LEARNING THROUGH ACTION WITH EMBODIED EDUCATION: A MULTISENSORY COMPONENT ANALYSIS IN AN EARLY LITERACY SKILLS INTERVENTION

by

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Abstract

Multisensory components have been used across various educational approaches for many decades; however, the specific contribution of multisensory components is not well documented or explained, especially from an embodied education approach. Thus, an investigation of the effectiveness of adding a multisensory component (i.e., sandpaper letters) to an early literacy skills intervention (i.e., modified *Road to the Code* program; Blachman, Ball, Black, & Tangle, 2000) was conducted. To accomplish this, a multiple-baseline multiple-sequence design was used with six kindergarten students identified as needing remediating instruction, comparing instruction with and without the multisensory component while keeping instructional time constant. It was hypothesized that participants would show greater gains in early literacy skills (i.e., naming letters, segmenting words into phonemes, and decoding phonetically regular words) following the intervention with the multisensory component, compared to the intervention without. The addition of a multisensory component (i.e., sandpaper letters) was time efficient and simple to implement, and appeared to result in differential growth for at least some students. Given that the addition of a modest multisensory component appeared to assist some students in improving their early literacy skills, results were consistent with theories of embodied cognition and suggested that a more robust multisensory intervention could be worth developing and researching further.

Preface

Data collection for this project was approved by the University of British Columbia's Research Ethics Board (certificate no. H13-02838) and was supported by the Social Sciences and Humanities Research Council of Canada, and the University of British Columbia Faculty of Education Graduate Student Research Grant. Dr. Sterett Mercer and I collaboratively created the basic design of the study with input from Dr. Ruth Ervin. I developed specific instructional procedures with input from Dr. Mercer. All written content of this thesis represents my original, unpublished work.

Table of Contents

List of Tables

List of Figures

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Introduction

Learning through action is a critical aspect of effective education. We acquire a better understanding of concepts and their relations through active exploration and manipulation of objects within our environment (James, 2010). The importance of sensorimotor experience for cognition is also emphasized by theories of embodied cognition which consider concepts as inseparable from physical experience and as being grounded in our sensory modalities (Pecher, Zelenberg, & Barsalou, 2004). Although it has been claimed that the concept of embodied cognition may have considerable implications for education, to date, surprisingly little research has been conducted on the development and the educational implications of embodied cognition (Rathunde, 2009). As a consequence, further research is necessary in order to understand the potential benefits of embodied education.

In contrast, the existing research on early literacy instruction is quite extensive. Early literacy skills lay the foundation of later reading skills and thus, it is important to establish such skills early in order to become a successful fluent reader. Explicit and systematic instruction that teaches phonological awareness (i.e., an awareness of the sounds or phonological segments in a spoken word and the ability to manipulate those segments) and the alphabetic principle (i.e., the notion that one symbol corresponds to each basic speech sound in language) has shown to be effective in instructing young children who are at-risk for reading failure [e.g., Ball & Blachman, 1991; Bradley & Bryant, 1983; Cunningham, 1990; Ehri et al., 2001; National Reading Panel (NRP), 2000].

The present study will combine these two lines of research to investigate the effectiveness of a multisensory component (i.e., sandpaper letters) in an early literacy program for kindergarten-aged children. The current section is a review of existing research on early literacy, phonological awareness instruction, and embodied cognition and multisensory learning. Following this overview, the rationale for the current study, as well as pertinent research questions, will be outlined.

The Importance of Early Literacy Instruction

Early literacy skills act as the building blocks of future reading success. Primary students who have mastered certain early reading skills, such as identifying letter sounds, are much more likely to becoming successful readers (Good, Simmons, & Kame'enui, 2001; Torgensen, 2000). In contrast, those students who have not mastered these early reading skills by kindergarten and first grade are at risk of continuing to fall further behind their peers and potentially become poor readers (Good et al., 2001; Torgensen, 2000). In 2009, 70% of 15-year-old Canadian students performed at or above a level that met or exceeded expectations for reading proficiency (Statistics Canada, 2009). Thus, 30% of such students are below those expectations and are likely to continue to struggle given that these students lack a solid foundation for future learning.

Intervening early is critical as failure to obtain early literacy skills creates a cumulative effect that decreases the likelihood of achieving age appropriate reading skills (Torgensen, 2000). Researchers speculate that as children lag behind in the development of critical early reading skills, they will receive less practice in reading (Allington, 1984), miss opportunities to develop reading comprehension strategies (Brown, Palincsar, & Purcell, 1986), acquire negative attitudes about reading itself (Oak & Paris, 1986), and be prevented from learning from educational sources available in print (Torgesen, 2000). Moreover, Pratt and Brady (1988) have demonstrated how early literacy skill deficits can persist even into adulthood, so the earlier one intervenes with such students the better the chances are for helping students become proficient readers later in life (Torgensen et al., 2001).

Due to the importance of early literacy skill acquisition, a substantial literature base exists outlining different ways to enhance such skills and ways to intervene if necessary at the initial stages of reading acquisition. Extensive research has been conducted to determine the most effective reading instruction approaches. The National Reading Panel (NRP, 2000) created a report which comprehensively reviews empirical reading research across the full spectrum of readings skills. According to the NRP (2000) regarding early literacy instruction, the inclusion of explicit, systematic phonics is an essential component to effective reading instruction as it enhances a student's ability to learn to read, with strongest effects in kindergarten and first grade. Instead of using a meaning-emphasis approach, the NRP (2000) recommends using a code-emphasis approach during the beginning stages of reading development where educators emphasize predictable letter-sound correspondences and the reading of words composed of those correspondences (Carnine et al., 2004; Cunningham, 1990; Ehri et al., 2001). By teaching an overt strategy, reading can be taught more efficiently to allow the student to understand errors and better facilitate generalization of reading skills.

Phonological awareness and decoding instruction. In addition to explicit, systematic phonics, research findings suggest that students with strong phonological awareness learn to read more readily (e.g., Bradley & Bryant, 1983; Cunningham, 1990). Phonological awareness is the understanding that language is made up of sounds. It is an awareness of the phonological segments in speech and that those segments are more or less represented by the letters of the alphabet (Blachman et al., 2000). Phonological awareness is a more encompassing term referring not only to phonemic awareness (i.e., the ability to focus on and manipulate phonemes in spoken words), but also to awareness of larger spoken units such as syllables and rhyming words (Ehri et al., 2001).

Phonological awareness plays a critical role in learning how to read. Children who lack this awareness are likely to be among the poorest readers since they are unable to understand how the alphabet transcribes speech and consequently may have poor decoding skills (Ehri et al., 2001; Pratt & Brady, 1988). In fact, longitudinal studies have identified phonological awareness as an extremely strong predictor of successes with early reading instruction (e.g., MacDonald & Cornwall, 1995; Torgensen, Wagner, & Rashotte, 1994). Moreover, skills in areas of phonemic awareness, phonics, and understanding of the alphabetic principle have been found to be a strong predictor of early literacy development (for a review, see Shapiro, 2011). Thus, in order to develop decoding skills, children must be explicitly taught phonological awareness and the principle that letters can represent sounds (i.e., the alphabetic principle).

Bringing together the research on early literacy, the characteristics of a good intervention should include an explicit approach to instruction, in which sounds of letters are taught in isolation and then blended to form words (Ehri et al., 2001; NRP, 2000). Moreover, good early literacy instruction should develop the alphabetic principle along with phonological awareness (Stahl, Duffy-Hester, & Stahl, 1998). Foorman and colleagues (2003) determined that phonics instruction along with phonemic instruction was most effective, suggesting that phonemic awareness is a necessary but not sufficient condition for learning to read. With relation to phonological awareness, instruction is most effective when it uses letters of the alphabet as students are taught to manipulate phonemes, focuses on only one or two rather than several types of phoneme manipulation, includes blending and segmenting of phonemes in words, and makes explicit how phonemic awareness skills are applied in reading and writing tasks (Carnine et al., 2004; NRP, 2000). Santi, Menchetti, and Edwards (2004) reiterate the importance of instruction stimulating phonemic awareness through a direct and explicit approach. Lastly, a good early literacy intervention should provide a thorough grounding in the letters, be stimulating, provide sufficient practice in reading words, and lead to fluent, automatic word recognition (Stahl et al., 1998).

As cognitive theories of reading suggest, the development of fluent word reading skills allows for more resources to be allocated toward reading comprehension – the purpose of reading. For example, LaBerge and Samuel's (1974) reading automaticity theory suggests that as reading subcomponents (i.e., letter, word identification) become more automatic with practice, there are less demands on the reader's limited attention and working memory resources. This allows for more attention to be allocated toward reading comprehension. Likewise, Perfetti's (1985) verbal efficiency model expands on the notion of automaticity by suggesting that other aspects of reading are capable of becoming automated over time, and emphasizing the importance of freeing attention and working memory resources through increasing verbal efficiency which in turn, increase comprehension. Thus, interventions which lead to automatic word recognition subsequently lead to more advanced skills in reading comprehension.

Students who enter first grade with a wealth of phonological awareness are less at risk for reading failure and will likely be more successful readers (e.g., Carnine et al., 2004; MacDonald & Cornwall, 1995; Torgensen et al., 1994). Educators are encouraged to implement core reading instruction that includes systematic, explicit phonics, and phonemic awareness instruction to serve as the foundation for primary reading skills. Certain students at risk may make gains with such instruction, but others may require further assistance. Possible solutions for such students may be through the supplementation of core early literacy skills instruction (that includes phonological awareness) with multisensory components to further promote the development of early literacy skills.

Embodied Cognition and Multisensory Learning

Recent cognitive theories challenge the traditional cognitive framework by contending that cognition, including language, is grounded in sensorimotor representations and that a close interaction exists between the brain, body, and environment (e.g., Barsalou, 2008; Gallese & Lakoff, 2005; Glenberg & Kaschak, 2002, 2003). Multisensory, embodied learning approaches utilize different sensory channels (i.e., sight, sound, and touch) allowing for a broader distribution of knowledge across multiple modalities in multiple neural networks (Barsalou, 2008). Through such senses, students are able to modify and manipulate the world around them, providing concrete experiences even with intangible concepts and ideas (Minogue & Jones, 2006). Thus, by strengthening the link between the body and the mind in education, it may allow for the creation and storage of more comprehensive representations of new concepts. For example, Moats and Farrell (2005) have speculated that children with dyslexia who have certain neural weaknesses can compensate by engaging alternative sensorimotor pathways to enhance learning with multisensory components. Traditional classroom approaches may be too far disembodied, taking the body out of the mind and lacking the beneficial integration of body-based experiences into learning (Rathunde, 2009). By establishing greater connections between various representations of concepts through the different modalities, more learning may occur as it is grounded in bodily experience (Nunez, Edwards, & Matos, 1999).

Additional evidence from empirical studies (e.g., Jeannerod, Decety, & Michel, 1994; Sirigu, Duhamel, Cohen, & Pillon, 1996) supports the idea that there are two distinct categories of motor knowledge: knowledge of how to use an object (i.e., functional knowledge) and knowledge of how to lift an object (i.e., volumetric knowledge). Through the use of priming paradigms, behavioural studies found that functional knowledge dominates over volumetric knowledge during object identification, and that object function is a key component of our understanding of a broad range of objects (e.g., Bub, Masson, & Cree, 2008; Kemler Nelson, Frankenfield, Morris, & Blair, 2000). Moreover, researchers investigating action-based priming (e.g., Mounound et al., 2007) suggested that younger children have a tendency to focus more on action-based information in comparison to older children and adults. Children as young as two and three years old have been found to have concepts that are closely tied to functional properties. In one study by Kemler Nelson, Chan Egan, and Holt (2004), children aged two- to four-years old were prompted to ask questions about 12 unfamiliar objects. The results showed that the majority of questions children asked related to the intended function of the object, suggesting that children are most concerned about the functional properties of objects. Additionally, Perraudin and Mounoud (2003) found stronger priming effects for functional word drawing pairs (e.g., knife-bread) in comparison to categorically related drawing pairs (e.g., cake-bread) in children aged five- to nine-years old. They also found that the advantage for the functional priming effect decreased as children aged. Their interpretation of this result was that younger children are more focused on functional relationships as they are in the process of refining concepts and building a conceptual foundation that heavily relies on action. Overall, functional knowledge has shown to play a major role in concept formation and may be a key component in learning, since it has been shown that purposeful actions can assist young children in acquiring a better understanding of concepts and their relations.

Even though scarce, research addressing the educational implications of embodied cognition has shown promise and some educational approaches have long since emphasized the importance of multisensory, embodied learning experiences. For example, Montessori education is based on the philosophy of guiding children through a prepared environment and stresses that children learn best through hands-on activities and the use of manipulatives (Montessori, 1912). A comparison of students from Montessori schools to those from other schools showed that Montessori elementary students had significantly higher scores on letter-word identification and phonological decoding (Lillard & Else-Quest, 2006).

Apart from Montessori education, broad multisensory structured language approaches have been developed over the years, including but not limited to The Lindamood-Bell Learning Processes (1997), The Orton-Gillingham Approach (Orton, 1966), Alphabetic Phonics (Cox, 1985), Project Read (Calfee & Henry, 1985), The Slingerland Approach (Slingerland, 1971), The Spalding Method (Spalding & North, 2003) and Wilson Reading System (Wilson, 1996). Such multisensory approaches differ according to the setting, materials and procedures, but all are similar in that they use visual, auditory, kinesthetic, and tactile senses for teaching language. Not only are broad multisensory approaches supported in the literature, but the positive effects of multisensory training have been shown in multiple empirical studies (e.g., Bara, Gentaz & Cole, 2007; Bara, Gentaz, Cole & Sprenger-Charolles, 2004; Campbell, Helf, & Cooke, 2008; Gentaz, Cole, & Bara, 2003; Joshi, Dahlgren, & Gooden, 2002). It is important to note, however, that the impact of multisensory components has not been thoroughly investigated given that the multisensory programs have been evaluated as a whole.

