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Mindfulness and Speed Testing for Children With Learning Disabilities: Oil and Water?

Julia Keller, Eric Ruthruff, and Patrick Keller

University of New Mexico, Albuquerque, New Mexico, USA

ABSTRACT

Metacognitive approaches are important in teaching reading skills, but experts know little about how to develop self-regulation through classroom interventions. This article reports results from a randomized controlled pilot trial in which we investigated whether mindfulness-based training improves literacy scores/attitudes in children with learning disabilities (LD). Mindfulness is a well-established metacognitive strategy for developing attention; it reduces anxiety and cognitive interference and improves positive affect. These benefits might help students with LD come to terms with their disability and improve their reading skills. We randomly assigned 20 elementary students with LD to either an active control or experimental group that received a 5-week intervention incorporating reading instruction and mindfulness. Quantitative results showed that training significantly increased response times during decoding (indicating possible increases in reflectiveness) and lowered heart rate. Qualitative analysis revealed themes pointing to improvements in literacy and affect. We discuss implications for intervention and assessment.

The cause of learning disabilities (LD) that affect reading skills is widely held to be a deficit in the phonological processing of sounds in language (Aylward et al., 2003; Eden et al., 2004; Vellutino, Fletcher, Snowling, & Scanlon, 2004). Consistent with this view, children with LD have difficulty deciding which words start with the same sound and cannot segment or blend the sounds in a word (e.g., *chat* is segmented into the sounds /ch/, /a/, and /t/, and blending these separate sounds makes the word *chat*). The phonological impairment of older children who have accumulated a limited sight word vocabulary is particularly marked when these children are asked to read nonsense words (like *twale*) that can be deciphered only by using decoding (phonological) strategies.

Many intervention studies of children with LD have reported improvement in children's word attack and decoding skills, but these gains have failed to generalize to other types of reading tasks. "In fact, generalization of remedial gains has proved a formidable hurdle for many intervention methods reported in the literature" (Lovett, Lacerenza, & Borden, 2000, p. 459). Numerous researchers have documented that children with LD are passive learners who seldom transfer newly acquired strategies to new learning tasks (Borkowski, Estrada, Milstead, & Hale, 1989).

The overall ineffectiveness of existing types of remediation might be due to the fact that they do not address metacognitive deficits common to children with LD. Borkowski et al. (1989)

CONTACT Julia Keller jkelle01@unm.edu Psychology Department, 2001 Redondo S. Dr., Albuquerque, NM 87106, USA.

Supplemental data for this article can be accessed here.

proposed a model of metacognition for children with general LD who have IQs between 80 and 95 (a range that would include 11 of the 18 participants in the present study). These children are slow learners who have repeatedly failed in academic situations, are easily distracted, and have low self-confidence and self-esteem. They are chaotic and inconsistent in applying learned strategies to solving problems as a result of deficiencies in executive processes and low self-worth that depresses mood and raises anxiety (Steca et al., 2014). Borkowski et al.'s metacognitive model is especially applicable for these types of children but is also relevant to children with specific LD, who have more well-defined deficits in areas such as math or decoding and who experience metacognitive failures that inhibit their use of reflective processes during novel tasks.

Even when children with LD are taught specific learning strategies and how to apply them, they have difficulty monitoring whether they are using a strategy correctly and efficiently (Lovett et al., 2000). Self-instruction training (or guided self-talk) may help develop self-monitoring skills and self-regulation (Harris, Graham, Brindle, & Sandmel, 2009). Bornstein and Quevillon (1976) investigated the efficacy of self-instructions for improving on-task behavior in three overactive preschool boys with generalized learning problems. At the beginning of each 2-hr session, the child watched the experimenter modeling overt self-verbalizations, after which the child completed the task with covert self-instructions. Mean rates of on-task classroom behavior increased from baseline (10.4%, 14.6%, and 10% for each child) to posttreatment (82.3%, 70.8%, and 77.8% for each child), which suggests successful transfer from the experimental tasks to the classroom. It is important to note that the benefits were maintained at a follow-up assessment 22.5 weeks after training.

Because of a long record of academic failure, children with LD do not believe that their efforts will improve their performance or that they can succeed in school tasks (Borkowski et al., 1989; Seyed, Salmani, Nezhad, & Noruzi, 2017). A child's beliefs about self-efficacy, which stem from prior use of strategies and the consequences of those strategic attempts, determine whether the child will continue to use a strategy or give up entirely, believing himself or herself unable to do the task. Given the importance of self-efficacy, a different approach to intervention might include the remediation of self-efficacy as well as phonological processing. Important to the development of motivation, persistence, resilience, and skillful performance, self-efficacy can be promoted by a warm and responsive environment, the encouragement of exploration and curiosity, the setting of goals that are specific, short term, and challenging but attainable, and performance feedback that focuses on developing self-awareness of strengths and limitations (Schunk & Pajares, 2001).

In a 20-year longitudinal study of adults with LD, Raskind, Goldberg, Higgins, and Herman (1999) collected data using public records, a life stressor checklist, cognitive and academic testing, and in-depth interviews. Qualitative analyses of interviews revealed a set of success attributes: perseverance, proactivity, emotional stability, goal setting, social support systems, and self-awareness. A quantitative analysis was conducted to determine predictors of success in employment, education, independence, family relationships, community relations/interests, and crime/substance abuse. Success attributes explained 49% to 75% of the variance, with either IQ or achievement making a minor contribution (0%–5%), depending on which outcome variable was used in the regression. Thus, success attributes differentiated between successful and unsuccessful individuals, with successful adults demonstrating greater self-awareness and self-acceptance of their LD.

Therefore, because Raskind et al.'s (1999) results suggest that developing self-awareness and self-acceptance of strengths and limitations is a predictor of success in adults with LD, interventions for children with LD should include training that increases self-awareness and self-acceptance, or attributional beliefs (self-efficacy), as well as training of executive processes needed to implement problem-solving strategies (Borkowski et al., 1989). Executive functions are typically viewed as cognitive processes used to self-regulate thoughts and goal-directed behaviors (Alvarez & Emory, 2006). Learners who develop self-regulation or metacognitive control—cognitive control informed by self-monitoring (Serra & Metcalfe, 2009)—are able to monitor their attention, retention, motivation, and self-awareness of thoughts, feelings, and actions in order to attain their learning goals (Zimmerman & Moylan, 2009). Zimmerman and Moylan's (2009) cyclical phase model of self-regulation includes a forethought phase in which goal setting and strategic planning occur and self-motivation beliefs (e.g., task interests and self-efficacy) are determined. During the performance phase, self-observation and self-control occurs, and time management, help seeking, self-instructions, imagery, and so on are used. During the self-reflection stage, self-judgment and self-reaction occur, and students decide whether they are satisfied with their performance and whether they will use/modify current strategies or, because of a low self-evaluation, find ways to avoid the task.

A metacognitive approach that includes training in self-awareness, self-acceptance, and self-regulation and that has promise to promote generalizable gains in literacy skills among children with LD is mindfulness. Mindfulness is a well-established technique for developing attentional capacities and emotional stability in adults and can be considered a metacognitive skill. It has been operationally defined by Bishop et al. (2004) as the self-regulation of attention involving sustained attention, attention switching between tasks, and the inhibition of elaborative processing. It has also been described as systematic training focused on developing meta-awareness (self-awareness; Vago & Silbersweig, 2012). Most of the research conducted on mindfulness over the past 20 years has been in the area of health psychology, and studies have consistently demonstrated benefits, including reduced pain and stress and an increase in positive emotion (Davidson et al., 2003; Majumdar, Grossman, Dietz-Waschkowski, Kersig, & Walach, 2002; Tang & Posner, 2009). So, many would ask, because mindfulness training is clearly linked to health outcomes, why focus on the cognitive benefits of mindfulness? The answer to this question is that changing mental processes has been the focus of mindfulness training for thousands of years (Wenk-Sormaz, 2005).

In a search of 4,515 articles in five databases, Chiesa, Calati, and Serretti (2011) found 23 controlled studies that provided objective measures of cognition following mindfulness training in adults. Ten studies assessed sustained attention, eight assessed selective attention, nine assessed executive attention, and four assessed attention switching. Overall, Chiesa et al. found that beginning phases of mindfulness training aimed at developing focused attention were associated with significant improvements in selective and executive attention (working memory [WM]). Later stages of mindfulness training, described as an open monitoring of internal and external perceptions, were associated with improvement in unfocused sustained attention skills.

