and writing (Troia, 2006). One approach to helping all students become better spellers involves explicit instruction (Troia & Graham, 2002; Troia, Graham, & Harris, 1999). Explicit instruction entails directly teaching spelling rules, the use and practice of spelling rules, and extending students spelling ability through word study activities (Graham & Santangelo, 2014). Research demonstrates that students profit from explicitly processing spelling rules with benefits such as transfer to spelling novel words (Hilte & Reitsma, 2011).

Beyond effective methods for directly teaching spelling, behavioral fluency has emerged as a line of research that may contribute to improving spelling. Behavioral fluency refers to a condition of true mastery achieved after a person has engaged in frequency building or effective practice (Binder, 1996; Datchuk, 2015; Kubina & Yurich, 2012; Ramey et al., 2016). A study by Datchuk (2015) illustrates behavioral fluency. Four students with writing difficulties received instruction on how to construct sentences and then frequency building (i.e., systematic, focused practice). Students built frequency though timed repetition and corrective feedback until meeting the performance criterion of 30 correct word sequences with 0–3 incorrect word sequence per minute. Once the performance criterion was met, students then received three lessons on paragraph construction. The results showed the combination of sentence writing instruction followed by frequency building to a performance criterion led to a functional relation; all students produced significantly more correct and fewer incorrect word sequences during sentence writing. Additionally, evidence showed the sentence writing transferred to improve descriptive paragraph construction.

Students who attain behavioral fluency show signature effects: long-term retention, endurance or the persistence of effort without fatigue, and in the face of distraction, maintenance, and application, the combination of element behaviors to a compound behavior (Johnson & Layng, 1992, 1996; Johnson & Street, 2013; Kubina & Morrison, 2000; Kubina & Yurich, 2012; McTiernan, Holloway, Healy, & Hogan, 2016). For teachers and researchers to continue examining and benefiting from the effects of application, however, a clear and consistent usage of the term needs to occur. For example, two literature reviews examined the effectiveness of a number of precision teaching strategies geared toward producing behavioral fluency for people with and without disabilities (Doughty, Chase, & O'Shields, 2004; Ramey et al., 2016). Both sets of authors misclassified application: "Application is synonymous with generalization or the occurrence of a skill in novel stimulus conditions" (Doughty et al., 2004, p. 9). Similarly, Ramey et al. (2016) defined application as "the assessment of learner performance in response to novel or untrained stimuli" (p. 3). In each definition, application takes the form of generalization but does not reference the original term (Kubina, 2005). Application takes place when two or more element (i.e., singular) behaviors combine and *apply* to one compound (i.e., more complex) behavior (Binder, 1996; Haughton, 1972, 1973, 1980; Johnson & Layng, 1992, 1996; Lin & Kubina, 2005). For example, the strength of an individual's repertoire of element behaviors such as turning a faucet, grasping a bar of soap, rubbing hands together, and so forth influences a compound behavior like washing hands.

A number of studies demonstrate the relationship between element behaviors reaching a performance standard (i.e., fluency aim or goal) and then affecting the emergence or betterment of one compound behavior (e.g., Branch, Hastings, Beverley, & Hughes, 2016; Bucklin, Dickinson, & Brethower, 2000; Cavallini, Berardo, & Perini, 2010; Eastridge & Mozzoni, 2005; Hughes, Beverley, & Whitehead, 2007; Kubina, Commons, & Heckard, 2009; McDowell & Keenan, 2001; McTiernan et al., 2016; Twarek, Cihon, & Eshleman, 2010). All studies included frequency building, the deliberate, systematic, focused practice of a skill (Kubina, 2019). Furthermore, the frequency building ended when participants reached a quantified goal, most often set as a specific count over time (i.e., rate). The research studies show the rapid, improved compound behavior coming together once the element behaviors reach certain rates.

As an example, three students with specific learning disabilities in reading all had trouble spelling words (Kubina, Young, & Kilwein, 2004). The experimenters targeted two element skills of the compound behavior (i.e., hearing a word and writing in sequence the letters of the heard word). The first element behavior involved hearing a letter and

then writing the corresponding letter. The multiple baseline across participants showed that when each participant reached their goal for the first element skill, their ability to spell words did not appreciably change. The second element skill consisted of hearing a word and simultaneously saying the letter sound and moving a piece of felt for each sound heard—a phonemic awareness skill called segmentation. As each student reached the performance standard or frequency aim/goal for the second element behavior, all students spelled the untaught words with 100% accuracy.