Early literacy skills interventions with multisensory components. The extant literature on the use of multisensory components in early literacy instruction is scarce. Few studies have examined the impact of multisensory training on early literacy interventions, the majority of which are between-subject designs evaluating the effectiveness of a combination of multisensory methods. Very few studies have examined the impact of a single multisensory component, making it difficult to interpret the various components' effectiveness on early literacy skills.

In the most recent of these studies, using a multiple-baseline design, Campbell, Helf, and Cooke (2008) examined the effects of adding various multisensory elements (e.g., use of finger tapping, letter formation on carpet squares, and magnetic letters) to a phonics program on decoding skills for six second grade students who were non-responsive to core and supplemental reading programs. Specifically, 20 sessions were completed during baseline using *Early Reading Tutor* (ERT; Gibbs, Campbell, Helf, & Cooke, 2006) and *Open Court Reading* (Adams et al., 2000). Using the baseline data, it was determined that participants fit into two distinct groups: Low Words/Low Sounds and Low Words/High Sounds. More specifically, the Low Words/Low Sounds group was comprised of those participants at baseline who read nonsense words below benchmark criteria (i.e., 50 sounds within nonsense words per minute) and below the ceiling criterion for selection (i.e., 18 whole nonsense words per minute), whereas those Low Words/High Sounds group was comprised of those participants at baseline who read nonsense words at or above benchmark criteria and below the ceiling criterion for selection. Thus, results are presented by group and individual participants.

The results of this study indicated that the fluency of decoding (i.e., nonsense word fluency, whole words read), sound recognition (i.e., nonsense word fluency, correct letter sounds), and oral reading skills (i.e., oral reading fluency) increased when multisensory components were added to the reading intervention. However, it is important to note certain limitations of this study. First, the design did not control for ordering effects given that the multisensory intervention was only presented after the ERT supplemental reading program. Second, a collection of multisensory components were used in the intervention making it difficult to determine what component(s) made the most impact on decoding abilities. Moreover, none of the participants reached the maintenance goal to allow for a phase change. Such an occurrence would have led to stronger conclusions given that removing the multisensory component would have allowed one to better determine the degree of impact of the multisensory elements.

Unlike the above study, the remaining reviewed studies used between-group designs. In a collection of studies by Gentaz, Bara and colleagues (i.e., Bara, Gentaz, & Cole, 2007; Bara, Gentaz, Cole & Sprenger-Charolles, 2004; Gentaz, Cole, & Bara, 2003), the authors examined the effects of adding visuo-haptic (i.e., visual and tactile exploration of the letters) and visual (i.e., visual exploration of the letters only) exploration of letters in reading training programs, comparing different modality interventions across groups of various populations. Collectively, this group of studies suggested that when the haptic modality is added to the reading training, reading acquisition is improved. The authors concluded that haptic exploration may increase letter knowledge and phonemic awareness, and speculated that haptic exploration may help establish the links between orthographic representation of the letters and the phonological representation of the corresponding sounds. Moreover, the authors speculated that incorporating the haptic mode may force children to process letters more analytically, allowing them to favour the association with the sound of the letter, which is processed auditorily (Bara et al., 2007; Bara et al., 2004; Gentaz et al., 2003). Their speculation is consistent with embodied views of cognition, as the use of multiple modalities may allow for a more distributed trace of knowledge in multiple neural networks (Barsalou, 2008). Additional between-group studies, such as those by Joshi, Dahlgren, and Gooden (2002), Ofman and Shawvitz (1963), and Rule, Dockstader, and

Stewart (2006) have all led to similar findings in that the use of various multisensory methods aids in the acquisition of reading skills for young children.

Overall, the above findings are in line with embodied views. The past findings may suggest that conceptual knowledge is distributed across multiple modalities in multiple neural networks (Barsalou, 2008). Utilizing multisensory methods may allow for letter shapes to be encoded in memory through visual, kinetic, and auditory modalities, creating a more distributed trace in memory which may facilitate knowledge retrieval (Barsalou, 2008; Kalénine, Pinet, & Gentaz, 2011).

Not only does embodied learning relate to literacy skill development, but other studies have demonstrated the effectiveness of manipulation in the learning of math concepts (Kalénine et al., 2011; Tall, 2002), reading comprehension (Glenberg, Gutierrez, Levin, Japuntich, & Kaschak, 2004), handwriting (Bara & Gentaz, 2011), and even musical concepts (Bakker, van den Hoven, & Antle, 2011). More notably, multisensory techniques also have greater potential in preparing children for writing, creating a link between spelling and writing acquisition. By using multisensory techniques, a stronger connection between reading and writing is established because the child is able to retain a visual image of the letter while simultaneously retaining the movement necessary for writing it (Bara et al., 2007; Bara et al., 2004). Thus, not only do multisensory techniques have the potential for more immediate advances in early literacy skills, but they also have the potential to prepare children for earlier writing acquisition (Bara et al., 2007). Furthermore, sensorimotor training has been used to enhance academic skills in certain special populations such as children with dyslexia (Oakland, Black, Stanford, Nussbaum, & Balise, 1998) and patients with aphasia (Lott, Carney, Glezer, & Friedman, 2010).

Although the current research in multisensory learning shows promise and the efficacy of multisensory learning within early literacy programs has been demonstrated across certain educational approaches, a major limitation exists in the current literature regarding the effectiveness of multisensory techniques. The above findings demonstrated positive effects of some condition or combination of conditions within multisensory treatments. Because the majority of these studies involved a collection of multisensory components, it is impossible to determine what component is responsible for the positive outcomes. Thus, very little scientific evidence exists behind the multisensory components themselves and the specific contribution of certain multisensory components to the overall success of early literacy programs has not yet been thoroughly documented or explained through rigorous studies (Birsh, 2006; Moats & Farrell, 2005). When an independent variable consists of multiple-components, it may be necessary to conduct a more careful analysis to determine the active ingredients or the components most critical to change (e.g., Campbell et al., 2008; Cooper, Heron, & Heward, 2007; Kazdin, 2000). Moreover, within this line of research, limited studies exist that investigate the value of a specific multisensory component and interpret results from an embodied cognition approach.

Overall, many effective interventions include multisensory components, but the extent to which the multisensory components produce or contribute to the intervention effects remains unknown. Thus, appropriate multisensory component analyses are warranted to effectively determine which components indeed have an effect on early reading skills. Moreover, further research is needed in understanding the practicality of embodied education in order to help create ways to engage different learners of all ages in actively constructing meaningful understandings (Minogue & Jones, 2006).

The Present Study

To address the limitations in the existing research, the aim of the present study was to conduct an analysis of one multisensory component (i.e., sandpaper letters) to better understand the impact of this component on the effectiveness of an early literacy skills program for kindergarten-aged children. A multiple-baseline multiple-sequence design across participants (Noell & Gresham, 2001) was implemented to determine the effectiveness of the same intervention supplemented with and without the multisensory component. The following research question was addressed:

1. *Does early literacy skills instruction that includes the multisensory component enhance early literacy skills (i.e., naming letters, segmenting words into phonemes, and decoding phonetically regular words) more than early literacy skills instruction that does not include the multisensory component?*

It was hypothesized that interventions with the multisensory component would enhance literacy skills more than the intervention without when controlling for or keeping intervention time constant.

Overall, few studies have shown careful in-depth analysis of a multisensory component from an embodied cognition approach, and this study looked to do so in order to better understand the practicality of embodied theories of cognition within an educational setting to potentially promote early literacy skills.

Method

Participants

Six kindergarten students, four boys and two girls, were nominated by classroom teachers and participated in the study. All participants were from two kindergarten classes, which were co-taught by two teachers from the same inner city school. Participants were similar in age (*M* = 5.42 years, *SD* = 0.21 years), ranging from 5.20 to 5.75 years old (see Table 1 for student demographics). To ensure nominated students were performing below benchmark level for their grade and would benefit most from early literacy skills instruction, the students' development of pre-reading skills (e.g., phonemic awareness, alphabetic principle) was assessed through a brief benchmark assessment (i.e., naming letters, segmenting words into phonemes, and decoding phonetically regular words; see Table 1). In addition to performing below benchmark level for their grade, it was required that none of the students had been retained and none had an identified low incidence disability.

Table 1.

Student demographics and pre-intervention assessment results.

Student Pseudonym	Grade	Age[a]	Language Spoken at Home	Letter Naming Fluency[b]	Phoneme Segmentation Fluency[c]	Nonsense Word Fluency[d]
Valerie	K	5.58	English	2	0	3
Alex	K	5.42	Vietnamese	17	0	7
Cameron	K	5.20	English	6	0	11
Xavier	K	5.75	English	2	0	1
Lyell	K	5.33	English	1	0	3
Natalie	K	5.25	English	13	13	16

Note. [a]In years, at the start of the study, [b]Correct Letter Names, [c]Correct Phonemes Segmented, [d]Correct Letter Sequences.

One participant began the study, but would not speak to the interventionists, so this participant was replaced by another participant after two weeks. Despite the original participant's limited engagement, he completed the remainder of the intervention, but did not contribute data to the present study. Pseudonyms are used in place of participants' real names.

Measures

Early reading skill probes from the *Dynamic Indicators of Basic Early Literacy Skills* (DIBELS Next; Good & Kaminski, 2011b) and the *Intervention Central* website (http://www.interventioncentral.org/) were used as outcome measures over the course of the intervention. As previously mentioned, skills in areas of phonemic awareness, phonics, and understanding of the alphabetic principle have been found to be a strong predictor of early literacy development (for a review, see Shapiro, 2011). Thus, student performance on *Intervention Central* letter naming fluency (LNF), DIBELS phoneme segmentation fluency (PSF) probes, and DIBELS nonsense word fluency (NWF) probes were the dependent measures and were collected during each intervention session in order to track pre-reading skill progress over time. All measures required the student to be accurate as well as fluent, since automaticity represents a higher level of skill mastery (Haring, Lovitt, Eaton, & Hansen, 1978). Each measure is described in more detail below.

Letter naming fluency (LNF). This measure is a standardized, individually administered assessment of a student's automaticity with letter naming. Fluency in naming letters is a strong and robust predictor of later reading achievement and can act as a risk indicator of early school-age children (Adams, 1990; Good et al., 2001). In LNF, students were provided with a page of lowercase letters arranged in random order and are asked to name the letters for one minute. The total score was the number of correct letter names that the student says in one minute. LNF has shown to be a reliable measure, with alternative forms and inter-rater reliability rs > .85 (Good et al., 2011). Moreover, LNF has good validity, as it shows moderate to strong relationships with other pre-reading skill measures, and has been shown to be a moderate to moderate-strong predictor of later reading achievement test scores (Good et al., 2011). It is important to note that DIBELS LNF probes were not used since they offer too few unique probes. Instead, LNF probes were created through the *Intervention Central* website in order for each probe to be unique and for all target letters to be lowercase, consistent with the intervention described below.

Phoneme segmentation fluency (PSF). This measure is a standardized, individually administered indicator of phonemic awareness, which is the understanding that spoken words are made up of sounds. In PSF, students were provided with orally presented words and asked to segment these words into their individual phonemes (i.e., their smallest individual sounds) for one minute. For example, if the examiner said, *sat*, the student would be expected to say /s/ /a/ /t/. Partial credit was given for partial segmentation [e.g., a student who says only the first sound of the word *sat* (/s/) received one point, a student who says the onset and rime (/s/ /at/) received two points, and a student who completely and correctly segmented all of the individual phonemes in the word (/s/ /a/ /t/) received three points]. The total score was the number of correct phonemes segmented by the student in one minute. PSF has shown to be a reliable measure, with inter-rater reliability *r*s > .98. Moreover, PSF has good validity, as it shows moderate relationships with other pre-reading skill measures, and has been shown to be a small to moderate predictor of later reading achievement test scores (Good et al., 2011).

Nonsense word fluency (NWF). This measure is a standardized, individually administered assessment of the alphabetic principle, including letter-sound correspondence and skills in blending letters into words. NWF is a test of decoding words that are not in a student's sight vocabulary. The student was provided a list of Vowel-Consonant (VC) and Consonant-Vowel-Consonant (CVC) nonsense words (e.g., ov, buk) and asked to say either the individual letter sounds or the whole nonsense word for one minute. For example, if the word was "buk" the student could say /b/ /u/ /k/ or /buk/. In NWF, students were provided with a page of VC and CVC nonsense words and asked to read the words. There were two final scores, the number of correct letter sounds (CLS) produced in one minute and the number of whole words read correctly (WWR). Mastery of the alphabetic principle is demonstrated when the student can read whole nonsense words fluently as opposed to simply sounding out each of the individual letters. Both CLS and WWR on NWF probes has shown to be reliable measures, with alternative forms reliability *r*s > .70, inter-rater reliability *r*s > .98 and test-retest reliability *r*s > .69. Moreover, CLS and WWR on NWF probes has good validity, as it shows moderate to strong relationships with other reading measures, and has been shown to be a moderate-strong predictor of later reading achievement test scores (Good et al., 2011).

Materials

Sandpaper letters. One multisensory component was used during the multisensory intervention phase of the study: sandpaper letters. Sandpaper letters were purchased from a curriculum supplier that sells Montessori Education materials. They are created by the letters of the alphabet being cut out in fine grit sandpaper and then mounted on a strong background. The vowels are mounted on a pale blue card and the consonants on a pale pink background. The purpose of sandpaper letters is to learn the sound and shape of the letters of the alphabet through the sense of touch and to gain a muscular memory of the shape of the letters as a prelude to writing.