One of the studies included in Chiesa et al.'s (2011) meta-analysis was Jha, Krompinger, and Baime's (2007) investigation of the effect of mindfulness training on particular aspects of attention as assessed by the Attention Network Test (Fan, McCandliss, Sommer, Raz, & Posner, 2002). Jha et al. (2007) recruited three groups of 17 participants: (a) experienced meditators who practiced concentrative meditation at a 1-month intensive retreat (the first experimental group), (b) novice meditators receiving instruction on mindfulness-based stress reduction (MBSR; see Kabat-Zinn, 2003) at the University of Pennsylvania (the second experimental group), and (c) novice meditators from the same population who had not yet received MBSR training (the control group). The experienced meditators demonstrated superior conflict monitoring performance compared to the control group and the second experimental group before they received MBSR training. There was a significant difference across groups for response time (RT; $p < .03$) and accuracy ($p < .001$). Furthermore, the second experimental group demonstrated significantly improved spatial orienting following MBSR training compared to before (an approximately 30 ms shorter RT on average at the second time point—after MBSR training—than the first group and the control group combined at the second time point). These results suggest that mindfulness training increases voluntary, top-down attentional skills such as orienting (or attending to the direction and constraint of attention to specific inputs) and conflict monitoring (or selecting between competing responses).

Another type of attentional skill is controlling working memory (WM). Chambers, Lo, and Allen (2008) found evidence that 20 novice meditators, in contrast to 20 controls, increased significantly on a measure of WM after a 10-day mindfulness meditation retreat. Jha, Stanley, Kiyonaga, Wong, and Gelfand (2010) examined the WM capacity and mood of military personnel as they prepared for active military service in a war zone before and after an MBSR program, dividing participants into those who practiced meditation frequently and those who practiced rarely. The study used an operation span task (Ospan) as the measure for WM; Ospan involves remembering letters over brief intervals while solving simple math problems. Results showed that frequent meditators maintained both their WM capacity and their positive mood over the course of training despite the stresses of preparing for combat, whereas the infrequent meditators suffered deterioration in both abilities.

Numerous studies on mindfulness in adults have also found that it diminishes anxiety (Davidson, 2010), a notable symptom of LD that particularly needs remediation. Students with LD and attention-deficit/hyperactivity disorder (ADHD) often experience higher levels of trait and state anxiety than their nonimpaired peers, especially during testing and problem solving (Alesi, Rappo, & Pepi, 2014; Fisher, Allen, & Kose, 1996). Connolly (1969) observed that dyslexic children react more impulsively than controls during testing, and Dean and Rattan (1987) discovered that children with LD responded more negatively to reading failure and had greater difficulty recovering from this stress. Other researchers have also found that children with LD exhibit higher levels of school anxiety than their nondisabled peers (Alesi et al., 2014) and that this leads to the development of poor motivational, coping, and task strategies (e.g., proneness to cheating and making careless errors, negative self-evaluation, trouble concentrating, and daydreaming). These strategies further increase test anxiety and exacerbate the cognitive interference that children with LD experience during learning and testing (Swanson & Howell, 1996).

Sarason, Sarason, Keefe, Hayes, and Shearin's (1986) cognitive interference model asserts that what people think about during a task affects their behavior. For example, if a person thinks repetitive negative thoughts during a test (e.g., "I don't know any of the answers" and "Everybody else is doing better than me"), he or she may fail to discriminate subtle differences between answers on a multiple-choice exam. The person's attention is divided between self-relevant and task-relevant variables, whereas the person with low anxiety can move his or her instructional focus away from distracting information, thus increasing space for WM (Alesi et al., 2014). Instructions to focus attention (a type of mindfulness) on the current task have been shown to greatly improve the performance of subjects with high anxiety (Sarason et al., 1986).

Despite the many reasons outlined above why mindfulness would benefit children, controlled studies on mindfulness and cognition in children are very limited and have numerous methodological issues (see Meiklejohn et al., 2012). Studies on the effect of mindfulness on children and/or adolescents with LD are even rarer. Using a pre/post, no-control design, Beauchemin, Hutchins, and Patterson (2008) conducted a pilot study on the use of mindfulness with 32 adolescents attending a private school for students with LD. For 5 to 10 min at the beginning of each class period, for a period of 5 weeks, students focused attention on their breath and intentionally observed their thoughts and feelings in a nonjudgmental manner. Students and two classroom teachers completed the Social Skills Rating System (Gresham & Elliott, 1990) before and after training, and students also filled out the State-Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970). Postintervention scores on the State-Trait Anxiety Inventory indicated that participants demonstrated decreased state and trait anxiety ($p < .05$). The student Social Skills Rating System forms showed that the students with LD thought that their social skills had increased ($p < .05$). The teacher Social Skills Rating System forms reflected the teachers' beliefs that their students had significantly improved behaviorally, socially, and academically ($p < .05$). Although the surveys used in this study were subjective measures, and as such were especially prone to demand characteristics, these outcomes are consistent with a cognitive interference model of LD:

The low performance of anxious individuals is caused by problems with attentional focus, self-efficacy, and a tendency to perseverate on self-oriented and negative thoughts (Beauchemin et al., 2008). In their conclusion, the authors postulated that methods like mindfulness and relaxation training reduced cognitive interference, allowing students to focus on their work without anxiety.

Although studies of mindfulness in children with LD are rare, a study by Tarrasch, Berman, and Friedmann (2016) on adults suggests that it might be effective. In a sample of 19 adults (12 with dyslexia and 13 with ADHD—six had both dyslexia and ADHD), Tarrasch et al. investigated whether mindfulness would affect the types of reading errors dyslexics made. The dual-route hypothesis (Pritchard, Coltheart, Palethorpe, & Castles, 2012) describes two separate mechanisms involved in reading aloud: the lexical route (or the immediate visual recognition of a word) and the sublexical route (when readers sound out a word). After participants completed a 2-month mindfulness workshop, Tarrasch et al. found that (in comparison to a control group of dyslexics [$n = 16$] whose error rate did not change after 3 months), the average error rate during reading decreased significantly from 12.7% ($SD = 6.4\%$) before the workshop to 9.7% after the workshop ($SD = 4.5\%$, $p = .02$, $d = 0.75$). Surface errors—those resulting from reading via the sublexical route—were the only type of error that decreased significantly ($p = .01$). When Tarrasch et al. compared dyslexic participants with and without ADHD, they found that only those with ADHD had a significant reduction in reading errors ($p = .04$). The authors concluded that mindfulness improved reading by keeping participants on the lexical route through improved sustained attention and reduced impulsivity. There were also significant improvements in all participants in perceived stress, rumination, depression, anxiety, and sleep disturbances.

Because these two studies indicate that mindfulness ameliorates some of the symptoms of LD in adolescents and adults, we wanted to know the impact of mindfulness in children with LD: Does it improve decoding and writing skills, improve the use of metacognitive strategies during decoding, and increase self-awareness, self-efficacy, and positive affect during instruction?

Methods

Participants

After approval was granted by the University of New Mexico's institutional review board, 20 students from Grades 2 through 5 were recruited from a school district in the Southwest. The students had been determined to have a specific LD by the school's Eligibility Determination Team. According to the New Mexico Public Education Department (2011), after the implementation of a three-tiered response-to-intervention model, a child is identified as having a specific LD if the following three conditions are met:

1. The child demonstrates significant academic underachievement that is documented and supported by a pattern of strengths and weaknesses in performance and/or achievement. This underachievement persists despite sustained, high-quality, scientific, research-based instruction and intervention.
2. There is evidence of basic neurological processing deficit(s).
3. The child's challenges are not caused by the following exclusionary factors: Lack of appropriate instruction in reading or math; limited English proficiency; visual, hearing, or motor disability; intellectual disability; emotional disturbance; cultural factors or environmental or economic factors. (pp. 185–186)

First the participants were matched in pairs (as well as possible) on age, sex, English language learner status, and level of service (see Table 1), and then the pairs were randomly assigned to either the experimental group ($n = 10$) or the active control ($n = 10$). Two of the students in the

Table 1. Matching experimental and control subjects on age, sex, ELL status, and level of service.

Experimental					Control				
Age	Sex	ELL?	IQ	Levela	Age	Sex	ELL?	IQ	Level[a]
8.4	F	No	84	D	8.1	F	No	92	C
8.4	M	No	90	C					
8.8	F	No	105	B	9.3	F	No	103	B
9.0	M	No	91	D	9.0	F	No	96	D
9.3	M	Yes	103	B	9.7	M	Yes	95	B
9.3	M	No	97	B	9.4	M	No	98	B
9.7	M	No	75	D					
9.8	M	Yes	96	B	10.3	M	Yes	94	B
10.6	M	Yes	89	C	10.6	M	Yes	87	C
10.6	F	Yes	76	B	9.11	F	No	85	B

Note. IQ was measured by assessors from the school district who used multiple cognitive tests: the Differential Ability Scales–Second Edition, the Wechsler Intelligence Scale for Children–Fourth Edition, and the Kaufman Assessment Battery for Children–Second Edition.

ELL: English language learner; F: female; M: male.