The database for application has potential for diagnosing and remediating learning problems. Taken a step further, frequency building and behavioral fluency with its critical outcomes like application, could form an essential instructional component for all students struggling with academic content. Yet vital questions remain for students and teachers to realize the full benefits of application. As an example, one of the people to do pioneering work on application, Haughton (1972), provides insight on one question: the performance standards necessary for application. Students who reached a certain rate threshold for math computations (30 per minute) would rapidly advance through higher order mathematical content. Haughton also observed the same for reading; when students could say their letter sounds at a high frequency (40 per minute), they would progress more rapidly through the reading curriculum. Just because a student attains a performance standard for a given behavior, what other behaviors must occur to combine and affect a compound behavior?

A certain degree of behavioral chemistry can occur if experimenters identify element behaviors, determine those behaviors' performance standards or frequency aims, and then select the best type of frequency building or effective practice that will bring about the performance standard. Understanding the ingredients (i.e., element behaviors) leading to the application will allow educators to remediate problems better and increase educational outcomes for students with and at-risk for disabilities. Therefore, the purpose of present study examined the effects of frequency building element spelling skills on the spelling behavior of students at-risk for spelling and reading disabilities. More specifically, the research question asked what effect does frequency building of letter sounds, letter naming, and sound segmenting to a performance criterion have on the application of spelling words for at-risk students in kindergarten.

2 | METHOD

2.1 | Participants and setting

Two 6-year-old males, Harold and Hal, and one 6-year-old female, Stella, participated in the current study. All three kindergarten students received education in an elementary school within a large, suburban school district. Over 45% of students received free or reduced lunch (Pennsylvania Department of Education, 2016). Following institutional review board and school district approval, the experimenter recruited all participants through referrals from the participants' kindergarten teachers. Teachers identified each participant as academically at-risk for learning disabilities in literacy based on informal classroom tests. Prior to study participation, students had to have parental consent, provide assent, and meet eligibility criteria. First, students had to say the alphabet. Second, students had to demonstrate an inability to spell 10 random three to four letters words in a hear word—say letter format.

All sessions occurred at a table in the hallway outside of the students' classroom. A graduate assistant (i.e., third year doctoral student) conducted all sessions and met with each participant on every available school day during the course of the study. The graduate assistant received training from the first author in all study-related procedures and demonstrated 100% treatment integrity prior to formal implementation. The school schedule and participant attendance (e.g., absences, school holidays, snow days, field trips, etc.) affected session days for each of the participants. The experimenter video recorded each session, which lasted approximately 5 to 7 min.

2.2 | Materials

The experimenter created all letter sound sheets, recordings, and words based on 11 initial letter sounds (n, c, r, a, m, d, e, i, t, s, and f; Carnine, Silbert, Kame'enui, Slocum, & Travers, 2017). Letter sound sheets contained 49 initial and repeated instances of the 11 letter sounds counterbalanced across four alternate forms to control for serial memorization. The experimenter used a web-based anagram program to create 162 three- and four-letter words based on the 11 initial letter sounds. Both regular and nonsense words met inclusion criteria as long as the letters in each word said its most common sound (except for the long e sound). Two lists of 81 words resulted from equally dividing the 162-word list balanced by initial sound. The experimenters used one list of words for the daily spelling assessment (see Section 2.6 below) and the other for the segmenting PowerPoint format.

Development of two PowerPoint, student-controlled formats allowed for the assessment of letter naming and sequencing. The letter-naming format presented 45 letter sounds audibly in four alternate forms for students to respond in a hear letter sound—say letter name format. The sequencing format contained the second list of 81 words presented audibly in four alternate forms to each student allowing for a sequencing task. In both format instances, the graduate student who implemented all daily sessions recorded all letter sounds and words into a digital recorder. Additional supplies included a computer, digital recorder, microphone, headphones, timer, video camera, stand, number two pencil, participation chart, and standard celeration charts (SCC).