Experimental Design

In order to compare the effectiveness of the multisensory component, a multiple-baseline multiple-sequence design was used (Noell & Gresham, 2001). This design consisted of two multiple-baseline designs that were linked with one another to include all possible sequences of the treatments. The counterbalanced sequencing of treatments allowed for the control of threats to interval validity since it allowed for the detection of potential sequence effects (Barger-Anderson, Domaracki, Kearnery-Vakulick, & Kubina, 2004; Noell & Gresham, 2001). Because of this design's greater experimental control, it was considered a suitable design in analysing the effectiveness of treatments in isolation (Noell & Gresham, 2001). As noted above, six students participated, given that three demonstrations per sequence were required to establish experimental control (Kratochwill et al., 2010). More specifically, experimental control was expected to be demonstrated if the design yielded three demonstrations of the experimental effect of the multisensory treatment across participants and sequences (Horner et al., 2005).

This design was conducted concurrently with four participants and non-concurrently with two participants due to absences and replacing a participant. It has been suggested that conducting this design non-concurrently has minimal impact on internal validity and allows for greater flexibility during recruitment and data collection (Christ, 2007). Each student was randomly assigned to begin with either a early literacy skills intervention with or without multisensory techniques with three experiencing each order. Intervention sessions generally occurred twice weekly, for a total of ten weeks of intervention. Due to absences, some students participated in three intervention sessions during a single week. Given that the purpose of this study was to compare two different intervention conditions, a baseline phase was deemed unnecessary, as with other designs which compare the effectiveness of two treatments (Dattilo, Gast, Loy, & Malley, 2000). To meet evidence standards as recommended by Kratochwill and colleagues (2010), a minimum of five points per phase was used. Furthermore, Watson and Workman (1981) recommend fixed phase lengths in non-concurrent multiple-baseline designs.

Thus, an a priori phase length was utilized with phase changes occurring after 5, 10, and 15 sessions for each triad, for a total of 20 sessions for each participant. This design allowed for a more rigorous analysis of the multisensory component with the counterbalancing and phase changes allowing for greater control of threats to internal validity.

Procedure

Recruitment and screening. Kindergarten classroom teachers nominated students with similar learning histories who would benefit from early literacy skills instruction. Informed consent was then obtained from parents and guardians prior to receiving participant assent from the students (see Appendix A). Prior to the intervention sessions, the student investigator administered the pre-intervention screening assessment in order to provide background information on the participant's baseline literacy skills to ensure that each participant met inclusion criteria. Specifically, a benchmark assessment was completed with each participant to ensure their performance on letter naming fluency, phoneme segmentation fluency, and nonsense word fluency was below benchmark levels for their grade-level (see Table 1). All students who were nominated by classroom teachers met inclusion criteria, and parent or guardian consent and participant assent was successfully obtained from all nominated students.

Early literacy skills intervention. Students of this study participated in an early literacy skills intervention delivered by graduate students in the UBC School Psychology program. Sessions were designed to last approximately 15 to 20 minutes, and the exact time for each session was recorded. All intervention sessions took place in the students' school. The intervention activities and procedures were identical across conditions, with the exception of the letter cards that the participants used to complete the activities. That is, during the early literacy skills training only phase, participants used black and white laminated alphabet letter cards;

whereas, during the multisensory and early literacy skills training, participants used the sandpaper letters and were encouraged to trace and manipulate the letters. Early literacy skills activities were chosen on the basis of ease in which they can be modified to involve sandpaper letter manipulation and the frequency of inclusion in past effective early literacy skills interventions. Specifically, selected activities from the *Road to the Code* program (Blachman et al., 2000) were used with modifications made to the sequence of the letters introduced (see Appendix B for a full list of activities and how they were modified for use with the sandpaper letters, and for the rationale and list of the intervention sequence). Additionally, the sequence of the *Road to the Code* program activities was modified with *Say-It-and-Move-It* and *Introducing Letter Cards and Sounds* being the main activities used from this program (Blachman et al., 2000). See Table 2 for a brief description of each of the main activities and how each activity was used across intervention conditions.

The same or similar early literacy skills activities used in the present study have been utilized across a number of successful intervention studies and related resources (e.g., Ball & Blachman, 1991; Ball & Blachman, 1988; Blachman et al., 1999; Cunninghan, 1990; Daly et al., 2005; Ehri et al., 2001; Slingerland, 1971; Stahl et al., 1998; Yopp & Yopp, 2000). For example, *Say-It-and-Move-It* is based on the work of Elkonin (1973) who devised a program to train children to segment words into phonemes. Moreover, Santi and colleagues (2004) reviewed the *Road to the Code* program, describing it as a program that is based on empirically validated instructional principles. Four activities were utilized per session and the activity sequence remained fairly consistent across the course of the intervention, with the letter sound being introduced changing weekly across sessions (see Appendix B for a more detailed outline of this sequence). Interventionists followed an error correction procedure during the intervention in

Table 2.

Main intervention activity descriptions across intervention conditions.

Activity	General Description	Early Literacy Skills Training Only	Multisensory and Early Literacy Skills Training
Say-It-and-Move-It	The participant was taught to segment words by first repeating a target word and then moving one disk (or alphabet letter card or supplemented sandpaper letter) for each sound that they say in the word.	An alphabet letter card was used in place of the disk if the letter has been previously introduced.	A sandpaper letter was used in place of the disk if the letter has been previously introduced. The participant was encouraged to trace over the sandpaper letter each time the associated sound was spoken.
Introducing Letter Cards and Sounds	The participant was introduced to the letter of the week, practicing the letter name and sound of each new or reviewed letter. The participant was asked questions about the sound, asked to think of other words that start with that sound, and so forth.	An alphabet letter card was used to introduce the letter.	A sandpaper letter was used to introduce the letter. The participant was encouraged to trace over the sandpaper letter each time the associated sound was spoken.

Note. See Appendix B for a complete description of all activities across conditions.

which students were made aware of their error, and then asked to try again (see Appendix C for more details). If after their second attempt, they continued to make an error, the interventionist provided scaffolded instruction. If the participant still made an error with this added support, the interventionist provided the student with the answer and had them repeat the answer. Interventionists were asked to record a comment on the participant’s checklist if similar errors were routinely made during the session. Additionally, a common reward procedure was used across conditions to keep the participants engaged (see Appendix B and C). Specifically, students would earn stickers for each session, which would be put on a chart. After completing two sessions, the students would choose one small prize (e.g., pencil, eraser, pen) from a grab bag.

Progress monitoring. Before each intervention session, three progress monitoring probes were administered in order to measure student performance (see Measures). Thus, the progress monitoring probes served as an indicator of the performance of the student at the completion of the previous session. It is important to note that on three occasions, a probe was spoiled due to external variables (e.g., outside noise, behaviour of participant, interventionist error) and the interventionist implemented an additional unique probe to be used in place of the spoiled probe.

Treatment Integrity and Inter-scorer Agreement

Two measures of treatment integrity were used to ensure interventionists followed the procedures correctly. First, a checklist of critical intervention steps for each condition was supplied to each interventionist (see Appendix C). Based on this checklist, the interventionists reported that one hundred percent of the steps for each condition were completed. In addition, forty percent of the recorded intervention sessions were reviewed (i.e., 8 out of 20 sessions for each participant). As with the first measure of treatment integrity, across all reviewed sessions, one hundred percent of the steps for each condition were completed by the interventionists.

In addition to the integrity checks, 40% of the intervention sessions (i.e., 8 out of 20 sessions for each participant) were audio recorded so that the pre-reading skill measures (i.e., letter naming fluency, phoneme segmentation fluency, and nonsense word fluency probes) could be independently scored to determine inter-scorer agreement. This percentage exceeded the acceptable twenty percent minimum outlined in the evidence standards (Kratochwill et al., 2010). Concordance correlation coefficients (CCC) were calculated for each audio recorded probe, including the correct, incorrect, and total attempted items for each participant (see Table 3; Lin, 1989; Quinn, Haber, & Pan 2009). The CCC was used since the goal was to examine whether the difference between the observed values across subjects was small, as opposed to whether the values differ by a fixed value or whether they vary in the same direction, in which case the intraclass or Pearson correlation coefficient would be appropriate. It was expected that the inter-scorer agreement would exceed minimal thresholds (i.e., greater than 0.80-0.90 on average; Kratochwill et al., 2010), with values ranging from 0.70 to 1.00 considered good agreement (Quinn et al., 2009). All results exceeded minimal thresholds and ranged from 0.94 to 1.00, suggesting good agreement between scorers across all measures.

Table 3.

Concordance correlation coefficients for inter-scorer agreement.

	Letter Naming Fluency	Phoneme Segmentation Fluency	Nonsense Word Fluency
Correct Items	1.00 (*0.99-1.00*)	0.99 (*0.99-1.00*)	0.99 (*0.98-1.00*)
Incorrect Items	0.97 (*0.95-0.98*)	0.94 (*0.90-0.97*)	0.95 (*0.92-0.97*)
Total Items Attempted	0.99 (*0.98-0.99*)	0.99 (*0.98-0.99*)	0.99 (*0.99-1.00*)

Note. 95% confidence intervals for each concordance correlation coefficient are italicized and shown in brackets. All values were rounded to two decimal places.

Data Analysis

Data from the interventions were graphed and analyzed according to conventions of single-subject design. Visual analysis techniques were used (including inspection for changes in level, trend, and variability), primarily inspecting changes in trend across phases (Riley-Tillman & Burns, 2009). As noted above, experimental control was expected to be demonstrated if the design yielded three demonstrations of the experimental effect across participants within each sequence, and also across sequences in order to examine potential order effects. Robust slope estimates that down-weight extreme values were used as an adjunct to visual analysis to assist with interpreting the variability within the data, given that these estimates are a preferred method to calculate rates of improvements for individual students during curriculum-based measurement progress monitoring in the presence of extreme values (Mercer, Lyons, Johnston, & Millhoff, in press). Specifically, robust slope estimates were calculated for correct and incorrect letter names, phonemes segmented, and letter sequences (see Tables 4 and 5, respectively). It is important to note that the robust slope estimates were not used as a statistical analysis, but simply for comparative means to have more information for demonstrations of experimental control. Growth rates were also calculated as an estimate of student progress per week using the pre-intervention screening and last session scores in order to provide another estimate of growth and to control for the variability within the data (see Table 6).

Results

Sequence A included early literacy skills training without the multisensory component, followed by early literacy skills training with the multisensory component. Sequence B was the counterbalanced sequence that included early literacy skills training with the multisensory component, followed by early literacy skills training without the multisensory component. See Table 4 for robust slope estimate values for correct letter names, phonemes segmented, and letter sequences for each student across intervention phases. Similarly, see Table 5 for robust slope estimate values for incorrect letter names, phonemes segmented, and letter sequences for each student across intervention phases. Robust slope estimates from Tables 4 and 5 represent change per intervention session for each student across phases. See Table 6 for pre- and post-intervention results across participants across each dependent measure. Also, see Figures 1, 2, and 3 for graphic representations of each sequence for each measure. It is important to note that four outlying data points (i.e., sessions 12 through 15) were excluded from the slope analysis for one of the participants (i.e., Alex), because he was absent for three weeks due to illness. Thus, some of his data were difficult to interpret due to his absence from the study, as he appeared to regress upon returning to the study (see Figures 1-3). Results are presented by dependent variable, first starting with an overview of the results across participants and sequences, and then analyzing each student by sequence.

Letter Naming Fluency (LNF)

Figure 1 compares students' LNF performance across phases and sequences, and Tables 4 and 5 present robust slope estimates across students and phases. The overall pattern across sequences and students revealed no clear differences between conditions as there were no consistent changes in level, trend, or variability across students. However, some students

Table 4.

Robust slope estimate values for correct letter names, phonemes segmented, and letter sequences, representing change per intervention session for each student during multisensory and early literacy skills training (i.e., EL+Multi), and early literacy skills training only (i.e., EL Only) phases.

Student	Letter Naming Fluency - Correct Letter Names		Phoneme Segmentation Fluency - Correct Phonemes Segmented		Nonsense Word Fluency - Correct Letter Sequences	
	EL+Multi	EL Only	EL+Multi	EL Only	EL+Multi	EL Only
Valerie	-0.26	-0.14	0.36	0.00	-0.17	2.00
Alex*	-0.97	0.66	0.31	0.00	-0.83	0.93
Cameron	1.50	0.60	0.49	0.08	0.35	0.71
Xavier	0.00	0.08	0.00	0.00	0.20	0.30
Lyell	0.57	0.19	0.00	0.02	0.64	-0.53
Natalie	1.69	-0.69	1.79	0.30	0.67	-3.00

Note. The participant marked with an asterisk (*) included four outlying data points that were not included in the slope analysis.

Table 5.

Robust slope estimate values for incorrect letter names, phonemes segmented, and letter sequences, representing change per intervention session for each student during multisensory and early literacy skills training (i.e., EL+Multi), and early literacy skills training only (i.e., EL Only) phases.

Student	Letter Naming Fluency - Incorrect Letter Names		Phoneme Segmentation Fluency - Incorrect Phonemes Segmented		Nonsense Word Fluency - Incorrect Letter Sequences	
	EL+Multi	EL Only	EL+Multi	EL Only	EL+Multi	EL Only
Valerie	-0.87	1.50	0.39	-0.10	-0.57	3.10
Alex*	0.17	0.09	0.54	0.02	0.35	-0.77
Cameron	-1.38	0.20	1.90	0.20	-1.34	0.10
Xavier	3.10	0.36	-0.10	0.13	1.30	0.27
Lyell	-0.17	-0.02	0.04	-1.54	0.09	-0.02
Natalie	-0.02	-0.05	-0.08	-2.00	-0.14	-1.30

Note. The participant marked with an asterisk (*) included four outlying data points that were not included in the slope analysis.