[a]Level of special education service from the school was based on the severity of need and/or parents' wishes. Level B students received 10 hr of intervention per week, Level C students received 15 hr of intervention per week, and Level D students received 20 hr of intervention per week.

control group whose parents gave consent did not show up for the intervention and so were dropped from the study. Overall, seven girls and 11 boys participated in this study. Seventeen students were Hispanic; one was Black. The mean IQs of the groups were not significantly different (experimental $M = 92.2$, control $M = 93.75$, $p > .05$).

Procedures

Before assignment to condition, participants were tested individually by assessors (blind to condition) on the Dynamic Indicators of Basic Early Literacy Skills (DIBELS; see the description below), a writing task (assessed after the conclusion of the study with the Six Traits Writing Rubric), and the lexical decision task. Interventions were given to participants in both conditions during the school district's 5-week (25 days, 6 hr a day) summer school program.

Measures

After the completion of the 5-week intervention, the premeasures listed above (the DIBELS, writing samples, and the lexical decision task) were readministered. Interviews were conducted with five of the participants and their families before the intervention and with four of the same five families to see whether there had been any changes in their attitudes toward school and their performance in school. Follow-up data on reading skills (using the DIBELS) were collected 4 months later from all participants. See Figure 1 for a simplified timeline of the study events.

The DIBELS (Kaminski, Cummings, Powell-Smith, & Good, 2008) is a standardized measure used by many school districts in the United States to assess children on reading accuracy, fluency, and comprehension. It is designed to be short (1 min) and to monitor progress in accuracy and fluency at a particular grade level. A teacher times a student for 1 min while the student reads a passage and marks the number of errors the student makes while reading. Words that are omitted or substituted and hesitations longer than 3 s are marked as errors. Words that are self-corrected within 3 s are scored as correct. A certified teacher blind to condition used the school district's protocol and materials for administering DIBELS benchmark testing on three separate passages at all three time points (pretest, posttest, and follow-up); the three resulting oral fluency scores at each time point were averaged to calculate a mean oral reading fluency score.

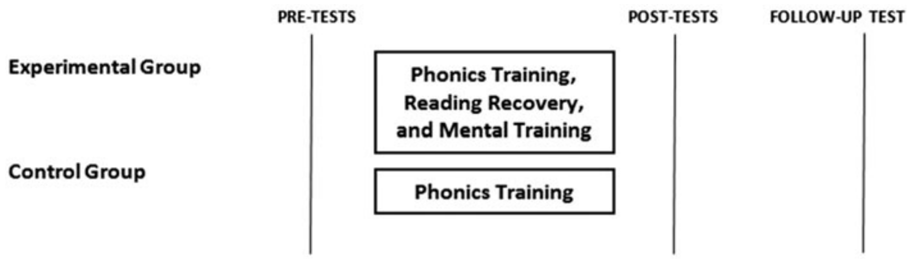

Figure 1. Simplified timeline of study events.

The Six Traits Writing Rubric (Six Traits Writing Rubric, 2014) is a scoring tool widely used to assess student writing using a set of criteria and standards (see the Appendix for the writing prompt used and Supplemental Appendix A for the rubric used). It assesses students on the following six traits: ideas and content, organization, voice, word choice, sentence fluency, and conventions. Participants in this study were only assessed on voice and word choice; these traits were considered to be sensitive to intervention effects because of its focus on developing awareness of thought, emotion, and body awareness. An exemplary score in the voice category (6 out of 6 points) meant that a student's writing was expressive, was engaging; was sincere, had a strong sense of audience, and showed emotion, humor, honesty, suspense, or life. An exemplary score in the word choice category meant that a student's words were precise, were carefully chosen, and contained strong, fresh, vivid images. A certified teacher blind to condition scored participants' pre- and postwriting samples on voice and word choice using the Six Traits Writing Rubric.

The lexical decision task (cf. Julca, Nenert, Chaix, & Demonet, 2010) is a computerized task that involves words, pseudowords (pronounceable, meaningless letter sequences; e.g., *gad* and *foge*), pseudo-homophones (words that sound the same as a real word but are spelled differently; e.g., *yoo* and *aftir*), and random letter strings (unpronounceable sequences of letters). Two lists of 120 items were created in order to have different stimuli in each session; these lists were balanced for lexical frequency, number of letters, and syllable structure. List order was randomly selected during each of the three blocks/sessions (40 words each block). Subjects were asked to indicate whether the letter sequence presented was a real word by pressing one of two designated keys on a keyboard. Two types of data were collected from this measure: accuracy and RT. RT outliers were defined as fast responses (<200 ms) or slow responses (>2.5 *SD* above the group mean).

Heart rhythm coherence biofeedback

Research using heart rhythm coherence biofeedback with students in the classroom has found improvements in academic performance, behavior, and emotional well-being (McCraty, 2005). The Institute of HeartMath has developed biofeedback technology that teaches individuals how to self-induce a state of psychophysical coherence—a highly efficient mode associated with increased synchronization between the sympathetic and parasympathetic nervous systems, improved emotional stability, and enhanced cognitive performance. Interactive hardware/software monitored and displayed heart rate variability (HRV) patterns as students practiced breathing mindfully. Heart rhythm patterns became smoother and more wavelike as the practitioner's state of coherence increased (see Figure 2). Note that we were not able to screen extraneous variables that may have affected coherence ratios (e.g., medication, stress at home).

Running records are individually administered assessments of reading accuracy, error rate, patterns of effective and ineffective strategy use, and self-correction rate (see Supplemental Appendix B for an example). This method was developed by Marie Clay (2017) to document reading progress over time and can be used to document self-talk during a child's reading of any text. The

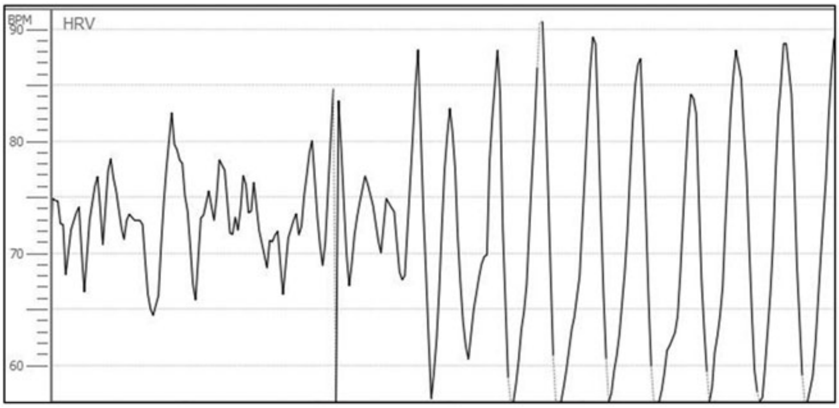

Figure 2. Example of a heart rate variability (HRV) pattern becoming more coherent over time.

Table 2. Summary of dependent measures.

Measure	Ability measured	Time points
DIBELS	Reading fluency and comprehension	3
Six Traits Writing Rubric	Voice and word choice	2
Lexical decision task	Reading accuracy and response time	2
Running records[a]	Reading accuracy, number of words read, self-corrections	16–20
HeartMath[a]	High coherence, low coherence, average heart rate	16–20

Note. Time points are the number of times each participant took the assessment.
DIBELS: Dynamic Indicators of Basic Early Literacy Skills.
[a]Measure was only administered to the experimental participants.

teacher uses the data to determine whether the child is ready to advance to a new reading level. See Table 2 for a summary of the dependent measures used in this study.

Intervention

During the intervention, all participants completed 10–15 min daily of computerized training using research-based software (SoundReadingSolutions: http://soundreading.com/) that included exercises in phonics, phonemic awareness, orthography (i.e., spelling), and fluency. The control group also completed 10–15 min daily of phonetic and orthographic activities with a trained research assistant. The experimental group received 30–45 min of literacy instruction and mindfulness. Students were taught how to use strategies (e.g., context cues and phonetic cues) to decode text, with mindfulness used as a metacognitive strategy to ameliorate symptoms of cognitive interference, fatigue, and anxiety that arose during instruction. Writing samples, running records, and heart rhythm patterns were collected daily.

The components of the experimental intervention were grounded in the first author's 17 years of experience as a special education teacher working primarily with students with LD. She has practiced mindfulness for 15 years and has 9 years of experience using the lens of cognitive psychology to conduct research on the effects of mindfulness on children. Given her experience with both mindfulness and LD, the first author designed and conducted the intervention herself so she could investigate the integration of mindfulness practice into literacy instruction when students became upset or distressed or confused. When participants became upset or anxious during the process of reading and writing, the first author encouraged them to use mindfulness strategies to increase their awareness of negative thoughts, emotions, physical sensations, and behaviors that interfered with their learning (for more information on the intervention, see "*Understanding the Intervention*").