2.3 | Dependent variables

Measurement of two dependent variables, the frequency of letters spoken correctly and incorrectly during the daily spelling assessment, took place during the study. Each student's response to “Spell <word>” created a letter/sound sequence. A letter spoken correctly in its correct sequence in relation to a presented word counted as a correct (i.e., Spell “CAT”—“C A T”—three corrects). Letters spoken incorrectly included incorrect letters spoken (i.e., Spell “CAT”—“A L L”—three incorrects) and letters spoken out of sequence (i.e., Spell “CAT”—“T C A”—three incorrects). The experimenters counted letter sounds spoken as incorrects but removed them from the sequence (Spell “C A T”—/c/ C /a/ A /t/ T—three corrects, three incorrects). The experimenters ignored (i.e., counted as neither correct nor incorrect) when a participant repeated the word, said other words, or failed to say the remaining letters in a world.

2.4 | Independent variable

The independent variable consisted the frequency building of spelling element skills. The practice contained three distinct parts following the same presentation order daily: sees letter/ says sound, hears letter sound/says letter name, and hears words/says sound segment.

2.4.1 | Sees letter/says sound practice

The experimenter presented each student with a letter sound sheet. After saying “go,” students had 15 s to say as many corresponding letter sounds as possible. After 15 s, the experimenter stopped the student and provided error correction (i.e., model–lead–test) and performance feedback. The experimenter also charted the first score on a standard celeration chart. The student completed a total of four 15-s trials daily.

2.4.2 | Hears letter sound/says letter name practice

The experimenter loaded the first PowerPoint format (i.e., letter sounds) into a computer and had the student wear headphones. After saying "go," the student hit space bar to advance each slide. After hearing each letter sound, the student provided the correct or incorrect letter name or advanced the slide with no response. The process continued for 20 s at which time the experimenter said "stop." The student received error correction and performance feedback, and the experimenter charted the initial performance. The student completed a total of three 20-s trials daily.

2.4.3 | Hears word/says sound segment practice

For the final practice, students interacted with the second PowerPoint format (i.e., words). For 20 s, students segmented words they heard from advancing the PowerPoint slides. Each segment counted as one correct. After charting the initial daily segmenting performance, the experimenter provided error correction and performance feedback after each performance. The student completed a total of three 20-s trials daily.

2.5 | Experimental design

The experimenters used a multiple baseline design across participants (Kennedy, 2005) to evaluate the effects of systematic element skill practice on spelling accuracy. All participants began in the baseline condition at the same time, and the experimenter staggered the introduction of the intervention condition across the three participants. To enter intervention, the experimenters required progress to maintain or worsen (e.g., incorrect celerations accelerating faster than correct celerations) as measured by the improvement index (I.I.) after a minimum of five daily sessions. An I.I. refers to a measure that compares the concurrent celeration of correct responses to the celeration of incorrect responses to determine if progress or deterioration occurs within a condition (Kubina, 2019; Pennypacker, Heckler, & Pennypacker, 1977; Pennypacker, Koenig, & Lindsley, 1972). Subsequent students entered intervention after (a) the student in intervention completed a minimum of five daily sessions in intervention and demonstrated progress (i.e., improving I.I.) and (b) the student waiting to enter intervention must have a worsening or maintaining I.I.

Segments of the SCC display the spelling data for all three participants. SCCs show proportional behavior change, normalize variability, depict learning as a straight line, place behavior in real time, and allow for the calculation of celeration, a quantitative measure of learning across time (Kostewicz & Kubina, 2011; Kubina & Yurich, 2012). The SCC uses a distinct set of symbols, standardizes all learning patterns, and reduces decision-making errors (Kubina, 2019).

Analysis of the data occurred via measures within and between conditions. Within condition measures included level, celeration, and I.I. The average (e.g., mean, median, and geometric mean) rate of responding in a condition represents level (Clark-Carter, 2005; Kennedy, 2005). Celeration refers to the change in behavior over time divided by time with accelerating or increasing celerations noted with an × (multiply) and decelerations or decreasing a ÷ (divide by; Johnston & Pennypacker, 2009). To calculate I.I., use two celerations within the same condition. For celerations sharing the same sign (i.e., both have a multiply by, ×, or a divide by, ÷, sign), divide the larger by the smaller. Multiply the values when the signs differ. The sign applied to the quotient or product results from whether progress has improved or deteriorated. For example, a ×2 celeration for corrects and a ÷2 for incorrects results in a ×4 I.I. (2 × 2 = 4: use an × due to the improving condition). On the other hand, a ×2 for corrects and ×4 for incorrects equals a ÷2 I.I. (4 ÷ 2 = 2, with a ÷ symbol indicating a deteriorating condition).