Table 6.

Pre- and post-intervention results across participants.

Student	Letter Naming Fluency - Correct Letter Names		Phoneme Segmentation Fluency - Correct Phonemes Segmented		Nonsense Word Fluency - Correct Letter Sequences	
	Pre-Intervention	Post-Intervention	Pre-Intervention	Post-Intervention	Pre-Intervention	Post-Intervention
Valerie	2	6	0	5	3	8
Alex	17	36	0	3	7	22
Cameron	6	18	0	7	11	17
Xavier	2	2	0	0	1	11
Lyell	1	5	0	0	3	7
Natalie	13	29	13	41	16	24

Note. The score obtained during the pre-intervention assessment represents the pre-intervention data point, and the score obtained during the last session represents the post-intervention data point.

experienced stronger gains in letter naming more quickly (i.e., Natalie), more accurately (i.e., Valerie), or both more quickly and accurately (i.e., Cameron) in comparison to others during the multisensory phase as evidenced by visual analyses (i.e., changes in trends) and robust slope estimate analysis. Individual student performance across sequences is discussed in more detail below.

Sequence A.

Valerie. Valerie experienced modest growth, as she was able to identify two letter names and six letter names before and after the intervention, respectively. Based on visual analyses and robust slope estimates for correct letter names, Valerie did not appear to benefit from using the added multisensory component to a significant degree. Although there did not appear to be any differential effects for correct letter naming (see Figure 1 and Table 4), there appeared to be differential effects for incorrect letter naming across phases. Specifically, the robust slope estimate for errors during the multisensory phase was -0.87, whereas the robust slope estimate during the early literacy skills only phase was 1.50 (see Figure 1 and Table 5). Thus, Valerie's

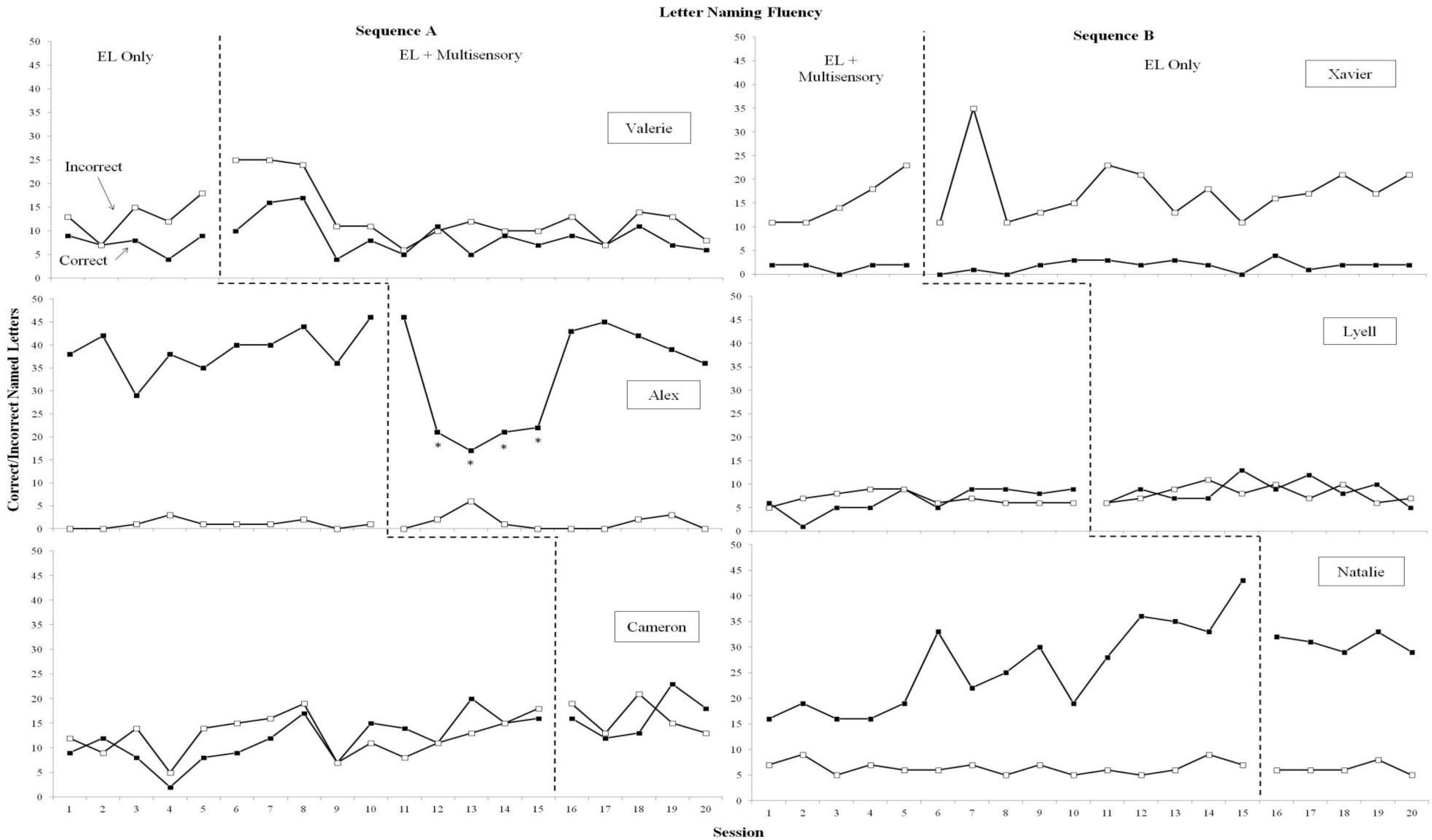

Figure 1. Sequence A and B of the multiple-baseline multiple-sequence design for letter naming fluency (LNF) across all participants, including correct and incorrect named letters.

Note. The sessions marked with an asterisk (*) indicate four outlying data points that were not included in the slope analysis accuracy appeared to improve to a relatively greater degree during the multisensory phase

Alex. Prior to intervention, Alex was able to identify 17 letter names; whereas, following the 20 intervention sessions, he was able to identify 36 letter names, experiencing an overall growth of 1.90 letter names per week. Based on the visual analysis and robust slope estimates for both correct and incorrect letter names, Alex did not appear to experience any differential effects across phases.

Cameron. Prior to intervention, Cameron was able to identify 9 letter names; whereas, following the 20 intervention sessions, he was able to identify 18 letter names, experiencing an overall growth of 0.90 letter names per week. Based on the visual analysis and robust slope estimates for both correct and incorrect letter names, Cameron appeared to experience greater gains during the multisensory phase (see Figure 1, Tables 4 and 5). The change in trend was steeper during the multisensory phase (robust slope estimates, 1.50) in comparison to the early literacy skills training only phase (robust estimate slope, 0.60). Additionally, Cameron's accuracy improved to a relatively greater degree during the multisensory phase. Specifically, the robust slope estimate for errors during the multisensory phase was -1.38, whereas the robust slope estimate during the early literacy skills only phase was 0.20.

Sequence B.

Xavier. Xavier experienced no growth over the course of the intervention, as he was able to identify two letter names before and after the intervention. His performance was variable and he made a number of errors likely due to random responding across phases.

Lyell. Lyell experienced modest growth, as he was able to identify one letter name and five letter names before and after the intervention, respectively. Lyell's performance remained consistently low across phases, suggesting no differential effects across phases.

Natalie. Prior to intervention, Natalie was able to identify 13 letter names; whereas, following the 20 intervention sessions, she was able to identify 29 letter names, experiencing an overall growth of 1.60 letter names per week. Differential effects appeared to be demonstrated, as robust slope estimate value was positive during the multisensory phase (1.69) and was negative during the early literacy skills training only phase (-0.69). Her performance with letter naming appeared to regress when conditions changed from using the multisensory component during instruction to no longer using the component (see Figure 1).

Phoneme Segmentation Fluency (PSF)

Figure 2 compares students' PSF performance across phases and sequences, and Tables 4 and 5 present robust slope estimates across students and phases. The overall pattern across sequences revealed no clear differences between conditions as there were no consistent changes in level, trend, or variability. Based on their performances, the majority of students (i.e., five out of six) frequently failed to meet the DIBELS PSF criterion to continue the task (i.e., did not correctly identify a sound segment in the first five words). Therefore, these students demonstrated a similar trend, experiencing modest gains towards the end of the study regardless of condition. Individual student performance across sequences is discussed in more detail below.

Sequence A.

Valerie. Valerie experienced modest growth, as she was able to segment zero and five phonemes before and after the intervention, respectively. Valerie did not appear to experience any differential effects across phases as her performance was consistently low over the course of the intervention, with a slight improvement towards the end of the intervention.

Alex. Alex experienced modest growth, as he was able to segment zero and three phonemes before and after the intervention, respectively. Like Valerie, Alex did not appear to

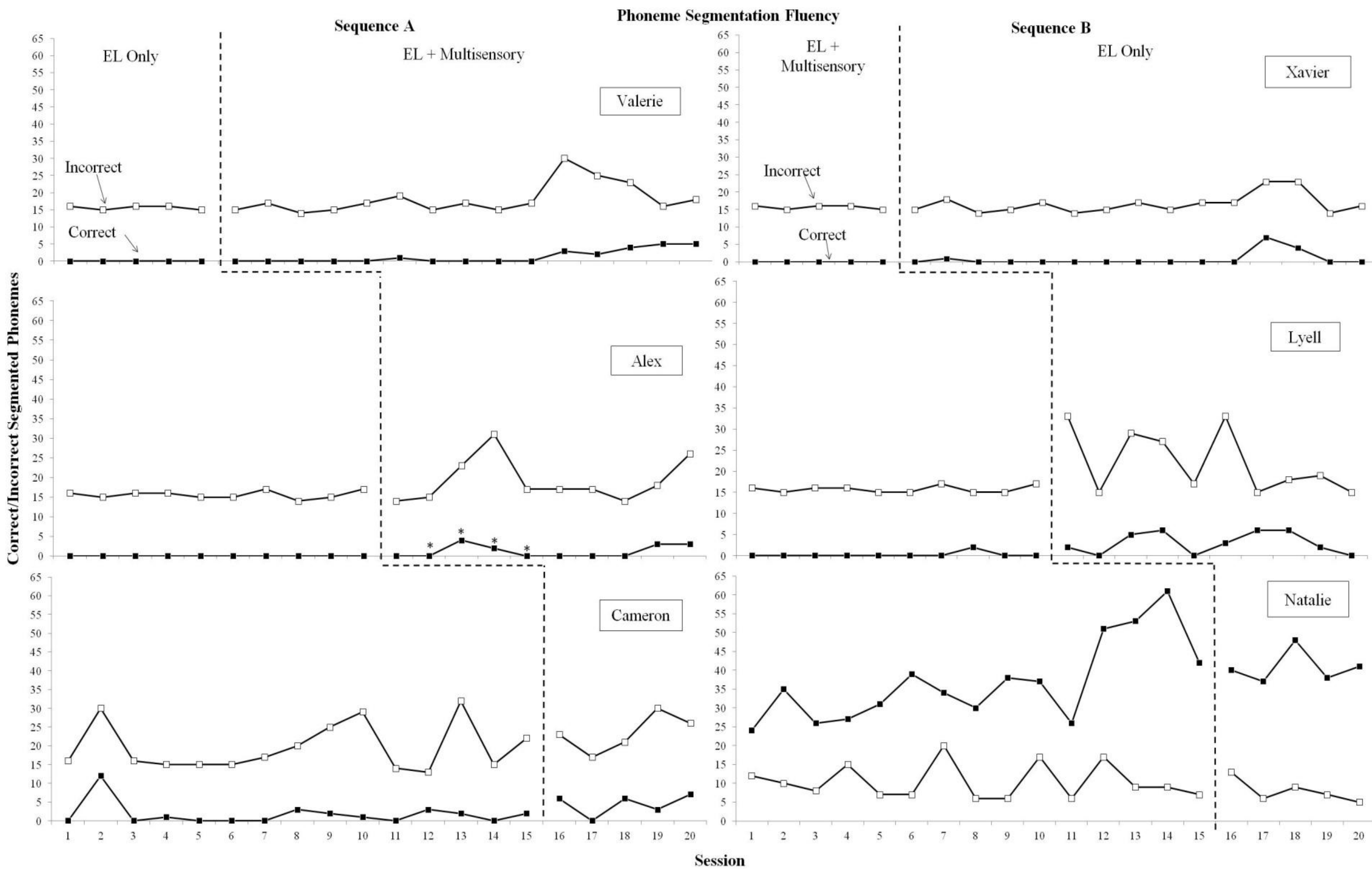

Figure 2. Sequence A and B of the multiple-baseline multiple-sequence design for phoneme segmentation fluency (PSF) across all participants, including correct and incorrect segmented words.

Note. The sessions marked with an asterisk (*) indicate four outlying data points that were not included in the slope analysis.

experience any differential effects across phases as his performance was consistently low over the course of the intervention, with a slight improvement towards the end of the intervention.

Cameron. Cameron experienced modest growth, as he was able to segment zero and seven phonemes before and after the intervention, respectively. Similar to Valerie and Alex, Cameron did not appear to experience any differential effects across phases as his performance was consistently low over the course of the intervention, with a slight improvement towards the end of the intervention.

Sequence B.

Xavier. Xavier experienced no growth over the course of the intervention, as he was unable to segment words into phonemes before or after the intervention. Thus, no differential effects across phases were observed.