Data analysis

Quantitative data analyses consisted of independent-samples *t* tests and follow-up tests on the dependent variables (decoding accuracy, fluency, voice, word choice, heart rate, and coherence) to see whether the independent variables of group (mindfulness vs. control) and time of test (before, after, and 4 months following the intervention) influenced the dependent variables. Difference scores (subtracting the first score from the last score) are reasonably reliable for determining whether an intervention works (Trafimow, 2015).

Qualitative data were collected from nine face-to-face interviews (see Supplemental Appendix C for the interview questions used), participant journals and drawings, individualized education plans, and 500 pages of researcher field notes/reflections written during the intervention. The data were then loaded into a software package (Dedoose Version 6.1.9, 2015) for sorting and analysis. Within Dedoose, an open coding process was used to develop general conceptual categories. The first author read all of the documents, highlighting excerpts and creating codes based on first impressions of the relevance and importance of the excerpt to the research questions (Merriam, 2009) and coding these excerpts with multiple themes regarding participant characteristics, instructional strategies, and behavioral/academic improvements.

Results

We investigated the link between mindfulness practices and the amelioration of symptoms of LD in children. We specifically wanted to know whether training in mindfulness, relative to control training, would result in decreasing anxiety and improvements in writing, reading, positive affect, self-awareness, self-efficacy, and the use of metacognitive strategies. Overall, the results suggested that it did.

Quantitative results

Analysis plan

Missing data (one lexical decision posttest) were estimated using maximum likelihood estimation (Baraldi & Enders, 2010). For the analysis of RTs for the lexical decision task, 60/4,200 trials (1%) were eliminated because the participant did not respond. RT outliers were defined as fast responses ($<$200 ms) or slow responses ($>$2.5 *SD* above the group mean). One experimental participant's data were excluded from further analysis because 88/120 (73%) of his RTs on the pretest and 49/120 (41%) of his RTs on the posttest were too slow or he did not respond. Altogether 98/4,080 (2.4%) of the RTs from the remaining 17 participants were eliminated from the analysis: 18 were too fast and 80 were too slow.

To determine overall improvement across the experiment as a function of condition (mindfulness vs. control), we calculated difference scores. Specifically, we subtracted the first test score from the last test score on three quantitative assessments of reading and writing. Independent-samples *t* tests on the group factor (experimental vs. control) were then conducted on these difference scores. Improvements in writing, reading, the use of metacognitive strategies, and affect are discussed below.

Improvement in writing

We wanted to know whether participant writing scores would improve, specifically in the areas of voice and word choice, as measured by the Six Traits Writing Rubric (n.d.). An improvement in voice meant that the student's writing became more expressive and showed more emotion, humor, honesty, or life. An improvement in word choice meant that the student used more strong, fresh, and vivid images in his or her writing. Although nonsignificant, experimental

Table 3. Summary of group means on reading difference *t* tests (first test score subtracted from last test score) and significance level.

Measure	Test	Group	*M*	*p*	*d*
DIBELS	Oral Reading Fluency	Control, Experimental	6.0, 1.41	*ns*	0.03
Lexical decision	Word accuracy	Control, Experimental	−.011, −.005	*ns*	0.0
Lexical decision	Nonword accuracy	Control, Experimental	.063, .046	*ns*	0.10

Note. DIBELS: Dynamic Indicators of Basic Early Literacy Skills.

difference scores (reflecting overall improvement) were higher on the voice test and the word choice test: voice test, experimental $M = 1.60$, control $M = 0.00$, $t_{diff}(16) = -1.11$, $p > .05$; word choice test, experimental $M = 0.50$, control $M = 0.25$, $t_{diff}(16) = -0.49$, $p > .05$. Cohen's d was 0.52 for the voice test (medium-size effect) and 0.23 (small effect) for the word choice test.

Improvement in reading

We wanted to know whether participants would improve their accuracy and fluency while decoding text. There was no evidence of this from the DIBELS *t*-test difference scores (see Table 3). Although it was a nonsignificant result, the control group read an average of 4.59 more words than the experimental group on the DIBELS Oral Fluency Test. We hypothesize that the experimental participants were trying to use metacognitive strategies during decoding.

Improvement in the use of metacognitive strategies

We wanted to know whether the intervention would increase mindfulness participants' use of metacognitive strategies while decoding text. During the intervention, students were encouraged to slow down, "use what they knew" about letters and sounds, and pay attention to negative self-talk that might interfere with their performance. In other words, students were taught to become more reflective while decoding words instead of just randomly guessing at words as fast as they could. Two results from the word and nonword lexical decision tasks indicated that difference scores on the RTs were significantly longer in the experimental group than in the control group.

Nonwords on the lexical decision task included letter strings (e.g., *bkw*), pseudowords (e.g., *weven*), and pseudo-homophones (e.g., *heer*). Mean difference RTs on the nonword subtest of the lexical decision task were longer in the experimental group (experimental $M = 213$, $SD = 548$; control $M = -362$, $SD = 599$; see Figure 3). The *t* test on the lexical decision nonword RTs approached significance, $t_{diff}(16) = 2.07$, $p < .056$, $d = 1.00$ (considered a large effect size; cf. Cohen, 1992).

Mean difference RTs on the word subtest of the lexical decision task were longer in the experimental group (experimental $M = 310$, $SD = 481$; control $M = -300$, $SD = 443$; see Figure 4). The *t* test on the lexical decision word RTs was highly significant, $t_{diff}(16) = 2.71$, $p < .016$, $d = 1.32$ (considered a very large effect size), which indicates that participants who practiced mindfulness became more reflective when decoding words. We elaborate more on the implications of this finding in the Discussion.

Affective improvement

We wanted to know whether the mindfulness intervention would decrease anxiety in experimental subjects. This research question was answered by the significant lowering of heart rate in the mindfulness group as measured by the HeartMath program.

The software analyzed and recorded heart rhythm patterns and calculated a coherence ratio for each session as either low, medium, or high. Low coherence is described as lower frequency, more chaotic heart rhythm patterns, and an increased average heart rate (McCraty, Atkinson,

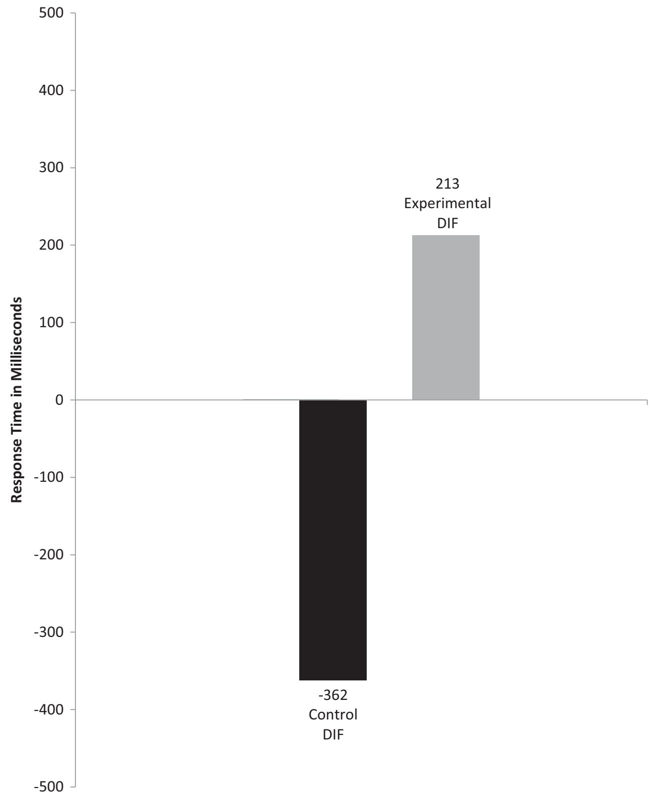

Figure 3. Difference scores for nonword response times.

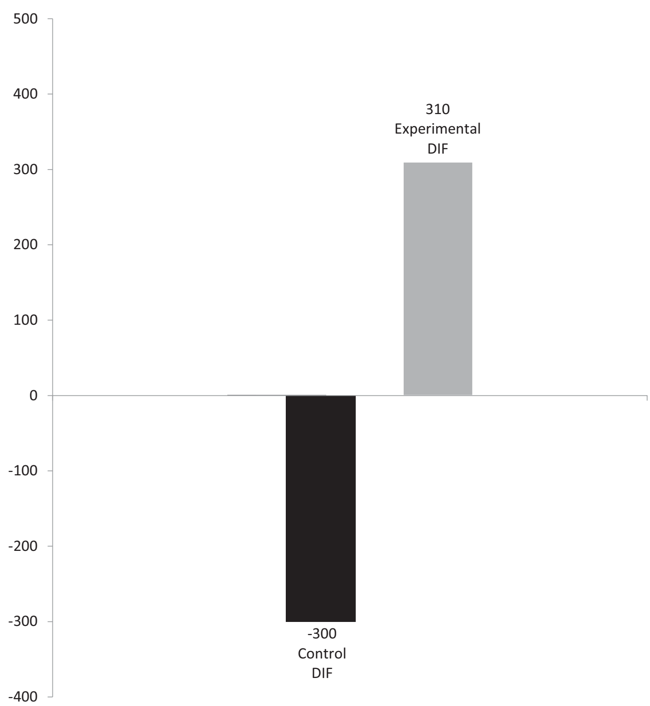

Figure 4. Difference scores for word response times.