Three measures, level change, celeration multiplier, and I.I. change provide direct comparisons between conditions (Kubina, 2019; Pennypacker et al., 1972; Pennypacker et al., 1977). Level change compares the level of baseline with intervention resulting from dividing the larger frequency by the smaller and providing the sign of change

(Kubina, 2019). Rising levels receive an ×, and falling levels a ÷. Celeration multipliers compares celerations between two conditions and follows the same formula as the I.I. above. An I.I. change compares two consecutive I.I. measures and follows the celeration multiplier and I.I. formula.

2.6 | Procedures

2.6.1 | Baseline

Following screening, all participating students started in baseline. Each baseline session started with the daily spelling assessment. Participating students had the opportunity to spell 10 words read by a trained graduate student who did not provide feedback or error correction. Each day, the experimenters chose 10 random words from the first group of 81 words. The experimenter chose another 10 from the remaining words for the next assessment without replacing the initial 10. The process continued until no words remained in the first group to restart the process with a full array of words. In other words, students only had the opportunity to spell each word approximately once every eight sessions. Experimenters timed all daily spelling assessments in seconds from the initial to final response. Students also received a sticker for each session regardless of performance. Students could accumulate the participation/attendance stickers for school-appropriate prizes (e.g., pencils, crayons, erasers, etc.) and turn in the stickers at the conclusion of any session (Kostewicz & Kubina, 2011).

2.6.2 | Intervention

All intervention sessions started with the daily spelling assessment and ended with students earning an attendance/participation sticker. In between, students engaged in the systematic practice sequence: sees letter/says sound, hears letter sound/says letter name, and hears word/says sound segment practice (see Figure 1). In each case, students followed the aforementioned practice procedures until reaching the fixed performance criteria for each skill (Kubina & Yurich, 2012). Students had to meet 25 correct letter sounds with one or fewer incorrects in 15 s on the sees letter/ says sound practice. For the hears letter sound/says letter name task students had to reach 20 correct letter names with one or less incorrects in 20 s. Finally, students needed 15 correct

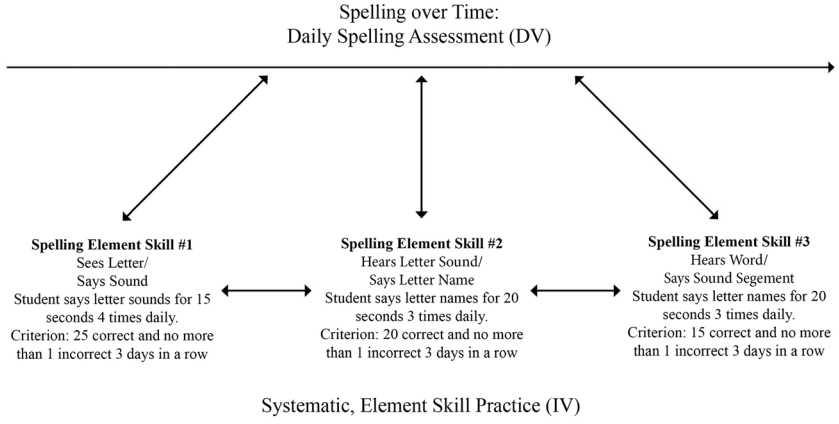

FIGURE 1 Element spelling skills (IV) practiced within the study related to the compound behavior of spelling during the spelling assessment (DV)

sound segments with one or less incorrects in 20 s on the hears word/ says sound segment practice. After meeting the performance criterion for any skill 3 days in a row, the student moved to a weekly probe on that skill. If during the weekly probe, the student's score dropped below the performance standard, they re-entered formal practice on that skill. To complete the intervention phase, students had to meet or have met the criterion on all three skills 3 days in a row.

2.6.3 | Instruction

Once students exited intervention, the experimenter conducted one session of formal spelling instruction provided in a direct instruction format (Carnine et al., 2017). The instruction covered how to spell words, modeled spelling words, and provided spelling prompting. Following instruction, the experimenter assessed participants' spelling behavior via the daily spelling assessment once.

2.7 | Procedural integrity and accuracy

The assessment of the independent (i.e., procedural integrity) and dependent (i.e., accuracy) variables occurred at multiple points within the study. A graduate assistant assessed procedural integrity on 100% of the sessions. To calculate procedural integrity, the graduate assistant reviewed each session and completed a checklist verifying specific steps of the procedure. Procedural integrity came to 100%. Accuracy of the measurement of the dependent variable also occurred. The procedure called for comparing observed values with true values. True values represent special efforts to record the dependent variable while minimizing measurement error (Johnston & Pennypacker, 2009). The graduate assistant first scored the dependent variable when working with each student. Next, she compared the observed scores with audio and video files resulting in 100% accuracy.