Lyell. Lyell experienced no growth over the course of the intervention, as he was unable to segment words into phonemes before or after the intervention. Lyell did not appear to experience any differential effects across phases as his performance was consistently low over the course of the intervention, with a slight improvement towards the end of the intervention, likely due to random responding.

Natalie. Prior to intervention, Natalie was able to segment 13 phonemes correctly; whereas, following the 20 intervention sessions, she was able to segment 41 phonemes correctly, experiencing an overall growth of 2.80 correct phonemes segmented per week. Based on the visual analysis and robust slope estimates (see Figure 2 and Table 4), Natalie appeared to experience stronger gains during the multisensory phase (robust slope estimate, 1.79) in comparison to the early literacy skills training only phase (robust slope estimate, 0.30).

Nonsense Word Fluency (NWF)

Figure 3 compares students' NWF performance across phases and sequences, and Tables 4 and 5 present robust slope estimates across students and phases. The overall pattern across sequences revealed no clear differences between conditions as there were no consistent changes in level, trend, or variability. However, some students experienced stronger gains in decoding nonsense words more quickly (i.e., Lyell and Natalie), or more accurately (i.e., Valerie and Cameron) in comparison to others during the multisensory phase as evidenced by visual analyses (i.e., changes in trends) and robust slope estimate analysis. Scores for the number of whole words read (WWR) correctly are not reported since participants rarely read nonsense words as whole words. Individual student performance across sequences is discussed in more detail below.

Sequence A.

Valerie. Valerie experienced modest gains in decoding nonsense words, correctly identifying three letter sequences and eight letter sequences before and after the intervention, respectively. Based on visual analysis and robust slope estimates for correct letter sequences, Valerie appeared to make stronger gains during the early literacy skills training only phase (robust slope estimate, 2.00) in comparison to the multisensory phase (robust slope estimate, -0.17; see Figure 1 and Table 4). In contrast, she appeared to become more accurate during the multisensory phase (robust slope estimate, -0.57) in comparison to the early literacy skills training only phase (robust slope estimate, 3.10; see Figure 3 and Table 5).

Alex. Prior to intervention, Alex was able to identify seven letter sequences; whereas, following the 20 intervention sessions, he was able to identify 22 letter sequences, experiencing an overall growth of 1.50 letter sequences per week. Based on the visual analysis and robust

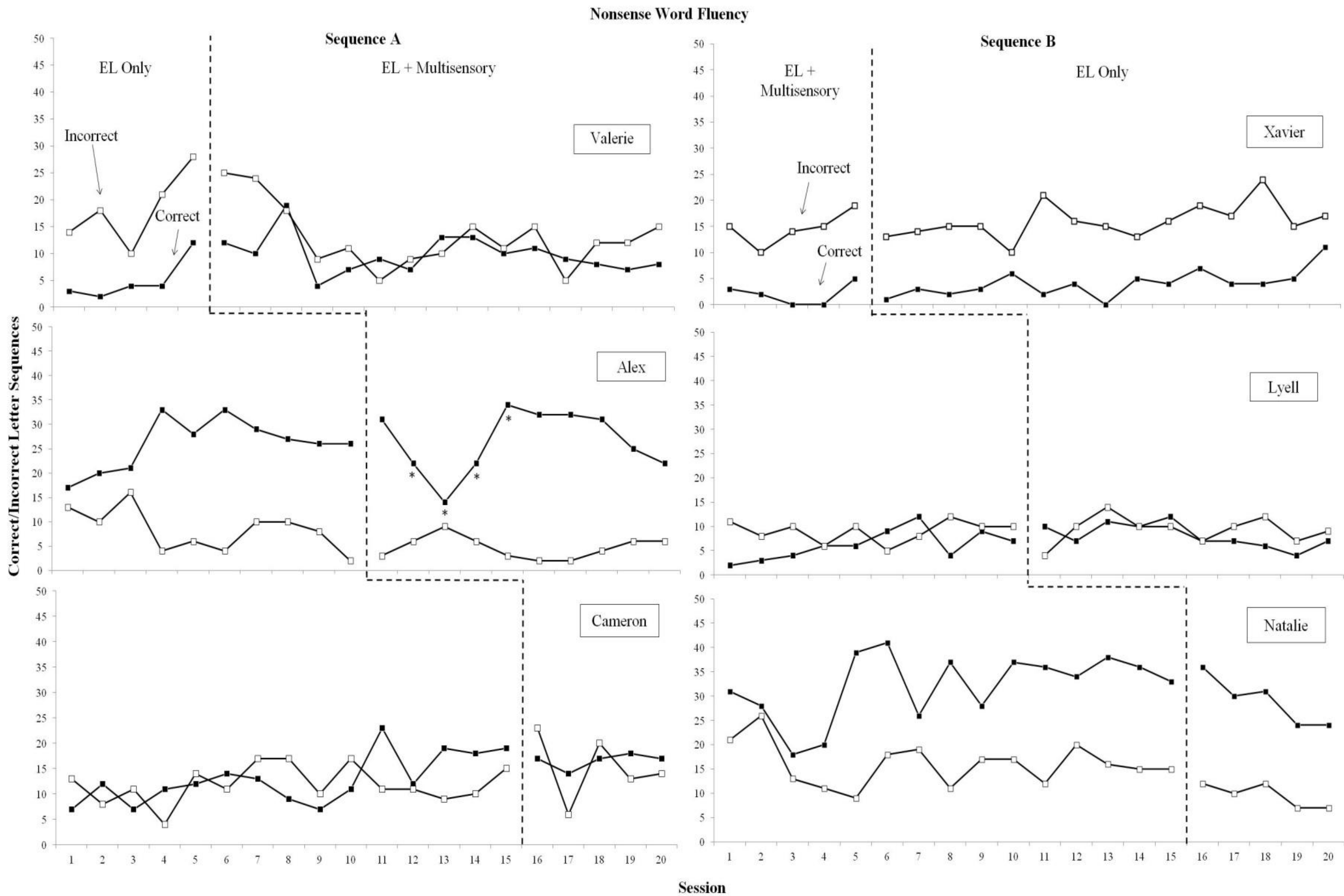

Figure 3. Sequence A and B of the multiple-baseline multiple-sequence design for nonsense word fluency (NWF) across all participants, including correct and incorrect letter sounds.

Note. The sessions marked with an asterisk (*) indicate four outlying data points that were not included in the slope analysis.

slope estimates for both correct and incorrect letter sequences, Alex did not appear to experience any differential effects across phases as his performance remained fairly consistent over the course of the intervention.

Cameron. Cameron experienced modest gains in decoding nonsense words, correctly identifying 11 letter sequences and 17 letter sequences before and after the intervention, respectively. Robust slope estimates for incorrect letter sequences suggest that his accuracy improved (see Table 5); however, this estimate may not be an accurate representation of his performance given that his accuracy appeared variable due to random responding (see Figure 3).

Sequence B.

Xavier. Unlike LNF and PSF where Xavier experienced no growth, he experienced modest gains in decoding nonsense words, identifying 11 letter sequences and 17 letter sequences before and after the intervention, respectively. Although he made some improvement in decoding nonsense words, there did not appear to be any differential effects across phases, and his errors remained fairly high over the course of the intervention likely due to random responding.

Lyell. Lyell experienced modest growth in decoding nonsense words, identifying three letter sequences and seven letter sequences before and after the intervention, respectively. Based on the robust slope estimates, he experienced more gains in the multisensory phase (0.64) in comparison to the early literacy skills training only phase (-0.53), although his performance remained consistently low over the course of the intervention (see Figure 3).

Natalie. Prior to intervention, Natalie was able to identify 16 letter sequences correctly; whereas, following the 20 intervention sessions, she was able to identify 24 letter sequences correctly, experiencing an overall growth of 0.80 correct letter sequences per week. Based on the visual analysis and robust slope estimates (see Figure 3 and Table 4), Natalie appeared to experience stronger gains during the multisensory phase (robust slope estimate, 0.67) in comparison to the early literacy skills training only phase (robust slope estimate, -3.00). Once the multisensory component was removed from instruction, Natalie's performance appeared to regress (see Figure 3).

Discussion

Research on the use of single multisensory components in early literacy programs is limited and little is known about the practicality of embodied approaches to cognition within an educational setting. For this reason, this study addressed limitations in the existing research by conducting an analysis of one multisensory component (i.e., sandpaper letters) to determine its impact on early literacy skills. It was hypothesized that interventions with the multisensory component would enhance literacy skills more than interventions without. The current section will first discuss the major findings, as well as the limitations and implications of the study.

Major Findings

Within each sequence, results demonstrated no consistent differences or patterns across the students, providing no clear evidence that multisensory was more or less effective than the early literacy skills training only. Likewise, the results demonstrated no consistent differences or patterns across sequences, providing no clear evidence the use of the multisensory component was more or less effective during instruction. The patterns were not consistent across the two sequences of introducing the intervention, suggesting no robust differential or sequence effects. Similarly, the effect was not consistent in Sequence A or B alone.

Although experimental control was not demonstrated across students or sequences, the addition of a multisensory component (i.e., sandpaper letters) was simple to implement and appeared to result in some differential growth for some students, especially on the letter naming fluency (LNF) and nonsense word fluency (NWF) measures. Thus, although there was no functional relation, the multisensory component appeared to benefit students on some measures of early literacy skills, given that some students appeared to experience stronger gains during the multisensory phase. For example, Natalie appeared to demonstrate differential effects across all measures and appeared to benefit most from the multisensory instruction; whereas, the other students did not consistently demonstrate the same effects. Valerie, Cameron, and Lyell appeared to benefit from the use of the multisensory component, but only for certain measures.

The inconsistency observed across participants and measures may, in part, be explained by a skill-by-treatment interaction (Burns, Codding, Boice, & Lukito, 2010). That is, students may have responded differently to instruction and the use of the multisensory component because of their varying levels of early literacy skills entering the study. For example, Natalie entered the study as the student with the strongest early literacy skills and appeared to benefit the most from the use of the multisensory component (see Table 1). Likewise, Alex entered the study with stronger early literacy skills and appeared to benefit well from the intervention as a whole, regardless of condition and despite an extended absence from school during the study. For Natalie and Alex, who were still below but performing closer to benchmark levels, the current intervention may have been more congruent with their current stage of development allowing them to make larger gains (Burns et al., 2010). On the contrary, Xavier and Lyell entered the study with the weakest early literacy skills and appeared to only modestly benefit from the intervention as a whole, regardless of condition. Specifically, using LNF as a predictor, Xavier and Lyell performed very low during the pre-screening assessment suggesting that their needs may have been higher in comparison to what was provided through the intervention. These two students may have been performing too far below the others that the treatment was not considered congruent with their stage of development, preventing them from making gains (Burns et al., 2010). Thus, the inconsistent patterns observed could potentially provide evidence of a skill-by-treatment interaction that should be explored in future research. That is, there appeared to be greater differentiation for the students with the highest skill levels entering the study. The students whom entered the study with stronger early literacy skills appeared to benefit the most from the intervention, regardless of sequence or condition; whereas, the students whom entered the study with weaker early literacy skills appeared to only modestly benefit from the intervention, regardless of sequence or condition.

Letter naming fluency (LNF). For letter naming, Natalie, Cameron, and Valerie appeared to benefit from using the multisensory component. Natalie and Cameron appeared to experience greater gains in identifying correct letter names more quickly, and Valerie became more accurate (i.e., made fewer errors) during the multisensory phase. The performance of the other students (i.e., Alex, Xavier, and Lyell) did not appear to be affected differentially across phases. Thus, it was unclear as to whether the multisensory component was more or less effective.

Phoneme segmentation fluency (PSF). The majority of the students (i.e. 5 out of 6) demonstrated a similar trend regardless of the sequence they were assigned. That is, based on their performances, they frequently failed to meet DIBELS PSF criterion to continue the task (i.e., did not correctly identify a sound segment in the first five words) during the beginning of the study. Subsequently, these same students experienced slight growth towards the end of the study, often correctly segmenting initial sounds of target words. This suggested that receiving ongoing practice with the task improved their performance over time and that the multisensory component did not significantly impact their early literacy skills. One student, Natalie, who entered the study with slightly higher early literacy skills (as evidenced by her pre-intervention assessment results; see Table 1), appeared to exhibit clear differential effects. As with letter naming, Natalie appeared to benefit from using the multisensory component, showing stronger gains in segmenting words in the multisensory phase in comparison to the early literacy skills training only phase.

Nonsense word fluency (NWF). For decoding nonsense words, the students experienced different patterns of effects across phases, making it unclear as to whether the multisensory component was improving their early literacy skills. Valerie appeared to experience differential effects in both the direction that was and was not hypothesized. Specifically, she appeared to make slightly stronger gains in decoding nonsense words correctly during the early literacy skills training only phase. However, in contrast, her accuracy appeared to improve to a greater degree during the multisensory phase. As with letter naming and segmenting words, Natalie appeared to demonstrate differential effects for decoding nonsense words, experiencing stronger gains during the multisensory phase with her performance regressing when the multisensory component was no longer used during instruction. Cameron may have experienced some differential effects in that his accuracy appeared to improve when in the multisensory phase. The other students (i.e., Alex, Cameron, Xavier, and Lyell) did not appear to experience any significant differential effectiveness across phases. Similar to letter naming and segmenting words into phonemes, using the multisensory component did not appear to clearly impact the students' performances in decoding nonsense words.