Tomasino, & Bradley, 2006). Here is an explanation of how coherence is calculated by the HeartMath program (McCraty et al., 2006):

> Heart rhythm coherence is reflected in the HRV power spectrum as a large increase in power in the low frequency (LF) band (typically around 0.1 Hz) and a decrease in the power in the very low frequency (VLF) and high frequency (HF) bands. A coherent heart rhythm can therefore be defined as a relatively harmonic (sine-wave-like) signal with a very narrow, high-amplitude peak in the LF region of the HRV power spectrum and no major peaks in the VLF or HF regions. Coherence thus approximates the LF/(VLF + HF) ratio … First, the maximum peak is identified in the 0.04–0.26 Hz range (the frequency range within which coherence and entrainment can occur). The peak is then determined by calculating the integral in a window 0.030 Hz wide, centered on the highest peak in that region. The total power of the entire spectrum is then calculated. The coherence ratio is formulated as: (Peak Power/[Total Power-Peak Power])^2. This method provides an accurate measure of coherence that allows for the nonlinear nature of the HRV waveform over time. (p. 8)

We calculated linear contrasts on low and high coherence scores and average daily heart rate collected over 16 sessions (time points) from experimental participants by weighting each session (e.g., we weighted Session 1 by multiplying by −15, Session 2 by −13, Session 3 by −11, … Session 16 by 15). After calculating contrasts, we calculated confidence intervals (CIs) and conducted one-sample *t* tests.

Linear contrast tests indicated no significant changes in low or high coherence levels over the course of the intervention: low coherence $M = -244$, $t(9) = -0.42$, $p > .05$, 95% CI [−1551, 1062]; high coherence $M = -256$, $t(9) = -0.44$, $p > .05$, 95% CI [−1562, 1050].

The test on heart rate was highly significant, $M = -535$, $t(9) = -3.48$, $p = .007$, 95% CI [−187, −883], indicating that the average heart rate of experimental participants became significantly lower over time (see Figure 5).

Qualitative results

Through the open coding process, three conceptually distinct and interconnected themes emerged pertaining to the researcher's understanding of the experimental group. *Understanding the Participants* (note that theme names are italicized) leads to *Understanding the Intervention,* because the intervention was individualized to address needs and develop strengths. *Understanding the Intervention* leads to *Understanding the Improvements.* (Note that the participants' names have been changed to maintain confidentiality. The original spellings of the participants have been preserved—with bracketed corrections—when excerpts from their writing are used.)

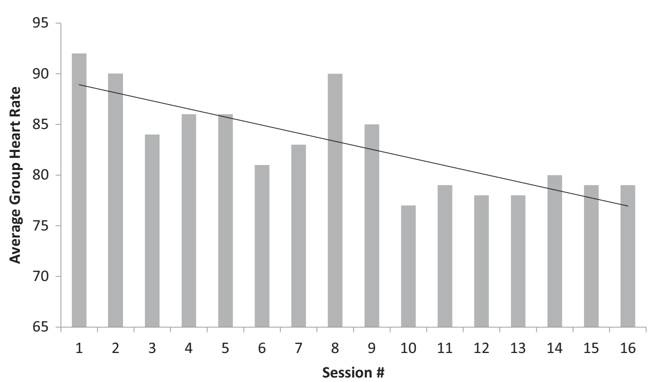

Figure 5. Experimental group means for daily average heart rate.

Understanding the Participants

Understanding the Participants includes the three subthemes of *student needs, student strengths,* and *student feelings.*

Student needs. One overall need was *needs positive reinforcement* (70 excerpts; see Supplemental Data Figure S1–S22), or, as described in the researcher's codebook, the participant's need for affectionate, humorous, and playful rapport. Using a kind and playful tone with students improved their ability to respond positively to requests and increased awareness of their own behavior in a nonthreatening manner. The greatest overall need was *behavioral, social* (378 excerpts; see Supplemental Data Figure S2). Two of the most common behavioral themes in student records and observations were *hyperactive* (42 excerpts) and *withdrawn or shut down* (41 excerpts) and included subthemes like *emotional intelligence* (19 excerpts), or the need to identify and manage emotions. Students who were hyperactive or withdrawn were also *off task* (36 excerpts), a term that describes a student who is unwilling/unable to complete assignments.

Contributing to and sometimes exacerbating severe behavioral problems were significant language needs. *Expressive language needs* (116 excerpts; see Supplemental Data Figure S3), or the ability to successfully convey thoughts and feelings, was a frequent theme in student records, observations, and interviews and was specifically addressed by encouraging students to explore thoughts/feelings during mindfulness breathing and then express them in writing.

Cognitive, reading, and writing needs. It is not surprising, in a sample of children with LD, that *cognitive needs* (202 excerpts; see Supplemental Data Figure S4), *reading need*s (200 excerpts; see Supplemental Data Figure S5), and *writing needs* (251 excerpts; see Supplemental Data Figure S6) were common themes. *Memory problems* (70 excerpts) and *needs attention skills* (64 excerpts) were the most frequently observed cognitive needs. *Needs attention skills* is directly related to *hyperactivity;* three participants had been diagnosed with ADHD and two were taking medication during the intervention (*ADHD meds:* 18 excerpts). However, other students not labeled as ADHD also exhibited significant difficulties with the self-regulation of attention. Unable to focus on the task at hand, they shut down in the regular classroom and found other things to do (e.g., sharpening pencils repetitively or diving under desks to retrieve fallen objects). *Memory problems* also influenced *off-task behavior* and *expressive language needs.* Unable to remember directions or to find an answer to a question in their long-term memory, students became *aggressive* (16 excerpts) and/or *defiant* (26 excerpts) because they could not express their feelings/thoughts.

Cognitive problems directly impact reading problems. The most frequent reading need was *decoding* (97 excerpts; see Supplemental Data Figure S7). *Word blindness* was observed when students miscued on words, reversing letters or seeing letters that were not there (e.g., one student read *holes* as if it had a *ch* at the beginning). *Word slamming* (11 excerpts) describes a behavior observed in four students. When decoding, these students made rapid guesses or slams at the word, looking at the researcher's face for nonverbal cues to see whether their guess was correct instead of using phonetic/contextual strategies.

Students with significant decoding problems are also not good spellers (*spelling:* 133 excerpts). Three participants hated writing because they thought their handwriting was "bad" or "dumb," and another girl perseverated on letter formation, taking as long as 10 min to write a simple sentence (*handwriting:* 19 excerpts). Struggling to grip a pencil and print letters neatly also affected writing *fluency* (28 excerpts), and so did expressive language difficulties and memory problems. If a child had problems coming up with original ideas, it impacted his or her ability to write fluently. Students who lacked emotional intelligence did not have voice (or distinct personality) and detail in their writing (e.g., they wrote sentences like "I am mad sad").

The behavioral and academic needs profile of the participants looks grim, but the strength profile, presented in the next section, offers hope that these children, after appropriate intervention, can still make valuable contributions to our society.

Student strengths. Many people—scholars as well as laypeople—associate LD with creativity (Wolff & Lundberg, 2002), especially within the fine arts. People with LD are said to have talents for seeing patterns in noise and pulling novel ideas out of the mundane (Chakravarty, 2009). In controlled studies, people with LD have been found to be better at visuospatial tasks, unusual or creative thinking measures like the Alternative Uses task, and artistic tasks like Picture Production (Attree, Turner, & Cowell, 2009; Everatt, Steffert, & Smythe, 1999; von Károlyi, 2001). Strengths identified by the school district, by parents, and by the children themselves correspond with these findings. Some participants said that they liked *math* (in which visuospatial skills are important) and were better at it than reading and writing (19 excerpts). Cognitive tests by the school district often indicated strengths in nonverbal ability (i.e., visual processing and fluid intelligence). Nine of the students had average or above-average nonverbal ability. Strengths in visuospatial ability (*observes visual details:* 9 excerpts, *visual memory:* 6 excerpts, *visual processing:* 4 excerpts; see Supplemental Data Figure S8) and *nonverbal reasoning* (4 excerpts) were observed in this sample by the school district and the researcher. "I like all the rainbow colors!" said Clara about the room decorations.