3 | RESULTS

In Figure 2, dots and Xs show corrects and incorrects per minute. Each data point's value appears on the left vertical axis. Some data points require estimation. The right vertical axis displays various counting times. The SCC calibrates various counting times to per minute measures for comparison (Kubina & Yurich, 2012). A dash (i.e., time bar) denotes the amount of time per observation. For instance, the labeled time bar on Figure 2 points to a 1-min observation. Dashes higher on the figure last between 1 min and 30 s. Dashes below the 1-min timing bar refer to observations running for 1 to 4 min. Dotted vertical lines represent condition changes (i.e., baseline to intervention to instruction). Solid black (corrects) and gray (incorrects) lines on Figure 2 through each data set per condition refer to celeration lines created using the quarter–middle intersect method (Pennypacker et al., 1972) and accompanying values.

3.1 | Baseline

The level in baseline refers to the average (i.e., geometric mean) correct and incorrect letters spoken in response to a spelling assessment. The experimenters chose to use the geometric mean to calculate level due to statistical advantages (e.g., less effect from very small and very large numbers; Clark-Carter, 2005). All three participants (Harold, Hal, and Stella) had higher levels of incorrects (28, 25, and 23) as compared with corrects (5, 15, and 10) in baseline (Figure 3). The celeration measure expressed the speed of change of the dependent measures. Incorrects grew by