Limitations

This study has limitations that should be recognized when considering the results. First, given that there appeared to be some evidence for a skill-by-treatment interaction, participants may not have been equal in their early literacy skills upon entering the study. Even though all participants met inclusion criteria, scoring below benchmark levels during the pre-intervention assessment, there may still have been too much variability between the six participants' performances. For example, some students exhibited very low early literacy skills upon entering the study (i.e., Xavier and Lyell). As a result, such students appeared to not respond to either early literacy skills intervention (either with or without the multisensory component) and appeared to require more intensive early literacy support in comparison to others. Fundamental to a multiple baseline design, it is required that all participants are comparable at the start of the study. Thus, the variability of the participants' entry early literacy skills may have made them incomparable, compromising the control of the design and making the findings difficult to interpret. To account for the unintended variability seen during the pre-screening assessment, it may have been necessary to screen participants with a cognitive measure to ensure students were indeed comparable at the outset of the study.

Second, with only six participants in the study, generalizability of the results across learners and environments is limited. Similarly, given that the students were recruited from two kindergarten classrooms from the same inner city school, the group may have exhibited certain characteristics that are not true for other kindergarten students. Additional replications would be needed to determine whether these results would be obtained with other students.

Third, some participants were absent from the study and were not seen as consistently as other participants. For example, Alex was away from the study for three weeks. Additionally, spring vacation disrupted the completion of the study for two students who made-up the sessions following the 2-week break. This variability in instruction delivery may have impacted the results.

Lastly, the intervention was modified to introduce letter-sound correspondences earlier in the sequence than was recommended by Blachman and colleagues (2000) in order to utilize the multisensory component. It is possible that the introduction of the letters was too rapid for some participants, making them respond less optimally to the intervention as a whole. If replicated, it may be useful to work on early literacy skills without introducing the letters as soon to ensure students have those fundamental skills.

Implications and Future Directions

While the current study adds to the body of research examining multisensory training techniques, it unfortunately does not fully clarify the link between multisensory training and early literacy outcomes. However, the addition of a modest, simple multisensory component appeared to assist some students in improving their early literacy skills and required little extra time to implement. The results may suggest that a more robust multisensory early literacy skills intervention could be worth developing and researching further.

Revisiting embodied education. Although the results were not conclusive, the findings still hold promise as they are somewhat consistent with theories of embodied cognition. According to these theories, the body is principal in cognition. Embodied cognition theorists suggest that cognition is grounded in modal representations related to perception, action, and affect (Barsalou, 2008). Further, theorists propose that many cognitive processes consist of mental simulations that are grounded within the modalities. Thus, if the body, movement, and perceptions are essential to cognition, using multisensory methods that utilize various manipulatives should foster learning and could allow one to establish sensorimotor routines that are embodied and lead to greater transfer of knowledge and understanding (Marley & Carbonneau, 2014; Pouw, van Gog, & Paas, 2014).

It is important to note that many researchers have emphasized that physicality of using manipulatives is not in and of itself important; rather, the manipulability and meaningfulness make the manipulatives educationally effective (Sarama & Clements, 2009). Similarly, research in embodied cognition have determined that functional knowledge (i.e., knowledge of how to use an object), rather than volumetric knowledge (i.e., knowledge of how to lift an object) plays a major role in concept formation and may be a key component in learning (e.g., Bub, Masson, & Cree, 2008; Kemler Nelson, Frankenfield, Morris, & Blair, 2000). Thus, purposeful actions may assist students in acquiring a better understanding of concepts and their relations. With the multisensory component used in the current study, the action (i.e., the "multisensory trace") is meaningful in that it is preparing the student for writing. Thus, embodied theories of cognition is a theoretical perspective that may account for the effectiveness of multisensory techniques, especially those that utilize actions with a functional application.

Linking early literacy with writing instruction. In line with embodied theories of cognition that emphasize the importance of functional sensorimotor experiences, research examining the link between writing and early literacy skills provides support for utilizing a component such as sandpaper letters. Research has shown that helping a young student learn to write has positive effects on future literacy skills (e.g., Anderson, Heibert, Scott, & Wilkinson, 1985; Boscolo & Cisotto, 1999). Some researchers suggest that early literacy instruction in only reading is not enough, and that writing is an integral component of language and should be included in early literacy instruction (e.g., D'on Jones, Reutzel, & Fargo, 2010; Shanahan, 2006). Similarly, Berninger and colleagues (2002) suggested that the writing and reading systems (i.e., language by hand and by eye) draw on common as well as on unique processes, and thus, reading and writing may be best taught as integrated components of the curriculum rather than as separate (Berninger et al., 2002). Empirical studies, such as the one conducted by D'on Jones and colleagues (2010), demonstrated that interactive writing (i.e., activity that involves negotiating, constructing, and rereading text) or writing workshops (i.e., activity that involves writing, conferencing, and sharing) for kindergarten students are equally effective in promoting acquisition of early reading skills (i.e., phonological awareness, alphabet knowledge, and word reading).

With regard to the current study, using sandpaper letters allows students to practice the "multisensory trace" which may not only allow for further fine motor development, but also mimics the writing process on a larger scale. Writing is a powerful cognitive procedure because by the very nature of the task, a writer is forced to act analytically on print, letter by letter (Luria & Yodovich, 1971; Clay, 2002). Further, as Pouw and colleagues (2014) suggested, the manipulations implied by an object should coincide with the intended learning outcomes. Ideally, learning that occurs in one setting should generalize to other relevant circumstances (Marley & Carbonneau, 2014). In line with these ideas, the "multisensory trace" implied by the sandpaper letters may be a learning technique that facilitates transfer of learning, or provides groundwork for further instruction that would subsequently promote transfer. Given that the "multisensory trace" is an active motor-muscular response similar to writing, it may aid students' memory of how each word and the separate elements in each words are formed (Hildreth, 1963). Thus, this technique could be of significant value to classroom teachers as early literacy skills have been shown to be reinforced by simultaneous experiences in writing (Hildreth, 1963). Research that continues to examine such multisensory components and their uses within the classroom is warranted.

Specific learners with specific needs. Not only would researching specific multisensory components be useful, but also the kind of learner who would benefit the most from the use of such components. First, as potentially demonstrated by the present study, it appeared as though students with higher early literacy skills may benefit most from using sandpaper letters within an early literacy skills intervention. Given that results may have suggested a skill-by-treatment interaction, it may be useful for future studies to examine certain skill levels in early literacy skills with certain interventions utilizing multisensory components (Burns, Codding, Boice, & Lukito, 2010). Interventions with particular multisensory strategies may be differentially effective according to level of skills proficiency. Research has shown that successful implementation of an intervention requires school professionals to select appropriate and functionally relevant interventions from the start, using assessment for the purposes of generating and verifying hypotheses. Further, the interventions selected should change as students enter different stages of skill development. Thus, the outcome of the current study may provide more support in linking assessment with selection of instructional strategies in early literacy skills. In the future, it may be useful to conduct a similar experiment ensuring the student's early literacy skills upon entering the study was not too far below grade level and less variable across participants.

As more research in this area is completed with the typically developing population, it may be useful to extend investigations of utilizing multisensory techniques with special populations. Future research could allow for further component analyses to discern whether one component is more effective for a student with a specific deficit. For example, students with dyslexia and patients with aphasia have been shown to respond well academically to various multisensory methods (Lott, Carney, Glezer, & Friedman, 2010; Oakland, Black, Stanford, Nussbaum, & Balise, 1998). Further, Hildreth (1963) emphasized that young students with attention difficulties or those students who seem overwhelmed by print may be able to concentrate better when partaking in overt activities, such as copying or writing. Given that the "multisensory trace" mimics the writing process, such a technique could potentially benefit students with greater attentive needs. Future research should aim to determine the benefit of multisensory training with special populations and whether or not it has special significance for particular learners (e.g., treatment resisters, English language learners, students with attention deficit hyperactivity disorder).

Multisensory learning across the curriculum. In addition to early literacy, hands-on learning strategies are frequently suggested as effective techniques for teaching across many other learning domains (e.g., Marley & Carbonneau, 2014). Strong connections have also been documented between action and learning in areas apart from literacy, such as listening comprehension or math. For example, a developmental study by Goldin-Meadow, Cook, and Mitchell (2009) examined the impact of producing gestures while solving math problems. Children in both gesturing groups (i.e., groups that used gestures to indicate concepts of summation and grouping) outperformed children who performed with no gestures while solving math problems. The researchers proposed that gesturing facilitates learning by allowing children to extract meaning from their actions and this finding suggests that concepts are, at least to some extent, grounded in action (Goldin-Meadow, Cook, & Mitchell, 2009).

Another example includes a study by Marley and Szabo (2010) that examined the cognitive benefits for kindergarten students of physical manipulation on listening comprehension. Results showed that the memory of kindergarten students for story events was significantly enhanced by the students' manipulations of objects to represent story events. Students' free and cued recall was significantly better in the manipulation condition in comparison to a control condition (i.e., pictures only). Marley and Szabo (2010) explained results as supporting an embodied theory of text comprehension, the indexical hypothesis, which explains how learning strategies that incorporate manipulation of concrete representations can enhance the efficacy of imagery instructions (Glenberg, 1997). Implications of this study suggested that physical manipulation can enhance young children's listening comprehension. Thus, multisensory techniques and instructional manipulatives may have a number of applications within classroom contexts (Marley & Carnonneau, 2014). Further research is needed not only regarding who, when, and how to apply such multisensory techniques, but also across what subject areas.

Conclusion

In the current study, there were no consistent differences or patterns across students and sequences providing no clear evidence that multisensory training was more or less effective than the early literacy skills training only. In spite of these inconclusive results and the study's limitations, the addition of a multisensory component (i.e., sandpaper letters) was simple to implement and appeared to result in differential growth for at least some students. As discussed above, the benefit of using sandpaper letters may possibly be two fold. That is, when completing the "multisensory trace" with a sandpaper letter, this purposeful action may help students learn such early literacy skills by forcing them to think more analytically about the letters while simultaneously allowing them to gain sensorimotor experience with the letters, encoding the letters across multiple neural networks. Results from the study showed some support for a skill-by-treatment interaction, in that there appeared to be differential effectiveness based on baseline skill levels. That is, there appeared to be greater differentiation for students with higher skill levels upon entering the study.

In line with embodied cognitive perspectives, it may be useful for educators to consider providing learners with more opportunities to physically interact with manipulatives during instruction in order to potentially help students internalize multimodal representations to promote stronger understandings. However, as emphasized by other researchers (e.g., Marley & Carbonneau, 2014), multisensory techniques have shown to play an important role in classroom instruction, although the role of such techniques is not fully understood across populations, treatments, subject areas, and circumstances. In order to support and promote high-quality educational experiences for learners, the use of instructional strategies with manipulatives requires further empirical examination in order to make evidence-based decisions on who, when, what subject manner, and how to apply a multisensory embodied learning approach. Hopefully, research relevant to embodied education, and classroom instruction and interventions utilizing multisensory methods stimulates further development in applying such practices to the classroom to promote richer learning experiences for all learners.

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Appendices

Appendix A: Consent and Assent

Sample parent consent form

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

Parent Consent Form

Multisensory Training in an Early Literacy Skills Intervention

Dear Parent/Guardian(s),

This is a request for permission for your child to participate in a one-on-one early literacy intervention at his or her school as part of a research study. Your child has been nominated by his or her classroom teacher as a candidate for the study. This research is being conducted to fulfill the requirements of the Student Investigator's thesis for a Master's of Arts degree. Please read the following form carefully.

Purpose:

The purpose of this study is to examine the impact of adding a multisensory component to early literacy skills instruction for kindergarten students.

Research Study Participation:

Taking part in this study means that:

1. You allow your child to receive ten weeks of one-on-one reading intervention, delivered twice a week, for a total of twenty intervention sessions. Each session will last approximately twenty minutes, and will involve practicing pre-reading skills. The sessions will be delivered during school hours by a UBC graduate research assistant.
2. You allow your child to be audio recorded during the reading intervention sessions. The recordings are for research purposes only, and will not be shared with your child's teacher, school administration, or school district. Only the study investigators will have access to the audio recordings. The recordings will be reviewed by the study investigators to verify that intervention sessions are being conducted correctly, and the recordings will be destroyed after they are reviewed by the research team.

Potential Risks:

In order to participate in the reading intervention sessions, your child will be taken out of the classroom twice a week for approximately twenty minutes. Therefore, time out of the classroom may be a concern. Times for intervention sessions will be selected in collaboration with classroom teachers to minimize the impact of lost instructional time.

Potential Benefits:

By participating in the study, your child will receive one-on-one reading instruction with a graduate research assistant. As a result, it is expected that your child will experience gains in early literacy skills. In addition, by allowing your child to participate in this study, you will help improve our understanding of the impact of adding multisensory instruction to early literacy skills interventions for kindergarten students.

Compensation:

Your child may receive small gifts such as stickers or colorful pencils at the end of each intervention session as a thank you for his or her participation.

Confidentiality:

Because your child's classroom teacher has nominated him or her for this study, and it is necessary to establish times that your child will receive the reading intervention, your child's classroom teacher will know that he is or she is participating in the study. However, outcomes of the early literacy skills intervention will not be shared with your child's teacher, school administration, or the school district without your permission. Only the study investigators and graduate research assistants will have access to information gathered about your child in the study, including audio recordings. Audio recordings of the sessions, as well as all information collected, will be securely stored in a locked lab office at the University of British Columbia. No individual student, teacher, or school will be identified by name in any reports of the study.

Contact for concerns about the rights of research subjects:

If at any time you have concerns about your child's treatment or rights as a research participant, you may contact the Research Subject Information Line in the Office of Research Services at UBC.

Consent:

Your consent for your child to participate in this study is entirely **voluntary** and you may refuse to participate or withdraw from the study at any time without harming your child's standing within the school.

If you have any questions or concerns, please contact the Principal Investigator.

Whether or not you allow your child to participate, please **sign this form** and **return it to your child's classroom teacher** within the next seven days so that we know your received the form and have been informed about the study. Please keep the first two pages of this consent form for your records.