Student feelings. Students with LD often experience higher levels anxiety than typical students (Fisher et al., 1996). *Anxiety* was the most frequently observed and/or reported negative feeling (80 excerpts; see Supplemental Data Figure S8). Anxiety was observed in nine of the experimental participants, especially during reading and writing, but only four self-reported being "worried," "scared," or "nervous because I can't read it." The other participants displayed anxious behaviors such as fidgeting, speeding up during reading, mumbling or whispering, or breathing quickly during mindfulness practice. *Frustration* (69 excerpts) was also a frequent negative feeling and may have been due to increased effort made during tasks that required phonological processing (Maurer et al., 2007). Parents and teachers often reported a child becoming frustrated when they could not do a task, sometimes crying, hitting their foreheads, or putting their heads down and refusing to do anything else. *Anger* (60 excerpts) is a common response to frustration. During the intervention, Zach was frustrated and angry because his regular teacher had not let him write about his favorite video game. The researcher asked him to write about his feeling: "I am not gub [good] at writing. and I suke [suck] at writing." He turned his anger inward because of *low self-esteem* (43 excerpts).

In contrast to the variety of negative feelings children expressed or demonstrated during the intervention, in interviews, or in school records, the *positive feelings* (see Supplemental Data Figure S9) they displayed or talked about were simple: *happy, excited* (82 excerpts), *pride, self-confidence* (33 excerpts), and *calm* (24 excerpts). It is interesting that only seven out of the 139 positive feelings excerpts came from school records. Teachers and evaluators were more likely to report negative feelings and behaviors than positive ones.

Understanding the Intervention

This theme includes three subthemes: *HeartMath, academic,* and *mindfulness strategies.* After examining school records and collecting background information during the preinterviews, the first author created individual intervention plans for each student and used the following instructional strategies.

HeartMath instructional strategies. During the students' first session, they were introduced to the HeartMath program—how to put the ear sensor on their ear (to get heart rate information from their pulse)—and shown how their HRV pattern was "jagged" when they started talking or got distracted and became smoother as they focused on taking deep breaths (see Figure 2).

It is not easy to teach children how to concentrate on their breathing. The most frequent difficulty that participants had during HeartMath was caused by *high arousal* (68 excerpts; see Supplemental Data Figure S10). When students were excited or silly (13/68 excerpts), were restless or distracted (46/68 excerpts), or had a high average heart rate (9/68 excerpts), they found it difficult to increase their coherence level and tended to fidget, disrupting their ear *sensor connection* (10 excerpts). It was also difficult for them to concentrate during periods of *low arousal* (18 excerpts)—when they were mind-wandering or daydreaming (3/18 excerpts in *low arousal*) or tired (15/18 excerpts).

Breathing problems (24 excerpts) included holding their in-breath (4/24 excerpts); engaging in shallow breathing through their chest instead of deep breathing with their stomach (8/24 excerpts); taking fast, short breaths instead of longer ones (3/24); and having a cough (2/24) or stuffy nose (7/24). The researcher tried a variety of strategies to address these problems, the most common of which were *breathing lessons* (105 excerpts; see Supplemental Data Figure S11) and *visualization* (31 excerpts)—having subjects visualize bubbles (14 excerpts), floating on water (11 excerpts), their mother's smiling face (5 excerpts), and being kind to another child (5 excerpts). The youngest children, who were not able to concentrate for more than a minute at a time, were asked to set daily *breathing goals* (25 excerpts). "How many breaths can you do today? Ten? Or twenty?" One boy with ADHD found it easier to focus with his *feet on a ball* (3 excerpts). Progressive relaxation, or tensing and relaxing the muscles (*relax:* 3 excerpts), was used with two students who had trouble reaching high levels of coherence; this practice seemed helpful. One boy said it felt "like [getting] a shot but my arms not numb."

Daily collection of HRV informed the researcher about the psychophysical effects of breathing lessons and helped to inform instruction on breathing (see Supplemental Data Figure S12). Many of the students, who were initially intrigued watching their HRV and coherence levels on the HeartMath display, became stressed about their performance. The researcher asked these students to lie on a *mat* (27 excerpts) and *close eyes* (3 excerpts) so they could not see the screen. Fawn wrote that when she was lying on the mat, she was calm, not thinking about anything and not "more worried because I was goin to get more red" (a red gauge on the display indicated low coherence; a green gauge indicated high coherence). Using breathing *visuals* (20 excerpts)—blowing bubbles (6 excerpts), blowing on a pinwheel (3 excerpts), moving a cotton ball to a "goal" by blowing through a straw (5 excerpts), and breathing with a stuffed animal on their stomach (6 excerpts)—helped children see the effects of making their breath softer or more forceful. Asking students to *smell a fragrant flower* (3 excerpts) encouraged them to breathe in more deeply. *Pushing* their breath out (3 excerpts), breathing *in nose, out mouth* (7 excerpts), and placing their *hands on stomach* (7 excerpts) helped them become more aware of in-breaths and out-breaths. The two youngest students were asked to *count breaths* (15 excerpts) out loud as they breathed in and out through a straw that the researcher held her hand over to feel their out-breaths.

Every session began with HeartMath. After focusing on breathing for a few minutes, children started reading and writing.

Academic instructional strategies. The academic strategy used most frequently was *using child's interests to motivate* (75 excerpts; see Supplemental Data Figure S13). Before the intervention, children filled out an interest inventory. Then we ordered books in their areas of interest to motivate them to read and write. For example, for a boy who liked making things we ordered a paper airplane kit with a book of instructions and diagrams. For a girl who loved clothes and shopping we ordered *A Smart Girl's Guide to Style* (Cindrich, 2010) and *Paper Fashions* (Editors of Klutz, 2006).

One intervention strategy commonly used with children with LD is *multisensory instruction* (34 excerpts)—using more than just the visual/auditory channels when presenting and practicing new concepts (i.e., using the sense of smell, taste, or touch) to strengthen memory traces (e.g., spelling words in colored sand or shaving cream). *Setting learning goals* (29 excerpts) included teaching Clara, who took as long as 10 min to write six words, how to ignore distraction by making it into a game: "Can you ignore me stomping around the room and slamming doors while you write a sentence? How long do you think it will take you to write your sentence today?"

Decoding and writing strategies. *Visual focus* (31 excerpts), *context clues* (27 excerpts), and *phonics* (26 excerpts) were the three decoding strategies used (see Supplemental Data Figure S14). Because of difficulties noted earlier in *decoding needs* (*word blindness* and *word slamming*), five *visual focus* strategies were used. One was *tracking strips or finger* (14 excerpts)—children were directed to use their finger to "point to the words" or put a paper strip under the words to block distractions and guide their eyes to the print. For students who repeatedly miscued on a word (e.g., reading *bears* as *babies*), the word they were saying (e.g., *babies*) was written on a sticky note and placed next to the word in the text so they could see that they were saying something different (*sticky note corrections:* 7 excerpts). "It's okay if you read the word as *babies* instead of *bears,*" they were told, "but you have to point to the sticky note instead of the word on the page." For some reason, they did not like doing this; it motivated them to correct themselves so they could pull off the sticky note. Sometimes the researcher would *cover the word* (4 excerpts) and say, "You're saying the word *could* instead of *can.* What letter would be at the end of *could?* Does this word have a *d* at the end of it?" *Finding words* (3 excerpts) meant asking students how often they could find a high-frequency word in a book, and *word shapes* (3 excerpts) meant outlining a word so that students noticed the word's shape.

Does that make sense? (13 excerpts) was the most common of the *context clues* used. When they could not sound out a word, students were prompted to look at the words around it and think about what they knew. In one of the postinterviews, a boy remembered this strategy as thinking "it doesn't sound right." Some of the *phonics* strategies included the traditional *sounding out* (8 excerpts) strategy, in which students said the sound of each letter in a word; breaking up long words into syllables (*syllabication:* 7 excerpts); and looking at *word families* (3 excerpts) or groups of words that have a common pattern that makes them rhyme. All of these decoding strategies involved training children to slow down, look carefully at the word, and think about what they knew.

All of the students had difficulty with writing, especially spelling. One *writing strategy* (see Supplemental Data Figure S15) used with some of the most challenged spellers was *word bank* (9 excerpts)—favorite words were kept in a "bank" of index cards, and these words were drawn from the bank when needed. Because writing letters was difficult for two students, the researcher focused on *kinesthetic letter formation* (18 excerpts) with them. These students formed letters with their bodies or wrote "the biggest letter you can" on the whiteboard or rolled letter shapes out of clay. *Writing on whiteboard* (15 excerpts) with dry erase markers was also helpful because students struggled with the mechanics of writing with cheap school materials—pencils that broke easily and erasers that smudged and often ripped holes in the paper. In addition to these academic strategies, the first author often incorporated mindfulness strategies while they were reading/writing to help them become aware of anxiety that arose during academic tasks.