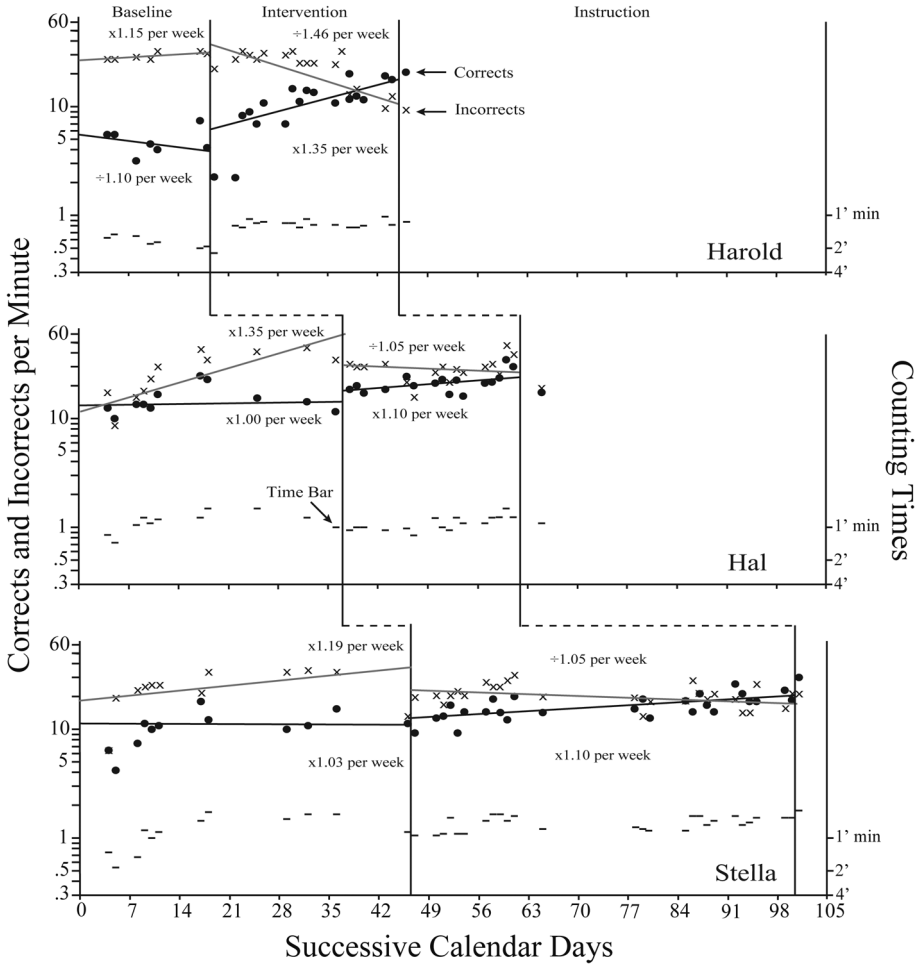

FIGURE 2 Spelling assessment performance by Harold, Hal, and Stella

×1.15 per week (Harold), ×1.35 per week (Hal), and ×1.19 per week (Stella), whereas correct celerations differed by ÷1.10 per week for Harold and ×1.00 per week and ×1.03 per week for Hal and Stella, respectively. Comparisons of concurrent baseline celerations (i.e., I.I.) for each participant quantified progress. Harold (÷1.27), Hal (÷1.35), and Stella (÷1.16) all demonstrated a deterioration of progress.

Intervention

Spelling scores changed after entering intervention and across the condition. Figure 2 shows Harold, Hal, and Stella respectively produced decelerating incorrects (÷1.46 per week, ÷1.05 per week, and ÷1.05 per week) and accelerating corrects (×1.35 per week, ×1.10 per week, and ×1.10 per week). Thus, the resulting I.I. scores all showed improving progress (Harold, ×1.97, Hal, ×1.16, and Stella, ×1.16). Incorrects per minute for Harold (23), Hal (29), and Stella (21) remained at higher levels than corrects (9, 22, and 16; Figure 3).

Between condition measures (i.e., level change, celeration multiplier, and I.I. change) showed evaluative effects of the intervention on both dependent variables. Level represents the average rate of responding within a condition. Figure 3 displays the visual representation of level, a horizontal line drawn across each condition. Harold had a ×1.80 correct level change, meaning his average corrects increased by 80% (Figure 3). Stella and Hal's average correct response rose by ×1.60 and ×1.47 times. Conversely, average incorrect performance dropped for two (Harold and

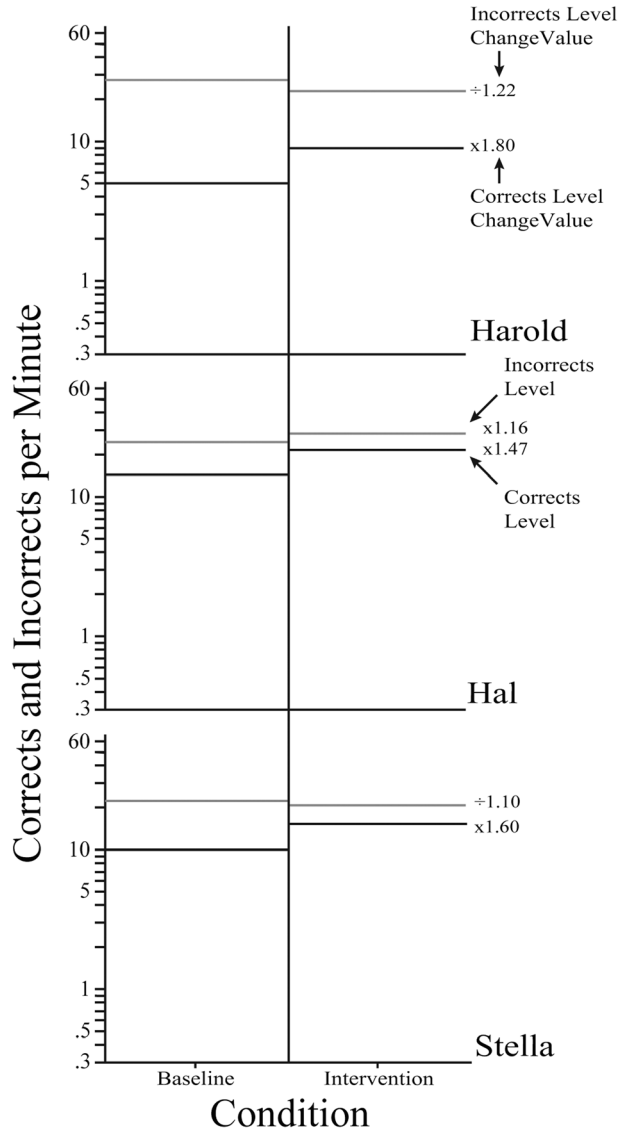

FIGURE 3 Correct and incorrect mean levels during baseline and intervention for Harold, Hal, and Stella

Stella) of three participants by ÷1.22 and ÷1.10, reductions of 18% and 9%, respectively. Hal spelled, on average, 16% more letters incorrectly, a ×1.16 level change.