I, ________________________ have read and understand the information about the project,

"Multisensory Training in Early literacy skills Interventions." I understand that my child,

______________________’s participation in the project is voluntary. He/she may stop at any time.

Please check one of the following options:

____ **Yes**, I agree that my child may take part in this project.

____ **No**, I do not wish my child to take part in this project.

If you answered **yes,** please answer the following questions:

I would like to receive a summary of my child’s intervention results:

Yes _____ No ______

I give permission for my child’s classroom teacher to receive a summary of my child’s intervention results, and for these results to be added to his or her school record:

Yes _____ No ______

Your signature: ____________________

Date: ____________________

Thank-you for your help!

Sample student assent form

Multisensory and Early Literacy Skills Study

Student Assent Form

Hi, my name is [student investigator] and I'm a student from the University of British Columbia. I am working on a project that involves reading with students at your school, and your teacher thought that you would be a good student to help me with the project. Your parent also knows about the project, and said it would be okay for you to take part. If you agree to help, we will do some different activities to help you with your reading. I will meet with you for about half an hour, twice a week for about two months, to work on reading. We'll go somewhere in the school outside of your classroom to read, like the library, or an empty classroom. If you agree now but don't want to take part in project later, you can stop at any time during the time we work together. Is this okay with you? **[wait for response]**

Do you have any questions?

Do you want to help with the project: ______**YES** ______**NO**

Student Name:____

Student Signature:_____________________________________ Date:______________

Investigator name:_____________________________________

Investigator signature:__________________________________ Date:______________

Appendix B: Intervention

Intervention activities

The following activities were obtained from the *Road to the Code* program (Blachman et al., 2000). Five activities from the *Road to the Code* program (i.e., *Fix-It*, *How Many Sounds?*, *Go Fish*, *Concentration*, and *Save the Rabbit*) were not selected to be included in the sequence of this intervention since they cannot be easily supplemented with sandpaper letters. It is important to note that the same or similar early literacy skills activities have been utilized across a number of successful intervention studies and related resources (e.g., Ball & Blachman, 1991; Ball & Blachman, 1988; Blachman et al., 1999; Cunninghan, 1990; Daly et al., 2005; Ehri et al., 2001; Slingerland, 1971; Stahl et al., 1998; Yopp & Yopp, 2000). The following activities are organized under two sections: Letter Name and Sound Instruction, and Phonological Awareness Practice. Sentences or words that appear in italics represent the alternative instructions for including the supplemental sandpaper letters.

A. Letter Name and Sound Instruction

I. Introducing Letter Cards and Sounds

- **a. Overview:** Introduce the alphabet letter card (*or supplemented sandpaper letter*) of the week, practicing the letter name and sound of each instructed letter. If the session takes place during a lesson where the participant is not being introduced to a new letter, the participant reviews past letters with prompting of the alphabet letter cards *or sandpaper letters*.
- **b. Materials:**
  - i. Alphabet letter cards *or supplemented sandpaper letters* (lower case only)
- **c. Instruction:**

i. Remind the participant that all letters have both a name and a sound.

    1. Blachman and colleagues (2000) suggest that this is an abstract concept and may need to be presented many times before the participants understand this idea.

ii. Introduce the letter sound (e.g., "One sound that this letter makes is /a/ as in apple, ant, and ask).

iii. *If supplementing with sandpaper letter, model the tracing of the letter while saying the sound and get the participant to do so.*

iv. Ask the participant questions about the sound (e.g., "Apple, do you hear the /a/ in apple?).

v. Help the participant think of other words that start with the sound of the week.

vi. Take turns asking the participant the letter's name.

vii. Take turns asking the participant the letter's sound.

viii. Then mix the two (letter name and sound).

d. For an example of this script, please see Blachman and colleagues (p. 9, 2000).

II. Alphabet Books

a. **Overview:** The participant constructs alphabet picture card books of each letter, coloring the letter while receiving instruction about the letter's name and sound. *If in the multisensory phase, the participant will work with sandpaper letter shapes and cut and paste them into their alphabet books with the help of the interventionist.*

b. **Materials**:

i. One large alphabet letter card or *supplemented sandpaper traced letter card*

ii. Crayons *and glue*

iii. Alphabet book folder (one for each participant)

c. Instruction:

i. The participant will colour the alphabet page, *or cut and paste the traced sandpaper letter card*, while receiving instruction about the letter name, sound and picture associations.

ii. The participant will compile their completed letters into an individual book kept with the interventionist. Each week the participant will add a new letter to their alphabet books.

iii. *If in multisensory phase, encourage participant to trace the sandpaper letter shape in their alphabet book while reviewing the letter name and sound.*

iv. For an example of this script, please see Blachman and colleagues (p. 19, 2000).

III. Sound Bingo

a. Overview: The participant receives practice in identifying initial sounds of words and in understanding letter-sound correspondence.

b. Materials:

i. Two Sound Bingo cards

ii. Bingo chips

iii. Canvas bag

iv. Cut individual picture cards, alphabet letter cards *or supplemented sandpaper letters*

c. **Instruction:**

i. The participant and interventionist receive one Bingo Card each and a handful of Bingo chips.

ii. Sound Bingo cards are cut into individual picture or letter squares and are placed in the canvas bag.

iii. If a picture is drawn, the participant names the picture and gives the first sound.

iv. Anyone with that picture card places a Bingo chip on the picture.

v. If a letter card is drawn, the participant gives the letter sound. Anyone with that letter places a Bingo chip on the letter.

vi. Lay the alphabet letter cards or sandpaper letters on the table.

1. After each individual picture card is drawn, ask the participant what letter the picture starts with, prompting with the alphabet letter cards or sandpaper letters.

    a. *In multisensory phase, the participant traces the sandpaper letter while doing so.*

    b. *For example, "Star starts with /s/" while tracing the s sandpaper letter.*

vii. For an example of this script, please see Blachman and colleagues (p. 40, 2000).

IV. Tracing

a. **Overview:** The participant practices tracing letters in the air *or with the supplemented sandpaper letters* to enhance letter-sound correspondence.

b. Materials:

i. None *or supplemented sandpaper letters*

c. Instruction:

i. The participant is instructed to either use their pointing fingers to trace a letter in the air *or to trace the sandpaper letters on the table*.

ii. The interventionist identifies a letter sound and models the procedure (e.g., "The first letter we are going to traces says /m/"), having the participant repeat the procedure after it is modeled.

iii. For an example of this script, please see Blachman and colleagues (p. 29, 2000).

V. Hand Clapping Game

a. Overview: The participant practices reviewing the name and sounds of letters, enhancing their understanding of letter-sound correspondence.

b. Materials:

i. Alphabet letter card *or supplemented sandpaper letters*

c. Instruction:

i. Using the large alphabet picture card *or supplemented sandpaper letter*, review that name and sound of the letter of interest.

ii. *If in the multisensory phase, the participant will trace the sandpaper letter while reviewing the letter name and sound.*

iii. The interventionist and participant use the jungle with a Hand-Clapping Game, where the participant and interventionist clap on every syllable.

iv. For an example of this script, please see Blachman and colleagues (p. 15, 2000).

VI. **I'm Thinking of a Word**

a. **Overview:** The participant tries to guess the secret word from clues that are given to them by the interventionist. The word begins with one of the letters of interest to prompt greater understanding of letter-sound correspondence.

b. **Materials**:

i. Alphabet letter cards *or supplemented sandpaper letters*

c. **Instruction**:

i. Review the letters of interests, have the participant identify the letter name and sound, and *trace over the supplemented sandpaper letter if appropriate*.

ii. Have the participant think of words that start with the letters of interest.

iii. The participant then guesses a word from clues given by the interventionist with prompts from the alphabet letter card *or supplemented sandpaper letters*.

iv. For an example of this script, please see Blachman and colleagues (p. 47, 2000).

VII. **Sound Boards**

a. **Overview:** Using alphabet letter cards *or sandpaper letters*, the participant chooses the letters that match the letter names or sounds given by the interventionist.

b. **Materials**:

i. Canvas bag

ii. Alphabet letter cards *or supplemented sandpaper letters*

c. **Instruction**:

i. The interventionist will model the activity by taking the letter of interest (based on letter name or sound) and taking it from the table and placing it in the canvas bag.

ii. The participant will be instructed to take down the letter whose name or sound is named by the interventionist.

iii. *In multisensory phase, the participant* ***<u>traces</u>*** *each sandpaper letter while giving the name and sound of each letter before placing it in the canvas bag.*

iv. For an example of this script, please see Blachman and colleagues (p. 179, 2000).

<u>B. Phonological Awareness Practice</u>

I. Say-It-and-Move-It

a. **Overview:** The participant is taught to segment words by first repeating a target words and then moving one disk (or alphabet letter card *or supplemented sandpaper letter*) for each sound that they say in the word. Finally, after the word is segmented, it is blended (spoken normally). The activities will start with using the disks only, to segment each sound on the first few trials of this activity. Then, any words which involve letters that were previously introduced, the alphabet letter cards *or sandpaper letters* will be used in place of the disks. Thus, during the beginning stages of the intervention, participants will use a mix of blank disk tiles and letter tiles, only using the letter tiles when they have been taught how to associate the letter names and sounds.

b. Materials:

i. Say-It-and-Move-It sheet

ii. Disks, alphabet letter cards *or supplemented sandpaper letter*

c. Instruction:

i. Begin by modeling the correct way to segment the target word.

ii. First the target word is spoken and then each sound is spoken in an elongated fashion as a disk (or alphabet letter *or sandpaper letter*) is moved for each sound.

1. Pause only if there is a ^ sign to represent a pause. Stop sounds (sounds that cannot be help without distortion, e.g., /b/, /d/, /p/, /t/) are spoken quickly and are not elongated.
2. Note: All vowels used in these activities have their short sounds.

iii. Encourage the participant to use only one finger when moving the manipulative objects (e.g., “Get your moving finger ready!”) and to store their manipulatives in one place on the Say-It-and-Move-It sheet.

iv. Also encourage the participant to “sweep” the objects back to the picture after completing each segmenting task.

v. *When using the sandpaper letter in place of the disk, encourage student to say the sound, move the sandpaper letter and then trace the letter, making the activity Say-It-Move-It-and-Trace-It.*

vi. For an example of this script, please see Blachman and colleagues (p. 3, 2000).

d. Note: The above procedure is a modification from the *Road to the Code* program, since this activity introduces the letter-sound correspondence (using alphabet cards and *sandpaper letters*) earlier in comparison to the program's sequence.

II. Sound Categorization by Rhyme

a. Overview: The participant practices grouping together words that rhyme and then identifies why those words go together with the help of the interventionist.

b. Materials:

i. Three-five sets of Sound Categorization by Rhyme cards

ii. Alphabet letter cards *or supplemented sandpaper letters*

c. Instruction:

iii. Place the sets of pictures on the table in front of the participant while singing or saying the following verse:

1. "One of these things is not like the others. One of these things does not belong. One of these things is not like the others. Which of these things does not belong?"

iv. First, the participant must name each picture and then must determine which one of the four pictures does not belong in a set.

v. Lay out the appropriate alphabet letter cards *or supplemented sandpaper letters* and ask the participant to tell why that card does not belong (or to supply the rule) using the alphabet cards *or sandpaper letters* as prompts.

1. For example, if the objects pictured were *hat*, *cat*, *fish* and *bat*, the participant might say, "*Hat*, *cat*, and *bat* all rhyme or end the same with the sound /t/, but *fish* doesn't." The interventionist would encourage the participant to identify the alphabet letter card *or sandpaper letter* that represents the /t/ sound, *having the participant trace the letter while repeating the sound in the multisensory phase*.

vi. For an example of this script, please see Blachman and colleagues (p. 11, 2000).

III. Sound Categorization by Initial Sound

a. Overview: The participant practices categorizing words by initial sounds to enhance sound segmentation.

b. Materials:

i. Three-five sets of Sound Categorization by Initial Sound cards

ii. Alphabet letter cards *or supplemented sandpaper letters*

c. Instruction:

i. Select a set of pictures that begin with the same initial sound.

ii. Place the four pictures on the table and the participant must decide which one of the four pictures does not belong in the set.

iii. First, the participant must name each picture and then must determine which one of the four pictures does not belong in a set.

iv. Lay out the appropriate alphabet letter cards *or supplemented sandpaper letters* and ask the participant to tell why that card does not belong (or to supply the rule) using the alphabet cards *or sandpaper letters* as prompts.

v. *In the multisensory phase, the participant traces the sandpaper letter while saying the corresponding letter sound or name.*

vi. For an example of this script, please see Blachman and colleagues (p. 61, 2000).

IV. Elkonin Cards

a. **Overview:** This activity is similar to Say-It-and-Move-It, but uses picture prompts while the participant isolates the target word's sounds.

b. **Materials**:

i. Elkonin cards

ii. Disk, alphabet letter cards, *or supplemented sandpaper letters*

c. **Instruction**:

i. Begin by modeling the correct way to segment the target word.

ii. First, the target word is spoken and then each sound is spoken in an elongated fashion as a disk (or alphabet letter *or sandpaper letter*) is moved for each sound.

1. Pause only if there is a ^ sign to represent a pause. Stop sounds (sounds that cannot be help without distortion, e.g., /b/, /d/, /p/, /t/) are spoken quickly and are not elongated.
2. Note: All vowels used in these activities have their short sounds.

iii. Encourage participant to use only one finger when moving the manipulative objects (e.g., “Get your moving finger ready!”) and to store their manipulatives in one place on the Say-It-and-Move-It sheet.

iv. Also encourage the participant to “sweep” the objects back to the picture after completing each segmenting task.

v. *When using the sandpaper letter in place of the disk, encourage student to say the sound, move the sandpaper letter and then trace the letter.*

1. *Ask the participant if they hear /m/ in the other words (e.g., wag).*

vi. For an example of this script, please see Blachman and colleagues (p. 79, 2000).