Mindfulness strategies. Most of the mindfulness strategies used can be categorized as *awareness* (278 excerpts; see Supplemental Data Figure S16), of which there were eight types. Instruction in *emotional awareness* (134 excerpts; see Supplemental Data Figure S17) is important for children with LD because they often experience higher levels of anxiety than non-LD peers, especially during difficult academic tasks. Many of the participants also lacked *emotional intelligence;* before the intervention started, they knew that some parts of school were "hard" for them but were not aware of anxiety while reading/writing. Participants worked on emotional awareness daily by choosing a feelings flashcard (Parr, 2010) illustrating a cartoon character feeling "calm" or "lonely" or "sad." Then they wrote about that feeling in their journals. Another way *emotional* and *body awareness* (74 excerpts) was increased was by the researcher pointing out—in a friendly, nonjudgmental, "this is interesting" way—that the students were yawning, fidgeting, tightening their jaw, or displaying other emotions while working on a task. Sometimes the students were asked what they were thinking during breathing practice or given reasons for their feelings to increase *thought awareness* (23 excerpts).

The researcher worked on *strength* (21 excerpts) and *disability* (10 excerpts) awareness by telling students when they were doing something well and giving them nonverbal, visuospatial opportunities to express themselves creatively (e.g., drawing or making things with clay). When Juan became tired while reading, the first author told him his brain was working very hard to read and that was why he took frequent "brain breaks" by talking about his video games.

Other mindfulness strategies used were *acceptance, transfer, modeling, energy,* and *writing dialogues.* Nonjudgmental *acceptance* (27 excerpts) is a critical component of mindfulness practice. Instead of becoming angry or irritated with students for negative behaviors, the researcher expressed compassion and understanding. For example, when Ángel was so depressed that he could not even choose an emotion flashcard, she said to him, "Is it hard to think sometimes?" He nodded his head to indicate yes. When students were trying to decode a word, trying to remember something, or talking about a distressing home situation, the researcher instructed them to use breathing to help them with academic and home situations (*transfer:* 39 excerpts). She used *modeling* (17 excerpts) to show children when to breathe (by taking a loud in-breath when they became nervous) or how to talk about feelings or thoughts. She used strategies to increase their *energy* (10 excerpts) when they were tired by teaching them how to breathe quickly and energetically. Finally, *writing dialogues* (8 excerpts; see Supplemental Appendix D for an example) were used with three of the students during the last days of the intervention. Students who had trouble verbalizing their emotions but could write fluently enjoyed answering questions about the color, shape, size, temperature, intensity, and thoughts of their emotions by writing a few words or drawing a picture in response to questions.

Understanding the Intervention or the instructional strategies used may help in *Understanding the Improvements* observed and/or documented.

Understanding the Improvements

In this section, we will discuss our study questions in light of our qualitative data.

Improvement in reading and use of metacognitive strategies. We wanted to know whether mindfulness instruction would improve literacy skills and the use of metacognitive strategies while decoding text. We found improvements in *self-corrections* (12 excerpts; see Supplemental Data Figure S18)—when a student realizes a decoding error and corrects it without prompting. Improvements in the use of *metacognitive strategies* (12 excerpts) were observed when students used context clues to figure out a word without prompting. Improvements in *reading level* (8 excerpts) and *accuracy* (5 excerpts) were supported by evidence from individual running records data for participants (see Supplemental Data: Running Records Figures S1–S11). Improvement in *phonemic awareness* (7 excerpts) could be seen when students who were very reluctant to sound out words began to do so on their own. Students demonstrated that they were *learning phonetic rules* (6 excerpts) like the silent *e* rule. A boy who could only read 10 words correctly at the beginning of the summer tripled the *number of words read* (2 excerpts) accurately in a book by summer's end.

Improvement in writing. The greatest improvement in writing was in *voice and detail* (38 excerpts; see Supplemental Data Figure S19). *Improvements in self-expression* (43 excerpts) transferred into the use of more vivid detail in their writing. Fawn wrote about how she felt while she was reading: "The thing that is happens in my body is my head start to tingol [tingle]. I am thinking about if I get the wards [words] wron I fill [feel] nervous." Paz, who hated his handwriting and wrote very little independently, showed improvement in writing *fluency* (9 excerpts) during a postinterview when he showed us he had started drawing and writing at home. *Improvement in timeliness* (6 excerpts) was evident in Clara, who at first took 10 min to write a short sentence; she was able to reduce this time to less than 8 min. *Improvement in spelling sounds* (6 excerpts) was especially noticeable in Paz, whose writing was unreadable at the beginning. After 5 weeks, he could write this sentence without any help: "Im shy mi frst day uv hl klas [I am shy my first day of my whole class]."

Affective improvement. We wanted to know whether positive affect during instruction would increase while negative emotions like anxiety and frustration would decrease. Mindfulness instruction resulted in *increases in positive affect* (58 excerpts; see Supplemental Data Figure S20). Every day, students practiced mindfulness breathing from 1 to 4 min and then often wrote about a positive emotion they felt during the HeartMath session, including *peace and calm* (29 excerpts), *relaxation* (15 excerpts), *happiness and fun* (6 excerpts), and *compassion* (4 excerpts). Ana wrote that when she was breathing, she was singing a Katy Perry song in her mind "and I felt come [calm] lik [like] if I was sliping [sleeping]." Ernesto wrote that he was thinking about being a bubble when he was breathing. Sam wrote about being an otter sleeping in the water, taking deep breaths and floating. "It would be relaceind [relaxing] … you coud just heaier [hear] the water making wafes [waves]." Sam, who was very detached and indifferent at the beginning of the intervention, discovered a strong feeling of compassion when visualizing a boy with no friends. Participants also found that mindfulness breathing *helps with negative emotions* (4 excerpts), like Ernesto, who said that he used breathing to help him when he was feeling sad at home.

Improvements in self-awareness and self-efficacy. Improvement in self-awareness can be seen in *thought, emotional awareness improvements* (59 excerpts; see Supplemental Data Figure S21) and *body awareness improvements* (21 excerpts). In a postinterview, while showing his father his coherence scores on HeartMath, Zach said, "On these two [days], I got really good because I was really excited. Right here I had a lot of blue because on the first day I was pretty nervous so I had some red here." *Improvements in self-efficacy* (25 excerpts) were evident in participants as the intervention progressed. When asked why his coherence levels were high that day, one boy said, "Because I'm proud of myself."

Another reader with severe disabilities did not like reading at the beginning of the intervention. When asked why, he said, "Cause I gotta read the words." He was 8 years old and still did not know all of his letter sounds and was decoding at a kindergarten level. He became very anxious when asked to read and often rushed through a book, reciting the text instead of reading it. Toward the end of the intervention, when asked how confident he was about reading on a scale from 1 to 3, he chose 8, he read four books, and he sounded out the word *can* without prompting. He did not want to leave that day. "I'll make you read books all day," the researcher teased him. "I can read all day!" he exclaimed.

Summary of results

When we disregard the quantitative results with very low effect sizes ($d < 0.05$), the data suggest that training in mindfulness had some behavioral benefits for children diagnosed with learning difficulties, including a decrease in anxiety, an increase in reflective processing during decoding, and improvements in voice and word choice during writing tasks.

Qualitative themes from this study are presented in Supplemental Data Figure S22 as the code application word cloud provided by the software package we used to analyze the qualitative data (Dedoose Version 6.1.9, 2015). In the word cloud, themes or codes that were most frequent appear in the largest size font (e.g., the most frequent code was *instruction in emotional awareness* with 134 excerpts, so it is in the largest font). Themes appear in random order, clustered around the largest themes.

The qualitative themes with the largest number of excerpts give a big picture of the intervention and its participants. Major components of the mindfulness intervention were *instruction in emotional awareness* (134 excerpts) and *instruction in body awareness* (74 excerpts). Many participants had *difficulty with oral or self-expression* (116 excerpts), needed *concentration or attention skills* (64 excerpts), had *difficulty remembering or retaining information* (70 excerpts), and experienced *anxiety* (80 excerpts) and *frustration* (69 excerpts) during academic tasks like reading and writing. However, during the intervention, students were usually *happy and excited* (82 excerpts), perhaps because a key instructional strategy used was *using a child's interests* (75 excerpts) to motivate him or her to learn. By the end of the intervention, participants showed *improvement in thought, emotion awareness* (59 excerpts) and *improvement in reading* (73 excerpts).

Implications and future research directions

This section outlines implications of the major findings for educators and researchers working in the field of LD. We discuss the implications for interventions and assessment, specifically speed testing.