Celeration multiplier quantifies the change that occurred between baseline and intervention celerations of both correct and incorrect spelling behavior. The resulting value establishes speed change. In all three cases, correct spelling performance quickened, and incorrect spelling performance slowed. Corrects for Harold (×1.49), Hal (×1.10), and Stella (×1.07) ranged in speed increases from 7% to 49%. Speed decreases for incorrects as participants moved from baseline to intervention measured ÷1.22 (Harold), ÷1.48 (Hal), and ÷1.25 (Stella), 12% to 32% reductions.

The final measure, I.I. change, provides a numerical value for the change in progress between baseline and intervention. The participating students had the following I.I. change values: Harold ×2.50, Hal ×1.57, and Stella ×1.35. Stated differently, the three students improved spelling words by magnitudes of 150% (Harold), 57% (Hal), and 35% (Stella).

3.2 | Instruction

During each student's final session (i.e., met the study criterion) prior to exiting the study, experimenters conducted a formal lesson on how to spell. Participants completed one final spelling assessment at the conclusion of the lesson. Harold scored 20 correct and 9 incorrect and Stella had 30 corrects and 21 incorrects. Hal had more incorrects (19) than corrects (18).

4 | DISCUSSION

The guiding experimental question asked what effect frequency building of letter sounds, letter naming, and sound segmenting (i.e., element behaviors) to fluency has on the application of spelling words (i.e., compound behavior) for at-risk students in kindergarten. Therefore, without formal direct instruction, would students learn to spell words better? The results from displaying a multiple baseline design on segments of the SCC indicate a clear experimental effect both visually and quantitatively. Visual analysis (Gast, 2010; Kennedy, 2005) of level shows a reliable effect. Average correct responses prominently increased for all participants. Average incorrect responses slightly decreased for two students with a slight increase for one. Incorrect celerations (i.e., trends) all changed from a path of growth to a decay. Correct celerations either inverted (i.e., decay to growth) or further accelerated (i.e., rate quickened). The overall visual patterns consistently changed from worsening to improving spelling behavior for all three participants.

Quantification of key between condition measures confirms that frequency building had an experimental effect on spelling words. Level changes for correct letters spoken in sequence rose by 47% to 80% in intervention, a compelling growth considering students received no spelling instruction. For incorrects, Harold and Stella had a reduction in mean levels with Hal increasing slightly (i.e., 10%). When combined, the difference between correct and incorrect mean level decreased for each student within intervention as compared with baseline.

Studies (e.g., Datchuk, 2015; Kostewicz & Kubina, 2010) often report the direct effects of an intervention (i.e., independent variable) producing gains in fluency (i.e., dependent variable). During the current study, however, frequency building, as an intervention, occurred only at the element skill level. The celeration multiplier, efficiency, and the I.I. change, effectiveness, provide further quantitative evidence suggesting at-risk kindergartners demonstrated application to a compound behavior: spelling words.

The current results extend previous literature focusing on spelling and application (Kubina et al., 2004). Although both contained frequency building element skills (i.e., segmenting), the current study incorporated saying letter sounds and letter naming. Kubina et al. identified letter sound writing as the other element skill. In each case, participants demonstrated application with spelling. Kubina et al. reported increases to writing words correctly, whereas kindergartners in the current study improved spelling verbally. Finally, data from the current study solidify application as an outcome of frequency building element skills (e.g., Cavallini et al., 2010; Hughes et al., 2007; McDowell & Keenan, 2001; McTiernan et al., 2016; Twarek et al., 2010).

Beyond the direct effects of the intervention, the data shed light on the argument for accelerated intensity. One method for enhancing intensity involves student receiving instruction for more than one session (Torgesen et al., 2001; Vaughn & Linan-Thompson, 2003). Participating students in the present study, instead of receiving a double dosing of instructional sessions (Marchand-Martella & Martella, n.d.), achieved intensity with only 3 to 5 min of daily element skill frequency building. For comparison purposes, 5 min of an instructional block (e.g., 50 min; Torgesen et al., 2001) equals 10% of the lesson. A double dose consumed 100 min or 200% (Torgensen et al., 2001). Thus, focused intensity channeled to precision-targeted skills increased instructional efficiency.