V. Post Office

a. Overview: The participant takes turn with interventionist delivering the pictures based on initial sound to the correct “mailbox” that are labeled with corresponding alphabet letter cards *or supplemented sandpaper letters*.

b. Materials:

i. Alphabet letter cards *or supplemented sandpaper letters*

ii. Brown lunch bags

iii. Pictures of objects that start with letters of interest

iv. Large canvas bag or shopping bag designated as letter carrier’s bag

c. Instruction:

i. The participant will isolate and identify the first sound of words, assuming the role of letter carrier and deliver the “mail” (pictures) to the appropriate "mailboxes" (lunch bags with alphabet letter cards *or sandpaper letters* that are placed in front of each bag).

ii. The participant picks one picture from their bag and names the picture, gives the initial sound of the object and delivers it to the appropriate "mailbox" putting it into the lunch bag that is labeled with the letter that represents the first sound of the pictured object.

iii. *In the multisensory phase, have the participant* ***trace*** *the sandpaper letter while saying the corresponding initial letter sound or name of the picture delivered.*

iv. For an example of this script, please see Blachman and colleagues (p. 135, 2000).

VI. Let's Fish!

a. Overview: The participant will isolate and identify the first sound of words that begin with the previously instructed letters.

b. Materials:

i. Fishing pole (magnet on end)

ii. Five "fish" (picture cards with paper clips) representing each of the sounds reviewed

iii. Alphabet letter cards *or supplemented sandpaper letters*

c. Instruction:

i. Place the "fish" (picture cards) randomly in the center of the table with the picture side down.

ii. Instruct the participant to catch a fish by means of the magnet on the end of the pole.

iii. When a fish is caught, the participant names the picture and gives the initial sound.

iv. Using the alphabet letter cards *or supplemented sandpaper letters*, the participant chooses the corresponding letter, *tracing the sandpaper letter while repeating the initial sound.*

   1. For example, if the participant catches a picture of a map, the participant would respond "Map, /m/" and then choose the alphabet *or sandpaper letter* of "m."

v. If the participant's response is correct, the participant keeps the "fish."

   1. Otherwise, the "fish" is returned to the table, face down with the other picture cards.

vi. The participant and interventionist can take turns, with the interventionist modeling the activity for the participant.

vii. For an example of this script, please see Blachman and colleagues (p. 93, 2000).

Intervention sequence

Four activities will be used per session and the general sequence of each session involves the following:

1. **Introducing Letter Cards and Sound**, introducing the letter of the week and reviewing the letters of the previous week(s).
2. **Say-It-and-Move-It** will be included in each lesson, utilizing disks and the alphabet letter cards or supplemented sandpaper letters that have been taught thus far in the Letter Name and Sound Instruction lessons.
    a. For example, if the participant has been taught the /a/ and /m/ sounds in previous lessons, the participant will utilize either the alphabet letter cards for those letters or the sandpaper letters in place of sound disks.
3. One additional Letter Name and Sound Instruction activity.
4. One additional Phonological Awareness activity.

The *Rode to the Code* program (Blachman, Ball, Black & Tangel, 2000) only introduces eight letters (i.e., a, m, t, i, s, r, b, f); however, the below sequence introduces more letters to make the intervention more comprehensive. The letter introduction sequence chosen was based off of Carnine and colleague's (2007) suggestion of an acceptable sequence for introducing letters. The sequence will introduce initially only the most common sound for a new letter, will separate letters that are visually or auditorily similar, and will introduce more useful letters before less useful letters (Carnine et al., 2007). A more detailed description of the sequence is shown in the below table.

Table 7.

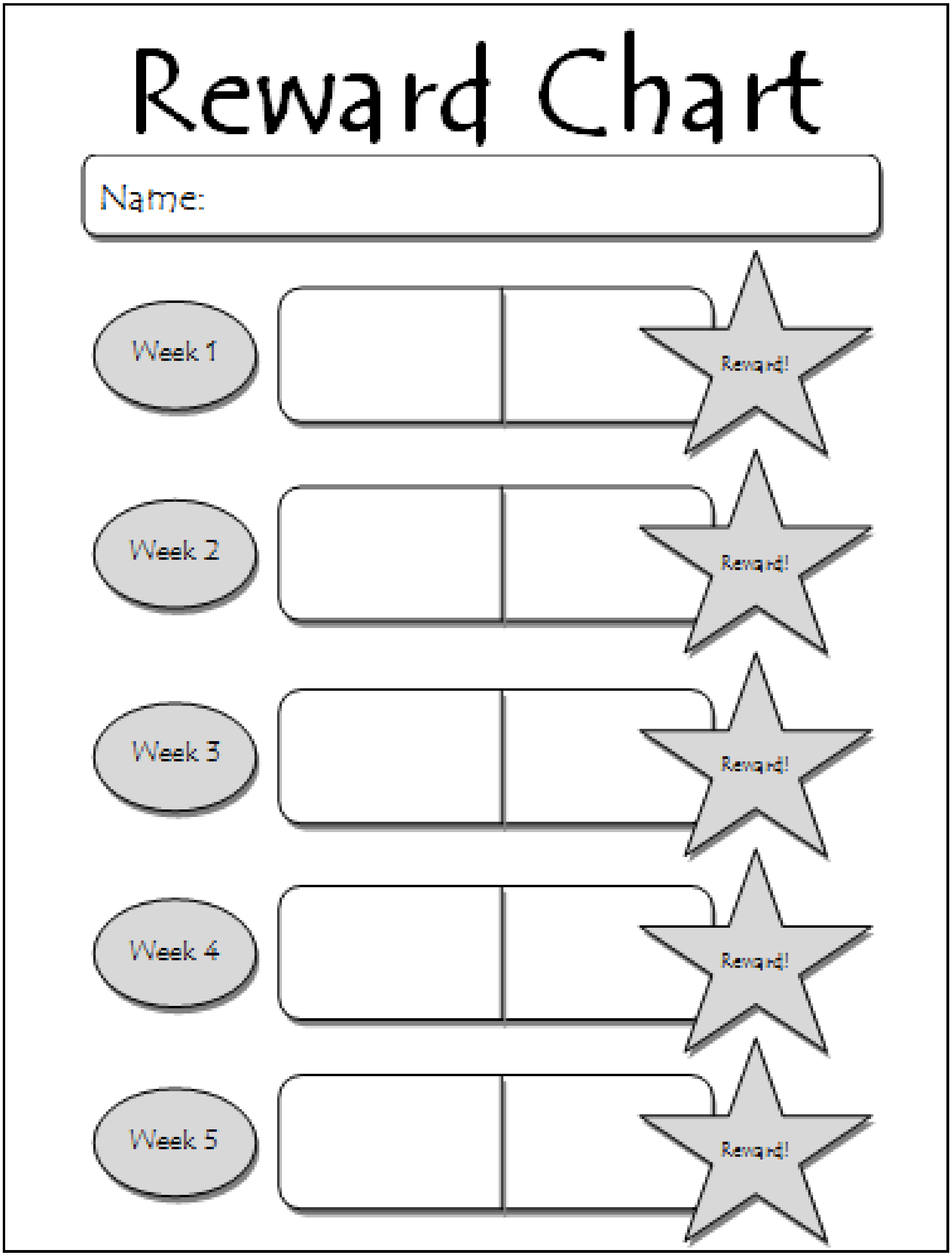
Intervention sequence of introduced letters and activities.

Week	Session	Letter Introduced/Reviewed	Activities
1	1	a	Introducing Letter Cards and Sounds Say it and Move it Alphabet Books Sound Categorization by Rhyme
	2	a	Introducing Letter Cards and Sounds Say it and Move it Hand Clapping Sound Categorization by Rhyme
2	3	m	Introducing Letter Cards and Sounds Say it and Move it Alphabet Books Elkonin Cards
	4	m, a	Introducing Letter Cards and Sounds Say it and Move it Sound Bingo Elkonin Cards
3	5	t	Introducing Letter Cards and Sounds Say it and Move it Alphabet Books Sound Categorization by Rhyme
	6	t, m, a	Introducing Letter Cards and Sounds Say it and Move it Tracing Let's Fish!
4	7	s	Introducing Letter Cards and Sounds Say it and Move it Alphabet Books Sound Categorization by Rhyme
	8	s, t, m, a	Introducing Letter Cards and Sounds Say it and Move it I'm Thinking of a Word Elkonin Cards
5	9	i	Introducing Letter Cards and Sounds Say it and Move it Alphabet Books Elkonin Cards
	10	i, s, t, m, a	Introducing Letter Cards and Sounds Say it and Move it Sound Bingo Let's Fish!

Table 7 continued.

6	11	f	Introducing Letter Cards and Sounds Say it and Move it Alphabet Books Sound Categorization by Initial Sound
	12	f, i, s, t, m, a	Introducing Letter Cards and Sounds Say it and Move it Hand Clapping Game Sound Categorization by Initial Sound
7	13	d	Introducing Letter Cards and Sounds Say it and Move it Alphabet Books Post Office
	14	d, f, i, s, t, m, a	Introducing Letter Cards and Sounds Say it and Move it Sound Boards Post Office
8	15	r	Introducing Letter Cards and Sounds Say it and Move it Alphabet Books Let's Fish!
	16	r, d, f, i, s, t, m, a	Introducing Letter Cards and Sounds Say it and Move it Tracing Sound Categorization by Initial Sound
9	17	o	Introducing Letter Cards and Sounds Say it and Move it Alphabet Books Sound Categorization by Initial Sound
	18	o, r, d, f, i, s, t, m, a	Introducing Letter Cards and Sounds Say it and Move it I'm Thinking of a Word Post Office
10	19	g	Introducing Letter Cards and Sounds Say it and Move it Alphabet Books Post Office
	20	g, o, r, d, f, i, s, t, m, a	Introducing Letter Cards and Sounds Say it and Move it Sound Boards Let's Fish!

Sample reward chart



Appendix C: Critical Steps for Intervention

Critical intervention steps

Each interventionist was provided with a checklist (see Participant Checklist below) for each participant that covered the following procedures. Each interventionist provided the date, placed a check mark under each completed step, commented on any noteworthy events of the session, and initialed the session upon its completion.

1. Record the date and the start time of the session.
2. Start audio recording the session.
    a. At the beginning of the recording announce the date, session number, and identification of the participant.
3. Administer one of each of the three DIBELS outcome measures.
    a. Letter naming fluency (LNF)
        i. Record the number of correct letter names that the participant says in one minute.
    b. Phoneme segmentation fluency (PSF)
        i. Record the number of correct phonemes segmented by the participant in one minute.
    c. Nonsense word fluency (NWF)
        i. Record the number of correct letter sounds (CLS) produced by the participant in one minute.
        ii. Record the number of whole words read correctly (WWR) by the participant in one minute.
4. Gather appropriate materials for the session.

a. Determine the appropriate phase of the participant, collecting the needed materials for the session.
    i. If the participant is not in the supplemental phase, use regular alphabet letter cards for all activities.
    ii. If the participant is in the supplemental phase, use sandpaper letter supplements for all activities.

5. Administer four intervention activities.
    a. Follow the sequence as outlined in Appendix B (see Intervention Sequence), following the appropriate scripts.
    b. If the participant makes any errors during the activities, follow the error correction procedures (see Error Correction Procedure below).
6. Implement the end of session reward procedure.
    a. Each participant will keep a sticker reward chart (see Appendix B), collecting one sticker after the successful completion of each session.
    b. After each week once the participant has collected two stickers on their chart, the participant can choose from a grab bag of small prizes and stickers to take home. Tell the participant to put the prize directly in their bag when they return to their classroom.
7. Record the time at the end of the session, record the number of steps completed, and sign your initials.
    a. Record any steps that were missed or implemented incorrectly.

Participant checklist

Participant:______________________________ Condition:______________________________

Session	Date	Start-End Time	Condition	Record Session	DIBELS MEASURES			ACTIVITIES				Reward Procedure	Comments	Initials
					LNF	PSF	NWF	1	2	3	4			
1			EL only											
2			EL only											
3			EL only											
4			EL only											
5			EL only											
6			EL+Multi											
7			EL+Multi											
8			EL+Multi											
9			EL+Multi											
10			EL+Multi											
11			EL+Multi											
12			EL+Multi											
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15			EL+Multi											
16			EL+Multi											
17			EL+Multi											
18			EL+Multi											
19			EL+Multi											
20			EL+Multi											

Error correction procedure

If the participant responded incorrectly, the interventionists would follow the below steps consistently. If the participant corrected themselves at any point during the error correction procedure, the procedure was discontinued and the interventionist would move on to the next word item or activity as appropriate. The interventionists were encouraged to provide the participants with a lot of positive feedback and praise.

1. Provide verbal feedback immediately following the error (e.g., "That’s not quite right").
2. Ask the participant to try again (e.g., "Let’s give that another try").
    a. You may need to repeat the question if the participant misunderstood the initial question or did not hear what was asked of them.
3. If the participant continues to make an error, provide scaffolded instruction (e.g., give the participant a hint or lead them to the answer with subtle clues).
    a. For example, if asking the participant to identify the initial sound of a word, provided scaffolded instruction by repeating the word and purposefully elongating the initial sound of the word (e.g., "Map: /m/, /m/, /m/, map".)
4. If the participant still makes an error, provide him or her with the answer and have the participant repeat the answer.
    a. If the participant continues to make the same error on more than one occasion during the session (e.g., fails to identify the initial sound /m/ across multiple target words), make note in the comment section of the participant’s checklist.