Applications to intervention: Metacognitive strategies

We found that experimental participants' RTs in the lexical decision task increased significantly more than the control group's RTs, which indicates a possible increase in reflectiveness and/or metacognition due to training in executive processes (self-regulation of attention) and awareness of self-attributional beliefs. Using mindfulness practices to become aware of self-talk during academic tasks could perhaps kill two birds with one stone—train children to regulate both attention and emotion. Children are constantly talking to themselves and others while completing (or not completing) classwork. For children with LD, this self-talk is mostly negative. Awareness of self-talk during academic tasks (e.g., when one participant wrote in his journal, "I suk at rding [suck at writing]") in the presence of a nonjudgmental, accepting observer enables the child to examine the truth of his or her self-talk. For example, before the intervention, one participant said that he hated writing and he did not like reading words. When the first author asked him, "Do they [his teachers] say you're very good at anything?" the boy answered, "Not really. No one say anything like *that*." After the intervention, this boy's self-talk had changed a little. When we asked him what he was good at, he said, "I don't have no idea now. I'm not good at writing or drawing or reading, *yet*." One implication for practice for educators and researchers is to record at-risk children's self-talk during academic tasks in their regular or special education classrooms and determine whether an intervention could be implemented that might change negative attributional beliefs. Mindfulness as a metacognitive strategy for training executive processes and attributional beliefs by becoming aware of one's thought processes and emotions without attempting to change such thoughts and emotions could be a useful intervention for other researchers investigating metacognition, problem solving, and academic progress in children with LD.

In this study, RTs during a decoding task (i.e., the lexical decision test) became significantly longer in experimental participants after the intervention, which indicates increased reflectiveness or use of self-regulatory processes. These participants were perhaps reflecting on prior knowledge about letter-sound relationships, focusing their attention on the letters, and/or monitoring their own emotional state or thoughts. Future research using functional magnetic resonance imaging might be helpful to investigate brain activation during decoding tasks after a mindfulness intervention that focuses on developing thought, emotion, and body awareness. However, a focus on increasing reflectiveness in children may be counterproductive in a school system that consistently emphasizes quantity over quality—or speed over thoughtfulness.

Application to assessment: Speed testing

Our study findings suggest that training in metacognitive strategies increased children's reflectiveness during decoding. However, one of the study measures we used—the DIBELS—penalizes children for reflection during decoding.

The DIBELS is a reading test used in many schools across the United States. It is composed of six subtests (e.g., Letter Name Fluency and Oral Reading Fluency), all designed to be administered in 1 min. Children from kindergarten to third grade take these tests at least three times a year. Teachers are required to use the results of the DIBELS to create reading groups and design lesson plans. The DIBELS was used in this study because it was the standardized reading test used by the state and the school where this study took place. The New Mexico Public Education Department (2016) declared on its website that the DIBELS is "brief, efficient, cost-effective, individually administered, standardized, and formative" (para. 2).

Dr. Goodman (2006), professor emeritus of language, reading, and culture at the University of Arizona, has written a book titled *The Truth About DIBELS: What It Is, What It Does.* According to Goodman, the authors of the DIBELS assume that a few minutes of reading or identifying letters or sounding out nonsense words can holistically represent progress in reading development. The authors of the DIBELS (Kaminski et al., 2008) affirm that, like other general outcome measures, the DIBELS is an efficient measure that takes only a few minutes to administer and score and yet still provides data that are highly relevant to instructional planning.

The authors of the DIBELS believe that formalized reading instruction (and formalized testing) should begin in kindergarten (Kaminski et al., 2008). Almost as soon as a 5-year-old begins kindergarten, the child is timed on how many alphabet letters he or she can read in a minute. Just as the child is getting used to the task, the timer interrupts him or her. Many early childhood educators and researchers question whether it is developmentally appropriate to have formalized reading instruction and testing at this young age. As Goodman (2006) wrote,

> Should five-year-olds be repeatedly tested with timed tests? Should those who can't perform on these one-minute tests be drilled on naming letters and sounding out words while their classmates play? And should children come to see themselves as failures before they even start first grade? (p. 11)

The use of timed tests gives an advantage to the learner who is impatient, impulsive, energetic, or drilled for the DIBELS. Learners who are slow, reflective, thoughtful, careful, distractible, talkative, and/or inquisitive will be more likely to have lower scores. Also, children who are in the process of discovering that reading needs to make sense will also read more slowly as they try to make sense out of what they read.

In response to the criticism that the DIBELS measures are about speed and not real reading, the authors of the DIBELS (Kaminski & Cummings, 2007) wrote the following:

> For all timed measures, the timing is as unobtrusive as possible. A silent count-down timer is used and no attention or emphasis is given to the timing aspect of the assessment. Most students are not even aware that timing is occurring. Students are never told to read as fast as possible; the DIBELS directions clearly state that students are to "do your best reading." … It doesn't do anyone any good to do something wrong, very, very fast. (p. 4)

However, in her decade of experience administering the DIBELS, the first author has not seen unobtrusive timing—students know that timing is occurring. Teachers are told to share the results with students immediately. Students learn that it does not matter how they read, but instead how many words they read. So, instead of trying to figure out an unknown word, they skip over it in the race to read only the words they know. And because the test protocol is to give students the answer if they pause for more than 3 s, some children learn to wait for the word instead of trying to figure it out themselves.

Kaminski and Cummings (2007) argued that the DIBELS measures are timed because they are a test of fluency. The ability to read smoothly and confidently is a skill that is critical for the development of skilled reading (National Reading Panel, 2000), and systematic observation helps teachers assess reading proficiency and determine instructional goals (Hudson, Lane, & Pullen, 2005). But is the DIBELS Oral Reading Fluency test the best assessment for emerging readers, who are far from fluent? In our study, four of the longest increases in RTs came from emerging readers—readers who understand basic sound/symbol relationships and have learned some high-frequency words but are reading at a very early level. They are not fluent readers at this stage. And yet it is common practice, because they fail to meet benchmarks, to test these emergent readers monthly or even weekly with this fluency test, a constant reminder to them of their reading failure.

In sum, educators and researchers who are investigating or implementing mindfulness training and/or other metacognitive strategies to help ameliorate the symptoms of LD need to be aware that the transfer of such strategy training to the classroom may be impeded by the frequent use of timed tests like the DIBELS and the national stress on the importance of speed over thoughtfulness.

Application to assessment and interventions: Testing anxiety

In our study, the chronic stress of continual standardized testing may have been relieved by mindfulness practice, as indicated by the significant decrease in the experimental students' heart rate over the course of the intervention. Future research could investigate whether heart rate remains low after breathing practice, especially during reading/writing.

The perception of a perceived threat (e.g., when the child hears the *beep! beep! beep!* of the DIBELS timer) causes the release of adrenaline, which increases heart rate and muscle tension and raises blood pressure. Repeated stimulation of the stress response system over long periods of time can cause numerous mental and physical problems, including anxiety, depression, sleep problems, impairment of memory and concentration, high blood pressure, irregular heart rhythms, digestive problems, and a weakened immune system (Cleveland Clinic, 2013; Mayo Clinic, 2013).

Breathing slowly can reverse some of the adverse effects of stress by increasing oxygen saturation in the cells, alpha waves, and HRV and by lowering heart rate, thereby releasing energy and improving cognitive abilities (Thompson, 2009). Educators and researchers endeavoring to improve the educational futures of children with LD need to remember that the present environment of continual standardized testing is extremely stressful for the underachieving child. They need to implement and/or continue to research more holistic methods of assessing children's academic skills and of relieving the stress of continual failure.

Study limitations

One limitation of this study is the small sample size. One reason for the small sample size was the large amount of data that we collected per participant to answer our research questions. Other limitations are that heart rate measures were not collected from the control group, so the influence of practice effects cannot be determined. Also, because the first author was a participant observer (both the interventionist and a data analyst), some bias may have entered into the qualitative analysis. However, several significant findings from this pilot study support the hypothesis that mindfulness training ameliorates symptoms of LD. Given the promising results and the importance of the problem, we argue that future research is needed to investigate whether the results generalize to larger samples.

Conclusion

This work was intended to provide clinicians, teachers, and school districts with a research-based intervention that will enable students with LD to be more positive and productive. It was also intended to investigate more deeply how a metacognitive strategy (in this case, mindfulness) improves the mental and emotional capacities of children with LD (specifically in the areas of reading, writing, emotional well-being, and self-efficacy). Quantitative results suggest that participants became more reflective during decoding and that their average heart rate declined over the course of the intervention. This latter finding may indicate reduced anxiety regarding reading, which could lead to further improvement later on. Qualitative results indicate that mindfulness can be a tool used by intervention researchers and educators to improve literacy, attention skills, the use of metacognitive strategies, positive affect, self-expression, self-awareness, and self-efficacy. Future research and educational reform movements need to examine the high cost of timed tests on mental and physical health and on academic performance and find more holistic ways to assess the strengths and limitations of underachieving children.

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Appendix

Writing Prompt

At pretest, 10 of the students were asked to answer the following prompt with the word *happy* and 10 were asked to answer with the words *mad/sad.* At posttest, this was reversed, so that students were writing about a different emotion for their second writing sample.

Think about a time you were happy or mad/sad. Think about what happened to make you feel happy or mad/sad. Write about it. Did someone do something to you? Or say something to you? What were you thinking that made you feel happy or mad/sad? What did happiness or madness/sadness feel like in your body? What did you do when you felt happy or mad/sad?