Element skill frequency building led to improvements in spelling. Nevertheless, the intervention had mixed effects on letters spoken incorrectly. Average incorrects dropped modestly for two students and slightly rose for one. Yet all students slowed their rate of incorrects across the intervention condition. Application does not involve direct feedback or error correction on the compound behavior (i.e., spelling). Instead, the power to affect change

resides in element skills reaching the performance standard (Kubina & Yurich, 2012). As students neared the completion of the intervention (i.e., met the performance criterion on all three element skills three times in a row), a replicable data pattern emerged. Incorrects slowed and crossed paths with accelerating corrects.

Application of a compound behavior results from frequency building element skills whereas acquisition of a single, compound behavior emanates from explicit instruction. As a teacher-directed method, explicit instruction provides students straightforward instruction in a single skill at a time (Archer & Hughes, 2011). Educators who teach students academically at-risk for spelling and reading failure may best optimize explicit instruction by including element skill frequency building. A combined approach would address (a) deficient underlying element skills and (b) refinement of the compound skill through focused instruction with corrective feedback.

The present research also addresses a growing concern within single-case design: supplemental statistics for visual analysis of graphed time series data (Bulté & Onghena, 2012; Lee & Cherney, 2018; Parker, Cryer, & Byrns, 2006; Shadish, 2014; Shadish, Hedges, Horner, & Odom, 2015). A lack of universal decision rules and unreliability across raters illustrate the limitations of visual analysis (Brossart, Parker, Olson, & Mahadevan, 2006; Campbell & Herzinger, 2010). Adding statistical or quantitative analyses to visual analysis provide objectivity, increased confidence of the results, and enhances the strength of the outcome (Campbell & Herzinger; Shadish, 2014).

One study demonstrated how hierarchical linear modeling produced growth models to augment visual analysis (Davis et al., 2013). The present study suggests a different way to provide supplemental analyses with alternative, direct statistics. The SCC quantifies behavior both within and between conditions (Kubina, 2019). As an example, the statistics associated with trend, celeration, reflect a percentage change across a time unit for a behavior trajectory within a condition. When contrasted with a celeration line in a subsequent condition, the celeration multiplier statistic directly reveals the magnitude of speed change.

The statistics inherent within the SCC attend to the concerns recommended by supporters of a visual/statistical analysis of single-case data (Campbell & Herzinger, 2010). The visual (i.e., replicated visual patterns of the data) and quantitative (i.e., objective) analyses in the current study combine to show a clear experimental effect expressing confidence in the results. Spelling behavior improved by magnitudes of 35% to 150% based on I.I. changes. The previously described metric for gaging effectiveness plainly shows strong intervention outcomes.

Some limitations occurred within the presented study. One limitation involved the two lists of 81 words created using the 11 initial letter sounds. Experimenters created 162 regular and nonsense words divided into two lists balancing for initial sound. Experimenters did not formally balance the number of nonsense and regular words within each list. The students may have come in contact with more regular words influencing practice and/or performance during the course of the study. However, results show students changing spelling performance following the introduction of the intervention suggesting minimal limiting effects. The location of study implementation may also have posed a limitation. People and other students did walk the halls during the course of the intervention potentially affecting scores. To minimize distraction, the intervention occurred around a final bend in the hallway away from the kindergarten rooms with classroom doors near the working area closed.

A variety of research avenues exist given the results from the current study. Kubina et al. (2004), combined with the current outcomes, showed frequency building across multiple element skills produced application with spelling. Researchers can implement a brand of educational chemistry—identifying and frequency building various element skills—to determine application effects on a variety of spelling behaviors. The testing process does not limit to spelling alone. Researchers can examine the effects of letter sounds, letter naming, sound segmenting, and so forth on other related academic behaviors (e.g., reading). Combining the two examinations may further refine the relative importance of certain element skills across the academic continuum.

An additional direction for future research involves the potential for blending explicit instruction and application. The present study contained only one instance of explicit instruction at the conclusion of the study. The rich history of explicit instruction tactically combined with frequency building could lead to dramatic student gains (Kostewicz & Lemons, 2012). Tier 1 would contain instruction and feedback on the critical compound skills (e.g., spelling) identified through an evidence-based curriculum. Tier 2 and/or Tier 3 practice would include

a clear focus on the deficient element skills (e.g., letter sounds). The proposed model would further address the relationship between frequency building/application and explicit instruction.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ETHICAL APPROVAL

All procedures performed in studies involving human participants were in accordance with the ethical standards and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

INFORMED CONSENT

Authors obtained prior institutional approval and informed consent for all individual participants included in the study.

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